STUDIES OF PROSTHETIC LOADING BY MEANS OF PYLON TRANSDUCERS

Volume 2

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APPENDIX I : Resistance Strain Gauges and their experimental use

General Description

Strain gauges are the most widely used devices for the measurement of force. There are various types of strain gauges : wire gauges, foil gauges and semiconductor gauges. The most commonly used type of strain gauges are the foil type gauges.

Foil type gauges are thin metal films fabricated on a polyester backing which in turn is bonded onto the material surface at the position under study . Provided that this area is properly chosen , the ability of the strain gauge to detect and monitor the average strain on this area gives the user useful information about the loads that the body is subjected to.

Because strain gauges detect strain in one direction only , for a more complete study to be achieved, several strain gauges are simultaneously used, each one in a different direction.

The Principle of Strain Gauges

The ability of strain gauges to detect strain is based upon the fact that strain modifies the gauges' resistance. The principle behind this is the following:

Electrically a strain gauge is a resistor and its resistance is given by :

$$R = \rho \frac{L}{A} \ (\Omega) \qquad (I.1)$$

where: ρ (in $\Omega \cdot m$) is the resistivity of the material
L (in m) is the length of the resistor and
A (in m^2) is the area of the cross-section of of the resistor.

When the region where the gauge is bonded is subjected to a certain stress, the developed strain of the material changes the overall length of the gauge and as a result the area of the cross-section changes as well as the resistivity (piezoresistive effect).

Differentiating equation I.1 , the following is obtained :

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - \frac{dA}{A} \qquad (I.2)$$

and because the area A is related to the square of a transverse dimension D :

$$\frac{dA}{A} = 2\,\frac{dD}{D} \qquad (I.3)$$

By substitution of (I.3) in (I.2) the following equation is obtained :

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - 2\,\frac{dD}{D} \qquad (I.4)$$

If this last equation is divided by the ratio $\frac{dL}{L}$, it leads to the general relationship :

$$\frac{dR/_R}{dL/_L} = 1 + 2\nu + \frac{d\rho/_\rho}{dL/_L} \qquad (I.5)$$

in which the Poisson's ratio $\nu = - \frac{dD\ /\ D}{dL\ /\ L}$ has been introduced .

The ratio of the percentage change in resistance to the ratio of the percentage change in length is called the g a u g e f a c t o r and is denoted by K and from equation (I.5) :

$$K = \frac{dR/_R}{dL/_L} = 1 + 2\nu + \frac{d\rho/_\rho}{dL/_L} \qquad (I.6)$$

where: ν is the Poisson's ratio of the material of the gauge and the ratio $\frac{d\rho/\rho}{dL/L}$ relates to the piezoresistive effect .

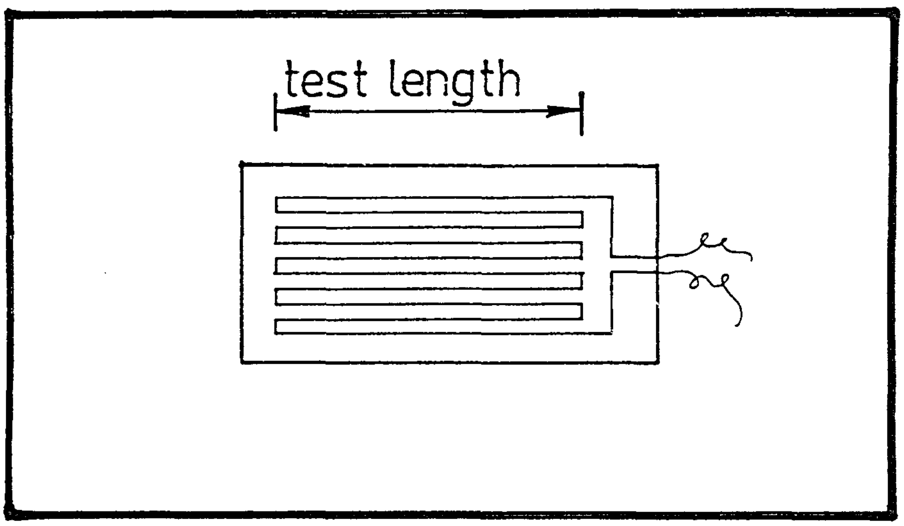


Fig I.1 The general form of a strain gauge

The gauge factors are provided by the manufacturer and typically vary between 2 and 4 for the commonly used metal foil gauges, the latter exhibiting a resistance between 100 and 1000 Ω.

In order to increase the effect of the strain under study on the strain gauge, strain gauges are not simply longitudinal conductors, but have the form shown in figure I.1 , allowing the strain of the material to affect the overall length of the gauge more decisively.

Generally, because the change in the resistance is small, to obtain more reliable results the strain gauges are used in a bridge configuration. The bridge supplied with a constant voltage exhibits an output voltage which varies with the changes of the resistance of the gauges, and is also normally subjected to subsequent amplification.

The Bridge configuration

The Wheatstone bridge is a commonly used type of bridge consisting of four resistances R_1, R_2, R_3 and R_4 and supplied with an input voltage Vs. The output of the bridge could either be a current monitored by a galvanometer (current-sensitive bridge) or a voltage monitored by a high-impedance device (voltage-sensitive bridge).

The voltage-sensitive Wheatstone bridge is the type of bridge adopted for the pylon transducers and as shown in figure I.2 , the output of the circuit is the voltage Vo .

Because of the high impedance of the device monitoring the output the following expressions stand for the currents shown :

$$i_1 = i_2 = \frac{Vs}{R_1 + R_2} \quad \text{and} \quad i_3 = i_4 = \frac{Vs}{R_3 + R_4} \qquad (I.7)$$

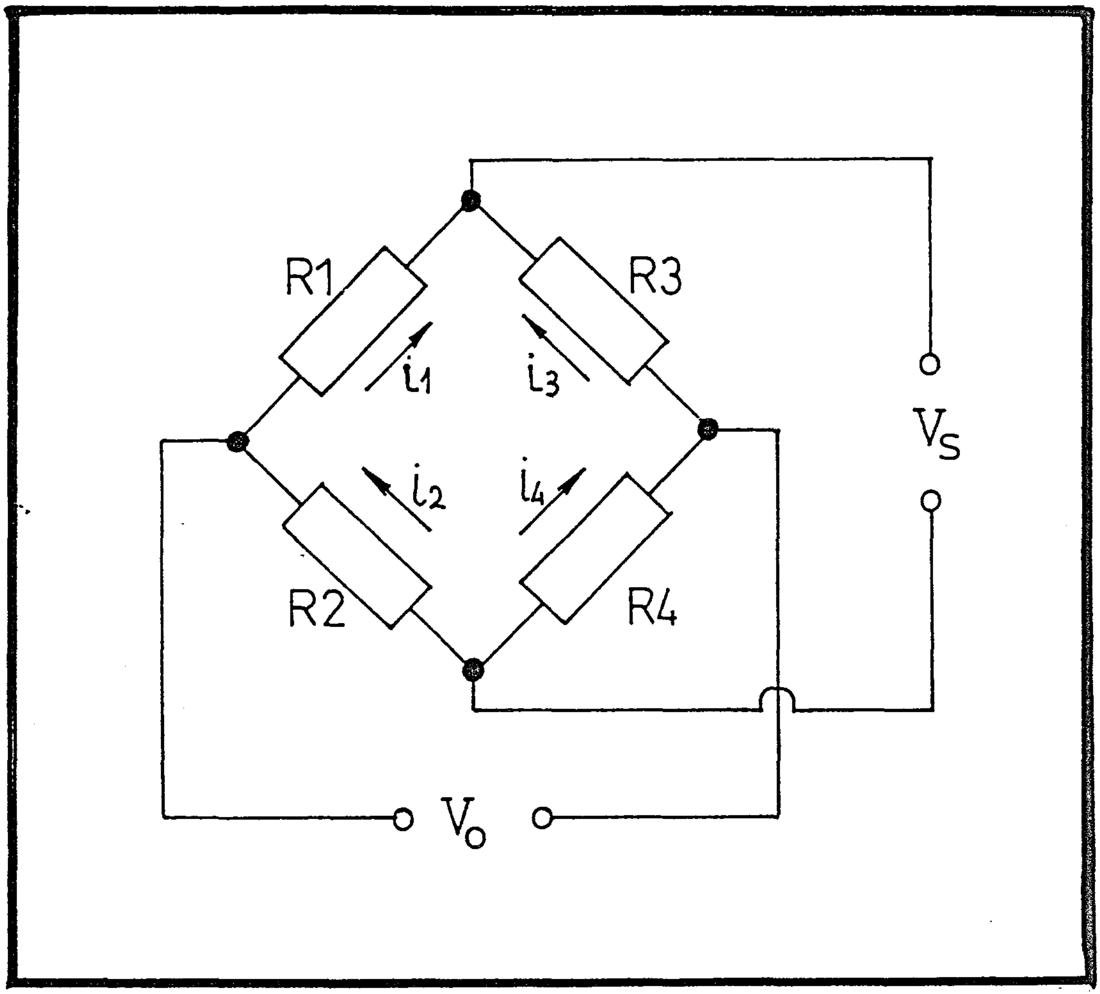


Fig I.2 Voltage-sensitive Wheatstone bridge.

Consequently the voltage drops for resistances R_1 and R_3 are given by :

$$V_1 = R_1 \frac{Vs}{R_1 + R_2}$$

$$V_3 = R_3 \frac{Vs}{R_3 + R_4} \qquad (I.8)$$

The output voltage Vo can thus be calculated as :

$$Vo = Vs \circ \left[\frac{R_3}{R_3 + R_4} - \frac{R_1}{R_1 + R_2} \right] \quad \text{or}$$

$$Vo = Vs \circ \left[\frac{1}{1 + \frac{R_4}{R_3}} - \frac{1}{1 + \frac{R_2}{R_1}} \right] \qquad (I.9)$$

the polarity depending on the wiring of the circuitry.

This expression shows that, for Vo to be zero the ratio (R_1 / R_2) should be equal to the ratio (R_3 / R_4). In this case the bridge is called " b a l a n c e d ".

If for any reason these two ratios are not equal , then voltage Vo is not zero and, unlike the previous situation the bridge is called " u n b a l a n c e d ".

The Variation of Voltage with Resistance

For strain gauges to be useful in the experimental evaluation of forces, a quantity is needed which can be related to the strain-caused change of the resistance and can be more readily detected.

By the use of the voltage-sensitive Wheatstone bridge configuration, the quantity of interest is the output voltage. It is of course necessary to determine

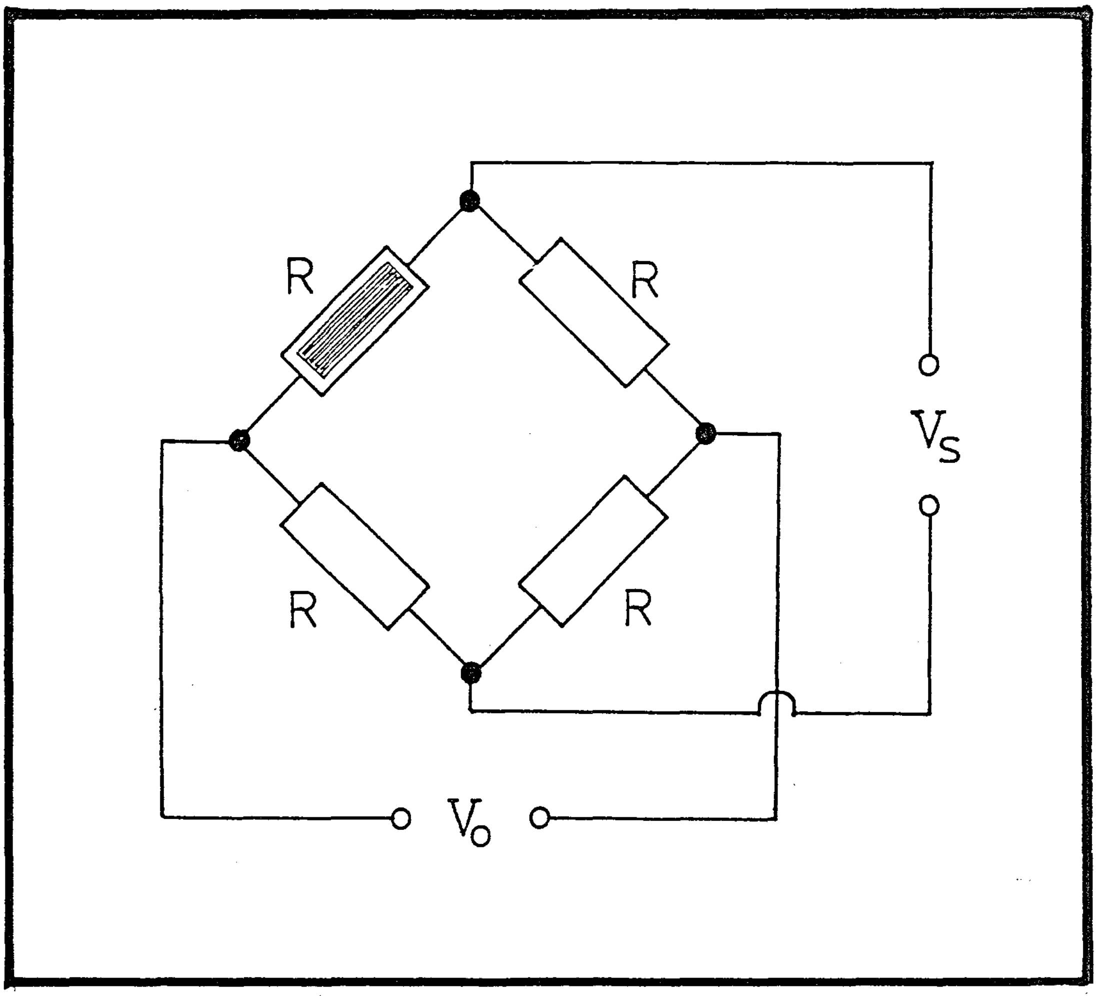


Fig I.3 Wheatstone bridge where one resistor has been substituted by a strain gauge.

the way a change of resistance affects the output voltage and brings an initially balanced bridge into an unbalanced situation.

Figure I.3 shows four resistances of value R in a configuration of Wheatstone bridge. The bridge supply is Vs and the bridge output voltage is Vo. If one of the resistances is considered to be a strain gauge with an increase dR of its resistance. The output voltage Vo will be given by equation (I.9) , with the appropriate substitutions :

$$Vo = Vs \circ \frac{dR}{(4R + 2\,dR)} =$$

$$= \frac{Vs}{2R} \circ \frac{dR}{(2 + dR/R)} \qquad (I.10)$$

From expression (I.10) one could conclude that the voltage response to the change in resistance is not linear. However, considering that the fractional change in resistance (dR/R) is a very small quantity, the relationship changes to :

$$Vo = \frac{Vs \circ dR}{4\,R} \qquad (I.11)$$

which shows a linear voltage response to the change dR. If in the above expression the gauge factor K is introduced (see first part of equation I.2), then Vo can be expressed as :

$$Vo = \frac{K}{4}\, Vs\, \frac{dL}{L} \qquad (I.12)$$

This last equation shows that the output voltage Vo is directly proportional to the strain (dL / L) , to which the strain gauge is subjected.

Experimental use

As already mentioned, the bridges used during experimental work consist of strain gauges only.

Each of the bridges is able to " detect " (strain effect on the gauges) and " report " (change in the output voltage) whether there is strain (and therefore stress) within the region of the material under test.

By doing so, the bridge gives the necessary information to the user to draw conclusions about that particular area of the material. However if the gauges of the bridge are located in the appropriate locations and are properly oriented, the bridge would eventually be able to " report " whether there is a particular force or moment component acting on the whole of the body. This is a very useful application since it allows for direct conclusions concerning a much wider area (in fact the whole body) than simply the area of the bridges .

In order to take advantage of such applications one must perform a qualitative study of the expected stresses and decide where the bridge gauges should be bonded in order to be affected by stresses of the same nature. A very important consideration at this stage concerns the wiring of the gauges and the decision should be made as to on which connections would help the existence of the particular load under study to be revealed.

This latter consideration in fact implies that one could actually prevent a bridge from "reporting" (although " detecting ") a load , by choosing the appropriate wiring connections between gauges. In such a case the bridge, although subjected to the corresponding strains , is balanced because the wiring is such that the resistance ratios are still equal (condition derived by equation I.9) .

To make this consideration clearer, it is useful to consider a bridge under experimental use. Suppose that the bridge in figure (I.2) consists of strain gauges only; all having the same nominal resistance R and the same gauge factor K. Suppose also that all gauges are bonded on directions subjected to equal absolute strain . In such a case the absolute changes in the resistances, due to the strain, are the same for all four gauges. From equation (I.6) this change in the resistances can be expressed as :

$$dR = K\,R\,\frac{dL}{L} \qquad (I.13)$$

Despite the fact that all four changes have the same absolute value dR, let us give them the notation dR_1, dR_2, dR_3 and dR_4.

In this case the output voltage of the bridge is given, again, by equation (I.9). By substituting the values of R and dR_1, dR_2, dR_3 and dR_4, the output voltage is :

$$Vo = Vs \circ \frac{R\,(\,dR_3 + dR_2 - dR_1 - dR4\,)}{(\,2R + dR_3 + dR_4)(\,2R + dR_1 + dR_2)} \qquad (I.14)$$

From equation (I.13) it becomes obvious that if gauges 1 and 2 were chosen to be two strain gauges bonded along directions which experience negative strains and gauges 3 and 4 were chosen to be two gauges bonded along directions which experience positive strains, then : $dR_1 = dR_2 = -\,dR$ and $dR_3 = dR_4 = dR$ and equation (I.14) would result in :

$$Vo = Vs \circ \frac{R\,(\,dR - dR + dR - dR\,)}{(\,2R + 2dR\,)(\,2R - 2dR\,)} = 0 \qquad (I.15)$$

in which case the bridge would have been balanced.

In the case, however, where the wiring was chosen to be different and gauges 1 and 4 were chosen, this time, to be two gauges bonded along directions which experience negative strains, but gauges 2 and 3 were chosen to be two gauges bonded along directions which experience positive strains, then : $dR_1 = dR_4 = - dR$ and $dR_2 = dR_3 = dR$ and equation (I.14) would result in:

$$Vo = Vs \circ \frac{R \ (dR + dR + dR + dR)}{(2R + dR - dR)(2R - dR + dR)} = \frac{Vs \ dR}{R} \qquad (I.16)$$

in which case the bridge would be unbalanced.

Equations (I.15) and (I.16) prove the importance of the wiring on the balance of a bridge under a particular load configuration.

Furthermore, since all gauges are the same, the gauge factor K, as expressed in equation (I.2), is common for all four gauges. Thus the ratio (dR / R) can also be expressed as : $(dR/R) = K \ (dL/L)$

and then equation (I.16) can be re-written as :

$$Vo = K \ Vs \ \frac{dL}{L} \qquad (I.16)$$

which is similar to equation (I.12) and also proves the linear relationship between the strain and the output voltage of the bridge. It should also be noticed that the use of four gauges has resulted ,in equation (I.16) , in an output voltage , which is four times higher than the one in equation (I.12) .

The initial qualitative study of stresses, the correct position and orientation of the gauges and the wiring of the bridges as well as the subsequent amplification of the output signals have resulted in strain-gauge configurations able to provide the user quantitative data about load components , which otherwise would have been very difficult to measure. The type of gauge used is also of major importance, and one should choose that particular type of gauges which will operate effectively under the expected stresses, in quantitative terms.

It is obvious that for a set of bridges to provide reliable results about the applied loads, a well planned calibration procedure is needed. Such a procedure would result in the correct evaluation of the coefficients relating to the output signals to the input loads. These coefficients will subsequently be used to convert any signals acquired during testing into the desired loads acting upon the body under test.

For more information about transducers the reader can refer to the literature, eg Cobbold (1974), Woolvet (1977), Bannister and Whitehead (1986).

APPENDIX II : Raw Data and Final Graphs obtained from the Calibration of the Pylon Transducer

In the following tables II.1 to II.7 the raw data of the calibration tests are presented. In figures II.1 to II.15 calibration graphs are exhibited for main and cross-effects. Figure II.16 shows the interface plate designed for the tests in the Instron machine.

L_I	F_X	output signals (mV)					
kg	(N)	SFx	SFy	SFz	SMx	SMy	SMz
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
1	9.81	9.5	0.0	0.0	0.0	-1.5	0.0
2	19.62	19.0	0.0	0.0	0.0	-2.0	0.5
3	29.43	29.0	0.0	0.0	0.0	-2.0	0.5
4	39.24	38.5	0.0	0.0	0.0	-3.0	1.0
5	49.05	47.5	0.0	0.0	0.0	-3.0	1.0
6	58.86	57.5	0.0	0.0	0.0	-3.5	1.0
7	68.67	67.5	0.0	0.0	0.0	-3.5	1.5
8	78.48	77.5	0.0	0.5	0.0	-2.5	1.5
9	88.29	87.0	0.0	0.5	0.0	-4.0	1.5
10	98.10	96.5	0.0	0.0	0.0	-5.0	2.5
11	107.91	106.5	0.0	0.0	0.0	-5.5	2.5
12	117.72	116.0	0.0	0.0	0.0	-5.0	3.0
13	127.53	126.0	0.0	1.0	0.0	-5.0	3.0
14	137.34	135.5	0.0	0.5	0.0	-6.5	3.5
15	147.15	144.5	0.0	0.5	0.0	-7.0	3.5
15	147.15	144.5	0.0	1.0	0.0	-7.0	3.5
14	137.34	135.0	0.0	1.0	0.0	-4.0	2.5
13	127.53	125.5	0.0	1.0	0.0	-3.5	2.0
12	117.72	115.5	0.0	1.0	0.0	-3.0	1.5
11	107.91	106.0	0.0	1.0	0.0	-2.5	1.0
10	98.10	97.0	0.0	1.0	0.0	-2.0	1.0
9	88.29	87.0	0.0	1.0	0.0	-2.0	1.0
8	78.48	77.5	0.0	0.5	0.0	-2.0	1.0
7	68.67	67.5	0.0	0.0	0.0	-1.5	0.0
6	58.86	58.5	0.0	0.5	0.0	-1.0	0.0
5	49.05	49.5	0.0	0.0	0.0	-1.0	0.0
4	39.24	39.5	0.0	0.0	0.0	-0.5	0.0
3	29.43	29.5	0.0	0.0	0.0	-0.5	0.0
2	19.62	20.0	0.0	0.0	0.0	-0.5	0.0
1	9.81	10.5	0.0	0.0	-0.5	-0.5	0.0
0	0.00	1.0	0.0	0.0	0.0	-0.5	0.0

Table II.1a The data for the anterio-posterior shear force calibration .

L_I kg	F_X (N)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
1	-9.81	-9.5	0.0	0.0	0.0	1.0	0.0
2	-19.62	-19.0	0.0	0.0	0.0	2.5	-0.5
3	-29.43	-29.0	0.0	0.0	0.0	2.0	-0.5
4	-39.24	-38.5	0.0	0.0	0.0	3.0	-1.0
5	-49.05	-47.5	0.0	0.0	0.0	3.0	-1.0
6	-58.86	-57.5	0.0	-0.5	0.0	3.5	-1.0
7	-68.67	-67.5	0.0	0.0	0.0	3.5	-1.0
8	-78.48	-77.5	0.0	-0.5	0.0	2.5	-1.5
9	-88.29	-87.0	0.0	0.0	0.0	3.5	-2.0
10	-98.10	-96.5	0.0	0.0	0.0	5.0	-2.5
11	-107.91	-106.5	0.0	0.0	0.0	5.5	-3.0
12	-117.72	-116.0	0.0	-1.0	0.0	5.0	-3.0
13	-127.53	-126.0	0.0	0.0	0.0	5.0	-3.0
14	-137.34	-135.5	0.0	0.0	0.0	6.5	-3.5
15	-147.15	-144.5	0.0	0.0	0.0	7.5	-3.5
15	-147.15	-144.5	0.0	-1.0	0.0	7.5	-3.5
14	-137.34	-135.5	0.0	-1.0	0.0	6.0	-3.0
13	-127.53	-125.5	0.0	-1.0	0.0	3.0	-2.0
12	-117.72	-115.5	0.0	0.0	0.0	3.5	-1.5
11	-107.91	-106.0	0.0	0.0	0.0	2.5	-1.5
10	-98.10	-97.0	0.0	0.0	0.0	2.0	-1.5
9	-88.29	-87.0	0.0	0.0	0.0	2.0	-1.0
8	-78.48	-77.5	0.0	0.0	0.0	2.0	-1.0
7	-68.67	-67.5	0.0	0.0	0.0	1.5	0.0
6	-58.86	-58.5	0.0	0.0	0.0	1.0	0.0
5	-49.05	-49.5	0.0	0.0	0.0	1.0	0.0
4	-39.24	-39.5	0.0	0.0	0.0	0.0	0.0
3	-29.43	-29.5	0.0	0.0	0.0	0.0	0.0
2	-19.62	-20.0	0.0	-0.5	0.0	0.0	0.0
1	-9.81	-10.5	0.0	0.0	-0.5	0.0	0.0
0	0.00	-1.0	0.0	0.0	0.0	0.5	0.0

Table II.1b The data for the anterio-posterior shear force calibration .

L_I kg	F_Z (N)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
1	9.81	0.5	0.0	8.5	-0.5	-1.0	0.0
2	19.62	1.5	0.0	18.0	0.0	-1.5	0.0
3	29.43	1.5	0.0	27.5	0.5	-2.0	0.0
4	39.24	1.5	-0.5	36.5	1.0	-2.0	0.0
5	49.05	2.0	-0.5	45.5	1.0	-2.0	0.0
6	58.86	1.5	-0.5	55.0	2.0	-3.0	0.0
7	68.67	2.0	-0.5	64.5	2.0	-4.0	0.0
8	78.48	1.5	-1.0	74.0	3.0	-4.0	0.0
9	88.29	2.5	-1.5	83.0	3.0	-5.0	0.0
10	98.10	2.0	-1.5	92.0	4.0	-5.0	0.0
11	107.91	2.5	-1.5	102.0	4.0	-5.0	0.0
12	117.72	2.5	-1.5	110.5	5.0	-5.5	0.0
13	127.53	2.0	-1.5	121.0	5.0	-6.0	0.0
14	137.34	4.0	-2.0	129.5	6.0	-6.5	0.0
15	147.15	3.5	-2.0	138.5	6.0	-6.5	0.0
15	147.15	4.0	-2.5	139.0	6.0	-7.0	0.0
14	137.34	3.5	-2.0	129.5	4.0	-7.0	0.0
13	127.53	4.5	-1.0	120.0	2.0	-7.0	0.0
12	117.72	4.5	-1.0	111.5	1.5	-6.5	0.0
11	107.91	4.0	-1.0	102.0	1.0	-7.0	0.0
10	98.10	3.0	-1.0	92.5	0.5	-6.5	0.0
9	88.29	4.5	-1.0	83.0	0.0	-7.5	0.0
8	78.48	4.5	-1.0	73.5	0.0	-7.0	0.0
7	68.67	4.0	0.0	64.0	-0.5	-7.5	0.0
6	58.86	3.5	-0.5	54.0	-0.5	-7.0	0.0
5	49.05	4.0	-0.5	45.5	-1.5	-7.5	0.0
4	39.24	5.0	0.0	36.5	-2.0	-7.0	0.0
3	29.43	4.0	0.0	27.0	-2.5	-5.5	0.0
2	19.62	4.5	0.0	18.5	-3.0	-6.5	0.0
1	9.81	3.0	0.0	8.0	-2.5	-4.0	0.0
0	0.00	2.0	0.0	0.0	-0.5	-1.0	0.0

Table II.2a The data for the medio-lateral shear force calibration.

L_I kg	F_Z (N)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
1	-9.81	0.0	0.0	-8.0	-0.5	0.0	0.0
2	-19.62	-1.0	0.0	-17.5	-0.5	1.5	0.0
3	-29.43	-1.5	0.0	-27.0	0.0	1.0	0.0
4	-39.24	-1.0	0.5	-36.5	-1.0	1.5	0.0
5	-49.05	-2.0	0.5	-45.5	-1.5	2.0	0.0
6	-58.86	-1.5	0.5	-55.5	-2.5	3.0	0.0
7	-68.67	-2.0	0.5	-64.5	-2.0	4.0	0.0
8	-78.48	-1.5	0.5	-74.5	-2.5	4.0	0.0
9	-88.29	-2.0	1.0	-83.0	-3.0	4.5	0.0
10	-98.10	-2.0	1.0	-92.5	-4.0	4.0	0.0
11	-107.91	-2.0	1.5	-102.0	-4.5	5.0	0.0
12	-117.72	-2.5	1.5	-110.5	-5.0	5.5	0.0
13	-127.53	-2.0	1.5	-121.0	-5.0	6.0	0.0
14	-137.34	-4.0	2.0	-129.5	-6.0	6.0	0.0
15	-147.15	-3.0	2.5	-138.0	-6.5	7.0	0.0
15	-147.15	-4.0	2.5	-139.0	-6.0	7.5	0.0
14	-137.34	-4.0	2.0	-129.0	-4.0	7.5	0.0
13	-127.53	-4.5	1.5	-120.0	-2.5	7.0	0.0
12	-117.72	-4.5	1.5	-111.5	-1.0	6.5	0.0
11	-107.91	-4.5	1.0	-102.5	-0.5	7.0	0.0
10	-98.10	-3.5	1.0	-92.5	-0.5	6.5	0.0
9	-88.29	-4.5	0.0	-83.0	0.0	6.5	0.0
8	-78.48	-4.0	0.0	-73.5	0.0	6.0	0.0
7	-68.67	-4.5	0.0	-64.5	0.0	7.0	0.0
6	-58.86	-3.0	-0.5	-54.0	0.5	6.0	0.0
5	-49.05	-4.0	-0.5	-45.5	1.0	7.0	0.0
4	-39.24	-4.5	0.0	-36.0	1.5	7.5	0.0
3	-29.43	-4.0	0.0	-27.0	2.0	6.5	0.0
2	-19.62	-3.5	0.0	-18.0	2.5	5.0	0.0
1	-9.81	-2.5	0.0	-8.0	2.0	4.0	0.0
0	0.00	-1.0	0.0	0.0	1.0	0.0	0.0

Table II.2b The data for the medio-lateral shear force calibration.

L_I kg	F_Y (N)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
10	98.10	0.0	-25.0	0.0	0.0	0.0	0.0
20	196.20	0.0	-49.5	-0.5	0.5	-0.5	0.0
30	294.30	0.0	-74.5	-1.0	1.0	-0.5	0.5
40	392.40	1.5	-99.0	0.0	1.0	-0.5	1.0
50	490.50	1.5	-124.0	-1.0	1.0	-1.0	1.0
60	588.60	2.5	-149.0	-0.5	1.0	-1.0	1.5
70	686.70	2.5	-173.5	-1.0	2.0	-2.5	1.5
80	784.80	2.5	-198.0	-1.0	2.0	-1.5	2.0
90	882.90	3.0	-223.0	-0.5	2.0	-2.0	2.0
100	981.00	4.5	-247.0	0.0	3.0	-2.5	2.5
100	981.00	4.5	-247.5	0.0	3.0	-2.5	3.0
90	882.90	3.5	-223.0	0.0	2.0	-2.5	2.0
80	784.80	3.0	-198.0	0.0	2.0	-1.5	2.0
70	686.70	3.0	-173.0	0.0	2.0	-1.5	2.0
60	588.60	2.0	-149.0	-0.5	2.0	-1.5	1.5
50	490.50	2.0	-124.0	-0.5	1.0	-1.5	1.0
40	392.40	2.0	-100.0	0.0	1.0	-1.0	1.0
30	294.30	0.5	-75.0	-1.0	1.0	-0.5	1.0
20	196.20	0.5	-50.5	-0.5	0.5	-0.5	1.0
10	98.10	0.5	-25.0	0.0	0.0	-0.5	0.0
0	0.00	0.5	0.0	0.0	0.0	0.0	0.0

Table II.3 The data for the axial load calibration.

L_I kg	net M_X (Nm)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
20	0.00	0.0	0.0	0.0	0.0	0.0	0.0
30	6.67	0.0	-0.5	0.5	-67.5	2.0	0.5
40	13.34	-2.0	2.0	2.0	-138.0	3.0	0.5
50	20.01	-4.0	5.0	3.5	-210.0	4.0	1.0
60	26.68	-5.5	7.0	3.5	-281.0	5.0	1.5
70	33.35	-8.0	9.0	5.0	-352.5	5.5	2.0
70	33.35	-7.5	9.5	5.0	-352.0	6.0	2.0
60	26.68	-6.5	12.5	5.5	-291.5	5.0	2.0
50	20.01	-4.5	14.5	5.0	-217.0	3.5	1.0
40	13.34	-3.0	11.0	5.0	-149.5	2.5	1.0
30	6.67	-1.0	5.5	3.5	-78.0	1.5	0.5
20	0.00	0.5	2.5	1.5	-0.5	0.0	0.0
20	0.00	0.0	0.0	0.0	0.0	0.0	0.0
30	-6.67	0.0	0.0	0.0	70.5	-2.5	-0.5
40	-13.34	3.5	-1.5	-2.0	140.0	-3.5	-1.0
50	-20.01	4.5	-5.0	-3.0	202.5	-4.0	-1.5
60	-26.68	5.5	-8.0	-3.5	274.5	-5.0	-1.5
70	-33.35	7.5	-9.5	-5.0	351.5	-5.5	-2.0
70	-33.35	7.5	-9.5	-6.0	352.0	-6.0	-2.5
60	-26.68	6.0	-11.5	-5.5	287.5	-5.5	-2.0
50	-20.01	4.5	-12.5	-5.5	223.0	-3.5	-1.5
40	-13.34	3.5	-12.5	-5.0	141.5	-2.0	-1.0
30	-6.67	1.5	-4.0	-3.0	83.5	-1.0	0.0
20	0.00	0.0	-1.0	-1.0	0.5	0.0	0.0

Table II.4 The data for the medio-lateral bending moment calibration.

L_I kg	net M_Z (Nm)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
20	0.00	0.0	0.0	0.0	0.0	0.0	0.0
30	6.67	1.0	-2.0	1.5	0.5	-0.5	33.5
40	13.34	2.0	-3.0	4.0	0.0	-2.0	69.0
50	20.01	2.0	-3.5	5.0	0.0	-3.0	105.0
60	26.68	1.0	-4.0	7.0	0.0	-4.0	141.0
70	33.35	0.0	-4.5	9.5	0.0	-5.0	178.0
70	33.35	0.0	-5.0	9.5	-0.5	-5.0	178.0
60	26.68	0.0	0.5	8.0	-0.5	-4.0	147.5
50	20.01	-1.5	6.0	6.0	-1.0	-3.0	109.0
40	13.34	-2.0	6.5	4.0	-1.0	-2.0	74.5
30	6.67	-1.5	3.5	2.0	-1.0	-1.0	39.0
20	0.00	0.0	2.5	0.5	-1.0	0.0	1.0
20	0.00	0.0	0.0	0.0	0.0	0.0	0.0
30	-6.67	-1.0	0.0	-1.5	0.5	0.5	-38.5
40	-13.34	-2.5	2.5	-4.5	0.0	2.5	-65.0
50	-20.01	-2.5	3.5	-5.5	0.0	3.0	-111.0
60	-26.68	-1.5	4.0	-8.0	0.0	4.5	-146.0
70	-33.35	-1.5	5.0	-9.5	0.0	5.0	-181.0
70	-33.35	-1.0	5.5	-10.0	0.5	5.5	-181.5
60	-26.68	0.0	0.5	-8.5	0.5	4.0	-150.5
50	-20.01	1.0	-5.5	-5.5	1.0	3.0	-108.0
40	-13.34	2.5	-6.5	-3.5	1.0	2.5	-72.5
30	-6.67	1.0	-2.5	-2.0	1.0	1.0	-34.0
20	0.00	0.0	-1.5	0.0	1.5	0.0	-1.0

Table II.5 The data for the anterio-posterior bending moment calibration.

L_I kg	net M_Y (Nm)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0
12	1.57	4.0	0.0	0.0	0.0	-25.0	0.0
14	3.14	5.5	0.0	0.5	0.0	-54.0	0.5
16	4.71	7.5	0.0	1.0	0.0	-83.5	1.0
18	6.28	9.0	-0.5	1.5	0.0	-114.0	1.5
20	7.85	13.5	-0.5	3.0	0.0	-144.0	2.0
22	9.42	18.0	-0.5	4.0	0.0	-173.5	3.5
24	10.99	22.5	-1.0	5.0	0.0	-203.0	5.0
26	12.56	27.5	-1.5	5.5	0.0	-233.0	6.0
28	14.13	34.5	-1.5	7.0	0.0	-262.5	7.5
30	15.70	37.5	-1.5	8.0	0.0	-292.5	8.0
30	15.70	37.0	-1.5	8.0	0.0	-292.5	8.0
28	14.13	32.0	-1.5	7.5	0.0	-267.5	7.0
26	12.56	27.0	-1.5	7.0	0.0	-240.0	6.0
24	10.99	22.5	-1.0	5.5	0.0	-209.5	5.0
22	9.42	19.5	-0.5	5.0	0.0	-180.0	4.0
20	7.85	17.5	-0.5	5.0	0.0	-150.0	3.5
18	6.28	14.5	0.0	4.0	0.0	-120.0	3.0
16	4.71	10.5	0.0	3.0	0.0	-89.0	2.0
14	3.14	6.5	0.0	2.0	0.0	-59.0	1.0
12	1.57	2.5	0.0	0.5	0.0	-28.5	0.0
10	0.00	0.0	0.5	0.0	0.0	0.5	0.0
10	0.00	0.0	0.0	0.0	0.0	0.0	0.0
12	-1.96	5.0	0.0	0.0	0.0	31.0	0.0
14	-3.92	7.0	0.0	-0.5	0.0	65.5	0.0
16	-5.89	9.5	0.0	-1.0	0.0	104.0	1.5
18	-7.85	11.5	0.5	-1.5	0.0	137.5	1.5
20	-9.81	15.5	0.5	-2.5	0.0	180.5	2.5
22	-11.77	24.5	0.5	-4.5	0.0	216.5	3.5
24	-13.73	29.0	1.0	-5.0	0.0	259.5	5.0
26	-15.70	34.0	1.0	-6.0	0.0	291.0	6.5
28	-17.66	42.5	1.5	-7.0	0.0	333.0	7.0
30	-19.62	46.0	1.5	-8.0	0.0	366.0	8.0
30	-19.62	46.5	2.0	-8.5	0.5	366.5	8.5
28	-17.66	40.0	1.5	-7.5	0.0	329.0	7.0
26	-15.70	34.5	1.5	-6.5	0.0	283.5	6.5
24	-13.73	28.0	1.5	-5.5	0.0	255.5	5.0
22	-11.77	24.0	0.5	-5.5	0.0	221.0	4.5
20	-9.81	22.0	0.0	-5.0	0.0	187.0	3.5
18	-7.85	18.5	0.0	-4.5	0.0	143.0	3.5
16	-5.89	13.0	0.0	-3.5	0.0	108.5	2.0
14	-3.92	8.0	0.0	-2.0	0.0	69.5	0.0
12	-1.96	3.0	0.0	-0.5	0.0	35.0	0.0
10	0.00	0.0	0.5	0.0	0.0	0.5	0.0

Table II.6 The data for the axial torque calibration (using system Mark I)

L_I kg	net M_Y (Nm)	output signals (mV)					
		SFx	SFy	SFz	SMx	SMy	SMz
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
5	4.17	-6.0	0.0	7.5	3.5	-75.5	-2.0
10	8.34	-12.5	-1.0	15.0	7.0	-151.0	-5.5
15	12.51	-17.5	-2.0	22.0	9.5	-230.0	-8.5
20	16.68	-23.0	-2.5	30.0	14.0	-305.0	-11.0
25	20.85	-29.5	-3.0	39.0	18.0	-381.5	-14.0
30	25.02	-34.5	-4.0	49.0	22.5	-457.5	-17.0
30	25.02	-34.0	-4.0	49.0	22.5	-457.0	-17.0
25	20.85	-27.0	-3.5	31.0	15.0	-390.5	-13.5
20	16.68	-12.5	-3.0	15.0	7.0	-323.5	-9.0
15	12.51	-6.0	-2.0	3.0	1.5	-251.0	-6.0
10	8.34	-3.5	-1.0	-4.0	-2.5	-174.5	-4.5
5	4.17	-1.0	-0.5	-6.5	-3.5	-93.0	0.0
0	0.00	0.0	1.0	0.0	0.0	-0.5	0.0
0	0.00	0.0	0.0	0.0	0.0	0.0	0.0
5	-4.17	-9.5	1.0	-6.0	-2.5	75.0	-2.0
10	-8.34	-14.0	1.5	-15.5	-7.0	147.5	-3.0
15	-12.51	-17.5	2.5	-24.5	-11.0	219.5	-3.5
20	-16.68	-21.5	3.5	-33.0	-15.0	293.0	-4.0
25	-20.85	-25.0	4.5	-45.5	-21.0	363.0	-5.0
30	-25.02	-29.5	5.5	-57.5	-26.5	433.5	-5.5
30	-25.02	-29.5	5.5	-57.5	-26.5	433.0	-5.5
25	-20.85	-27.0	4.5	-36.0	-17.0	372.5	-5.5
20	-16.68	-17.5	4.0	-17.5	-7.5	310.5	-3.5
15	-12.51	-12.0	3.0	-2.5	-0.5	244.0	-1.5
10	-8.34	-8.0	2.0	8.5	4.5	175.5	-1.5
5	-4.17	-6.0	1.0	7.0	3.5	91.0	-1.5
0	0.00	2.5	0.0	0.0	-0.5	5.0	1.0

Table II.7 The data for the axial torque calibration (using system Mark II)

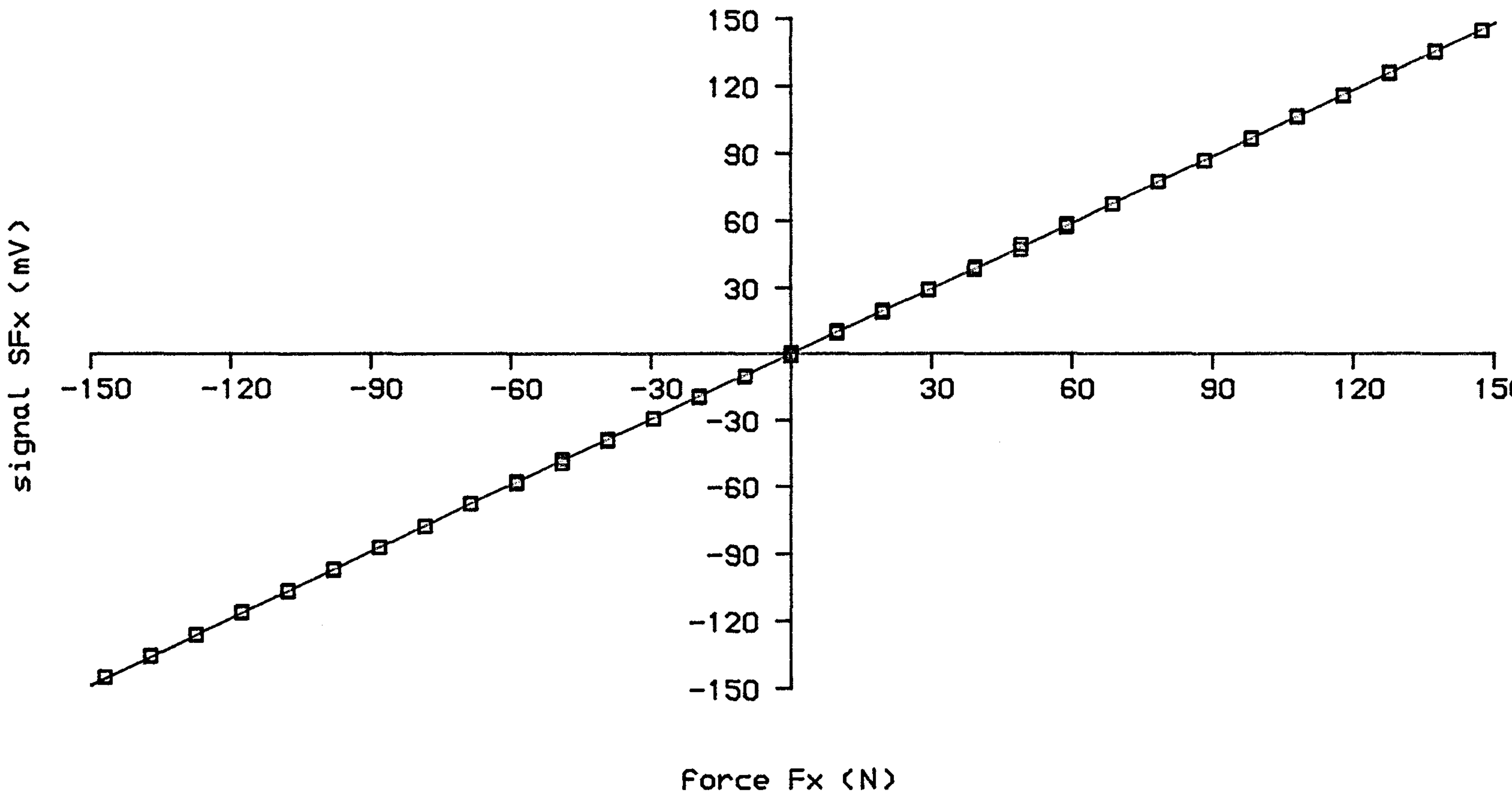


Fig II.1 Calibration graph for channel 1 (SFx)

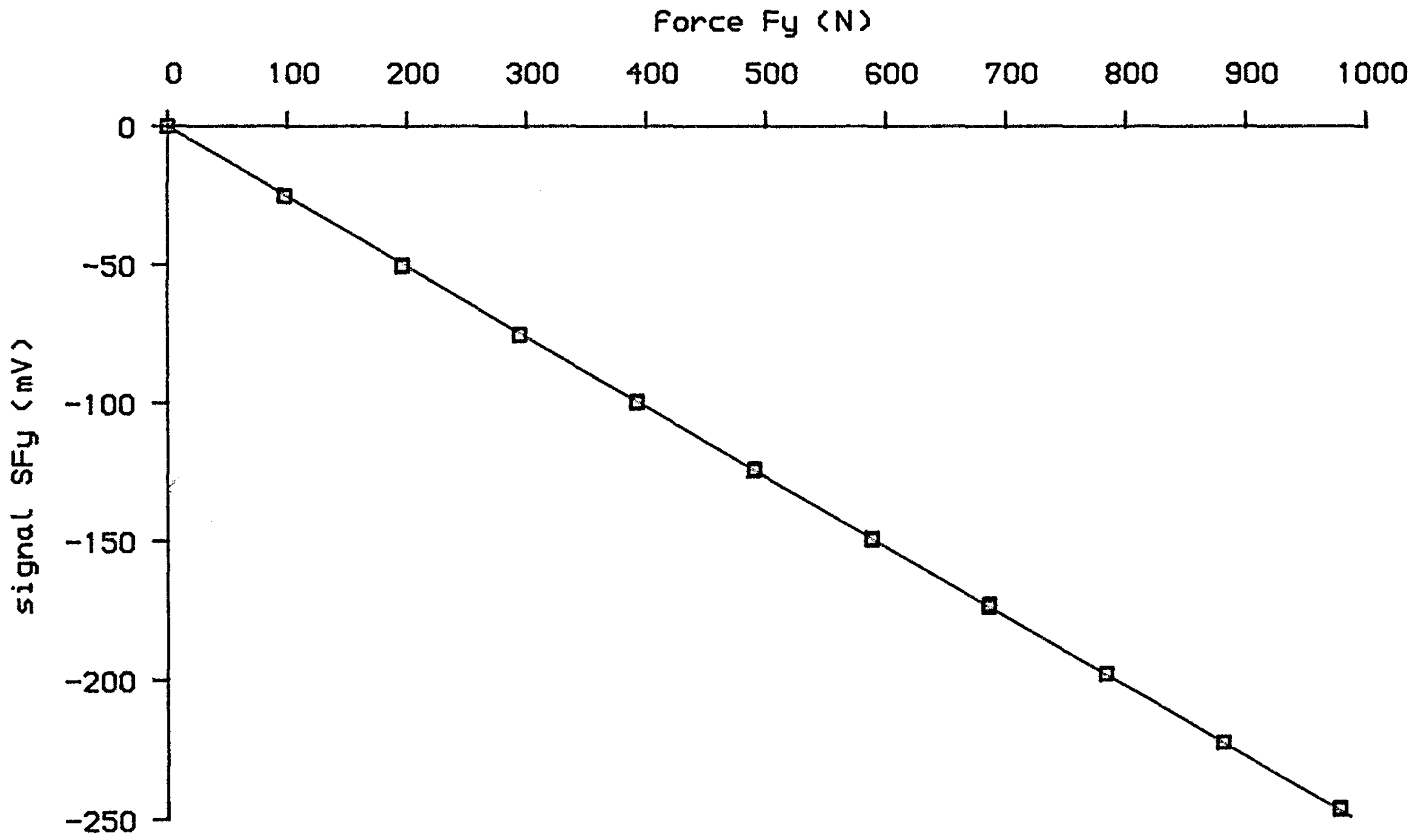


Fig II.2 Calibration graph for channel 2 (SFy)

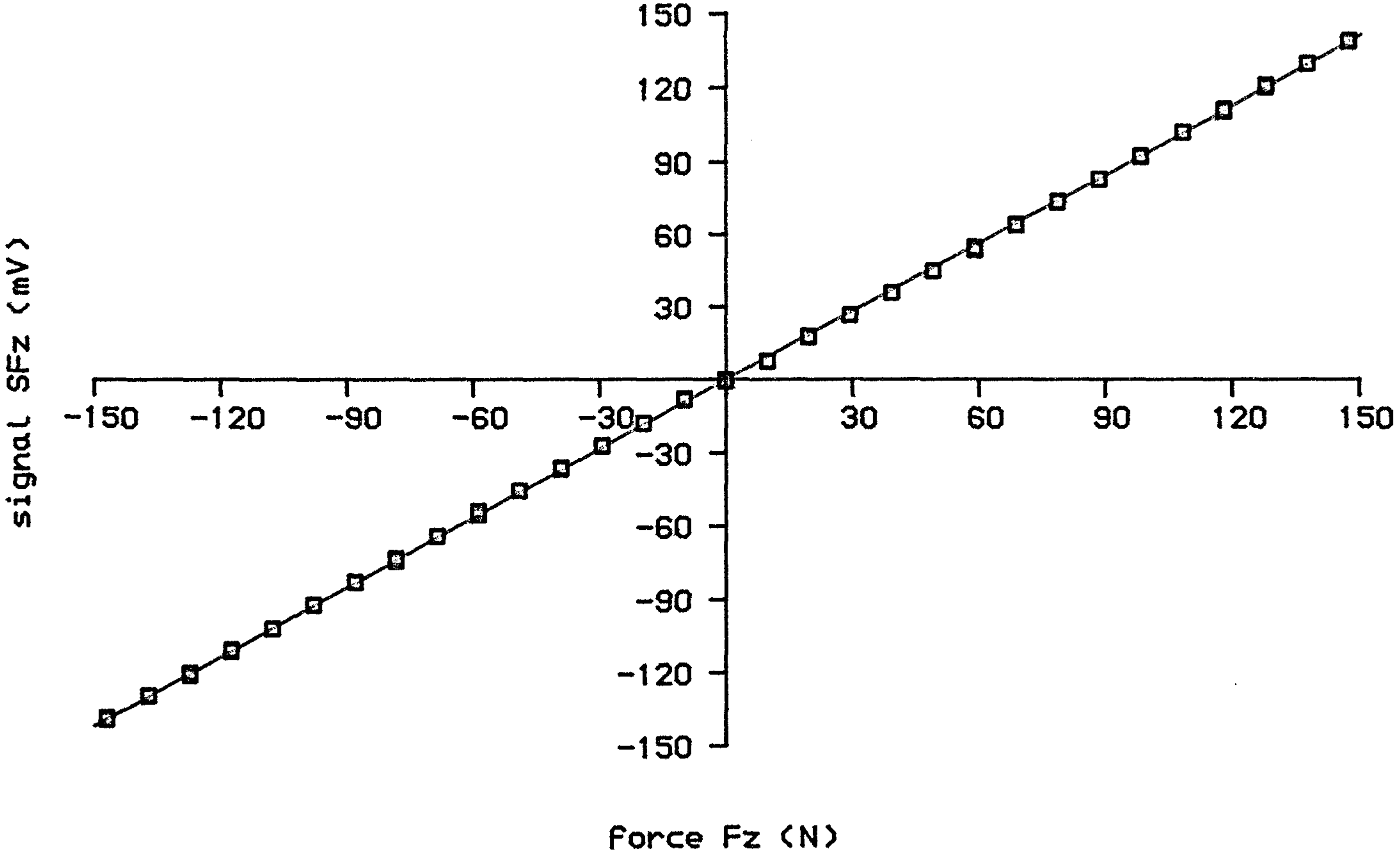


Fig II.3 Calibration graph for channel 3 (SFz)

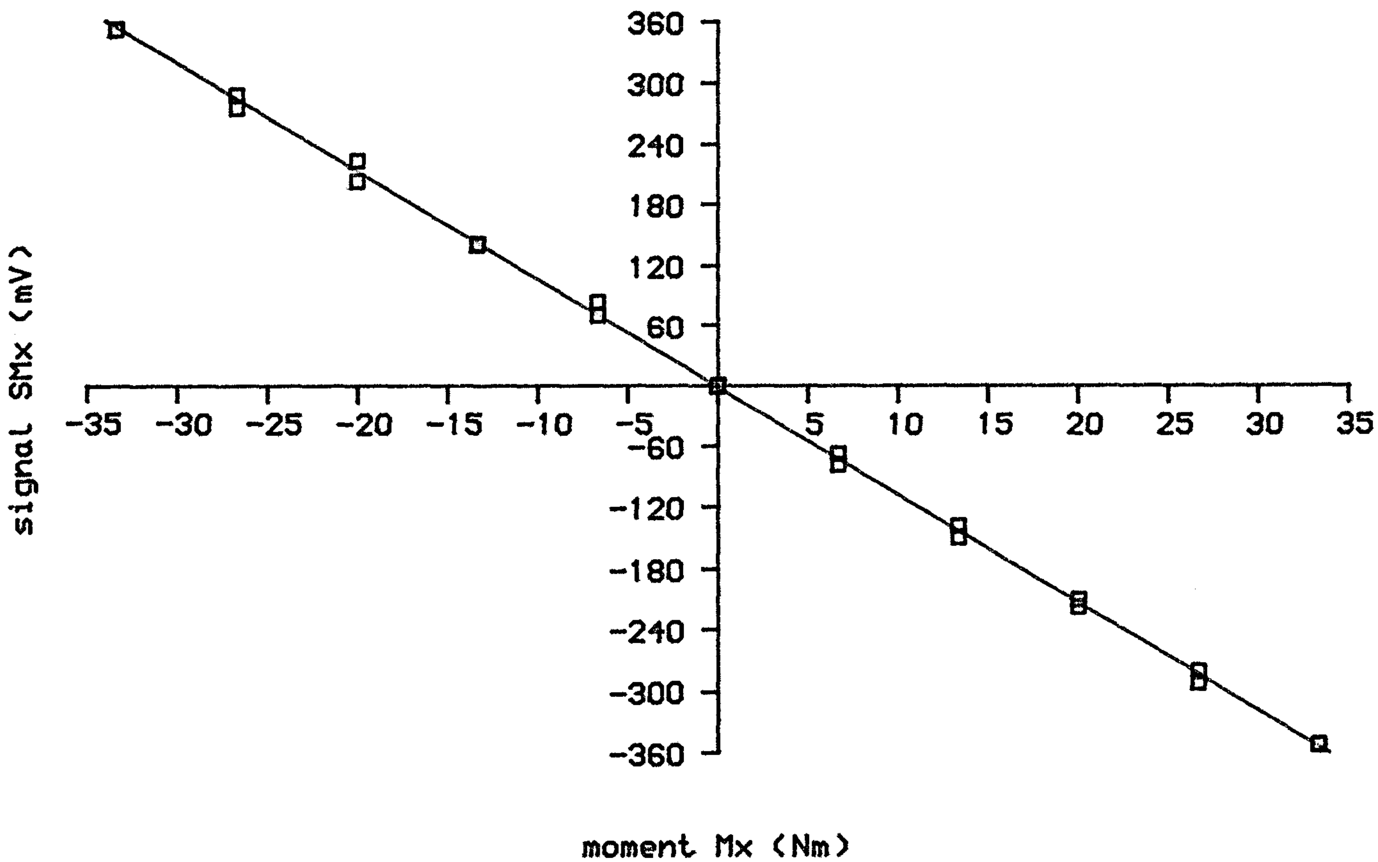


Fig II.4 Calibration graph for channel 4 (SMx)

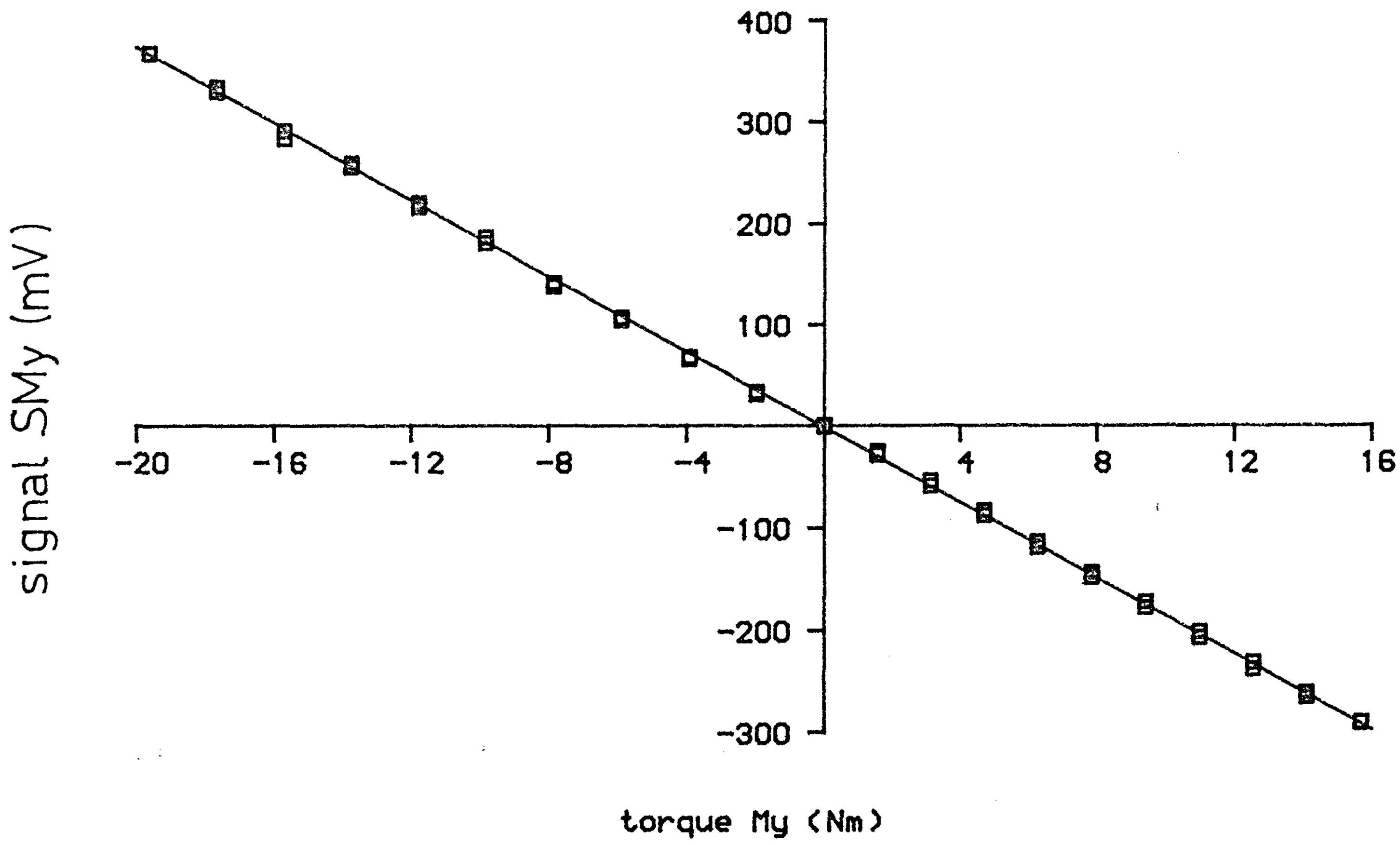


Fig II.5 Calibration graph for channel 5 (SMy) using system Mark I

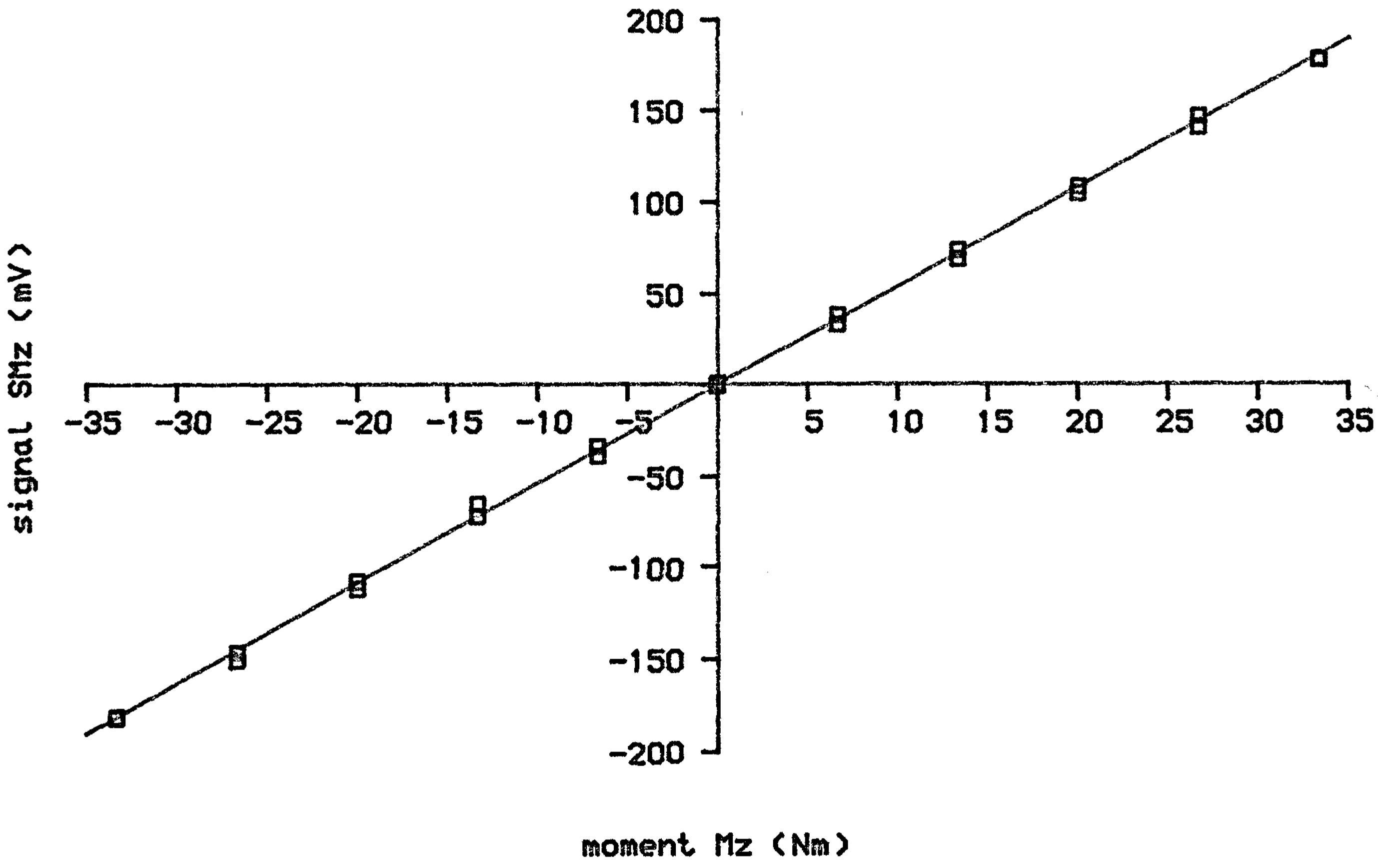


Fig II.6 Calibration graph for channel 6 (SMz)

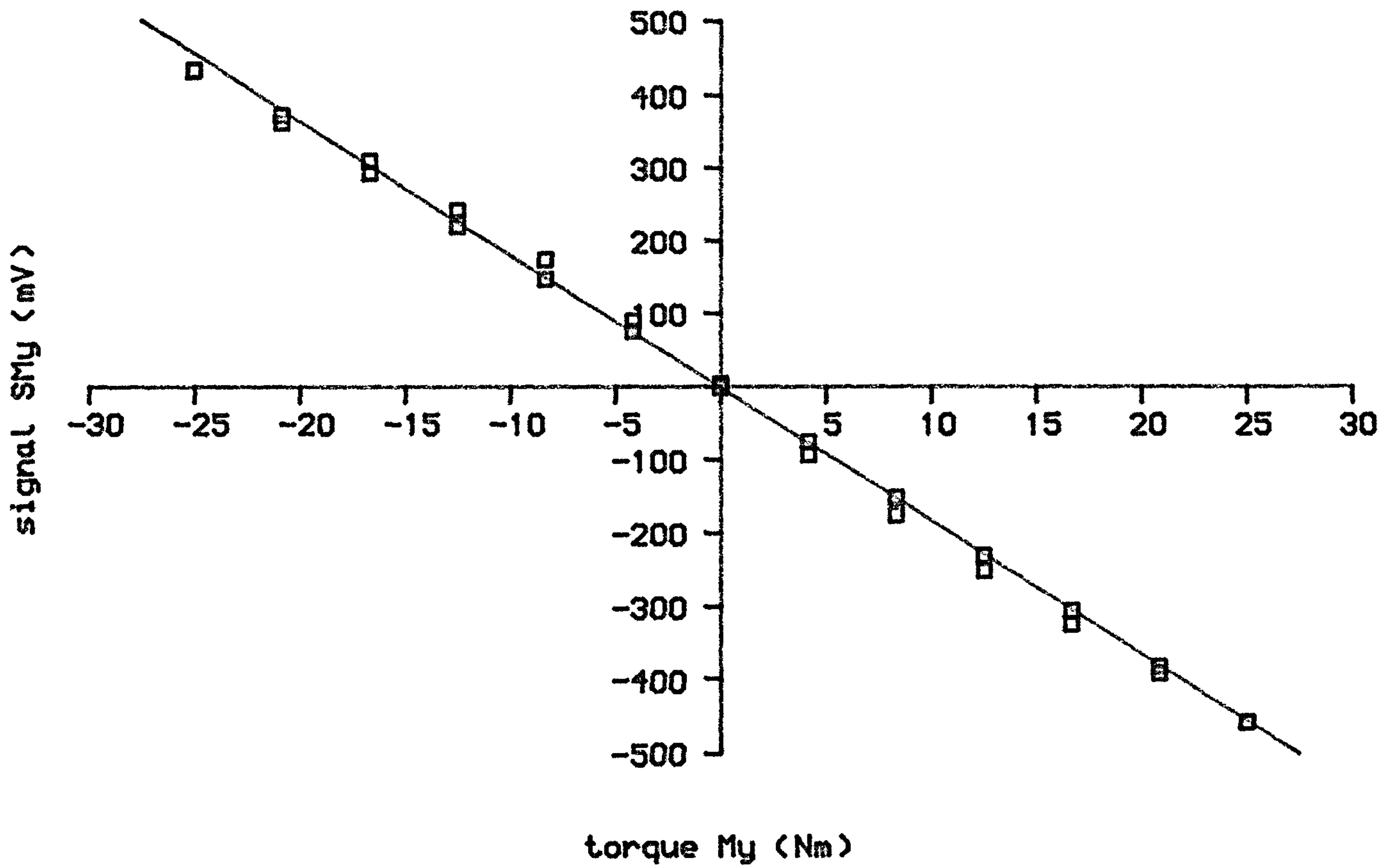


Fig II.7 Calibration graph for channel 5 (SMy) using system Mark II

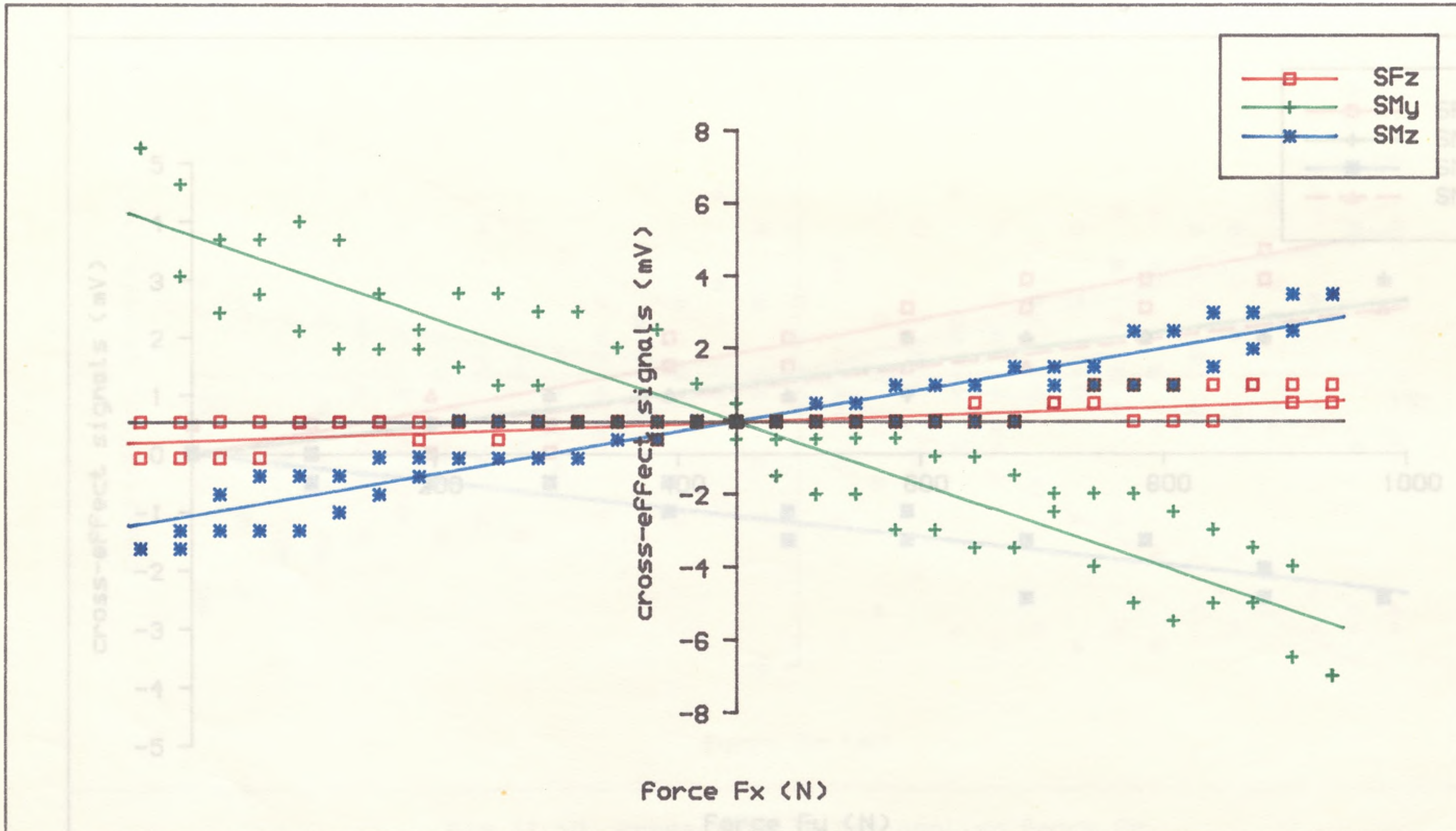
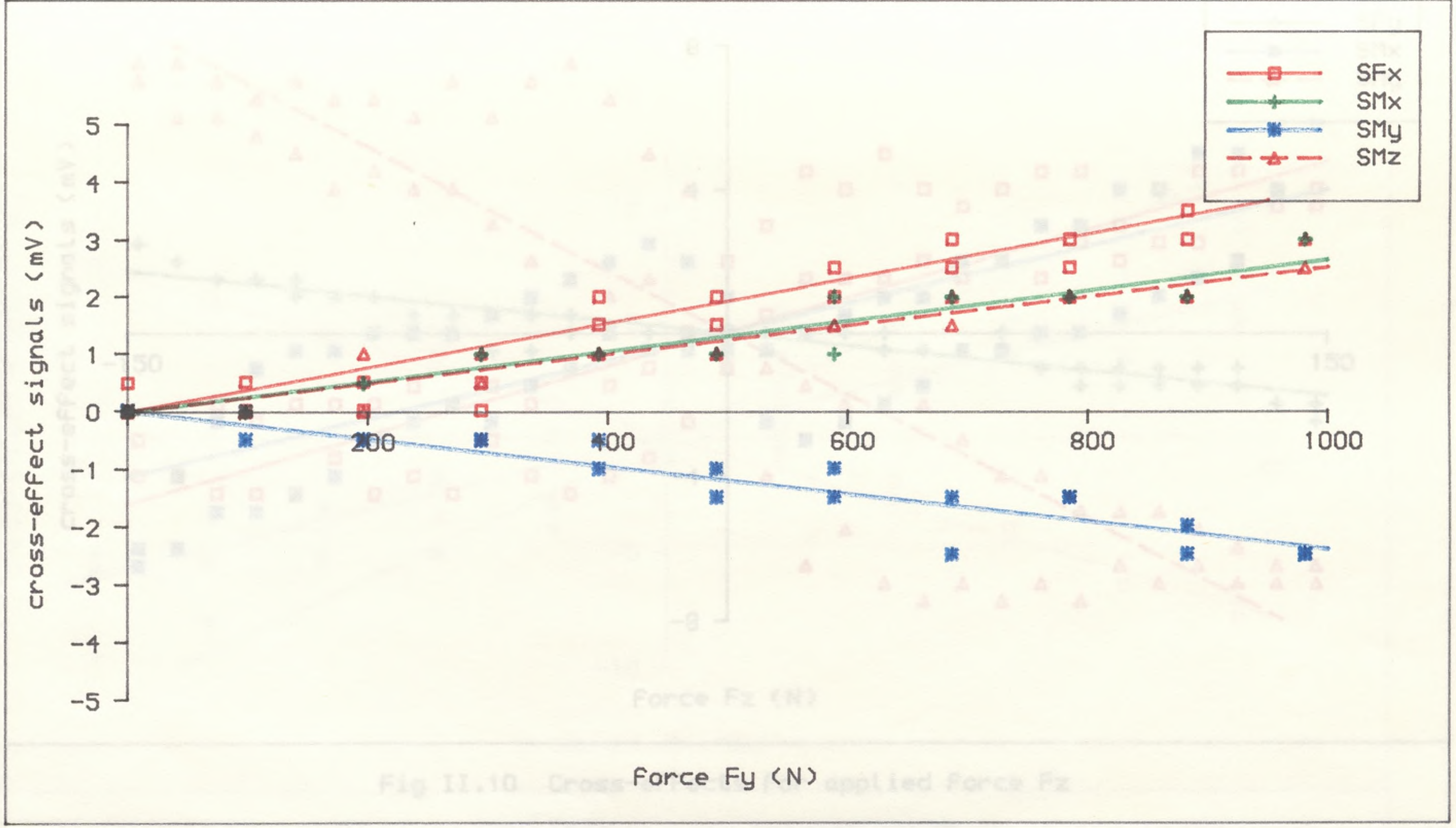


Fig II.8 Cross-effects for applied force Fx

Fig II.9 Cross-effects for applied force Fy



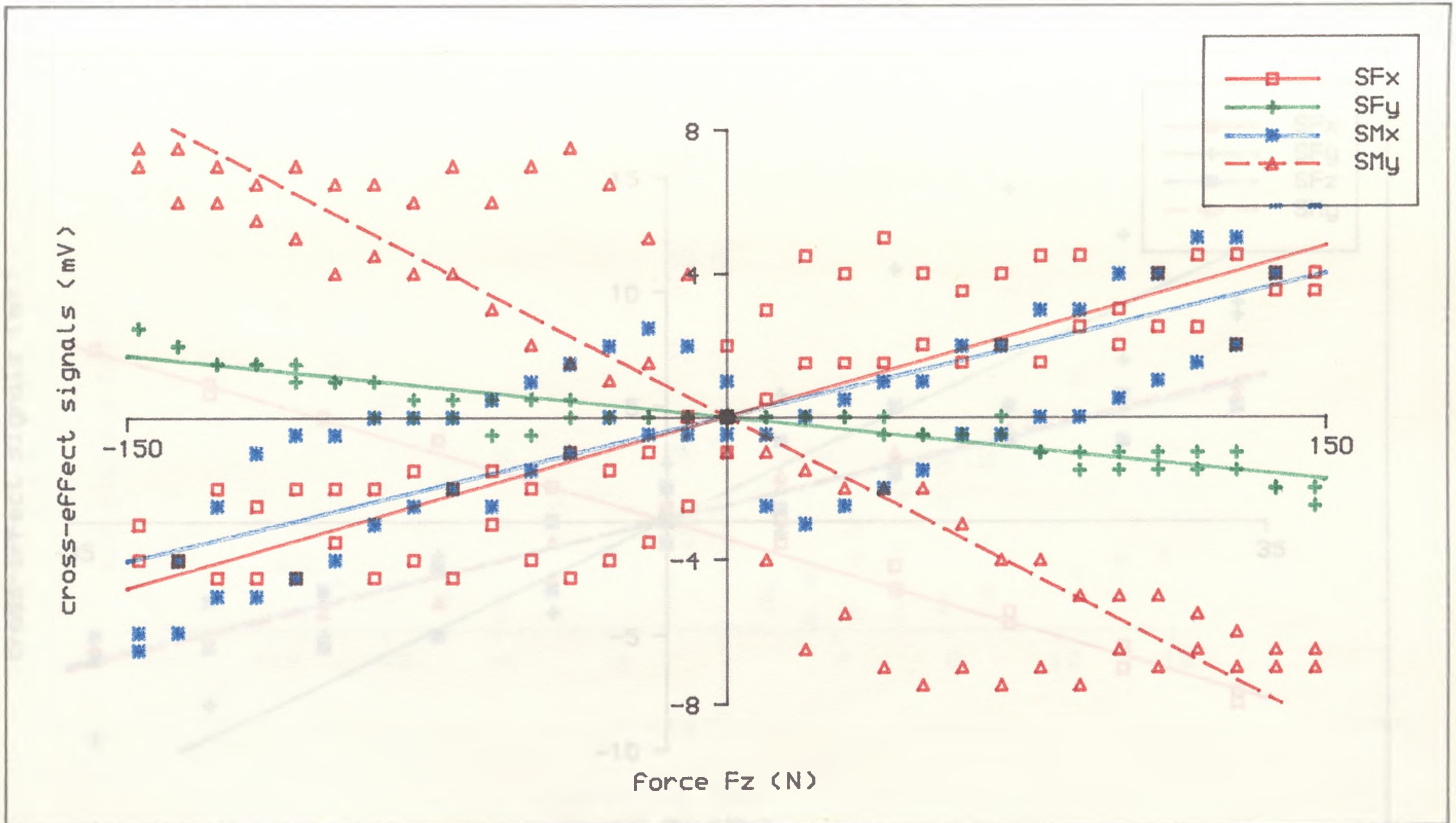


Fig II.10 Cross-effects for applied force Fz

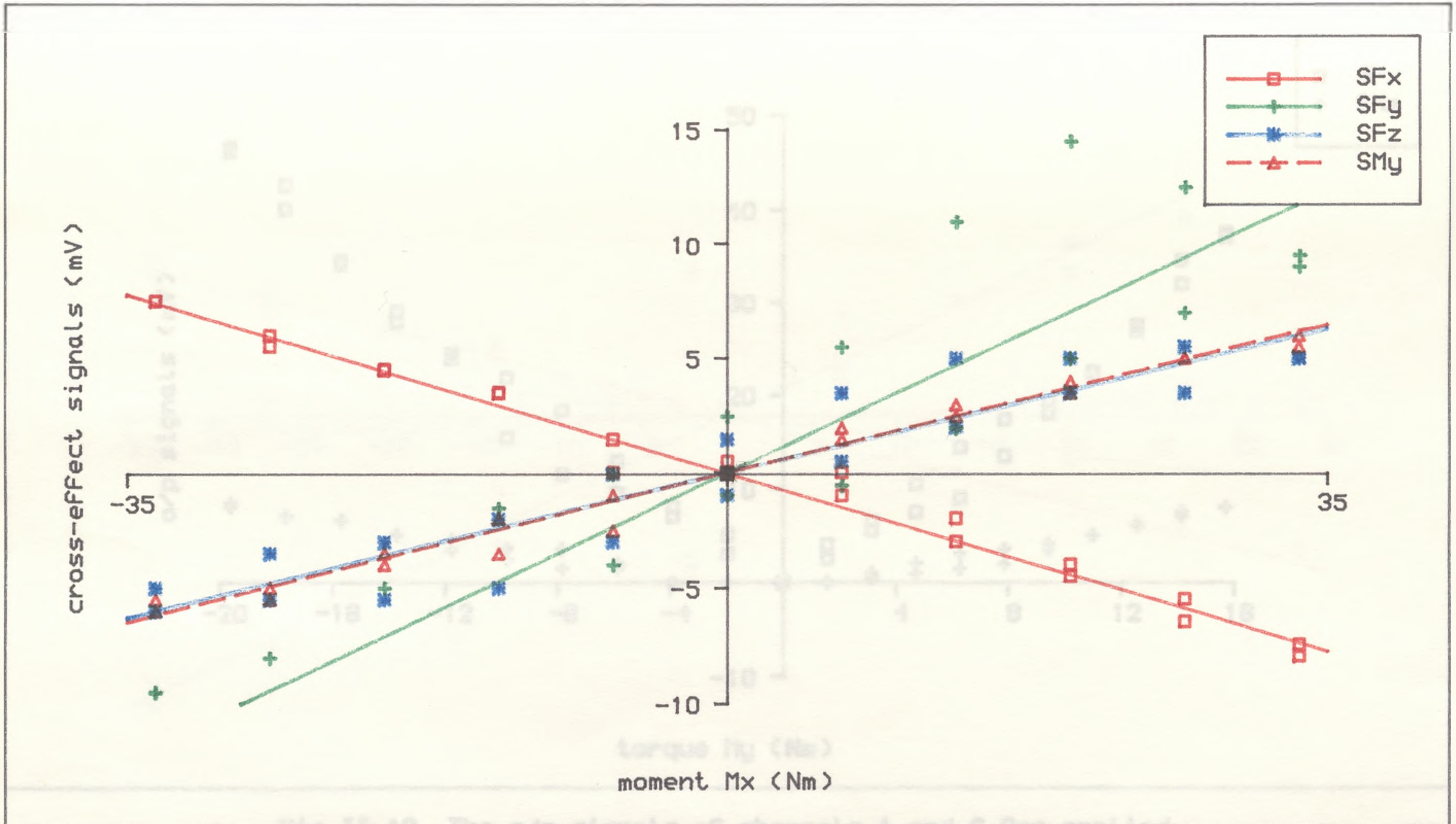


Fig II.11 Cross-effects for applied moment Mx

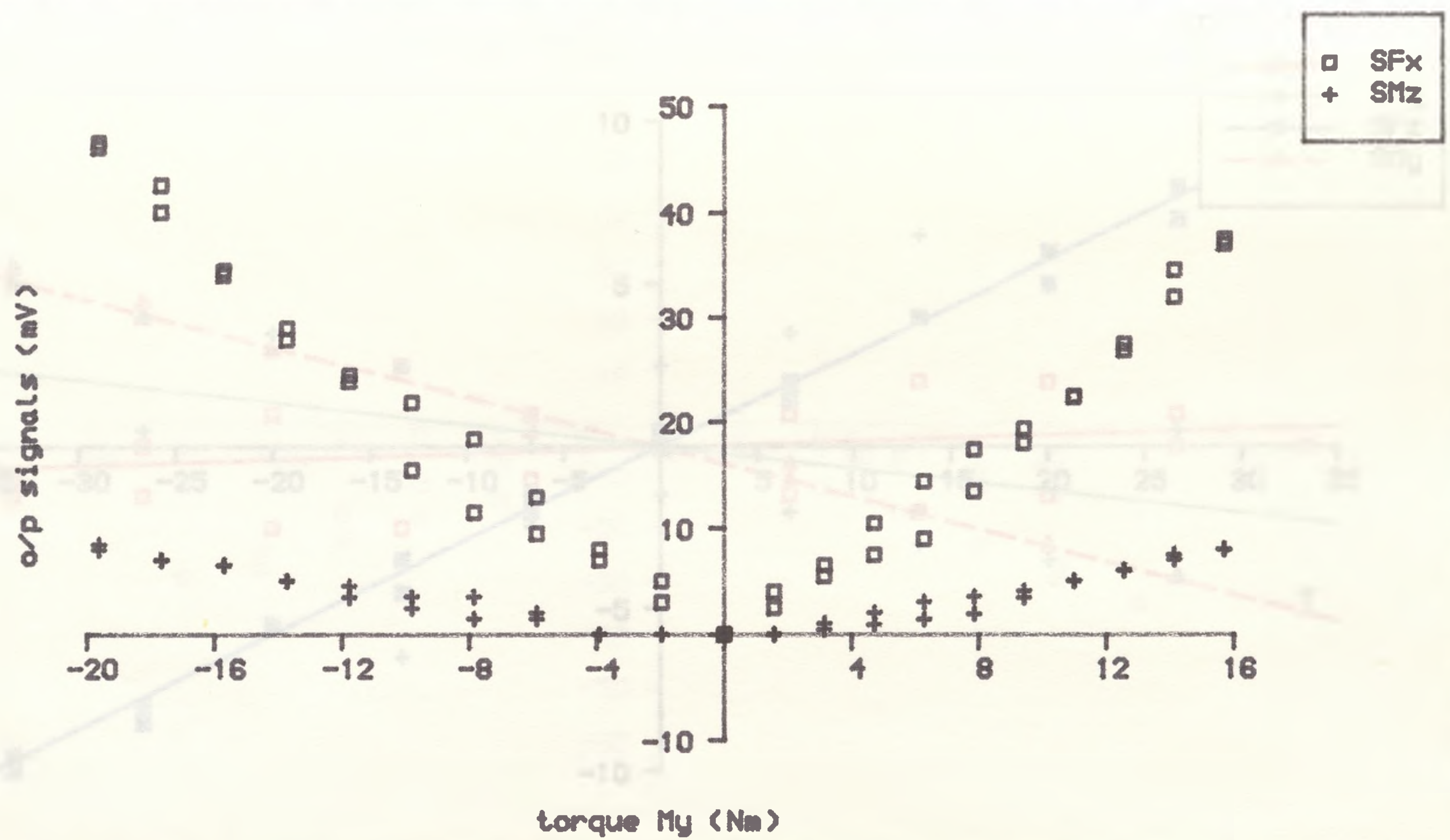


Fig II.12 The o/p signals of channels 1 and 6 for applied torque My using the system Mark I

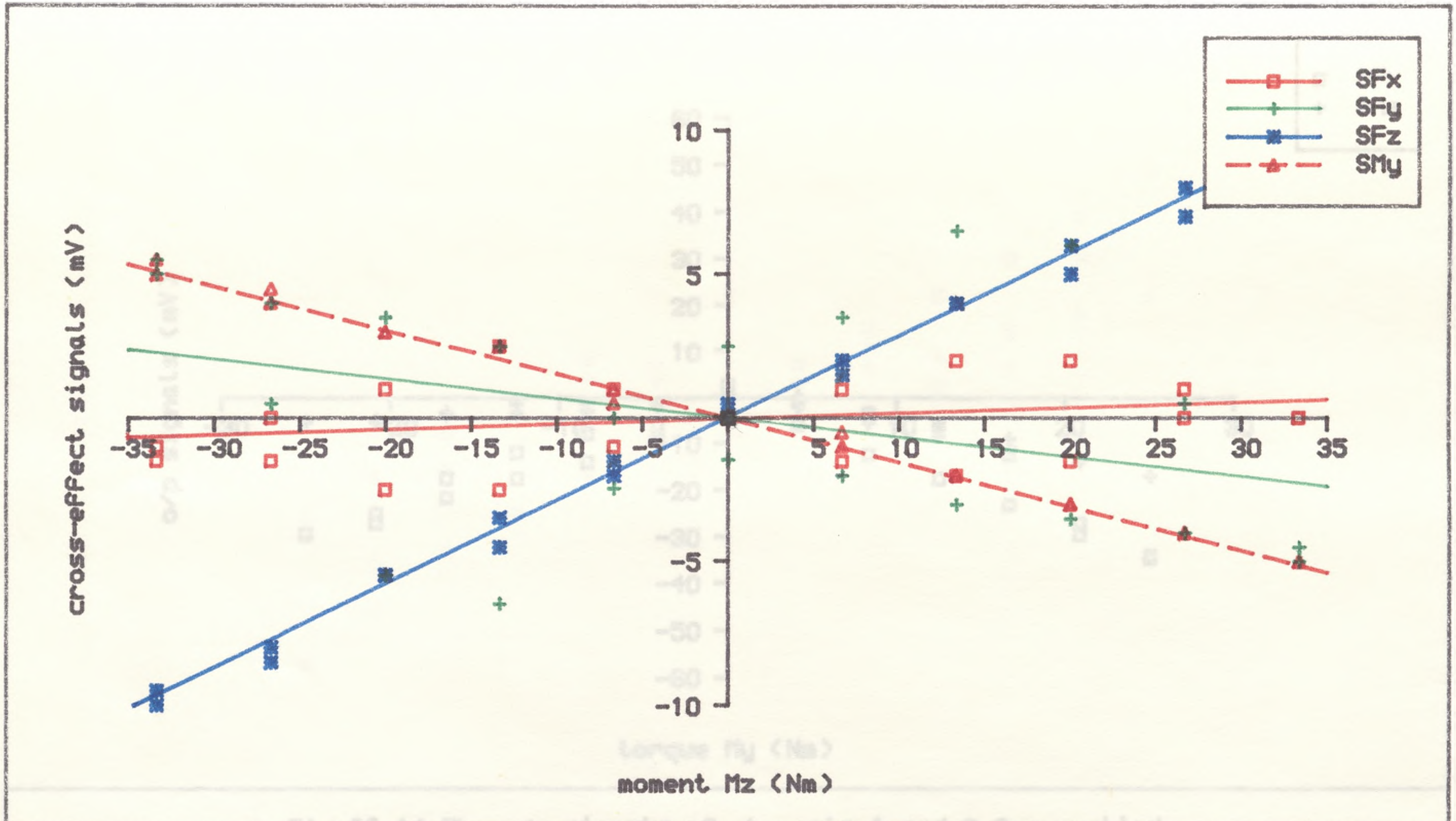


Fig II.13 Cross-effects for applied moment Mz

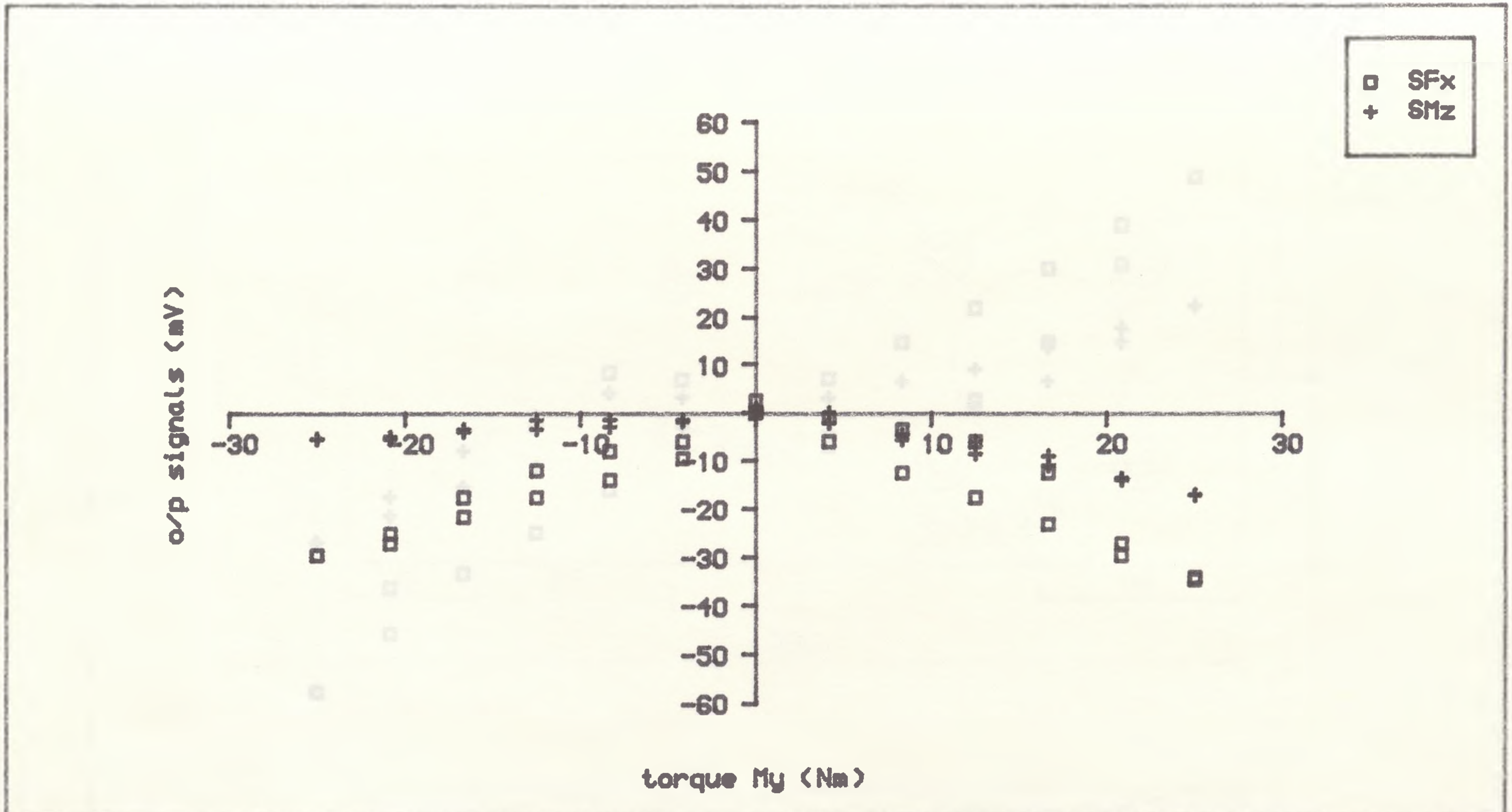


Fig II.14 The o/p signals of channels 1 and 6 for applied torque My using the system Mark II

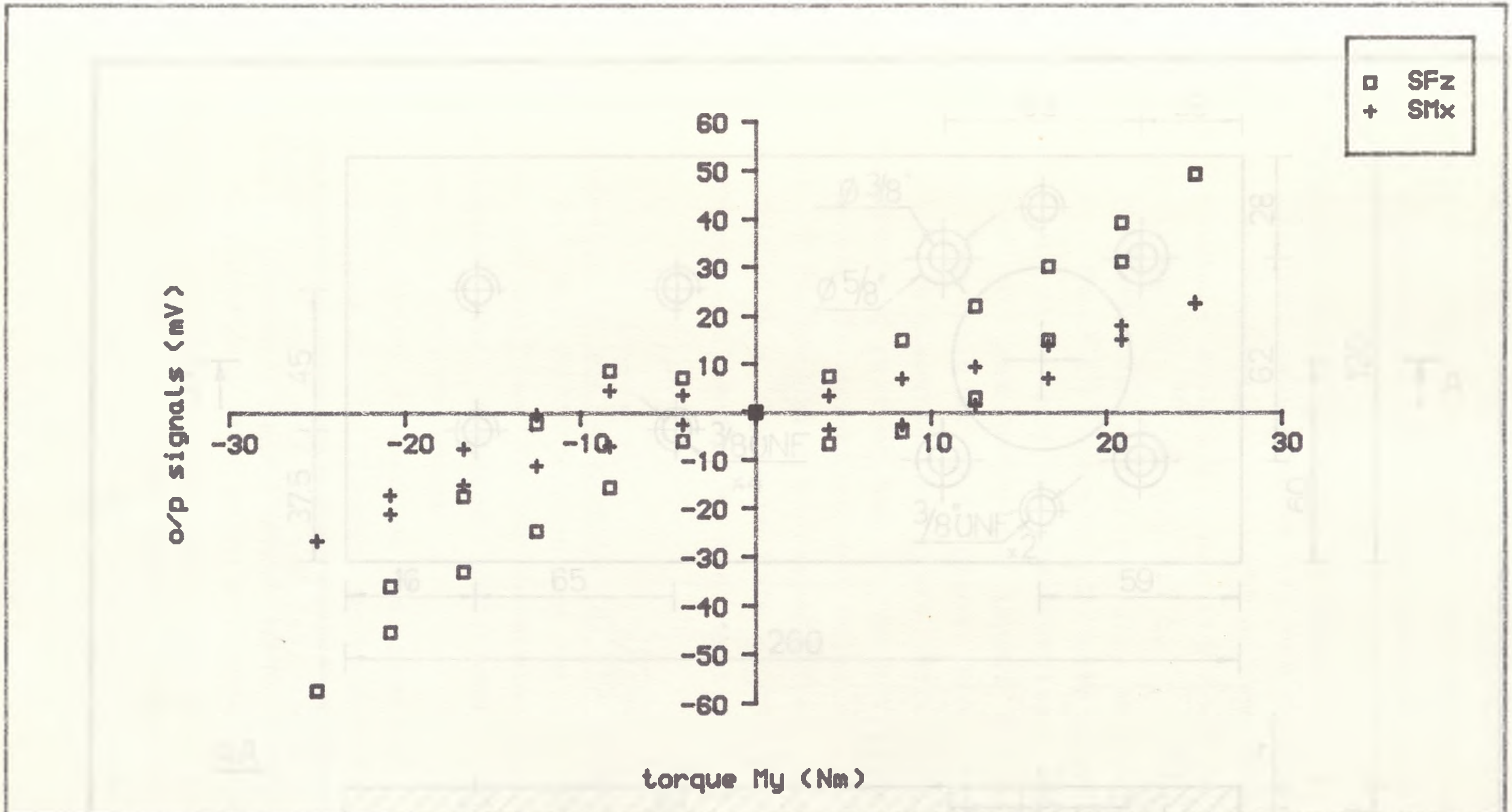


Fig II.15 The o/p signals of channels 3 and 4 for applied torque My using the system Mark II

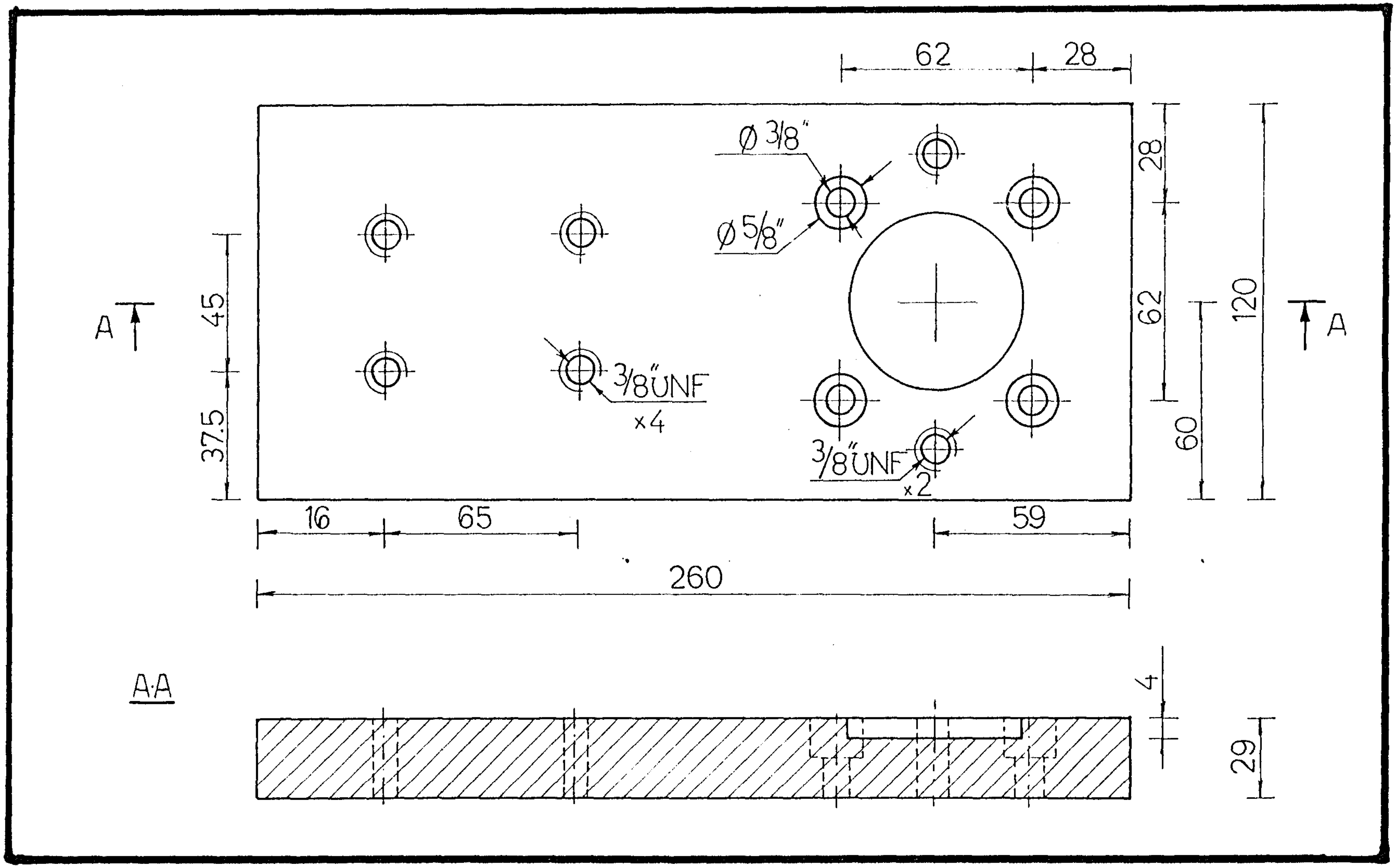


Fig 11.16 The interface plate

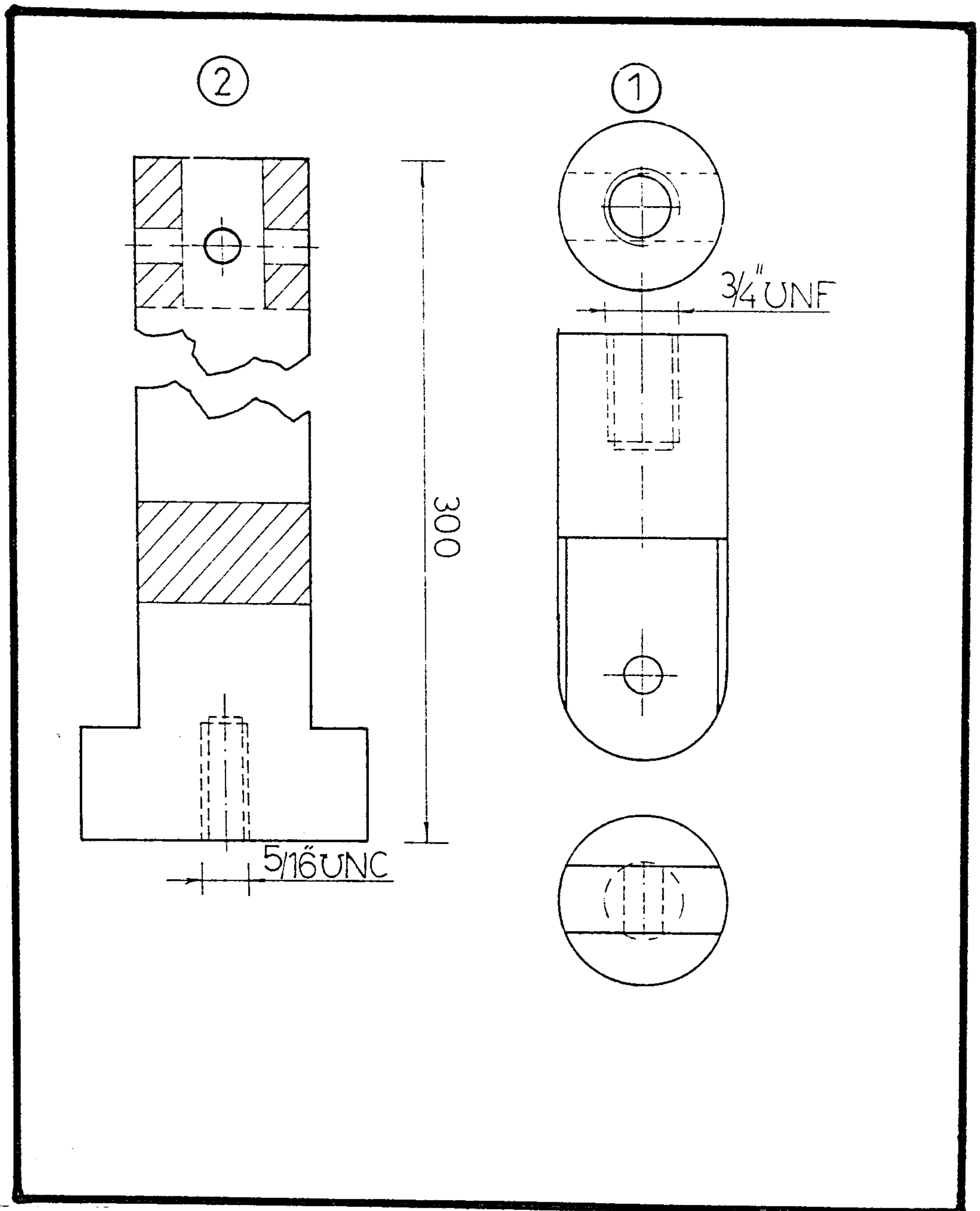


Fig III.1 The vertical bar and the load cell adaptor
(all dimensions in mm except when otherwise stated)

APPENDIX III : Design of the components for chapter 5 and data from the related tests

The device described in chapter 5 consists of a number of components which were designed as follows (all dimensions in mm except otherwise stated) :

The design of the bars and adaptor

The load cell adaptor (1) was designed to match a 0-100 kg compression load cell and was provided with an appropriately machined lower end to a hinge with the vertical bar (2), (see fig III.1).

The upper horizontal bar (3), as well as the lower bar (4), shown in figure III.2, were made from the same aluminium alloy bar as the vertical bar. Both were machined to have pairs of tapped holes along their length, arranged at 20 mm pitch. Each pair of holes on the top horizontal bat were arranged to match a corresponding pair on the bottom horizontal bar ; when the device was assembled and balanced. Each bar had a total of twelve pairs of tapped holes. The top bar was provided with a clearance hole at the left hand side, in order to be mounted at the lower end of the vertical bar.

The design of the components for the rotations

For the pylon transducer to be mounted on the bars, as well as to be possible for the user to implement the required rotations, two pairs of components were designed.

The pylon transducer is provided with centred tapped holes on its flanges. On both these flanges, two specially machined adaptors (5,6) had to be fitted (fig III.3). These two components were identical; flat on the side meeting the pylon's flanges and cylindrical (radius = 50 mm) on the other side. Laterally they were both provided with two tapped holes. From the top of the cylindrical surface, properly machined recesses

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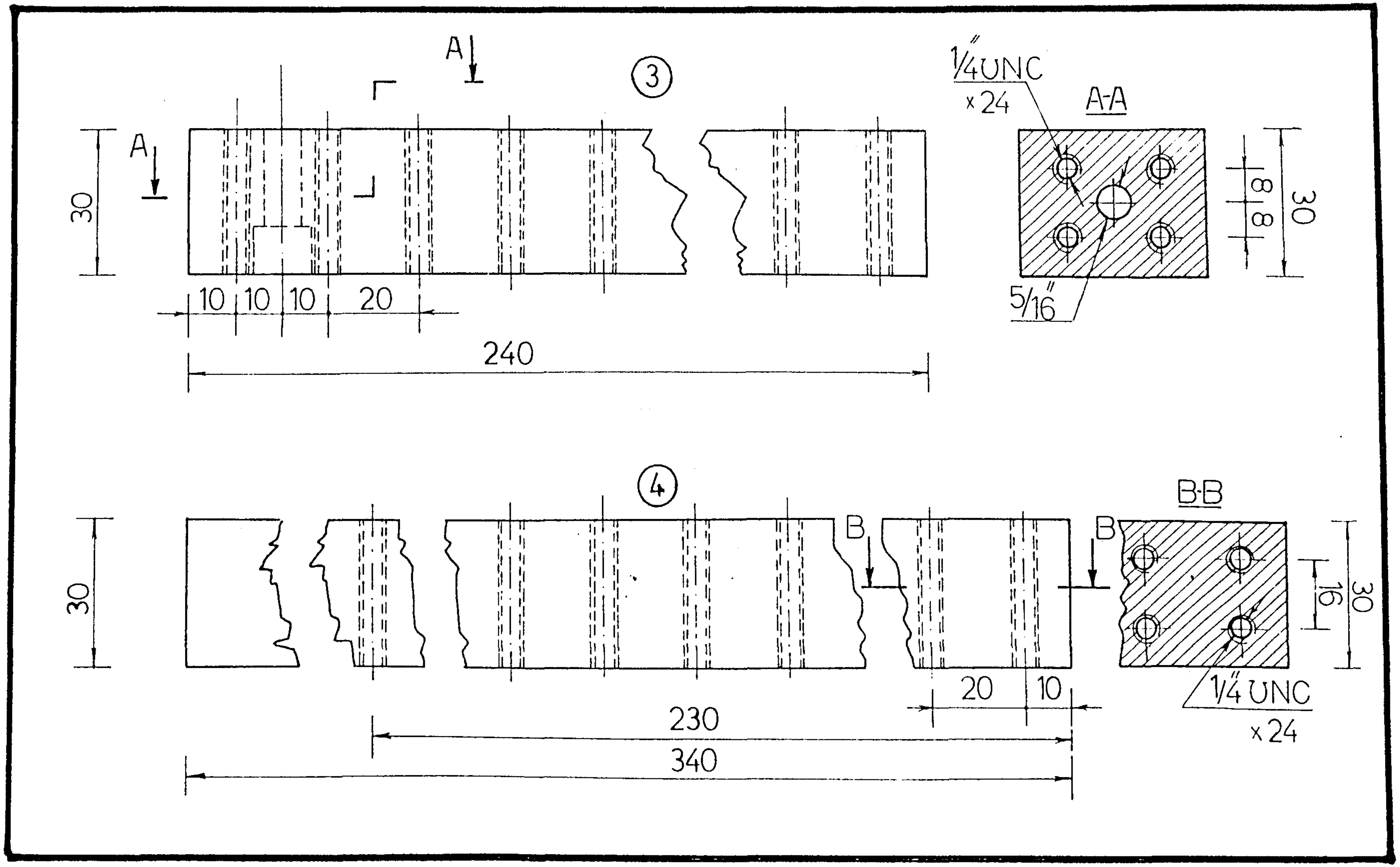

Fig III.2 The two horizontal bars (all dimensions in mm except when otherwise stated) were made to fit in the small foot bolts needed to mount the adaptors on the pylon's flanges.

The pylon transducer total length is 70 mm and so the depth (= 15 mm) of the two components was designed so that when both fitted onto the transducer, the resulting structure corresponded to a cylindrical surface of a diameter of $70 + (2 \times 15) = 100$ mm.

At the flat surface of the one of them, angular graduations were scribed so that the user could assess immediately the orientation in which the pylon would have been fixed.

The last set of components required is shown in figure III.4. These are two components (7,8) having the form of a drilled protractor on one view and the form of a cylindrical bracket on the other view. They were designed to have the same dimensions, with the only difference being that they were the mirror image of one another and thus, the whole setup about the pylon was symmetrical.

These two components were provided with small clearance holes drilled at an angular distance of 18^{o} from one another. These small holes were eight for each of (7) and (8) and provided the user with the possibility of fitting the transducer system at various angular inclinations using the symmetrical pairs of holes of (7) and (8).

Components (7) and (8) were also provided with a set of four clearance holes at the flattened portion of their external cylindrical surface. These latter holes were drilled from the concave to the convex side and were intended to accept screws for the mounting of these protractor shaped components against the top and bottom horizontal bars respectively.

The description of the device's assembly is presented in chapter 5.

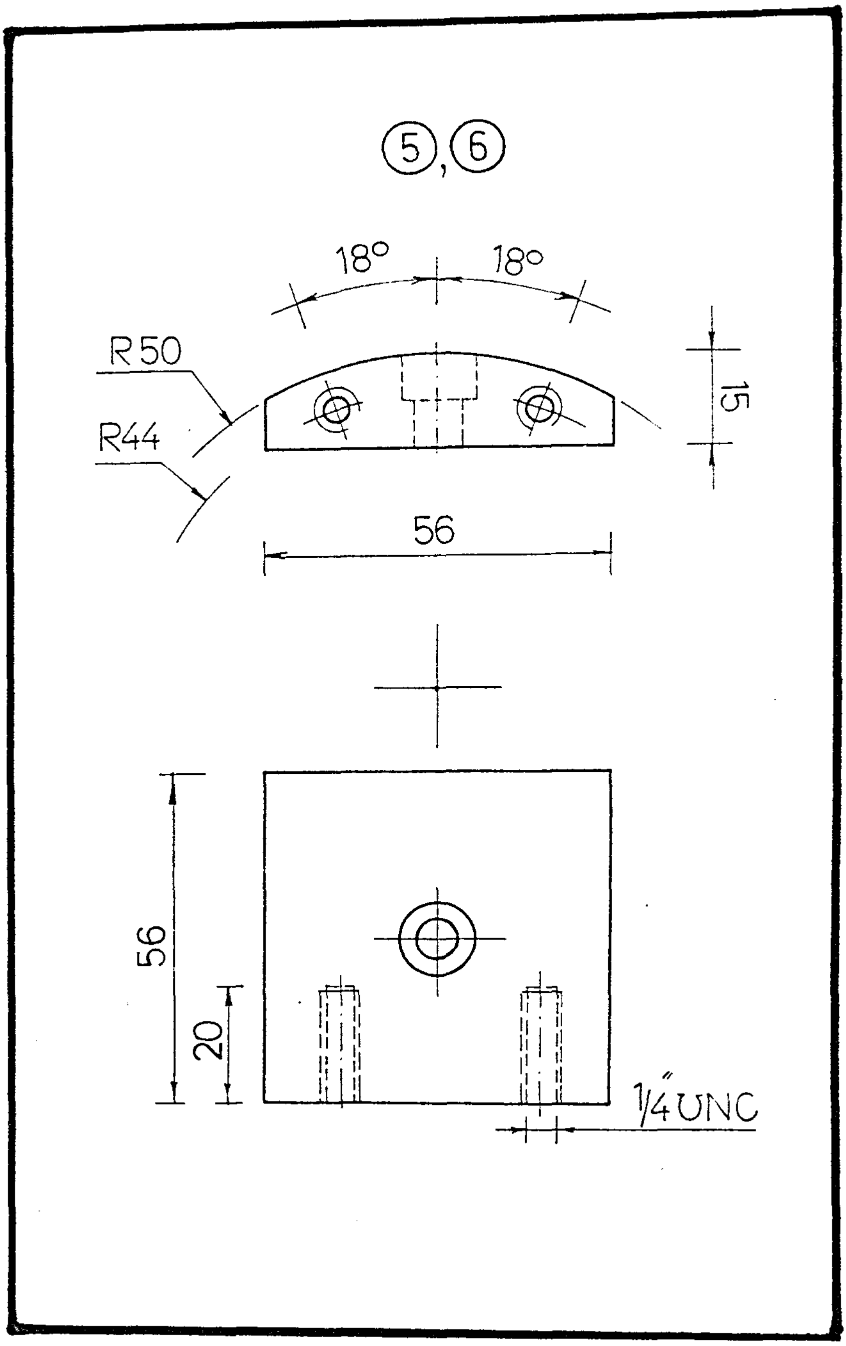

Fig III.3 The two adaptors for the implementation of angle θy (all dimension in mm except when otherwise stated)

The data acquired during the tests are as follows:

applied Fx	predicted Fx	difference
0.000 N	-3.073 N	-3.073 N
-15.160	-14.190	0.970
-28.830	-28.407	0.423
-19.840	-19.311	0.529
-23.320	-22.982	0.338
-24.530	-23.943	0.587
0.000	1.625	1.625
-39.380	-35.281	4.099
-49.940	-46.454	3.486
-34.370	-32.263	2.107
-40.400	-38.514	1.886
-25.490	-24.491	0.999
0.000	4.449	4.449
22.740	26.042	3.302
28.830	30.200	1.370
19.840	20.969	1.129
23.320	24.903	1.583
24.530	24.997	0.467
0.000	4.352	4.352
39.380	41.659	2.279
49.940	53.008	3.068
34.370	35.586	1.216
40.400	41.828	1.428
42.480	44.683	2.203

applied Fy	predicted Fy	difference
98.100 N	100.116 N	2.016 N
93.300	92.453	-0.847
79.360	79.966	0.606
28.830	31.649	2.819
15.160	13.101	-2.059
0.000	1.135	1.135
147.150	144.454	-2.696
139.950	132.058	-7.892
79.360	75.946	-3.414
28.830	30.256	1.426
15.160	15.913	0.753
0.000	2.355	2.355
147.150	153.380	6.230
139.950	147.126	7.176
79.360	79.091	-0.269
28.830	30.775	1.945
15.160	14.107	-1.053
0.000	1.840	1.840
147.150	153.290	6.140
139.950	146.221	6.271
79.360	85.555	6.195
28.830	29.118	0.288
15.160	17.802	2.642
0.000	0.996	0.996

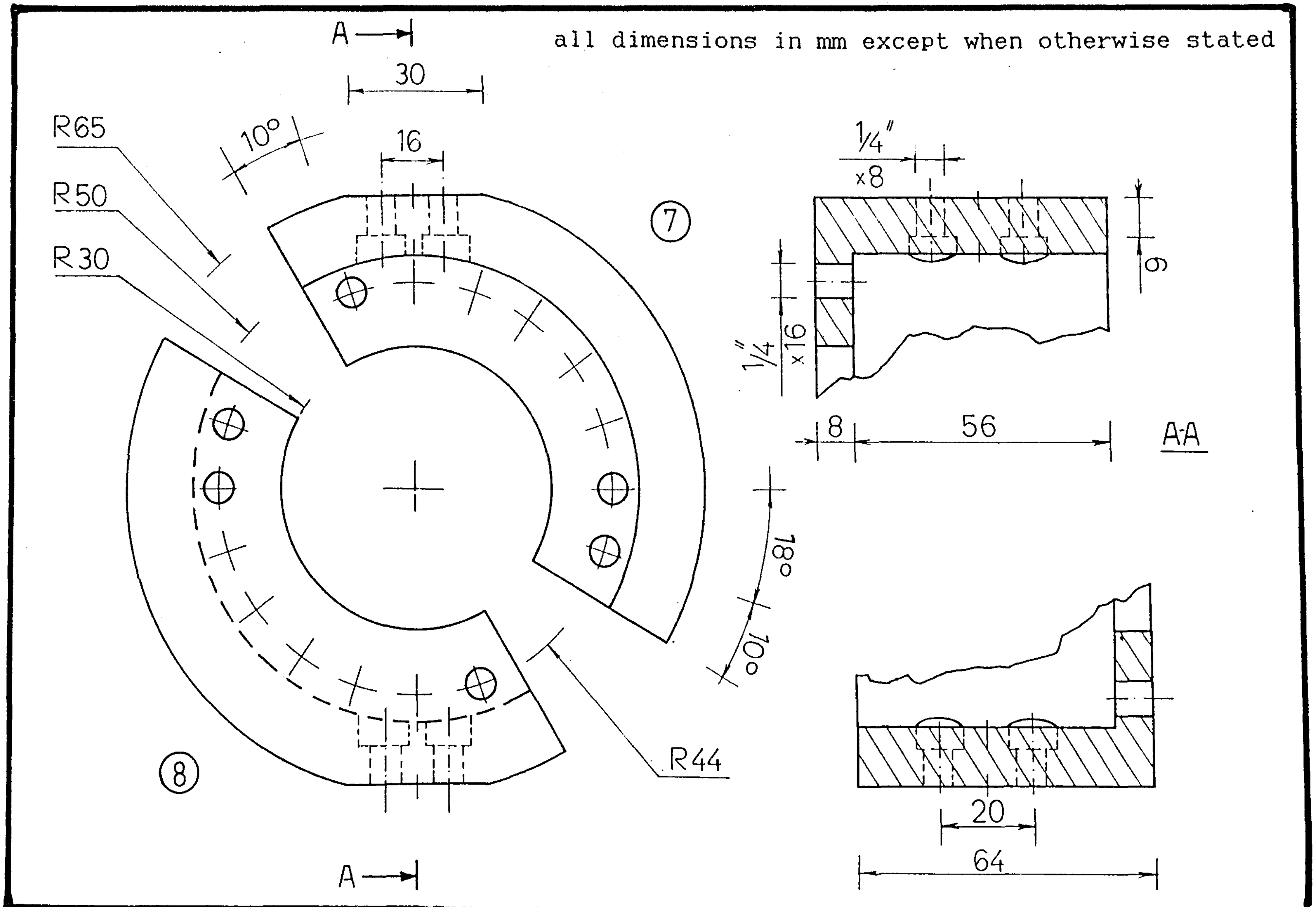

Fig III.4 The two adaptors for the implementation of angle θx

applied Fz	predicted Fz	difference
0.000 N	1.665 N	1.665 N
26.250	30.917	4.667
49.940	57.376	7.436
34.370	39.477	5.107
40.400	46.199	5.799
42.480	48.111	5.631
0.000	3.781	3.781
22.740	32.655	9.915
28.830	36.366	7.536
19.840	26.029	6.189
23.320	29.220	5.900
14.710	17.293	2.583
0.000	-2.423	-2.423
39.380	42.926	3.546
49.940	54.972	5.032
34.370	37.112	2.742
40.400	45.165	4.765
42.480	47.618	5.138
0.000	-4.176	-4.176
22.740	24.936	2.196
28.830	33.488	4.658
19.840	22.523	2.683
23.320	28.181	4.861
24.520	29.228	4.708

applied Mx	predicted Mx	difference
4.910 Nm	4.915 Nm	0.005 Nm
4.660	4.415	-0.245
3.970	3.665	-0.305
1.440	1.333	-0.107
0.760	0.666	-0.094
0.000	0.000	0.000
12.740	12.370	-0.370
12.120	11.495	-0.625
6.870	6.456	-0.414
2.500	2.332	-0.168
1.310	1.208	-0.102
0.000	0.000	0.000
-7.360	-6.789	0.571
-7.000	-6.622	0.378
-3.970	-3.832	0.138
-1.440	-1.416	0.024
-0.760	-0.833	-0.073
0.000	-0.083	-0.083
-12.740	-11.995	0.745
-12.120	-11.662	0.458
-6.870	-6.664	0.206
-2.500	-2.416	0.084
-1.310	-1.291	0.019
0.000	-0.083	-0.083

applied My	predicted My	difference
0.000 Nm	-0.356 Nm	-0.356 Nm
3.030	2.596	-0.434
5.770	5.140	-0.630
3.970	3.613	-0.357
4.660	4.479	-0.181
4.910	4.708	-0.202
0.000	-0.280	-0.280
4.550	4.250	-0.300
5.770	5.497	-0.273
3.970	3.868	-0.102
4.660	4.580	-0.080
2.940	2.926	-0.014
0.000	-0.102	-0.102
4.550	4.224	-0.326
5.770	5.446	-0.324
3.970	3.766	-0.204
4.660	4.453	-0.207
4.910	4.733	-0.177
0.000	-0.102	-0.102
4.550	4.275	-0.275
5.770	5.446	-0.324
3.970	3.792	-0.178
4.660	4.479	-0.181
4.910	4.759	-0.152

applied Mz	predicted Mz	difference
-8.500 Nm	-8.520 Nm	-0.020 Nm
-8.080	-8.009	0.071
-6.870	-6.816	0.054
-2.500	-2.556	-0.056
-1.310	-1.193	0.117
0.000	0.000	0.000
-7.360	-7.157	0.203
-7.000	-6.731	0.269
-3.970	-3.919	0.051
-1.440	-1.363	0.077
-0.760	-0.682	0.078
0.000	0.000	0.000
-12.740	-12.439	0.301
-12.120	-11.843	0.277
-6.870	-6.475	0.395
-2.500	-2.300	0.200
-1.310	-1.022	0.288
0.000	0.000	0.000
-7.360	-7.157	0.203
-7.000	-6.646	0.354
-3.970	-3.578	0.392
-1.440	-1.108	0.332
-0.760	-0.511	0.249
0.000	0.000	0.000

APPENDIX IV : Print-outs obtained from the kneeling tests

The files with the parameters of the prosthesis for the two different types of feet and the two different toe-out angles (0^o and 90^o) are as follows (parameters p_1 to p_8 in meters) :

Multiflex foot		SACH foot	
MULT00.DAT	MULT90.DAT	SACH00.DAT	SACH90.DAT
0.1960	0.0500	0.1950	0.0450
0.0400	0.0480	0.0400	0.0480
0.0000	0.1200	0.0000	0.1200
0.4875	0.4650	0.4825	0.4500
0.0015	0.0015	0.0015	0.0015
0.1810	0.1810	0.1760	0.1660
0.4620	0.4620	0.4570	0.4470
0.4875	0.4875	0.4825	0.4725

In chapter 10 it is mentioned that 9 different pilot tests were performed. Each one consisted of 3 trials. Furthermore, a second series of 15 tests were carried out. The complete print-outs for all these trials are presented in this appendix :

Test No 1

THIS IS FILE WR21

WITH RESULTS OF TEST KNEEL021.DAT

DURATION	4.80	s
MAX.REACTION FY1	-123.3	N
OCCURING AT TIME	4.64	s

LOADS

ON FP1	ON FP2	ON PT	
41.2	-26.1	-114.1	N
123.3	452.6	6.9	N
13.2	-76.1	11.4	N
12.8	15.5	-1.9	Nm
-4.2	-4.7	-1.4	Nm
9.2	-32.9	-24.1	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.088 ZF1 = -0.099 m

XF2 = -0.075 ZF2 = -0.041 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-130.2 R2 = 2.4 R3 = -10.6 N

R4 =-412.1 R5 =-197.3 R6 = -50.9 N

WEIGHT LEVERARM % = 21.4 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-59.7	-56.1
SHIN LOAD (N)	2800.3	2643.1
KNEE LOAD (N)	2324.0	2181.9

COMPARISON RESULTS

DIFF1 = -16.1 N

DIFF2 = -4.6 N

DIFF3 = -22.0 N

DIFF4 = 3.8 Nm

DIFF5 = 3.4 Nm

DIFF6 = 1.0 Nm

EVAL1 = 4.8 Nm

EVAL2 = 0.1 Nm

EVAL3 = -0.9 Nm

THIS IS FILE WR22

WITH RESULTS OF TEST KNEEL022.DAT

DURATION	4.46	s
MAX.REACTION FY1	-128.2	N
OCCURING AT TIME	4.36	s

LOADS

ON FP1	ON FP2	ON PT	
41.2	-20.1	-118.2	N
128.2	384.9	1.8	N
14.4	-89.7	22.9	N
13.0	7.2	-4.3	Nm
-4.1	-5.9	-3.5	Nm
10.8	-26.3	-24.5	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.097 ZF1 = -0.097 m

XF2 = -0.070 ZF2 = -0.028 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-135.1 R2 = 1.3 R3 = -10.4 N

R4 =-346.6 R5 =-180.0 R6 = -64.2 N

WEIGHT LEVERARM % = 25.0 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-62.1	-57.7
SHIN LOAD (N)	2875.2	2684.0
KNEE LOAD (N)	2451.1	2277.1

COMPARISON RESULTS

DIFF1 = -16.9 N

DIFF2 = -0.5 N

DIFF3 = -33.3 N

DIFF4 = 6.2 Nm

DIFF5 = 5.5 Nm

DIFF6 = 0.3 Nm

EVAL1 = 3.5 Nm

EVAL2 = -0.1 Nm

EVAL3 = -1.0 Nm

THIS IS FILE WR23

WITH RESULTS OF TEST KNEEL023.DAT

DURATION	4.58	s
MAX.REACTION FY1	-128.2	N
OCCURING AT TIME	4.48	s

LOADS

ON FP1	ON FP2	ON PT	
46.5	-62.2	-120.6	N
128.2	421.3	3.1	N
9.4	-85.7	17.5	N
0.4	18.1	-3.3	Nm
0.6	-4.7	-3.1	Nm
-0.3	-34.5	-25.3	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.012 ZF1 = 0.000 m

XF2 = -0.088 ZF2 = -0.051 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-136.5 R2 = 5.8 R3 = -5.5 N

R4 =-375.1 R5 =-210.0 R6 = -62.2 N

WEIGHT LEVERARM % = 23.3 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-61.9	-59.2
SHIN LOAD (N)	2915.4	2791.5
KNEE LOAD (N)	2470.2	2363.2

COMPARISON RESULTS

DIFF1 = -16.0 N
DIFF2 = 2.7 N
DIFF3 = -23.0 N
DIFF4 = 4.3 Nm
DIFF5 = 4.2 Nm
DIFF6 = 1.8 Nm

EVAL1 = 4.1 Nm
EVAL2 = -0.1 Nm
EVAL3 = -0.3 Nm

Test No 2

THIS IS FILE WR25

WITH RESULTS OF TEST KNEEL025.DAT

DURATION	4.26	s
MAX.REACTION FY1	-175.4	N
OCCURING AT TIME	3.90	s

LOADS

ON FP1	ON FP2	ON PT	
66.4	-4.8	-169.1	N
175.4	331.0	-0.2	N
2.3	-49.8	5.3	N
15.6	9.6	-1.2	Nm
-5.0	-6.9	1.0	Nm
-3.4	-45.3	-37.5	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = -0.004 ZF1 = -0.089 m

XF2 = -0.138 ZF2 = -0.035 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-185.0 R2 = 2.6 R3 = -30.9 N

R4 =-306.5 R5 =-128.4 R6 = -40.8 N

WEIGHT LEVERARM % = 34.6 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-85.0	-85.0
SHIN LOAD (N)	3745.4	3730.4
KNEE LOAD (N)	3294.1	3295.3

COMPARISON RESULTS

DIFF1 = -16.0 N

DIFF2 = 2.8 N

DIFF3 = -36.2 N

DIFF4 = 6.8 Nm

DIFF5 = 5.0 Nm

DIFF6 = 4.5 Nm

EVAL1 = 6.8 Nm

EVAL2 = -0.2 Nm

EVAL3 = -2.1 Nm

THIS IS FILE WR26

WITH RESULTS OF TEST KNEEL026.DAT

DURATION	6.14	s
MAX.REACTION FY1	-141.9	N
OCCURING AT TIME	4.62	s

LOADS

ON FP1	ON FP2	ON PT	
47.6	-18.4	-131.8	N
141.9	337.3	1.8	N
6.1	-71.5	13.9	N
13.8	31.3	-2.1	Nm
-4.3	-5.0	-1.4	Nm
1.0	-32.4	-27.6	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.020 ZF1 = -0.096 m

XF2 = -0.098 ZF2 = -0.101 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-149.2 R2 = 0.7 R3 = -13.3 N

R4 =-307.4 R5 =-145.9 R6 = -58.3 N

WEIGHT LEVERARM % = 29.6 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-68.8	-64.6
SHIN LOAD (N)	3098.4	2915.4
KNEE LOAD (N)	2687.7	2521.8

COMPARISON RESULTS

DIFF1 = -17.4 N
DIFF2 = -1.1 N
DIFF3 = -27.2 N
DIFF4 = 4.5 Nm
DIFF5 = 4.0 Nm
DIFF6 = 0.7 Nm

EVAL1 = 4.1 Nm
EVAL2 = 0.4 Nm
EVAL3 = -1.3 Nm

THIS IS FILE WR27

WITH RESULTS OF TEST KNEEL027.DAT

DURATION	3.70	s
MAX.REACTION FY1	-221.4	N
OCCURING AT TIME	3.20	s

LOADS

ON FP1	ON FP2	ON PT	
81.4	-31.0	-211.3	N
221.4	263.3	-3.3	N
12.3	-100.7	29.1	N
9.2	4.4	-6.2	Nm
-2.3	-9.3	-4.6	Nm
1.2	-26.8	-45.0	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.020 ZF1 = -0.039 m
XF2 = -0.106 ZF2 = -0.032 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-234.9 R2 = 7.7 R3 = -23.3 N
R4 =-229.3 R5 =-147.6 R6 = -78.2 N

WEIGHT LEVERARM % = 45.7 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-107.0	-104.4
SHIN LOAD (N)	4696.3	4568.0
KNEE LOAD (N)	4273.4	4170.8

COMPARISON RESULTS
DIFF1 = -23.5 N
DIFF2 = 11.0 N
DIFF3 = -52.4 N
DIFF4 = 10.4 Nm
DIFF5 = 9.1 Nm
DIFF6 = 4.0 Nm

EVAL1 = 6.1 Nm
EVAL2 = -0.9 Nm
EVAL3 = -1.1 Nm

Test No 3

THIS IS FILE WR28

WITH RESULTS OF TEST KNEEL028.DAT

DURATION	5.08	s
MAX.REACTION FY1	-320.7	N
OCCURING AT TIME	4.74	s

LOADS

ON FP1	ON FP2	ON PT	
83.1	-81.4	-303.6	N
320.7	326.0	63.3	N
10.6	-55.1	-11.6	N
15.6	14.7	-3.3	Nm
-3.0	-2.8	-15.6	Nm
30.2	-38.7	-51.5	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.104 ZF1 = -0.047 m

XF2 = -0.129 ZF2 = -0.052 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-321.0 R2 = 65.7 R3 = -50.2 N

R4 =-325.6 R5 = -98.2 R6 = 17.1 N

WEIGHT LEVERARM % = 49.6 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-145.0	-136.8
SHIN LOAD (N)	6526.1	6183.9
KNEE LOAD (N)	5899.7	5575.0

COMPARISON RESULTS

DIFF1 = -17.4 N

DIFF2 = 2.4 N

DIFF3 = -38.6 N

DIFF4 = 4.5 Nm

DIFF5 = -20.4 Nm

DIFF6 = -3.3 Nm

EVAL1 = -0.3 Nm

EVAL2 = 2.2 Nm

EVAL3 = -20.2 Nm

THIS IS FILE WR29

WITH RESULTS OF TEST KNEEL029.DAT

DURATION	6.64	s
MAX.REACTION FY1	-261.1	N
OCCURING AT TIME	6.62	s

LOADS

ON FP1	ON FP2	ON PT	
61.1	-63.9	-245.8	N
261.1	288.4	45.4	N
-3.4	-51.9	-8.1	N
-3.3	11.6	-3.7	Nm
3.2	0.2	-14.4	Nm
33.5	-13.6	-41.8	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.138 ZF1 = 0.012 m

XF2 = -0.056 ZF2 = -0.048 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-261.3 R2 = 46.8 R3 = -38.0 N

R4 =-288.1 R5 = -83.4 R6 = -5.5 N

WEIGHT LEVERARM % = 47.5 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-118.4	-110.9
SHIN LOAD (N)	5352.9	5040.4
KNEE LOAD (N)	4822.6	4525.7

COMPARISON RESULTS

DIFF1 = -15.4 N
DIFF2 = 1.4 N
DIFF3 = -29.9 N
DIFF4 = 4.9 Nm
DIFF5 = -15.1 Nm
DIFF6 = -3.2 Nm

EVAL1 = -0.5 Nm
EVAL2 = 0.3 Nm
EVAL3 = -14.7 Nm

THIS IS FILE WR30

WITH RESULTS OF TEST KNEEL030.DAT

DURATION	5.50	s
MAX.REACTION FY1	-242.5	N
OCCURING AT TIME	5.34	s

LOADS

ON FP1	ON FP2	ON PT	
72.1	-42.6	-225.7	N
242.5	333.5	51.7	N
9.3	-38.7	-13.7	N
16.7	25.9	-2.3	Nm
-3.3	-1.1	-19.9	Nm
15.4	-43.7	-39.5	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.076 ZF1 = -0.067 m

XF2 = -0.136 ZF2 = -0.082 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-242.7 R2 = 59.1 R3 = -40.9 N

R4 =-333.3 R5 = -59.0 R6 = -0.7 N

WEIGHT LEVERARM % = 42.1 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-109.2	-103.0
SHIN LOAD (N)	4965.1	4701.8
KNEE LOAD (N)	4401.1	4156.1

COMPARISON RESULTS

DIFF1 = -17.0 N

DIFF2 = 7.4 N

DIFF3 = -27.2 N

DIFF4 = 2.7 Nm

DIFF5 = -7.1 Nm

DIFF6 = -1.5 Nm

EVAL1 = 1.2 Nm

EVAL2 = 1.4 Nm

EVAL3 = -6.5 Nm

Test No 4

THIS IS FILE WR31

WITH RESULTS OF TEST KNEEL031.DAT

DURATION	3.10	s
MAX.REACTION FY1	-123.3	N
OCCURING AT TIME	2.60	s

LOADS

ON FP1	ON FP2	ON PT	
28.0	-28.4	-116.1	N
123.3	398.7	-6.9	N
1.0	-78.1	8.7	N
4.5	-0.8	-1.2	Nm
-1.0	-9.1	-0.5	Nm
5.6	-50.9	-23.3	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.055 ZF1 = -0.036 m
XF2 = -0.130 ZF2 = -0.006 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-124.9 R2 = -14.2 R3 = -13.3 N
R4 =-360.0 R5 =-182.9 R6 = -53.0 N

WEIGHT LEVERARM % = 23.6 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-59.9	-55.9
SHIN LOAD (N)	2779.1	2613.8
KNEE LOAD (N)	2358.0	2200.2

COMPARISON RESULTS
DIFF1 = -8.8 N
DIFF2 = -7.3 N
DIFF3 = -22.1 N
DIFF4 = 3.5 Nm
DIFF5 = 3.1 Nm
DIFF6 = -1.5 Nm

EVAL1 = 1.5 Nm
EVAL2 = 0.4 Nm
EVAL3 = -1.2 Nm

THIS IS FILE WR32

WITH RESULTS OF TEST KNEEL032.DAT

DURATION	4.84	s
MAX.REACTION FY1	-112.1	N
OCCURING AT TIME	4.20	s

LOADS

ON FP1	ON FP2	ON PT	
14.5	-14.5	-98.4	N
112.1	376.1	-12.4	N
9.1	-91.6	23.9	N
-0.2	7.8	-4.1	Nm
-0.2	-9.6	-4.0	Nm
3.5	-39.2	-21.0	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.037 ZF1 = 0.005 m

XF2 = -0.106 ZF2 = -0.030 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-111.9 R2 = -18.2 R3 = 3.2 N

R4 =-343.8 R5 =-159.6 R6 = -80.0 N

WEIGHT LEVERARM % = 23.0 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-54.7	-48.7
SHIN LOAD (N)	2525.1	2274.5
KNEE LOAD (N)	2127.9	1890.3

COMPARISON RESULTS

DIFF1 = -13.5 N

DIFF2 = -5.9 N

DIFF3 = -20.8 N

DIFF4 = 3.5 Nm

DIFF5 = 3.4 Nm

DIFF6 = -2.2 Nm

EVAL1 = 1.3 Nm

EVAL2 = 0.1 Nm

EVAL3 = -0.7 Nm

THIS IS FILE WR33

WITH RESULTS OF TEST KNEEL033.DAT

DURATION	4.92	s
MAX.REACTION FY1	-140.7	N
OCCURING AT TIME	4.48	s

LOADS

ON FP1	ON FP2	ON PT	
28.0	-32.4	-131.6	N
140.7	441.3	-17.7	N
7.3	-83.0	15.0	N
9.2	22.8	-2.1	Nm
-2.2	-7.1	-1.6	Nm
6.9	-46.4	-26.1	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.057 ZF1 = -0.063 m

XF2 = -0.108 ZF2 = -0.059 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-142.6 R2 = -16.0 R3 = -6.0 N

R4 =-400.0 R5 =-197.9 R6 = -59.8 N

WEIGHT LEVERARM % = 24.2 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-68.3	-63.1
SHIN LOAD (N)	3153.6	2937.8
KNEE LOAD (N)	2680.2	2477.0

COMPARISON RESULTS

DIFF1 = -11.0 N
DIFF2 = 1.6 N
DIFF3 = -21.0 N
DIFF4 = 3.1 Nm
DIFF5 = 2.8 Nm
DIFF6 = -2.1 Nm

EVAL1 = -0.5 Nm
EVAL2 = 0.5 Nm
EVAL3 = -1.3 Nm

Test No 5

THIS IS FILE WR34

WITH RESULTS OF TEST KNEEL034.DAT

DURATION	8.10	s
MAX.REACTION FY1	-201.5	N
OCCURING AT TIME	8.08	s

LOADS

ON FP1	ON FP2	ON PT	
49.4	-58.2	-190.1	N
201.5	338.5	38.3	N
-5.0	-42.4	3.2	N
-12.8	6.5	-3.0	Nm
3.9	-1.4	-19.3	Nm
19.3	-22.6	-31.3	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.106 ZF1 = 0.063 m

XF2 = -0.074 ZF2 = -0.024 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-201.2 R2 = 40.6 R3 = -30.3 N

R4 =-339.0 R5 = -69.6 R6 = -5.3 N

WEIGHT LEVERARM % = 37.3 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-88.1	-84.7
SHIN LOAD (N)	4116.5	3968.6
KNEE LOAD (N)	3594.1	3457.7

COMPARISON RESULTS

DIFF1 = -11.2 N
DIFF2 = 2.4 N
DIFF3 = -33.4 N
DIFF4 = 3.1 Nm
DIFF5 = -3.4 Nm
DIFF6 = -0.3 Nm

EVAL1 = 1.4 Nm
EVAL2 = 2.1 Nm
EVAL3 = -3.6 Nm

THIS IS FILE WR35

WITH RESULTS OF TEST KNEEL035.DAT

DURATION	4.60	s
MAX.REACTION FY1	-202.7	N
OCCURING AT TIME	4.14	s

LOADS

ON FP1	ON FP2	ON PT	
46.5	-43.3	-190.0	N
202.7	372.4	35.8	N
6.4	-79.8	-1.1	N
12.5	23.8	-1.8	Nm
-3.1	-3.8	-21.3	Nm
20.1	-33.7	-32.3	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.108 ZF1 = -0.061 m

XF2 = -0.095 ZF2 = -0.072 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-202.5 R2 = 40.3 R3 = -26.3 N

R4 =-372.9 R5 = -83.0 R6 = -30.5 N

WEIGHT LEVERARM % = 35.3 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-88.7	-85.7
SHIN LOAD (N)	4195.9	4064.6
KNEE LOAD (N)	3642.4	3524.3

COMPARISON RESULTS

DIFF1 = -12.5 N
DIFF2 = 4.5 N
DIFF3 = -25.2 N
DIFF4 = 1.3 Nm
DIFF5 = -1.8 Nm
DIFF6 = 0.5 Nm

EVAL1 = 2.4 Nm
EVAL2 = 2.3 Nm
EVAL3 = -1.5 Nm

Note : the third trial is not presented; not taken into account either (unsuccefull data acquisition).

Test No 6

THIS IS FILE WR38

WITH RESULTS OF TEST KNEEL038.DAT

DURATION	4.84	s
MAX.REACTION FY1	-164.3	N
OCCURING AT TIME	4.04	s

LOADS

ON FP1	ON FP2	ON PT	
36.6	-3.8	-157.5	N
164.3	347.3	-12.6	N
1.7	-41.2	2.0	N
14.9	23.0	-0.2	Nm
-3.6	-2.7	-1.1	Nm
15.9	-26.3	-30.3	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.106 ZF1 = -0.090 m

XF2 = -0.076 ZF2 = -0.071 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-166.4 R2 = -19.0 R3 = -16.2 N

R4 =-323.5 R5 =-128.5 R6 = -34.1 N

WEIGHT LEVERARM % = 32.1 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-79.8	-74.6
SHIN LOAD (N)	3520.8	3306.7
KNEE LOAD (N)	3077.2	2870.7

COMPARISON RESULTS

DIFF1 = -8.9 N

DIFF2 = -6.4 N

DIFF3 = -18.2 N

DIFF4 = 3.0 Nm

DIFF5 = 4.3 Nm

DIFF6 = -2.7 Nm

EVAL1 = 0.1 Nm

EVAL2 = 0.2 Nm

EVAL3 = 0.7 Nm

THIS IS FILE WR39

WITH RESULTS OF TEST KNEEL039.DAT

DURATION	4.94	s
MAX.REACTION FY1	-163.0	N
OCCURING AT TIME	3.76	s

LOADS

ON FP1	ON FP2	ON PT	
35.5	-30.0	-154.8	N
163.0	368.6	-16.0	N
7.2	-70.7	9.2	N
10.5	13.2	-1.1	Nm
-2.9	-5.2	-2.3	Nm
12.3	-32.6	-30.0	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.084 ZF1 = -0.062 m

XF2 = -0.092 ZF2 = -0.043 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-165.8 R2 = -16.9 R3 = -10.8 N

R4 =-332.5 R5 =-170.2 R6 = -47.6 N

WEIGHT LEVERARM % = 30.7 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-79.1	-73.5
SHIN LOAD (N)	3558.6	3326.5
KNEE LOAD (N)	3117.7	2896.8

COMPARISON RESULTS

DIFF1 = -11.0 N
DIFF2 = -1.0 N
DIFF3 = -20.0 N
DIFF4 = 3.0 Nm
DIFF5 = 4.4 Nm
DIFF6 = -2.5 Nm

EVAL1 = -0.4 Nm
EVAL2 = 0.5 Nm
EVAL3 = 0.5 Nm

THIS IS FILE WR40

WITH RESULTS OF TEST KNEEL040.DAT

DURATION	4.44	s
MAX.REACTION FY1	-195.3	N
OCCURING AT TIME	3.68	s

LOADS

ON FP1	ON FP2	ON PT	
44.7	-23.7	-187.8	N
195.3	339.8	-21.8	N
5.9	-51.4	-0.6	N
15.4	18.9	0.4	Nm
-3.8	-3.8	-0.5	Nm
11.6	-36.3	-35.4	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.068 ZF1 = -0.077 m

XF2 = -0.110 ZF2 = -0.062 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-198.8 R2 = -19.6 R3 = -16.1 N

R4 =-309.6 R5 =-147.2 R6 = -33.9 N

WEIGHT LEVERARM % = 36.5 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-94.7	-88.2
SHIN LOAD (N)	4172.5	3904.0
KNEE LOAD (N)	3714.4	3457.8

COMPARISON RESULTS

DIFF1 = -11.1 N

DIFF2 = 2.2 N

DIFF3 = -15.5 N

DIFF4 = 2.4 Nm

DIFF5 = 3.7 Nm

DIFF6 = -3.4 Nm

EVAL1 = -1.9 Nm

EVAL2 = 0.3 Nm

EVAL3 = 0.7 Nm

Test No 7

THIS IS FILE WR41

WITH RESULTS OF TEST KNEEL041.DAT

DURATION	3.54	s
MAX.REACTION FY1	-176.7	N
OCCURING AT TIME	3.30	s

LOADS

ON FP1	ON FP2	ON PT	
52.6	-30.0	-161.0	N
176.7	282.1	45.1	N
5.8	-36.6	-5.1	N
5.8	12.2	-1.8	Nm
-2.4	-0.1	-12.4	Nm
27.8	-15.7	-24.9	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.169 ZF1 = -0.031 m

XF2 = -0.060 ZF2 = -0.048 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-176.4 R2 = 43.6 R3 = -31.5 N

R4 =-282.4 R5 = -45.0 R6 = -6.4 N

WEIGHT LEVERARM % = 38.5 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-76.9	-70.1
SHIN LOAD (N)	3550.5	3267.9
KNEE LOAD (N)	3101.7	2833.9

COMPARISON RESULTS

DIFF1 = -15.4 N
DIFF2 = -1.4 N
DIFF3 = -26.4 N
DIFF4 = 1.8 Nm
DIFF5 = -7.3 Nm
DIFF6 = -2.4 Nm

EVAL1 = 0.2 Nm
EVAL2 = 2.8 Nm
EVAL3 = -6.7 Nm

THIS IS FILE WR42

WITH RESULTS OF TEST KNEEL042.DAT

DURATION	3.94	s
MAX.REACTION FY1	-190.3	N
OCCURING AT TIME	3.70	s

LOADS

ON FP1	ON FP2	ON PT	
69.3	-12.8	-174.4	N
190.3	208.2	60.3	N
7.8	-7.5	-7.5	N
12.0	18.9	-0.9	Nm
-5.3	0.4	-10.2	Nm
12.1	-26.8	-25.3	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.078 ZF1 = -0.061 m
XF2 = -0.131 ZF2 = -0.092 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-189.9 R2 = 59.3 R3 = -38.6 N
R4 =-208.3 R5 = -13.2 R6 = 2.5 N

WEIGHT LEVERARM % = 47.8 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-82.2	-74.3
SHIN LOAD (N)	3649.4	3319.7
KNEE LOAD (N)	3249.9	2935.2

COMPARISON RESULTS
DIFF1 = -15.5 N
DIFF2 = -1.0 N
DIFF3 = -31.1 N
DIFF4 = 0.2 Nm
DIFF5 = -10.9 Nm
DIFF6 = -3.6 Nm

EVAL1 = -1.0 Nm
EVAL2 = 5.1 Nm
EVAL3 = -10.4 Nm

THIS IS FILE WR43

WITH RESULTS OF TEST KNEEL043.DAT

DURATION	5.80	s
MAX.REACTION FY1	-220.1	N
OCCURING AT TIME	5.60	s

LOADS

ON FP1	ON FP2	ON PT	
65.7	-32.4	-205.4	N
220.1	297.2	59.1	N
11.8	-29.7	-10.7	N
24.4	25.4	-0.7	Nm
-8.9	-1.0	-13.4	Nm
15.7	-48.2	-30.9	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.083 ZF1 = -0.109 m

XF2 = -0.167 ZF2 = -0.089 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-219.8 R2 = 53.9 R3 = -41.4 N

R4 =-297.5 R5 = -41.7 R6 = 4.5 N

WEIGHT LEVERARM % = 42.6 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-95.8	-88.7
SHIN LOAD (N)	4349.1	4051.9
KNEE LOAD (N)	3840.0	3555.9

COMPARISON RESULTS

DIFF1 = -14.4 N

DIFF2 = -5.3 N

DIFF3 = -30.7 N

DIFF4 = 1.1 Nm

DIFF5 = -11.1 Nm

DIFF6 = -3.1 Nm

EVAL1 = -0.5 Nm

EVAL2 = 4.6 Nm

EVAL3 = -10.8 Nm

Test No 8

THIS IS FILE WR44

WITH RESULTS OF TEST KNEEL044.DAT

DURATION	5.34	s
MAX.REACTION FY1	-189.1	N
OCCURING AT TIME	4.46	s

LOADS

ON FP1	ON FP2	ON PT	
42.3	-27.7	-183.4	N
189.1	411.2	-19.7	N
7.6	-45.3	-3.0	N
29.9	37.0	0.9	Nm
-7.7	-3.0	2.5	Nm
13.4	-50.1	-34.7	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.080 ZF1 = -0.156 m

XF2 = -0.124 ZF2 = -0.094 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME

R1 =-192.0 R2 = -20.6 R3 = -17.8 N

R4 =-376.7 R5 =-172.1 R6 = -21.4 N

WEIGHT LEVERARM % = 31.5 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-91.8	-86.3
SHIN LOAD (N)	4089.3	3864.2
KNEE LOAD (N)	3580.2	3363.9

COMPARISON RESULTS

DIFF1 = -8.5 N
DIFF2 = -1.0 N
DIFF3 = -14.8 N
DIFF4 = 2.3 Nm
DIFF5 = 1.0 Nm
DIFF6 = -3.1 Nm

EVAL1 = -1.4 Nm
EVAL2 = 0.3 Nm
EVAL3 = -1.9 Nm

THIS IS FILE WR45

WITH RESULTS OF TEST KNEEL045.DAT

DURATION	5.56	s
MAX.REACTION FY1	-166.7	N
OCCURING AT TIME	5.16	s

LOADS

ON FP1	ON FP2	ON PT	
40.5	-6.8	-161.7	N
166.7	372.4	-12.9	N
1.3	-39.7	-2.7	N
20.5	32.9	0.5	Nm
-5.1	-3.2	2.8	Nm
11.6	-39.2	-29.9	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.079 ZF1 = -0.123 m

XF2 = -0.106 ZF2 = -0.093 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-169.6 R2 = -17.1 R3 = -19.4 N

R4 =-346.6 R5 =-138.6 R6 = -30.7 N

WEIGHT LEVERARM % = 30.9 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-80.9	-75.4
SHIN LOAD (N)	3583.6	3358.8
KNEE LOAD (N)	3116.7	2899.3

COMPARISON RESULTS

DIFF1 = -8.0 N

DIFF2 = -4.2 N

DIFF3 = -16.7 N

DIFF4 = 2.9 Nm

DIFF5 = 1.0 Nm

DIFF6 = -3.3 Nm

EVAL1 = -1.0 Nm

EVAL2 = 0.0 Nm

EVAL3 = -2.2 Nm

THIS IS FILE WR46

WITH RESULTS OF TEST KNEEL046.DAT

DURATION	5.18	s
MAX.REACTION FY1	-190.3	N
OCCURING AT TIME	4.70	s

LOADS

ON FP1	ON FP2	ON PT	
47.6	-16.8	-182.9	N
190.3	379.9	-14.8	N
3.5	-44.4	9.1	N
11.0	11.6	-1.1	Nm
-2.0	-3.7	1.2	Nm
12.8	-38.2	-34.7	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.078 ZF1 = -0.057 m

XF2 = -0.102 ZF2 = -0.035 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-194.4 R2 = -17.0 R3 = -20.1 N

R4 =-350.6 R5 =-150.8 R6 = -30.6 N

WEIGHT LEVERARM % = 33.4 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-92.2	-86.1
SHIN LOAD (N)	4074.7	3824.0
KNEE LOAD (N)	3581.8	3342.3

COMPARISON RESULTS

DIFF1 = -11.5 N

DIFF2 = -2.2 N

DIFF3 = -29.2 N

DIFF4 = 4.7 Nm

DIFF5 = 2.7 Nm

DIFF6 = -2.8 Nm

EVAL1 = -0.4 Nm

EVAL2 = 0.5 Nm

EVAL3 = -3.0 Nm

Test No 9

THIS IS FILE WR47

WITH RESULTS OF TEST KNEEL047.DAT

DURATION	5.26	s
MAX.REACTION FY1	-266.1	N
OCCURING AT TIME	4.74	s

LOADS

ON FP1	ON FP2	ON PT	
92.0	-39.3	-254.1	N
266.1	184.4	61.3	N
-3.4	-24.0	-30.6	N
11.2	16.0	-0.4	Nm
-3.1	0.0	-25.7	Nm
8.5	-24.7	-42.2	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.046 ZF1 = -0.043 m

XF2 = -0.142 ZF2 = -0.092 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-265.6 R2 = 73.5 R3 = -57.7 N

R4 =-184.7 R5 = -44.7 R6 = 4.2 N

WEIGHT LEVERARM % = 59.1 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-115.4	-113.6
SHIN LOAD (N)	5074.4	4990.9
KNEE LOAD (N)	4627.3	4557.5

COMPARISON RESULTS

DIFF1 = -11.5 N

DIFF2 = 12.2 N

DIFF3 = -27.0 N

DIFF4 = 1.2 Nm

DIFF5 = -3.6 Nm

DIFF6 = 1.4 Nm

EVAL1 = 2.8 Nm

EVAL2 = 1.8 Nm

EVAL3 = -3.4 Nm

THIS IS FILE WR48

WITH RESULTS OF TEST KNEEL048.DAT

DURATION	4.20	s
MAX.REACTION FY1	-307.0	N
OCCURING AT TIME	3.90	s

LOADS

ON FP1	ON FP2	ON PT	
96.3	-30.0	-292.0	N
307.0	228.2	85.3	N
28.6	9.0	-14.6	N
33.2	14.7	-2.9	Nm
-12.1	4.0	-20.8	Nm
23.7	-36.9	-44.5	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.090 ZF1 = -0.104 m

XF2 = -0.167 ZF2 = -0.063 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK EXPRESSED IN THE PT FRAME

R1 =-306.5 R2 = 84.5 R3 = -57.4 N

R4 =-228.3 R5 = -10.2 R6 = 29.1 N

WEIGHT LEVERARM % = 57.4 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-133.2	-126.6
SHIN LOAD (N)	5791.5	5517.4
KNEE LOAD (N)	5252.5	4992.3

COMPARISON RESULTS

DIFF1 = -14.4 N

DIFF2 = -0.8 N

DIFF3 = -42.7 N

DIFF4 = 2.3 Nm

DIFF5 = -13.4 Nm

DIFF6 = -2.5 Nm

EVAL1 = -0.1 Nm

EVAL2 = 4.9 Nm

EVAL3 = -13.6 Nm

THIS IS FILE WR49

WITH RESULTS OF TEST KNEEL049.DAT

DURATION	5.44	s
MAX.REACTION FY1	-248.7	N
OCCURING AT TIME	5.08	s

LOADS

ON FP1	ON FP2	ON PT	
48.3	-33.0	-236.2	N
248.7	242.0	54.1	N
6.9	-30.3	4.8	N
20.0	15.0	-1.2	Nm
-4.9	-2.8	-8.1	Nm
18.0	-41.9	-33.4	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.080 ZF1 = -0.079 m
XF2 = -0.179 ZF2 = -0.067 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-248.4 R2 = 38.9 R3 = -31.5 N
R4 =-242.3 R5 = -43.0 R6 = 4.5 N

WEIGHT LEVERARM % = 50.7 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-109.3	-99.7
SHIN LOAD (N)	4863.9	4474.5
KNEE LOAD (N)	4384.1	4003.5

COMPARISON RESULTS
DIFF1 = -12.3 N
DIFF2 = -15.2 N
DIFF3 = -36.3 N
DIFF4 = 1.8 Nm
DIFF5 = -20.3 Nm
DIFF6 = -6.1 Nm

EVAL1 = -3.4 Nm
EVAL2 = 6.1 Nm
EVAL3 = -20.5 Nm

After having presented the results of the pilot kneeling tests, the presentation of another fifteen tests follows. The patient was the same and the foot used was the SACH foot at 0 degrees toe-out angle. The body mass of the subject was 104.1 kg.

THIS IS FILE R05.DAT

WITH RESULTS OF TEST KNEEL005.DAT

DURATION 6.76 s
MAX.REACTION FY1 -271.0 N
OCCURING AT TIME 6.40 s

LOADS

ON FP1	ON FP2	ON PT	
72.4	-17.3	-268.8	N
271.0	255.9	-74.5	N
8.1	-53.2	-4.5	N
34.5	28.9	-0.5	Nm
-10.0	0.9	-3.1	Nm
24.4	-5.0	-53.8	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.101 ZF1 = -0.126 m
XF2 = -0.022 ZF2 = -0.121 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-278.1 R2 = -29.9 R3 = -22.8 N
R4 =-226.6 R5 =-124.9 R6 = -41.1 N

WEIGHT LEVERARM % = 51.4 %
APPLIED WEIGHT % = 51.6 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-133.7	-133.7
SHIN LOAD (N)	5757.4	5747.8
KNEE LOAD (N)	5297.3	5307.6

COMPARISON RESULTS
DIFF1 = -9.3 N
DIFF2 = 44.6 N
DIFF3 = -18.3 N
DIFF4 = 4.2 Nm
DIFF5 = 8.1 Nm
DIFF6 = 2.8 Nm

EVAL1 = -5.6 Nm
EVAL2 = -1.2 Nm
EVAL3 = 4.1 Nm

THIS IS FILE R06.DAT

WITH RESULTS OF TEST KNEEL006.DAT

DURATION 4.74 s
MAX.REACTION FY1 -235.0 N
OCCURING AT TIME 3.48 s

LOADS

ON FP1	ON FP2	ON PT	
73.8	-42.5	-239.0	N
235.0	250.9	-42.4	N
7.4	-61.0	3.1	N
17.5	5.3	-2.0	Nm
-5.9	-2.6	-3.2	Nm
10.4	-16.7	-41.4	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.057 ZF1 = -0.073 m
XF2 = -0.073 ZF2 = -0.031 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-244.1 R2 = -18.1 R3 = -28.8 N
R4 =-211.9 R5 =-150.0 R6 = -33.3 N

WEIGHT LEVERARM % = 48.4 %
APPLIED WEIGHT % = 47.6 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-115.5	-112.4
SHIN LOAD (N)	5045.9	4918.7
KNEE LOAD (N)	4637.2	4521.1

COMPARISON RESULTS
DIFF1 = -5.1 N
DIFF2 = 24.3 N
DIFF3 = -31.8 N
DIFF4 = 6.6 Nm
DIFF5 = 9.5 Nm
DIFF6 = -1.6 Nm

EVAL1 = -6.1 Nm
EVAL2 = -1.5 Nm
EVAL3 = 2.5 Nm

THIS IS FILE R07.DAT

WITH RESULTS OF TEST KNEEL007.DAT

DURATION 4.72 s
MAX.REACTION FY1 -304.5 N
OCCURING AT TIME 4.46 s

LOADS

ON FP1	ON FP2	ON PT	
83.1	-12.0	-299.9	N
304.5	266.0	-75.7	N
8.6	-63.4	0.6	N
26.0	19.8	-1.6	Nm
-8.9	-1.6	-4.4	Nm
18.2	-11.1	-58.7	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.071 ZF1 = -0.084 m
XF2 = -0.044 ZF2 = -0.084 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-313.1 R2 = -32.0 R3 = -25.6 N
R4 =-236.4 R5 =-127.2 R6 = -53.2 N

WEIGHT LEVERARM % = 53.4 %
APPLIED WEIGHT % = 55.9 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-150.1	-147.8
SHIN LOAD (N)	6446.1	6339.7
KNEE LOAD (N)	5942.7	5859.7

COMPARISON RESULTS
DIFF1 = -13.2 N
DIFF2 = 43.7 N
DIFF3 = -26.3 N
DIFF4 = 5.7 Nm
DIFF5 = 10.1 Nm
DIFF6 = 1.6 Nm

EVAL1 = -5.9 Nm
EVAL2 = -1.5 Nm
EVAL3 = 4.3 Nm

THIS IS FILE R08.DAT

WITH RESULTS OF TEST KNEEL008.DAT

DURATION	6.36	s
MAX.REACTION FY1	-246.2	N
OCCURING AT TIME	5.72	s

LOADS

ON FP1	ON FP2	ON PT	
63.5	-15.6	-243.5	N
246.2	243.4	-63.6	N
9.8	-58.5	0.2	N
30.9	23.4	-1.6	Nm
-9.6	-1.0	-4.0	Nm
13.8	-10.3	-48.0	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.066 ZF1 = -0.124 m

XF2 = -0.045 ZF2 = -0.106 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK

EXPRESSED IN THE PT FRAME

R1 =-252.2 R2 = -28.4 R3 = -18.4 N

R4 =-214.4 R5 =-121.8 R6 = -46.2 N

WEIGHT LEVERARM % = 50.3 %

APPLIED WEIGHT % = 47.9 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-121.5	-120.4
SHIN LOAD (N)	5244.9	5191.8
KNEE LOAD (N)	4821.4	4785.2

COMPARISON RESULTS

DIFF1 = -8.6 N

DIFF2 = 35.2 N

DIFF3 = -18.5 N

DIFF4 = 4.6 Nm

DIFF5 = 8.0 Nm

DIFF6 = 1.4 Nm

EVAL1 = -4.9 Nm

EVAL2 = -1.6 Nm

EVAL3 = 3.9 Nm

THIS IS FILE R09.DAT

WITH RESULTS OF TEST KNEEL009.DAT

DURATION 4.64 s
MAX.REACTION FY1 -292.1 N
OCCURING AT TIME 4.04 s

LOADS

ON FP1	ON FP2	ON PT	
78.1	-20.3	-281.6	N
292.1	230.9	-77.6	N
-2.5	-62.1	9.8	N
8.9	15.9	-3.2	Nm
-2.7	-0.3	-5.7	Nm
16.1	-6.6	-55.9	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.066 ZF1 = -0.031 m
XF2 = -0.032 ZF2 = -0.080 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-299.3 R2 = -33.4 R3 = -26.8 N
R4 =-202.8 R5 =-116.9 R6 = -52.6 N

WEIGHT LEVERARM % = 55.9 %
APPLIED WEIGHT % = 51.2 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-144.1	-139.5
SHIN LOAD (N)	6179.5	5979.3
KNEE LOAD (N)	5720.4	5548.2

COMPARISON RESULTS
DIFF1 = -17.7 N
DIFF2 = 44.2 N
DIFF3 = -36.6 N
DIFF4 = 7.5 Nm
DIFF5 = 11.6 Nm
DIFF6 = 0.6 Nm

EVAL1 = -6.2 Nm
EVAL2 = -1.6 Nm
EVAL3 = 3.5 Nm

THIS IS FILE R10.DAT

WITH RESULTS OF TEST KNEEL010.DAT

DURATION 4.00 s
MAX.REACTION FY1 -238.7 N
OCCURING AT TIME 3.94 s

LOADS

ON FP1	ON FP2	ON PT	
77.0	-34.9	-235.4	N
238.7	268.5	-45.7	N
-2.1	-60.4	-4.9	N
16.7	10.5	-0.6	Nm
-6.0	-3.3	-1.8	Nm
7.6	-21.7	-41.8	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.045 ZF1 = -0.070 m
XF2 = -0.086 ZF2 = -0.048 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-247.4 R2 = -19.8 R3 = -36.4 N
R4 =-231.2 R5 =-148.4 R6 = -38.3 N

WEIGHT LEVERARM % = 47.1 %
APPLIED WEIGHT % = 49.7 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-117.4	-111.7
SHIN LOAD (N)	5122.0	4884.7
KNEE LOAD (N)	4691.3	4472.4

COMPARISON RESULTS
DIFF1 = -12.0 N
DIFF2 = 25.9 N
DIFF3 = -31.5 N
DIFF4 = 6.5 Nm
DIFF5 = 9.9 Nm
DIFF6 = -2.1 Nm

EVAL1 = -5.9 Nm
EVAL2 = -1.4 Nm
EVAL3 = 2.9 Nm

THIS IS FILE R11.DAT

WITH RESULTS OF TEST KNEEL011.DAT

DURATION 4.28 s
MAX.REACTION FY1 -168.0 N
OCCURING AT TIME 4.18 s

LOADS

ON FP1	ON FP2	ON PT	
63.2	-9.0	-209.2	N
168.0	271.0	-32.4	N
40.7	-43.8	5.6	N
32.0	12.1	-2.1	Nm
-12.0	-3.5	-4.1	Nm
16.6	-24.3	-36.1	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.114 ZF1 = -0.181 m
XF2 = -0.091 ZF2 = -0.051 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-183.4 R2 = 11.0 R3 = -10.5 N
R4 =-241.5 R5 =-127.9 R6 = -27.3 N

WEIGHT LEVERARM % = 38.3 %
APPLIED WEIGHT % = 43.0 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-81.4	-98.2
SHIN LOAD (N)	3601.5	4292.6
KNEE LOAD (N)	3212.7	3888.4

COMPARISON RESULTS
DIFF1 = 25.8 N
DIFF2 = 43.4 N
DIFF3 = -16.1 N
DIFF4 = 3.7 Nm
DIFF5 = 6.4 Nm
DIFF6 = 9.2 Nm

EVAL1 = -4.5 Nm
EVAL2 = -1.2 Nm
EVAL3 = 2.8 Nm

THIS IS FILE R12.DAT

WITH RESULTS OF TEST KNEEL012.DAT

DURATION 4.98 s
MAX.REACTION FY1 -242.5 N
OCCURING AT TIME 4.64 s

LOADS

ON FP1	ON FP2	ON PT	
58.5	-8.7	-221.9	N
242.5	277.3	-51.4	N
11.4	-55.2	13.5	N
17.2	20.1	-3.8	Nm
-5.0	-3.7	-6.1	Nm
4.7	-22.5	-42.3	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.029 ZF1 = -0.069 m
XF2 = -0.082 ZF2 = -0.080 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-247.6 R2 = -30.0 R3 = -11.9 N
R4 =-249.6 R5 =-124.2 R6 = -47.6 N

WEIGHT LEVERARM % = 46.7 %
APPLIED WEIGHT % = 50.9 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-119.8	-108.2
SHIN LOAD (N)	5175.5	4694.9
KNEE LOAD (N)	4723.3	4273.6

COMPARISON RESULTS
DIFF1 = -25.7 N
DIFF2 = 21.4 N
DIFF3 = -25.4 N
DIFF4 = 5.7 Nm
DIFF5 = 8.7 Nm
DIFF6 = -3.9 Nm

EVAL1 = -4.5 Nm
EVAL2 = -1.7 Nm
EVAL3 = 3.1 Nm

THIS IS FILE R13.DAT

WITH RESULTS OF TEST KNEEL013.DAT

DURATION 3.84 s
MAX.REACTION FY1 -263.6 N
OCCURING AT TIME 3.84 s

LOADS

ON FP1	ON FP2	ON PT	
59.2	-3.7	-242.9	N
263.6	321.1	-71.6	N
0.2	-53.0	-3.5	N
-1.4	2.0	-0.2	Nm
-0.3	-3.3	-3.3	Nm
10.2	-19.3	-48.5	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.048 ZF1 = 0.005 m
XF2 = -0.061 ZF2 = -0.013 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-266.2 R2 = -40.5 R3 = -21.7 N
R4 =-292.8 R5 =-133.8 R6 = -47.9 N

WEIGHT LEVERARM % = 45.1 %
APPLIED WEIGHT % = 57.3 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-130.6	-120.6
SHIN LOAD (N)	5636.6	5221.0
KNEE LOAD (N)	5128.7	4744.1

COMPARISON RESULTS
DIFF1 = -23.3 N
DIFF2 = 31.1 N
DIFF3 = -18.2 N
DIFF4 = 3.7 Nm
DIFF5 = 8.0 Nm
DIFF6 = -3.0 Nm

EVAL1 = -6.1 Nm
EVAL2 = -0.8 Nm
EVAL3 = 4.0 Nm

THIS IS FILE R14.DAT

WITH RESULTS OF TEST KNEEL014.DAT

DURATION 3.36 s
MAX.REACTION FY1 -272.3 N
OCCURING AT TIME 2.82 s

LOADS

ON FP1	ON FP2	ON PT	
65.3	-4.7	-251.0	N
272.3	327.4	-65.5	N
13.0	-53.9	-1.2	N
7.9	0.2	-1.3	Nm
-3.5	-2.1	-4.0	Nm
22.3	-13.0	-50.1	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.092 ZF1 = -0.027 m
XF2 = -0.040 ZF2 = -0.007 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-277.5 R2 = -35.0 R3 = -17.5 N
R4 =-296.9 R5 =-140.9 R6 = -46.2 N

WEIGHT LEVERARM % = 45.4 %
APPLIED WEIGHT % = 58.7 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-134.5	-124.6
SHIN LOAD (N)	5815.9	5397.9
KNEE LOAD (N)	5293.2	4909.1

COMPARISON RESULTS
DIFF1 = -26.5 N
DIFF2 = 30.5 N
DIFF3 = -16.3 N
DIFF4 = 4.1 Nm
DIFF5 = 7.8 Nm
DIFF6 = -2.0 Nm

EVAL1 = -4.5 Nm
EVAL2 = -1.5 Nm
EVAL3 = 4.2 Nm

THIS IS FILE R15.DAT

WITH RESULTS OF TEST KNEEL015.DAT

DURATION	4.24 s
MAX.REACTION FY1	-264.8 N
OCCURING AT TIME	4.00 s

LOADS

ON FP1	ON FP2	ON PT	
69.9	-13.3	-249.1	N
264.8	318.6	-57.3	N
0.3	-54.5	-6.2	N
5.0	2.7	-0.2	Nm
-2.5	-1.7	-2.1	Nm
23.3	-8.2	-48.0	Nm

CENTRES OF PRESSURE ON FPs 1 and 2

XF1 = 0.099 ZF1 = -0.019 m

XF2 = -0.027 ZF2 = -0.015 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK

EXPRESSED IN THE PT FRAME

R1 =-270.4 R2 = -32.9 R3 = -28.8 N

R4 =-286.3 R5 =-144.0 R6 = -44.0 N

WEIGHT LEVERARM % = 45.4 %

APPLIED WEIGHT % = 57.1 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-130.8	-122.0
SHIN LOAD (N)	5665.9	5296.0
KNEE LOAD (N)	5160.8	4818.2

COMPARISON RESULTS

DIFF1 = -21.3 N

DIFF2 = 24.4 N

DIFF3 = -22.6 N

DIFF4 = 4.9 Nm

DIFF5 = 8.4 Nm

DIFF6 = -2.5 Nm

EVAL1 = -4.5 Nm

EVAL2 = -1.2 Nm

EVAL3 = 3.4 Nm

THIS IS FILE R16.DAT

WITH RESULTS OF TEST KNEEL016.DAT

DURATION 4.92 s
MAX.REACTION FY1 -258.6 N
OCCURING AT TIME 4.06 s

LOADS

ON FP1	ON FP2	ON PT	
59.2	-8.3	-239.7	N
258.6	312.3	-56.1	N
15.7	-48.0	15.2	N
18.2	23.4	-3.9	Nm
-6.4	-1.6	-7.1	Nm
15.3	-15.1	-46.1	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.068 ZF1 = -0.068 m
XF2 = -0.049 ZF2 = -0.081 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-263.5 R2 = -33.5 R3 = -8.3 N
R4 =-283.5 R5 =-133.7 R6 = -41.1 N

WEIGHT LEVERARM % = 45.3 %
APPLIED WEIGHT % = 55.9 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-127.8	-117.3
SHIN LOAD (N)	5524.3	5084.9
KNEE LOAD (N)	5026.4	4616.3

COMPARISON RESULTS
DIFF1 = -23.8 N
DIFF2 = 22.6 N
DIFF3 = -23.5 N
DIFF4 = 5.2 Nm
DIFF5 = 8.9 Nm
DIFF6 = -3.5 Nm

EVAL1 = -4.6 Nm
EVAL2 = -1.4 Nm
EVAL3 = 3.7 Nm

THIS IS FILE R17.DAT

WITH RESULTS OF TEST KNEEL017.DAT

DURATION	2.10 s
MAX.REACTION FY1	-312.0 N
OCCURING AT TIME	0.28 s

LOADS

ON FP1	ON FP2	ON PT	
77.0	-1.0	-294.6	N
312.0	263.5	-75.4	N
-0.3	-53.5	0.8	N
8.9	19.6	-1.5	Nm
-3.4	0.2	-4.9	Nm
31.6	0.0	-58.7	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.111 ZF1 = -0.029 m
XF2 = 0.000 ZF2 = -0.082 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-317.9 R2 = -40.6 R3 = -24.3 N
R4 =-240.7 R5 =-108.7 R6 = -50.5 N

WEIGHT LEVERARM % = 54.2 %
APPLIED WEIGHT % = 56.3 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-154.2	-146.2
SHIN LOAD (N)	6581.9	6244.1
KNEE LOAD (N)	6067.4	5760.6

COMPARISON RESULTS
DIFF1 = -23.2 N
DIFF2 = 34.8 N
DIFF3 = -25.1 N
DIFF4 = 5.4 Nm
DIFF5 = 10.2 Nm
DIFF6 = -1.1 Nm

EVAL1 = -5.0 Nm
EVAL2 = -1.4 Nm
EVAL3 = 4.7 Nm

THIS IS FILE R18.DAT

WITH RESULTS OF TEST KNEEL018.DAT

DURATION 5.82 s
MAX.REACTION FY1 -293.4 N
OCCURING AT TIME 5.40 s

LOADS

ON FP1	ON FP2	ON PT	
73.5	-7.7	-274.2	N
293.4	250.9	-73.6	N
7.5	-50.4	5.0	N
27.3	20.9	-1.9	Nm
-9.5	1.2	-4.5	Nm
39.4	4.2	-53.6	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.144 ZF1 = -0.092 m
XF2 = 0.016 ZF2 = -0.091 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-299.3 R2 = -37.0 R3 = -23.6 N
R4 =-225.4 R5 =-113.8 R6 = -42.7 N

WEIGHT LEVERARM % = 53.9 %
APPLIED WEIGHT % = 53.3 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-144.9	-135.0
SHIN LOAD (N)	6205.5	5790.1
KNEE LOAD (N)	5724.6	5342.7

COMPARISON RESULTS
DIFF1 = -25.1 N
DIFF2 = 36.6 N
DIFF3 = -28.5 N
DIFF4 = 5.7 Nm
DIFF5 = 9.7 Nm
DIFF6 = -2.4 Nm

EVAL1 = -6.5 Nm
EVAL2 = -1.1 Nm
EVAL3 = 3.4 Nm

THIS IS FILE R19.DAT

WITH RESULTS OF TEST KNEEL019.DAT

DURATION 4.92 s
MAX.REACTION FY1 -335.6 N
OCCURING AT TIME 4.82 s

LOADS

ON FP1	ON FP2	ON PT	
87.3	-17.6	-313.5	N
335.6	269.7	-78.9	N
13.6	-56.8	5.8	N
33.8	20.9	-2.3	Nm
-11.3	0.8	-5.6	Nm
40.1	-1.1	-62.6	Nm

CENTRES OF PRESSURE ON FPs 1 and 2
XF1 = 0.130 ZF1 = -0.099 m
XF2 = -0.007 ZF2 = -0.086 m

LOADS APPLIED FROM THE F/PLATES TO THE SHANK
EXPRESSED IN THE PT FRAME
R1 =-343.9 R2 = -38.2 R3 = -26.2 N
R4 =-238.5 R5 =-132.5 R6 = -43.3 N

WEIGHT LEVERARM % = 55.4 %
APPLIED WEIGHT % = 59.3 %

	BY FPs	BY PT
NUTCRACKER MOMENT (Nm)	-165.6	-155.7
SHIN LOAD (N)	7095.7	6674.3
KNEE LOAD (N)	6562.5	6180.7

COMPARISON RESULTS
DIFF1 = -30.4 N
DIFF2 = 40.6 N
DIFF3 = -32.1 N
DIFF4 = 6.5 Nm
DIFF5 = 11.3 Nm
DIFF6 = -0.9 Nm

EVAL1 = -4.9 Nm
EVAL2 = -1.4 Nm
EVAL3 = 4.3 Nm

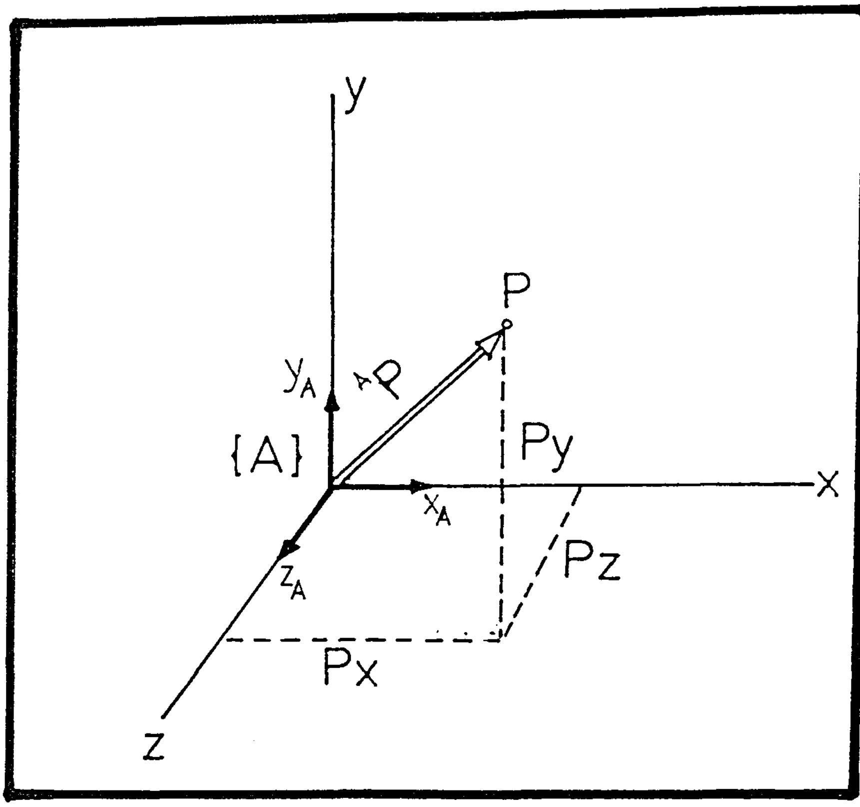

Fig V.1 Point P within frame <A>.

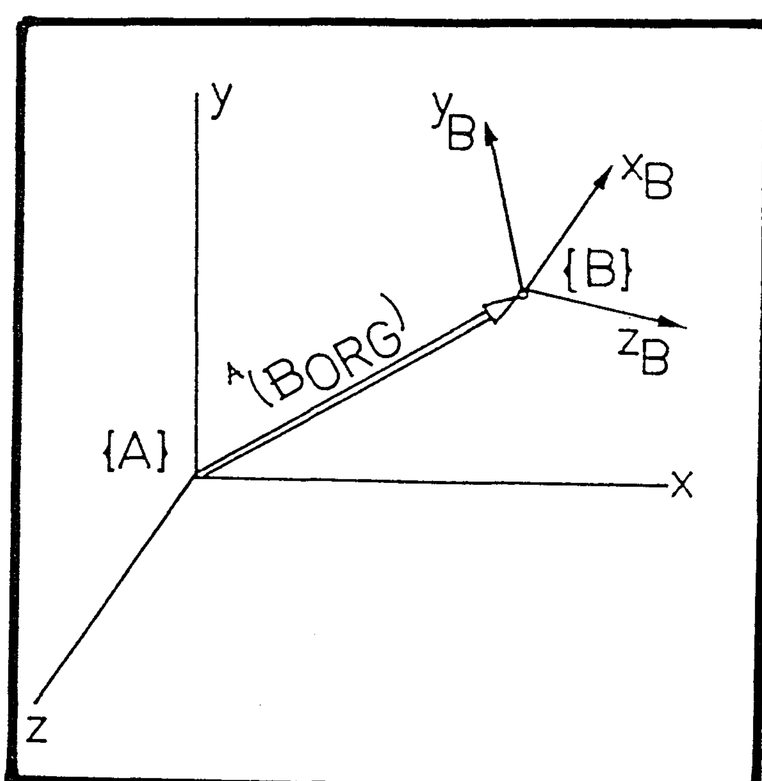

Fig V.2 Frame <B> within frame <A>.

APPENDIX V : Spatial Descriptions and Transforms

Description of a point

Any point P within a frame {A} with unit vectors $\vec{x}_A$ $\vec{y}_A$ $\vec{z}_A$,can be described, with respect to this frame, by a vector of the form (see figure V.1) :

$$\overrightarrow{{}^{A}P} = \begin{bmatrix} P_X \\ P_Y \\ P_Z \end{bmatrix} \qquad (V.1)$$

where P_X P_Y P_Z are the projections of $\overrightarrow{{}^{A}P}$ on the axes of frame {A}.

Description of a frame

Any frame {B}, is in fact a set of three axes with unit vectors $\vec{x}_B$ $\vec{y}_B$ $\vec{z}_B$, all perpendicular to each other having the same origin B_{ORG}. If such a frame is considered within frame {A} (fig V.2) , then every one of its unit vectors can be described using equation (V.1) as follows :

$$\overrightarrow{{}^{A}(x_B)} = \begin{bmatrix} (\vec{x}_B)x \\ (\vec{x}_B)y \\ (\vec{x}_B)z \end{bmatrix} \quad \overrightarrow{{}^{A}(y_B)} = \begin{bmatrix} (\vec{y}_B)x \\ (\vec{y}_B)y \\ (\vec{y}_B)z \end{bmatrix} \quad \overrightarrow{{}^{A}(z_B)} = \begin{bmatrix} (\vec{z}_B)x \\ (\vec{z}_B)y \\ (\vec{z}_B)z \end{bmatrix} \qquad (V.2)$$

the elements of the vectors being the projections of the unit vectors under study on the axes of frame {A} . These elements can also be considered as the direction cosines l, m, n of the unit vectors of frame {B}, with respect to frame {A}. Thus :

$$\overrightarrow{^{A}(x_B)} = \begin{bmatrix} l_1 \\ m_1 \\ n_1 \end{bmatrix} \quad \overrightarrow{^{A}(y_B)} = \begin{bmatrix} l_2 \\ m_2 \\ n_2 \end{bmatrix} \quad \overrightarrow{^{A}(z_B)} = \begin{bmatrix} l_3 \\ m_3 \\ n_3 \end{bmatrix} \qquad \text{(V.3)}$$

If frame {B} is to be fully described, then the location of its origin B_{ORG}, with respect to {A} has to be taken into account too. Since B_{ORG} is a point within {A}, equation (V.1) can be used, resulting in :

$$\overrightarrow{^{A}(B_{ORG})} = \begin{bmatrix} (B_{ORG})x \\ (B_{ORG})y \\ (B_{ORG})z \end{bmatrix} \qquad \text{(V.4)}$$

Equations (V.3) and (V.4) can all be written together, in the form of a 4 x 4 matrix. This matrix, then describes both the position and orientation of frame {B}, with respect to frame {A} and is called the transform of frame {B}, with respect to frame {A} and is denoted as ${}^{A}_{B}T$:

$${}^{A}_{B}T = \left[\begin{array}{ccc|c} l_1 & l_2 & l_3 & (B_{ORG})x \\ m_1 & m_2 & m_3 & (B_{ORG})y \\ n_1 & n_2 & n_3 & (B_{ORG})z \\ \hline 0 & 0 & 0 & 1 \end{array}\right] \qquad \text{(V.5)}$$

,the last row having been added for reasons due to homogeneity needed during further matrix operations (ie all resulting matrices being 4 x 4) .

The top left 3 x 3 submatrix, is the orientation portion of ${}^{A}_{B}T$ and is noted ${}^{A}_{B}R$.

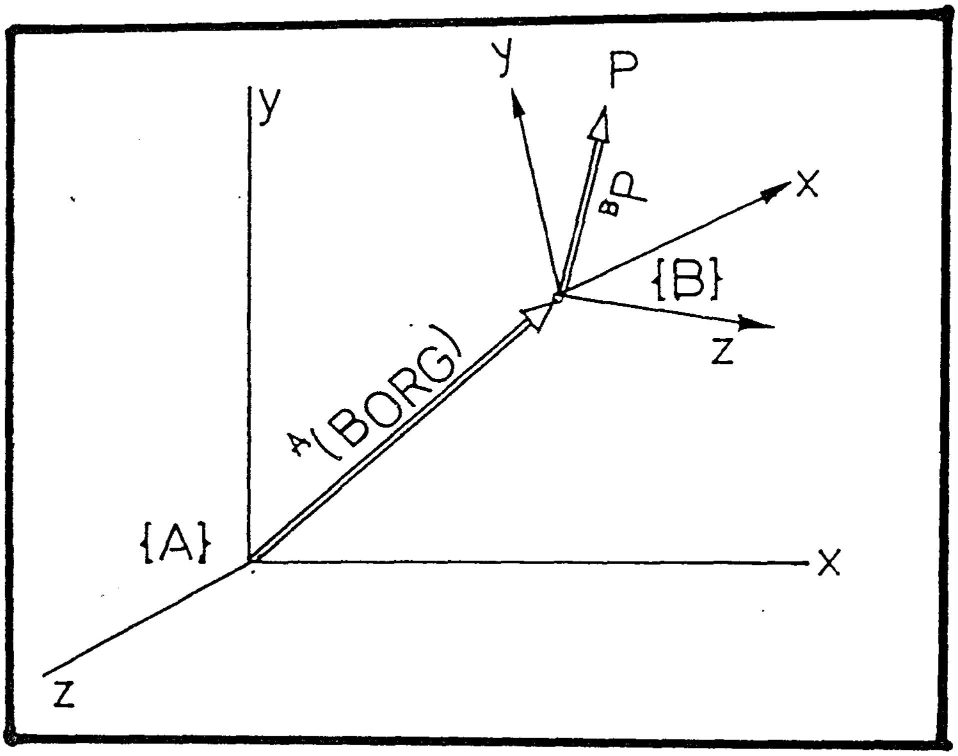

Fig V.3 General transformation mapping.

The top right 3 x 1 vector, is the position portion of ${}^{A}_{B}T$ and is noted as $\overrightarrow{{}^{A}(B_{ORG})}$.

Thus, (V.5) would be rewritten as :

$$ {}^{A}_{B}T = \left[\begin{array}{ccc|c} & {}^{A}_{B}R & & \overrightarrow{{}^{A}(B_{ORG})} \\ \hline 0 & 0 & 0 & 1 \end{array} \right] \qquad (V.6) $$

General transformation mapping

If a point P is considered within {B}, the latter being within {A} (fig V.3), then P is described by $\overrightarrow{{}^{B}P}$ with respect to {B} and frame {B} is described by ${}^{A}_{B}T$ with respect to {A}.

If the description of P , with respect to {A}, is required, it can be readily derived by :

$$ \overrightarrow{{}^{A}P} = {}^{A}_{B}T \circ \overrightarrow{{}^{B}P} \qquad (V.7) $$

Note : For homogeneity the two vectors must be considered having a fourth unit element.

More general considerations could involve more frames and result to more general equations. Suppose, for instance, that P is within a frame {C}, and that {C} is within {B} and the latter is within {A}. Knowing, only, the intermediate descriptions, the description of P, with respect to {A} can be readily derived by :

$$ \overrightarrow{{}^{A}P} = {}^{A}_{B}T \circ {}^{B}_{C}T \circ \overrightarrow{{}^{C}P} \qquad (V.8) $$

where,

$$ {}^{A}_{B}T \circ {}^{B}_{C}T = {}^{A}_{C}T \qquad (V.9) $$

Convention: the build up of the products starts from the right side and progresses to the left side, with the succession of matrices, dictated by the transform to be derived (in this case, from C to A, through B).

Considering equation (V.9) and the form of the matrices involved, as derived from (V.6), it can be appreciated that the following also stands :

$$
{}^{A}_{C}T = \left[\begin{array}{c|c} {}^{A}_{B}R \circ {}^{B}_{C}R & {}^{A}_{B}R \circ \overrightarrow{{}^{B}(C_{ORG})} + \overrightarrow{{}^{A}(B_{ORG})} \\ \hline 0 \quad 0 \quad 0 & 1 \end{array}\right]
\tag{V.10}
$$

Inverse of a transform

To derive matrices ${}^{B}_{A}T$ from ${}^{A}_{B}T$, is the inverse transform problem which can be solved by considering the following :

(i) ${}^{A}_{B}R = {}^{B}_{A}R^{-1}$ (ie inverse), since their elements represent direction cosines and

(ii) ${}^{B}_{A}R^{-1} = {}^{B}_{A}R^{T}$ (ie transpose), since the inverse of a matrix with orthonormal columns is equal to its transpose .

Thus : ${}^{A}_{B}R = {}^{B}_{A}R^{T}$ or ${}^{B}_{A}R = {}^{A}_{B}R^{T}$ (V.11)

(iii) ${}^{B}(\overrightarrow{{}^{A}(B_{ORG})}) = {}^{B}_{A}R \circ \overrightarrow{{}^{A}(B_{ORG})} + \overrightarrow{{}^{B}(A_{ORG})}$ applying the top right component of (V.10) .

(iv) But it is obvious that ${}^{B}(\overrightarrow{{}^{A}(B_{ORG})}) = \overrightarrow{0}$, since B_{ORG} is the origin of frame {B}.

Thus : $\overrightarrow{{}^{B}(A_{ORG})} = - {}^{B}_{A}R \circ \overrightarrow{{}^{A}(B_{ORG})}$ (V.12)

Equations (V.11) and (V.12) provide the solution to the inverse problem :

$$
{}^{B}_{A}T = \left[\begin{array}{c|c} {}^{B}_{A}R & \overrightarrow{{}^{B}(A_{ORG})} \\ \hline 0 \quad 0 \quad 0 & 1 \end{array}\right]
$$

or

$$
{}^{B}_{A}T = \left[\begin{array}{c|c} {}^{A}_{B}R^{T} & -\,{}^{A}_{B}R \circ \overrightarrow{{}^{A}(B_{ORG})} \\ \hline 0 \quad 0 \quad 0 & 1 \end{array}\right] \qquad (V.13)
$$

Translation of a frame

If a frame {B} initially coincident with {A}, is to be translated by a vector $\overrightarrow{{}^{A}P}$, to another position, then the transform describing this change is :

$$
T = \begin{bmatrix} 1 & 0 & 0 & P_x \\ 0 & 1 & 0 & P_y \\ 0 & 0 & 1 & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (V.14)
$$

Rotation of a frame

If a frame {B}, initially coincident with {A}, is to be rotated about a (unit) vector $\overrightarrow{{}^{A}K}$, by an angle ϑ (fig V.4) to another orientation, then the transform describing this change is :

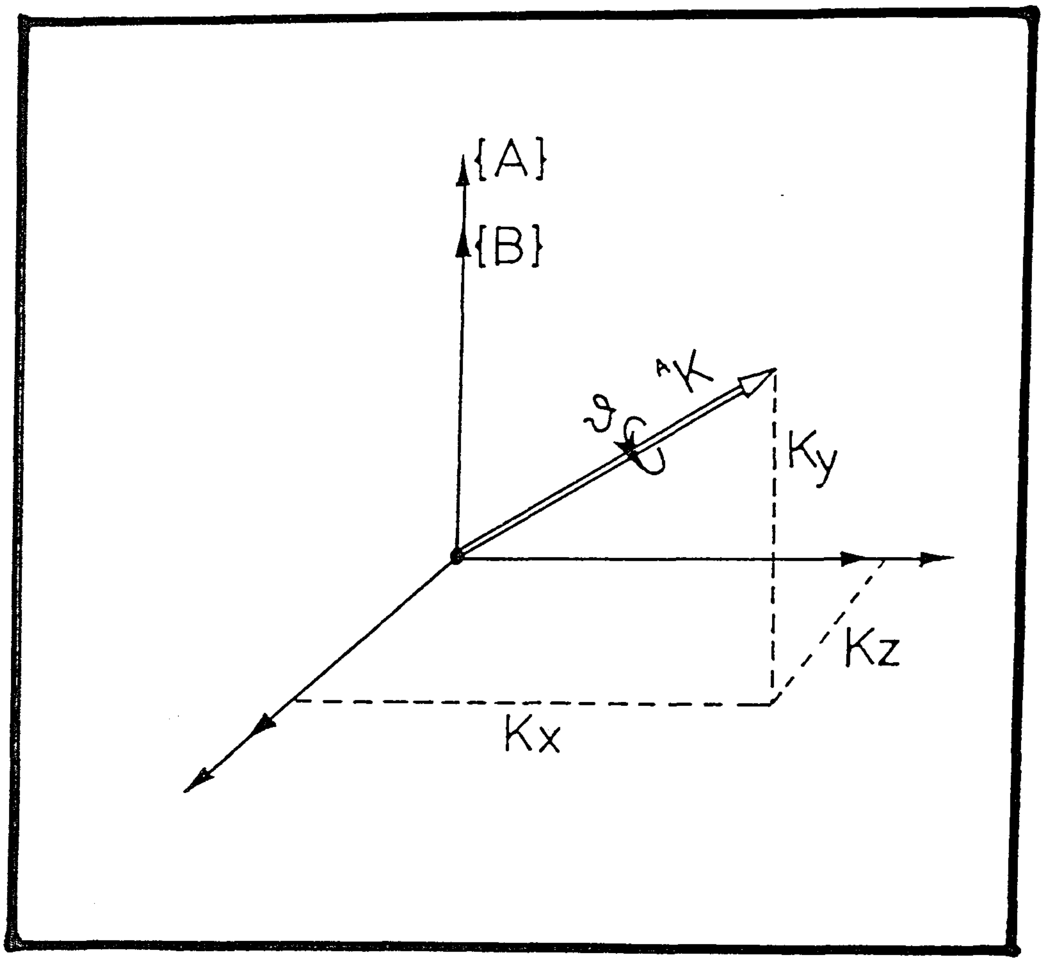

Fig V.4 Rotation of frame {B} about vector ^{A}K by angle ϑ.

$$T = \left[\begin{array}{ccc|c} K_xK_xv\vartheta + c\vartheta & K_xK_yv\vartheta - K_zs\vartheta & K_xK_zv\vartheta + K_ys\vartheta & 0 \\ K_xK_yv\vartheta + K_zs\vartheta & K_yK_yv\vartheta + c\vartheta & K_yK_zv\vartheta - K_xs\vartheta & 0 \\ K_xK_zv\vartheta - K_ys\vartheta & K_yK_zv\vartheta + K_xs\vartheta & K_zK_zv\vartheta + c\vartheta & 0 \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

(V.15)

where, $\begin{bmatrix} K_x \\ K_y \\ K_z \end{bmatrix} = \overrightarrow{^AK}$ and $s\vartheta = \sin\vartheta$, $c\vartheta = \cos\vartheta$, $v\vartheta = (1-\cos\vartheta)$

and the sign of ϑ given by the right hand rule .

General Case of Rotation

Consider now a frame {B}, within {A}, having the general position and orientation shown in figure V.5 and described by equation (V.6). Consider also,a (unit) vector $\overrightarrow{^AK}$, within {A} passing through the point P described by the vector $\overrightarrow{^AP}$ shown.

If {B} is to be rotated by an angle ϑ, about $\overrightarrow{^AK}$, then two auxiliary frames must be also considered in order to understand how this operation is performed.These two frames { A′} and { B′} are shown, located at point P and have the orientation of {A}.

It can be appreciated that :

$$^{A}_{A'}T = \begin{bmatrix} 1 & 0 & 0 & Px \\ 0 & 1 & 0 & Py \\ 0 & 0 & 1 & Pz \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (V.16)$$

and also that :

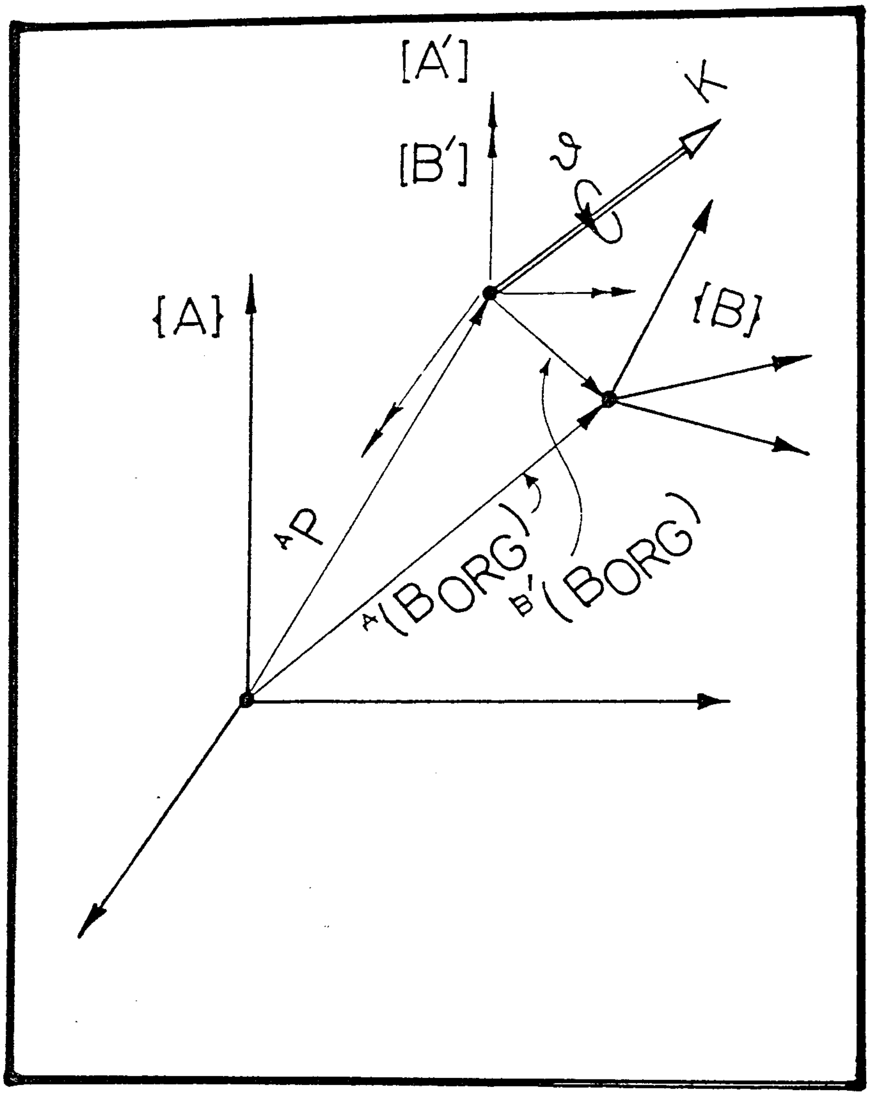

Fig V.5 General case of rotation.

$$\overrightarrow{{}^{B'}(B_{ORG})} = \overrightarrow{{}^{A}(B_{ORG})} - \overrightarrow{{}^{A}P} \qquad (V.17)$$

Frame {B} can thus be described with respect to frame { B'}, as follows :

$$ {}^{B'}_{B}T = \left[\begin{array}{ccc|c} & {}^{A}_{B}R & & \overrightarrow{{}^{B'}(B_{ORG})} \\ \hline 0 & 0 & 0 & 1 \end{array} \right] \qquad (V.18)$$

Therefore, the rotation required could be implemented by a rotation of { B'} relative to { A'}, described by the known formula (V.15) and the overall effect of the operation on {B} can be derived as :

$$ {}^{A}_{B}T = {}^{A}_{A'}T \circ {}^{A'}_{B'}T \circ {}^{B'}_{B}T \qquad (V.19)$$

where ${}^{A'}_{B'}T$ is given by formula (V.15) and ${}^{A}_{A'}T$ and ${}^{B'}_{B}T$ are already provided by equations (V.16),(V.17),(V.18).

Thus, the description of any frame, with respect to a frame of reference, is possible as long as the initial transform and the subsequent changes are known and can be defined relative to the frame of reference.

Appendix VI : Print-outs obtained using the new alignment method

The data file for the prosthesis is as follows :

filename : PATIENT3.DAT

data :

```
11.09
1.20

 0.0   389.46 0.0
-7.28 427.37 0.0
 0.74 434.42 0.0
 0.0   466.92 0.0

 3.88 735.00  79.16
16.12 732.11 -76.69
38.46 521.39  46.50
39.90 516.30 -33.58
78.42 741.32   9.00

1.35   -2.14

29.1356 1.94080
28.8669 1.91488
30.9643 1.94790
27.5873 1.99596
32.8778 2.11131
31.5288 1.84433

1.0
```

The complete print-outs provided by the program for the four sessions are as follows :

THIS IS FILE : SESSION1.LIS

DATE OF THE SESSION : 19- 7-91

ORDER NUMBER OF THIS SESSION : 1

FILE OF THE PROSTHESIS DATA : PATIENT3.DAT

WHAT THE OPTIONS ARE :

OPTION 1 :FOOT ADAPTOR A/P CHANGES
OPTION 2 :............ M/L ....
OPTION 3 :DISTAL KNEE ADAPTOR A/P CHANGES
OPTION 4 :..... .... M/L ....
OPTION 5 :PROX. KNEE ADAPTOR A/P CHANGES
OPTION 6 :.................. M/L ....
OPTION 7 :ROTATION ABOUT SHANK ADAPTOR
OPTION 8 :.............. SOCKET.......

THE ALIGNMENT PROCEDURE FOLLOWED :

THE INITIAL ALIGNMENT WAS :

KAPS=	-7.28 mm	KMLS=	0.00 mm	KH=	426.17 mm
KMLT=	0.00 deg	KR=	0.00 deg		
SAPS=	10.00 mm	SMLS=	1.24 mm	SH=	732.35 mm
SAPT=	7.74 deg	SMLT=	-1.39 deg	SR=	-4.49 deg

THEN OPTION 5 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 15.90300 mm
LATERAL SCREW LENGTH AFTER = 17.01300 mm
THE ANGULAR CHANGE IMPOSED = -2.34356 deg

KAPS=	-7.28 mm	KMLS=	0.00 mm	KH=	426.17 mm
KMLT=	0.00 deg	KR=	0.00 deg		
SAPS=	22.22 mm	SMLS=	1.24 mm	SH=	731.73 mm
SAPT=	5.40 deg	SMLT=	-1.39 deg	SR=	-4.44 deg

THEN OPTION 6 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 16.10100 mm
LATERAL SCREW LENGTH AFTER = 14.40800 mm
THE ANGULAR CHANGE IMPOSED = 3.12245 deg

```
KAPS=   -7.28 mm   KMLS=    0.00 mm   KH= 426.17 mm
KMLT=   0.00 deg   KR=   0.00 deg
SAPS=   22.24 mm   SMLS=   17.46 mm   SH= 731.22 mm
SAPT=   5.40 deg   SMLT=   1.74 deg   SR= -4.37 deg
```

THEN OPTION 7 WAS FOLLOWED

THE ANGULAR CHANGE IS = 12.91000 deg

```
KAPS=   -7.10 mm   KMLS=    1.63 mm   KH= 426.17 mm
KMLT=   0.00 deg   KR= 12.91 deg
SAPS=   25.58 mm   SMLS=   12.05 mm   SH= 731.22 mm
SAPT=   4.87 deg   SMLT=   2.90 deg   SR= -4.37 deg
```

THIS IS FILE : SESSION2.LIS

DATE OF THE SESSION : 19- 7-91

ORDER NUMBER OF THIS SESSION : 2

FILE OF THE PROSTHESIS DATA : PATIENT3.DAT

WHAT THE OPTIONS ARE :

```
OPTION 1 :FOOT ADAPTOR A/P CHANGES
OPTION 2 :............ M/L .......
OPTION 3 :DISTAL KNEE ADAPTOR A/P CHANGES
OPTION 4 :.....  ............ M/L .......
OPTION 5 :PROX.  KNEE ADAPTOR A/P CHANGES
OPTION 6 :................... M/L .......
OPTION 7 :ROTATION ABOUT SHANK ADAPTOR
OPTION 8 :...............SOCKET ......
```

THE ALIGNMENT PROCEDURE FOLLOWED :

THE INITIAL ALIGNMENT WAS :

```
KAPS=   -7.28 mm   KMLS=    0.00 mm   KH= 426.17 mm
KMLT=   0.00 deg   KR=   0.00 deg
SAPS=   10.00 mm   SMLS=    1.24 mm   SH= 732.35 mm
SAPT=   7.74 deg   SMLT= -1.39 deg   SR= -4.49 deg
```

THEN OPTION 1 WAS FOLLOWED

```
ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE =    15.15700 mm
LATERAL SCREW LENGTH AFTER  =    15.94300 mm
THE ANGULAR CHANGE IMPOSED  =    -1.52547 deg
```

KAPS=	4.39 mm	KMLS=	0.00 mm	KH=	426.21 mm
KMLT=	0.00 deg	KR=	0.00 deg		
SAPS=	29.82 mm	SMLS=	1.24 mm	SH=	731.82 mm
SAPT=	6.21 deg	SMLT=	-1.39 deg	SR=	-4.46 deg

THEN OPTION 6 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 15.90700 mm
LATERAL SCREW LENGTH AFTER = 14.94800 mm
THE ANGULAR CHANGE IMPOSED = 1.76871 deg

KAPS=	4.39 mm	KMLS=	0.00 mm	KH=	426.21 mm
KMLT=	0.00 deg	KR=	0.00 deg		
SAPS=	29.82 mm	SMLS=	10.46 mm	SH=	731.64 mm
SAPT=	6.21 deg	SMLT=	0.38 deg	SR=	-4.47 deg

THEN OPTION 7 WAS FOLLOWED

THE ANGULAR CHANGE IS = 17.95000 deg

KAPS=	4.75 mm	KMLS=	2.24 mm	KH=	426.20 mm
KMLT=	0.49 deg	KR=	17.94 deg		
SAPS=	32.55 mm	SMLS=	6.87 mm	SH=	731.57 mm
SAPT=	5.72 deg	SMLT=	2.75 deg	SR=	-4.47 deg

THIS IS FILE : SESSION3.LIS

DATE OF THE SESSION : 19- 7-91

ORDER NUMBER OF THIS SESSION : 3

FILE OF THE PROSTHESIS DATA : PATIENT3.DAT

WHAT THE OPTIONS ARE :

OPTION 1 :FOOT ADAPTOR A/P CHANGES
OPTION 2 :............ M/L ....
OPTION 3 :DISTAL KNEE ADAPTOR A/P CHANGES
OPTION 4 :..... .... M/L ....
OPTION 5 :PROX. KNEE ADAPTOR A/P CHANGES
OPTION 6 :.................. M/L ....
OPTION 7 :ROTATION ABOUT SHANK ADAPTOR
OPTION 8 :...............SOCKET ......

THE ALIGNMENT PROCEDURE FOLLOWED :

THE INITIAL ALIGNMENT WAS :

KAPS= -7.28 mm	KMLS= 0.00 mm	KH= 426.17 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= 10.00 mm	SMLS= 1.24 mm	SH= 732.35 mm
SAPT= 7.74 deg	SMLT= -1.39 deg	SR= -4.49 deg

THEN OPTION 1 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 15.16000 mm
LATERAL SCREW LENGTH AFTER = 14.31300 mm
THE ANGULAR CHANGE IMPOSED = 1.64386 deg

KAPS= -19.86 mm	KMLS= 0.00 mm	KH= 425.78 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= -11.37 mm	SMLS= 1.24 mm	SH= 732.34 mm
SAPT= 9.38 deg	SMLT= -1.40 deg	SR= -4.52 deg

THEN OPTION 5 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 15.04400 mm
LATERAL SCREW LENGTH AFTER = 15.96300 mm
THE ANGULAR CHANGE IMPOSED = -1.94030 deg

KAPS= -19.86 mm	KMLS= 0.00 mm	KH= 425.78 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= -1.23 mm	SMLS= 1.24 mm	SH= 732.14 mm
SAPT= 7.44 deg	SMLT= -1.39 deg	SR= -4.49 deg

THEN OPTION 6 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 15.94100 mm
LATERAL SCREW LENGTH AFTER = 16.96400 mm
THE ANGULAR CHANGE IMPOSED = -1.88675 deg

KAPS= -19.86 mm	KMLS= 0.00 mm	KH= 425.78 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= -1.23 mm	SMLS= -8.58 mm	SH= 732.02 mm
SAPT= 7.45 deg	SMLT= -3.29 deg	SR= -4.59 deg

THIS IS FILE : SESSION4.LIS

DATE OF THE SESSION : 19- 7-91

ORDER NUMBER OF THIS SESSION : 4

FILE OF THE PROSTHESIS DATA : PATIENT3.DAT

WHAT THE OPTIONS ARE :

OPTION 1 :FOOT ADAPTOR A/P CHANGES
OPTION 2 :............ M/L ....
OPTION 3 :DISTAL KNEE ADAPTOR A/P CHANGES
OPTION 4 :..... .... M/L ....
OPTION 5 :PROX. KNEE ADAPTOR A/P CHANGES
OPTION 6 :................... M/L ....
OPTION 7 :ROTATION ABOUT SHANK ADAPTOR
OPTION 8 :...............SOCKET ......

THE ALIGNMENT PROCEDURE FOLLOWED :

THE INITIAL ALIGNMENT WAS :

KAPS= -7.28 mm	KMLS= 0.00 mm	KH= 426.17 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= 10.00 mm	SMLS= 1.24 mm	SH= 732.35 mm
SAPT= 7.74 deg	SMLT= -1.39 deg	SR= -4.49 deg

THEN OPTION 5 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 15.90300 mm
LATERAL SCREW LENGTH AFTER = 14.39900 mm
THE ANGULAR CHANGE IMPOSED = 3.17541 deg

KAPS= -7.28 mm	KMLS= 0.00 mm	KH= 426.17 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= -6.58 mm	SMLS= 1.24 mm	SH= 732.41 mm
SAPT= 10.91 deg	SMLT= -1.41 deg	SR= -4.54 deg

THEN OPTION 6 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 16.10100 mm
LATERAL SCREW LENGTH AFTER = 18.19500 mm
THE ANGULAR CHANGE IMPOSED = -3.86203 deg

KAPS= -7.28 mm	KMLS= 0.00 mm	KH= 426.17 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= -6.57 mm	SMLS= -18.93 mm	SH= 731.81 mm
SAPT= 10.95 deg	SMLT= -5.29 deg	SR= -4.65 deg

THEN OPTION 5 WAS FOLLOWED

ADJUSTMENT MADE :
LATERAL SCREW LENGTH BEFORE = 14.47400 mm
LATERAL SCREW LENGTH AFTER = 13.50200 mm
THE ANGULAR CHANGE IMPOSED = 2.05219 deg

KAPS= -7.28 mm	KMLS= 0.00 mm	KH= 426.17 mm
KMLT= 0.00 deg	KR= 0.00 deg	
SAPS= -17.26 mm	SMLS= -18.93 mm	SH= 731.36 mm
SAPT= 13.00 deg	SMLT= -5.33 deg	SR= -4.81 deg

Appendix VII : Results obtained from the level walking tests

Information about the patient :

Patient reference	PATIENT 3
Amputation level	AK
Amputation side	RIGHT
Activity level	AVERAGE
Cause of amputation	TRAUMA
Period since amputation	25 YEARS
Bodymass (kg)	105.3 (for tests 1,2,3 and 10) 104.1 (for tests 4 to 9)
Bodyheight (m)	1.87
Age of patient	45
Sex of patient	MALE

Information about the walking tests :

Trial coding	FIGURE "8"
Equipment used	1) SHORT PYLON TRANSDUCER CONNECTED TO SGAs 2) SGAs CONNECTED TO THE MICRO-VAX COMPUTER

Information about the prosthesis :

Type of prosthesis	OTTO BOCK MODULAR
Type of socket	QUADRILATERAL
Suspension type	WAIST BELT
Knee unit (AK only)	SINGLE AXIS
Foot type	SACH FOOT
Information on shoes	WELL USED SHOE
Prosthesis weight (kg)	4.70

Alignment parameters :

Toe out angle	(degrees)	=	3.8
Pylon A/P shift	(mm)	=	0.5
Pylon M/L shift	(mm)	=	0.0
Pylon Height	(mm)	=	97.5
Pylon A/P tilt	(degrees)	=	-0.3
Pylon M/L tilt	(degrees)	=	0.0
Pylon Rotation	(degrees)	=	0.0
Socket A/P shift	(mm)	=	1.8
Socket M/L shift	(mm)	=	1.3
Socket Height	(mm)	=	732.5
Socket A/P tilt	(degrees)	=	9.8
Socket M/L tilt	(degrees)	=	-0.7
Socket Rotation	(degrees)	=	-4.5
Knee A/P shift	(mm)	=	-5.3
Knee M/L shift	(mm)	=	0.5
Knee Height	(mm)	=	426.2
Knee M/L tilt	(degrees)	=	0.0
Knee Rotation	(degrees)	=	3.8
Knee to Gr. trochanter	(mm)	=	455.0

In the following tables the maximum value of each load is framed and shown with the simultaneous values of the the other components of the same frame (pylon, ankle or knee frames).

TEST 1

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	152.01	1267.48	-102.23	11.42	0.12	-5.93
Pylon My	-127.60	934.67	-62.07	0.17	27.49	101.66
Ankle Mx	-34.23	970.13	-79.04	-23.87	23.93	75.65
Ankle Mz	-112.61	962.32	-50.47	-2.32	20.53	120.66
Knee Mx	159.14	1242.35	-98.59	48.93	1.09	49.45
Knee Mz	-57.92	909.12	-44.99	14.56	20.53	86.89

TEST 2

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	113.14	1256.93	-97.43	15.70	3.22	-4.45
Pylon My	-122.37	948.50	-61.47	0.96	27.97	97.69
Ankle Mx	-23.93	960.15	-80.47	-22.37	20.00	72.25
Ankle Mz	-85.96	988.84	-59.28	-3.44	19.61	118.79
Knee Mx	128.16	1255.37	-90.85	49.46	3.64	37.32
Knee Mz	-62.94	980.18	-62.76	21.00	18.85	85.79

TEST 3

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	151.71	1317.70	-100.84	10.83	-1.08	-11.86
Pylon My	-42.92	898.76	-47.51	-14.26	28.43	63.22
Ankle Mx	-70.48	932.09	-66.09	-25.04	26.76	84.81
Ankle Mz	-97.89	943.42	-45.43	-3.94	16.98	119.93
Knee Mx	148.15	1253.50	-98.78	52.78	0.80	43.65
Knee Mz	-66.76	923.68	-41.46	10.87	17.06	85.04

TEST 4

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	97.05	1210.18	-91.37	13.77	4.98	5.49
Pylon My	-81.85	971.16	-50.68	-5.12	26.47	85.18
Ankle Mx	-19.92	957.71	-74.07	-19.72	17.67	65.62
Ankle Mz	-112.63	932.17	-43.38	1.58	19.72	118.58
Knee Mx	126.53	1135.09	-88.59	44.53	2.67	37.47
Knee Mz	-33.57	1029.48	-44.65	14.65	20.66	87.81

TEST 5

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	128.17	1227.49	-93.66	6.28	4.85	-6.21
Pylon My	-114.72	964.00	-53.25	-0.54	26.52	101.38
Ankle Mx	-26.31	990.77	-70.05	-17.96	22.14	69.33
Ankle Mz	-110.10	999.62	-52.92	-3.35	22.76	119.51
Knee Mx	130.08	1224.41	-99.55	49.21	1.89	35.84
Knee Mz	-62.63	956.52	-54.52	18.53	19.79	82.80

TEST 6

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	125.66	1238.80	-91.23	8.50	2.29	-14.83
Pylon My	-68.86	934.95	-36.18	-7.32	27.00	83.95
Ankle Mx	-14.61	924.88	-42.72	-17.41	23.23	60.22
Ankle Mz	-82.45	1004.19	-43.54	-2.81	17.69	120.09
Knee Mx	102.73	1162.50	-81.81	43.10	5.95	32.71
Knee Mz	-73.45	988.79	-45.36	14.46	17.73	85.11

TEST 7

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	137.27	1372.22	-60.46	-4.27	7.43	-11.69
Pylon My	-51.48	967.27	-38.69	-10.09	30.98	73.67
Ankle Mx	-31.25	975.94	-41.11	-18.98	30.17	70.27
Ankle Mz	-89.71	999.08	-38.57	-1.24	20.64	119.77
Knee Mx	90.41	1209.78	-73.85	41.07	4.80	33.39
Knee Mz	-57.04	969.51	-42.03	24.67	14.33	89.25

TEST 8

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	96.38	1216.80	-70.85	1.87	6.31	-5.14
Pylon My	-65.65	987.08	-12.23	0.16	27.20	88.50
Ankle Mx	-15.68	981.41	-46.17	-13.01	21.63	65.39
Ankle Mz	-102.39	1017.00	-26.61	-0.74	20.10	121.89
Knee Mx	90.56	1151.22	-76.87	41.49	3.09	40.85
Knee Mz	-66.63	964.92	-40.93	16.82	17.83	88.52

TEST 9

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	87.37	1220.49	-52.20	-0.46	9.87	-4.65
Pylon My	-61.33	993.06	-32.78	-1.76	27.12	85.74
Ankle Mx	-31.71	984.69	-52.07	-15.00	24.90	71.06
Ankle Mz	-98.23	1008.47	-27.28	0.30	19.25	121.10
Knee Mx	109.07	1168.13	-72.52	36.91	4.96	30.06
Knee Mz	-77.38	992.58	-35.09	9.98	23.17	86.51

TEST 10

	Fx	Fy	Fz	Mx	My	Mz
Pylon Fy	218.57	1637.01	-96.90	10.72	-0.39	-9.10
Pylon My	-23.58	904.93	-50.11	-15.52	27.86	62.31
Ankle Mx	-80.45	876.20	-75.39	-27.67	21.96	91.79
Ankle Mz	-103.00	900.90	-54.25	-7.57	22.98	120.50
Knee Mx	211.14	1522.11	-116.14	58.96	1.53	68.28
Knee Mz	-41.42	961.58	-70.18	31.94	9.63	95.24

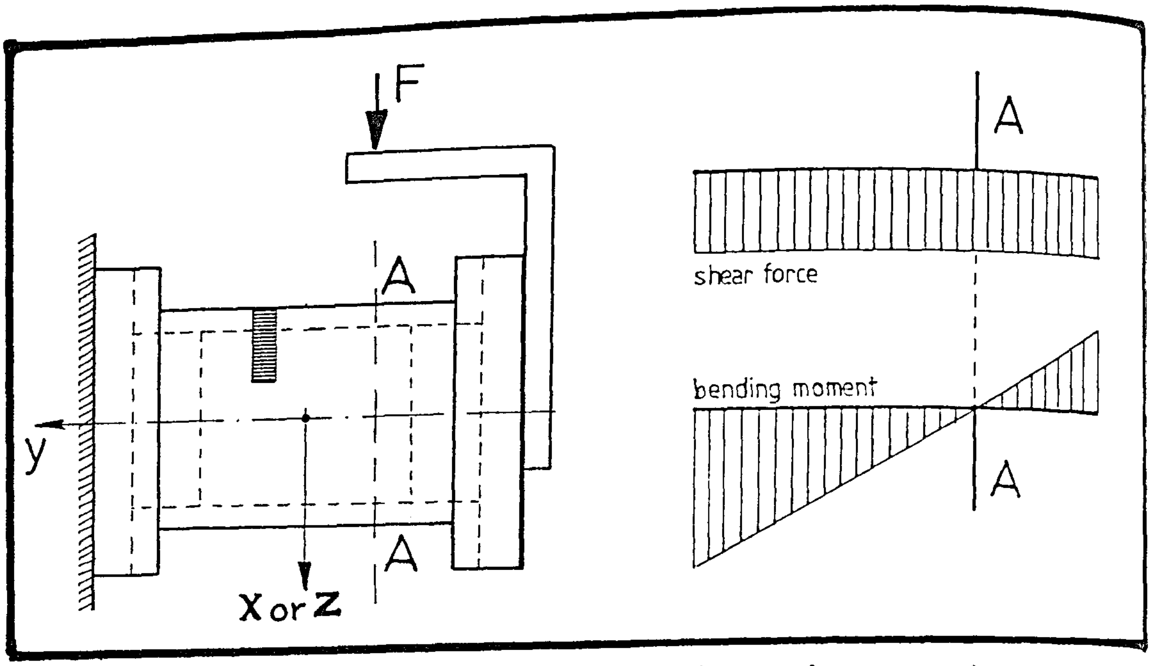

Fig VIII.1 Loading configuration for application of pure shear force through section A-A

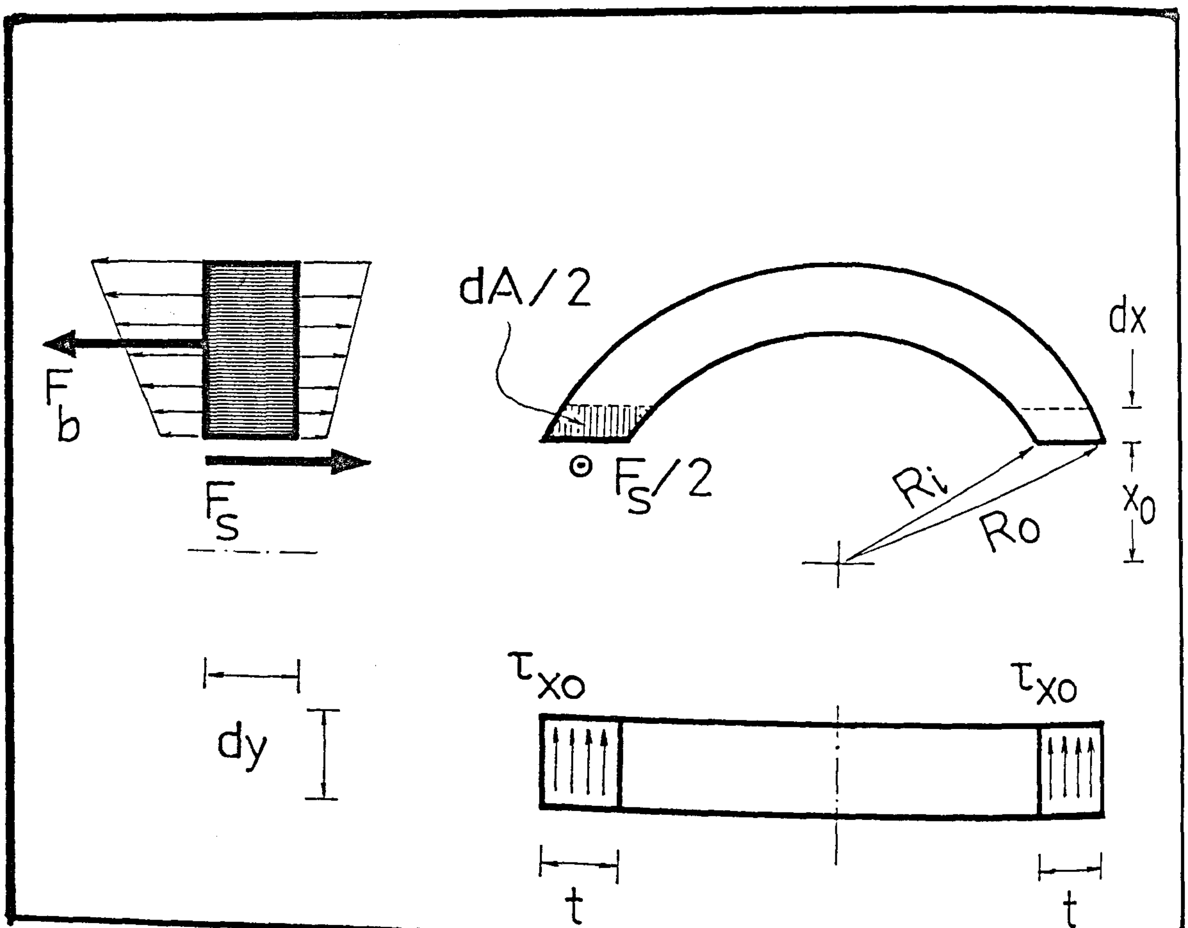

Fig VIII.2 Stresses and forces acting on a portion of the transducer

Appendix VIII : Shear stress on the pylon transducer for applied pure shear load .

Figure VIII.1 shows the loading configuration for which a pure shear force F is applied through a cross-section of the pylon transducer. Despite the fact that all other cross-sections of the device are subjected to bending moment and shear force simultaneously, section A-A is only subjected to a pure shear force F.

To derive the shear stresses on the surface of the transducer the following analysis is required .

A general portion of the transducer is subjected to the bending-resulted normal stresses shown in figure VIII.2. For equilibrium to be established, the residual bending-generated force F_b :

$$F_b = \int \frac{dM \cdot x}{I} \, dA = \frac{(F \, dy)}{I} \cdot \int x \cdot dA \qquad \text{(VIII.1)}$$

must be balanced by a shear-generated force F_s :

$$F_s = \tau_{xo} \cdot (2 \cdot t) \cdot dy \qquad \text{(VIII.2)}$$

where τ_{xo} is the shear stress at the lower surface of the considered portion and which is assumed uniform throughout the whole depth $2 \cdot t$.

The following substitutions can be made according to figure VIII.2 :

$$dA = 2 \cdot t \cdot dx \quad \text{and}$$

$$t = \sqrt{Ro^2 - xo^2} - \sqrt{Ri^2 - xo^2} \qquad \text{(VIII.3)}$$

With these substitutions equations (VIII.1) and (VIII.3) can be written as follows :

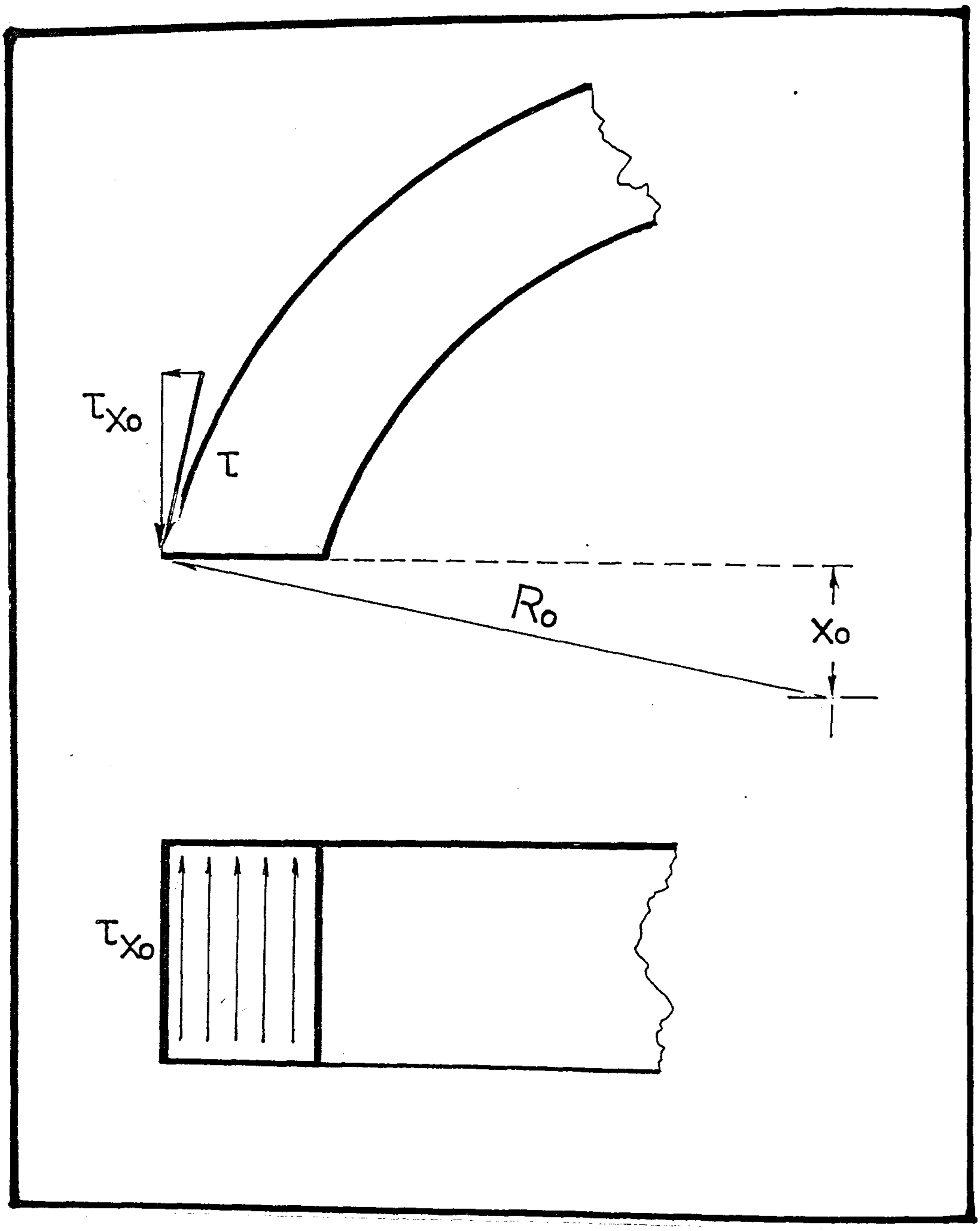

Fig VIII.3 The surface shear stress τ

$$F_b = 2 \frac{(F\,dy)}{I} \cdot \int x \cdot \left(\sqrt{Ro^2 - xo^2} - \sqrt{Ri^2 - xo^2}\right) dx$$

(VIII.4)

$$F_s = 2 \cdot \tau_{xo} \cdot \left(\sqrt{Ro^2 - xo^2} - \sqrt{Ri^2 - xo^2}\right) dy$$

(VIII.5)

Thus, since F_b and F_s must be equal the following equations are derived, by evaluating the integral in two distinct ranges :

$0 \le xo \le Ri$:

$$\tau_{xo} = \frac{F}{3 \cdot t \cdot I} \cdot \left[\left(Ro^2 - xo^2 \right)^{3/2} - \left(Ri^2 - xo^2 \right)^{3/2} \right]$$

where : $t = \sqrt{Ro^2 - xo^2} - \sqrt{Ri^2 - xo^2}$

and $Ri < xo \le Ro$:

$$\tau_{xo} = \frac{F}{3 \cdot t \cdot I} \cdot \left(Ro^2 - xo^2 \right)^{3/2} \quad \text{where } t = \sqrt{Ro^2 - xo^2}$$

(VIII.6)

Figure VIII.3 shows that shear stress τ_{xo} is equal to the stress component shown on the cross-section surface. However, shear stress τ_{xo} is not equal to the total shear stress τ present on the surface of the component. This surface stress τ , as shown , can only be tangential to the circumference of the cross-section because the surface of the component is not loaded and it is known that shear stresses cannot cross over unloaded surfaces.

Therefore the total shear stress τ can be calculated using equations (VIII.6) and the following geometrical relationship, which simply implements what is stated above (see figure VIII.3) :

$$\frac{\tau}{\tau_{xo}} = \frac{Ro}{\sqrt{Ro^2 - xo^2}} \qquad \text{(VIII.7)}$$

Thus the required shear stress τ for a given position xo can be expressed as follows :

$0 \leq xo \leq Ri$:

$$\tau = \frac{F}{3 \cdot t \cdot I} \frac{Ro}{\sqrt{Ro^2 - xo^2}} \left[\left(Ro^2 - xo^2\right)^{3/2} - \left(Ri^2 - xo^2\right)^{3/2} \right]$$

where : $t = \sqrt{Ro^2 - xo^2} - \sqrt{Ri^2 - xo^2}$

and $Ri < xo \leq Ro$:

$$\tau = \frac{F \cdot Ro}{3 \cdot I} \cdot \sqrt{Ro^2 - xo^2} \qquad \text{(VIII.8)}$$

It can be noted that the last of equations (VIII.8) is the equation for the shear stress developed, under the same conditions, on a solid cylindrical component .

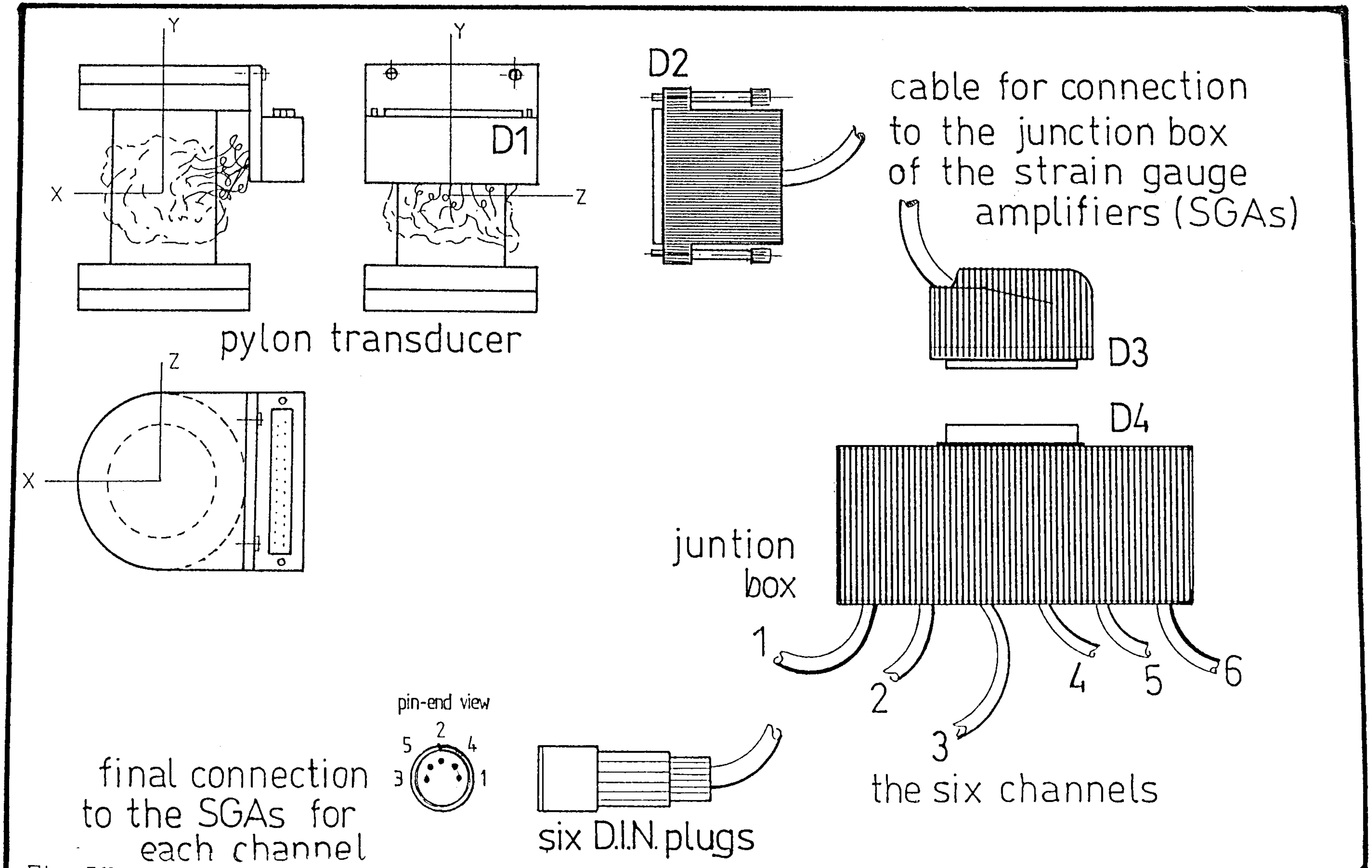

Fig IX.1 Connection of the pylon transducer to the amplifiers (SGAs) .

Appendix IX : Information regarding Wiring Connections and Settings of the system used in this study.

In the experimental work presented in this thesis the short pylon transducer was used, for prosthetic loading data acquisition. These tests involved the system of the transducer and its strain gauge amplifiers. The wiring connections of this set-up are explained in this appendix.

Regardless of whether the output signals of the amplifiers were fed to the micro-VAX computer (as in kneeling and gait analysis) or simply recorded using a digital voltmeter (as in calibration and Instron tests), the set-up was always the same. Figure IX.1 shows this set-up in detail, where the amplifiers are referred to as SGAs.

The instrumented surface of the pylon transducer had been covered in the past by a protective coat of polyethylene foam (Lawes ,1982), from which the bridge wires emerge. These wires are soldered on a 25-pin D-connector plug (D1 in the figure). The plug was appropriately mounted on the posterior and proximal side of the transducer. The D - shaped top flange provided the appropriate support for this purpose. An aluminium box was built during this project to provide safe accommodation for wires and solderings.

A long 25-core cable (14 m) was prepared for all tests, which could connect the transducer to the amplifiers. The cable had to be long enough to ensure safe and reliable amputee testing. One side of the cable was soldered to a 25-pin D-connector socket (D2 in the figure) and the other side to a 25-pin D-connector plug (D3 in the figure) . The former was safely connected to the transducer by means of two jack-screws and the latter was connected to the socket (D4) of a junction box.

This junction box , available from previous research projects, was meant to convert the D-connector configuration into D.I.N. - plug configurations as shown. Each one of the six D.I.N. plugs corresponded to one of the transducer channels in the order shown. These plugs were then connected to input sockets of the six SGAs .

Table IX.1 shows the connections for connector D1. Tables IX.2 and IX.3 show the correspondence between transducer channels and D-connector pins for connectors D2 and D3. Table IX.4 shows the connections for each of the six D.I.N. plugs.

The gain settings of the amplifiers were , in any case, as follows : 1000, 500, 1000, 200, 500, 100 for channels 1 to 6 respectively.

trans. signal	pin number	wire colour	function	pin number	wire colour	function
SMy	2 3	black red	−ve o/p +ve supply	14 15	green white	+ve o/p −ve supply
SFz	4 5	black red	−ve o/p +ve supply	16 17	green white	+ve o/p −ve supply
SMx	6 7	black red	−ve o/p +ve supply	18 19	green white	+ve o/p −ve supply
SFx	8 9	black red	−ve o/p +ve supply	20 21	green white	+ve o/p −ve supply
SMz	10 11	black red	−ve o/p +ve supply	22 23	green white	+ve o/p −ve supply
SFy	12 13	black red	−ve o/p +ve supply	24 25	green white	+ve o/p −ve supply

Note : pin 1 was screened .

Table IX.1 The connections for D-connector D1 .

trans. signal	pin number	wire colour	function	pin number	wire colour	function
SMy	2 3	green / red grey	-ve o/p +ve supply	14 15	red / blue red / yellow	+ve o/p -ve supply
SFz	4 5	orange/green white/green	-ve o/p +ve supply	16 17	white / red orange	+ve o/p -ve supply
SMx	6 7	yellow/green yellow	-ve o/p +ve supply	18 19	black / red pink	+ve o/p -ve supply
SFx	8 9	black orange/blue	-ve o/p +ve supply	20 21	light blue red / brown	+ve o/p -ve supply
SMz	10 11	blue / black white	-ve o/p +ve supply	22 23	red yellow/blue	+ve o/p -ve supply
SFy	12 13	brown blue	-ve o/p +ve supply	24 25	white/blue green	+ve o/p -ve supply

Note : pin 1 was not connected.

Table IX.2 The connections for D-connector D2 .

trans. signal	pin number	wire colour	function	pin number	wire colour	function
SFx	1 2	orange/blue light blue	+ve supply +ve o/p	14 15	red / brown black	-ve supply -ve o/p
SFy	3 4	blue white/blue	+ve supply +ve o/p	16 17	green brown	-ve supply -ve o/p
SFz	5 6	white/green white / red	+ve supply +ve o/p	18 19	orange orange/green	-ve supply -ve o/p
SMx	7 8	yellow black / red	+ve supply +ve o/p	20 21	pink yellow/green	-ve supply -ve o/p
SMy	9 10	grey red / blue	+ve supply +ve o/p	22 23	yellow / red green / red	-ve supply -ve o/p
SMz	11 12	white red	+ve supply +ve o/p	24 25	yellow/blue blue/black	-ve supply -ve o/p

Note : pin 13 was not connected.

Table IX.3 The connections for D-connector D3 .

pin number	wire colour	function
1 ┐ 2 ┘	red	+ve supply
3	black or blue	-ve supply
4	yellow or white	-ve o/p
5	green	+ve o/p

Table IX.4 The connections for the six DIN plugs

Appendix X : Presentation of the inverse alignment problem mentioned in chapter 7

Introduction

In this appendix a brief presentation is made of what was defined as " inverse alignment problem " in chapter 7 of this thesis. The subject is presented under the 3-D mathematical modelling point of view.

Besides its substantial contribution to the method for the assessment of a particular alignment, the modelling of a prosthesis is also the necessary tool for the achievement of an alignment configuration, which has already been considered appropriate, but is not available any more.

As mentioned in the introduction of chapter 7, it is quite often necessary to establish on a prosthesis, for various reasons, such an alignment. One example of such a situation is the need of repeating a particular alignment on a prosthesis, which due to stump shrinkage has been fitted with a new socket. In this case although the prosthetist could be already aware of the desired alignment parameters (using for example the method described in chapter 8), is generally obliged to repeat a full alignment session to obtain a satisfactory alignment configuration again.

The situation is similar in the case of an accidental change in the alignment of a prosthesis. Then again, although there are no new components, the prosthetist is generally obliged to repeat the necessary laborious work .

However, if it was possible to reach fast and accurately the alignment configuration, which has been used previously, then the starting point for the prosthetic procedure could be considered better and the result more easily obtained. Here is exactly the point where the modelling of an artificial leg and its alignment could significantly contribute and result to a solution of this problem.

Mathematical considerations

Some mathematical considerations are needed in order to clarify various theoretical aspects of the problem.

It is necessary to refer again to a modelled AK Otto Bock prosthesis (see figure 7.11). The problem discussed in this appendix has to do with the determination of the values of the angular adjustments ω_1 to ω_8 , which are the appropriate ones for the achievement of an already known alignment.

Compared to the problem discussed in chapter 8 , the present problem can be considered as its m a - t h e m a t i c a l i n v e r s e . Some questions may now be posed, from the mathematical point of view :

a) If the prosthesis is regarded as a linkage mechanism (say, similar to the ones assumed for manipulators), with the frames shown in figure 7.11, is there only one set of values for angles ω_1 to ω_8 which could satisfy the alignment configuration required ?

b) Is the alignment configuration required a feasible one for the prosthesis, with its actual geometry and functional limits ?

c) Is there any chance to obtain the required alignment configuration using different successions by which the various angular adjustments are performed ?

d) In case the above question has a positive answer, should the general prosthetic objective of optimum alignment range be converted to a new one, namely that of optimum permutations of angular adjustments for the achievement of the optimum range ?

The above questions consist the complex problem of the uniqueness and feasibility of the solution, as well as the problem of the functional dexterity of the mechanism under study. The discussion in this chapter is limited to a brief investigation for a solution satisfying the required alignment, under the following assumptions :

a) The angular adjustments sought are performed with the order specified by their subscripts (1 to 8) and not with any other general way.

b) The alignment configuration to be achieved is one that has already been previously obtained and falls, therefore, within the functional dexterity of the prosthesis.

The Analysis for the Problem

In the analysis presented, use of the following will be made :

- the spatial descriptions and transforms discussed in appendix V,
- the considerations discussed in chapter 7 for the mathematical modelling of a prosthesis, and
- the alignment equations (8.4) presented in chapter 8.

Since the alignment configuration of the prosthesis is known, the alignment parameters are known too, and therefore the frames of the knee and the socket can be known and their transforms determined .

In order to do so, the relationship between the alignment parameters and the elements of these matrices must be established. This has already been done in chapters 7 and 8. The formulae are repeated here for convenience.

If the matrix of the knee frame is denoted by [K] and the matrix for the socket frame is denoted by [S], then the alignment parameters are expressed as follows:

$$\text{Knee AP Shift} = KAPS = K(1,4)$$

$$\text{Knee ML Shift} = KMLS = (\pm 1) \cdot K(3,4)$$

$$\text{Knee Height} = KH = K(2,4) - (H_c + t_1)$$

$$\text{Knee ML Tilt} = KMLT = (\pm 1) \cdot \arctan\left(\frac{K(2,3)}{K(3,3)}\right)$$

$$\text{Knee Rotation} = KR = (\pm 1) \cdot \arctan\left(\frac{K(1,3)}{K(3,3)}\right)$$

$$\text{Socket AP Shift} = SAPS = S(1,4)$$

$$\text{Socket ML Shift} = SMLS = (\pm 1) \cdot S(3,4)$$

$$\text{Socket Height} = SH = S(2,4) - (H_c + t_1)$$

$$\text{Socket AP Tilt} = SAPT = \arctan\left(\frac{-S(1,2)}{S(2,2)}\right)$$

$$\text{Socket ML Tilt} = SMLT = (\pm 1) \cdot \arctan\left(\frac{-S(3,2)}{S(2,2)}\right)$$

$$\text{Socket Rotation} = SR =$$

$$= (\pm 1) \cdot \left[\arctan\left(\frac{-S(1,3)}{S(3,3)}\right) - \arctan\left(\frac{K(1,3)}{K(3,3)}\right) \right]$$

or

$$= (\pm 1) \cdot \left[\arctan\left(\frac{-S(1,3)}{S(3,3)}\right) - (\pm 1) \cdot KR \right] \qquad (X.1)$$

From the equations for the shifts the corresponding matrix elements are directly known. In order to solve the equations of tilts and rotations for the elements involved, the following substitutions are required :

$$f_1 = \tan(\pm 1 \cdot KMLT) = -K(2,3) / K(3,3)$$
$$f_2 = \tan(\pm 1 \cdot KR) = K(1,3) / K(3,3) \quad \text{or}$$
$$K(2,3) = -f_1 \cdot K(3,3) \qquad (X.2)$$
$$K(1,3) = f_2 \cdot K(3,3) \qquad (X.3)$$

Similarly for the socket equations :

$$f_3 = \tan(\pm 1 \cdot SAPT) = -S(1,2) / S(2,2)$$
$$f_4 = \tan(\pm 1 \cdot SMLT) = S(3,2) / S(2,2)$$
$$f_5 = \tan\left[(\pm 1 \cdot SR) + (\pm 1 \cdot KR) \right] = S(1,3) / S(3,3)$$

or

$$S(1,2) = -f_3 \cdot S(2,2) \qquad (X.4)$$
$$S(3,2) = f_4 \cdot S(2,2) \qquad (X.5)$$
$$S(1,3) = f_5 \cdot S(3,3) \qquad (X.6)$$

The top left (3x3) submatrices of each of the transforms [K] and [S], is actually representing the direction cosines of the corresponding frames (see appendix V) and therefore are orthonormal matrices. Using the qualities of orthonormal matrices the following are derived from equations (X.2) to (X.6) :

$$K(1,3)^2 + K(2,3)^2 + K(3,3)^2 = 1 \Rightarrow$$

$$K(3,3)^2 \cdot (f_1^2 + f_2^2 + 1) = 1 \Rightarrow$$

$$K(3,3) = \frac{1}{\sqrt{f_1^2 + f_2^2 + 1}} \qquad (X.7)$$

and K(1,3) and K(2,3) are given by (X.2) and (X.3).

Similarly ,

$$S(2,2) = \frac{1}{\sqrt{f_3^2 + f_4^2 + 1}} \qquad (X.8)$$

and S(1,2) and S(3,2) are given by (X.4) and (X.5).

Also because :

$$S(1,3)^2 + S(2,3)^2 + S(3,3)^2 = 1 \text{ and} \qquad (X.9)$$
$$S(1,3) \cdot S(1,2) + S(2,3) \cdot S(2,2) + S(3,3) \cdot S(3,2) = 0$$

using the equation (X.6) the three unknown elements S(1,3) , S(2,3) and S(3,3) can be determined :

$$S(2,3) = \pm \frac{f_6}{\sqrt{f_6^2 + f_7^2}} \quad , \quad S(3,3) = \frac{\sqrt{1 - S(2,3)^2}}{\sqrt{1 + f_5^2}}$$

and S(1,3) given by (X.6).

Considering the fact that all the above elements are actually representing the projections of the corresponding unit vectors on the axes of the reference frame, the following can be appreciated :

i) Element K(3,3) is always positive because it is the projection of the knee Z-axis to the reference Z-axis and therefore only the positive value of the square root is kept in equation (X.7).These two values result to two different values for S(3,3) and another two different values for S(1,3). Thus after the calculation of all possible values equation

ii) Element S(2,2) similarly, is always positive because it is the projection of the socket Y-axis to the reference Y-axis and therefore only the positive value of the square root is kept in equation (X.8).

iii) Element S(2,3) is the projection of the socket Z-axis to the reference Y-axis and could be either positive or negative and therefore both signs are kept in equation (X.10). These two values result to two different values for S(3,3) and another two different values for S(1,3). Thus after the calculation of all possible values, the second of equations (X.9) should be applied to decide about the appropriate set of values S(1,3) , S(2,3) , S(3,3).

If the whole range of the qualities related to orthonormal matrices is applied, all the elements of matrices [K] and [S] can be determined. However since there are only eight unknown quantities in the initial problem (ω_1 to ω_8) not all elements of these matrices are needed to be determined.

Having partially determined the transforms [K] and [S] of the knee and socket frames with respect to the universal reference frame, next task should be to relate these transforms to the required quantities. In other words the next step is to express the elements of these two matrices in terms of the angular adjustments ω_1 to ω_8.

The unknown quantities may be calculated using linear programming or techniques for the solution of simultaneous transcendental equations.

APPENDIX XI : The data for the investigation of the second-order calibration model

1) Loading data (116 tests)

Fx(N)	Fy(N)	Fz(N)	Mx(Nm)	My(Nm)	Mz(Nm)
0.00	196.20	0.00	0.00	0.00	-39.20
0.00	0.00	78.50	0.00	15.70	0.00
0.00	196.20	0.00	19.60	0.00	-34.00
-30.30	186.60	52.50	18.70	12.10	-32.30
-28.80	79.40	49.90	7.90	11.50	-13.70
-39.70	57.70	68.70	5.80	15.90	-10.00
-46.60	30.30	80.80	3.00	18.70	-5.30
-49.10	0.00	85.00	0.00	19.60	0.00
0.00	98.10	0.00	4.91	0.00	-8.50
-15.16	93.30	26.25	4.66	3.03	-8.08
-28.83	79.36	49.94	3.97	5.77	-6.87
-19.84	28.83	34.37	1.44	3.97	-2.50
-23.32	15.16	40.40	0.76	4.66	-1.31
-24.53	0.00	42.48	0.00	4.91	0.00
0.00	147.15	0.00	12.74	0.00	-7.36
-39.38	139.95	22.74	12.12	4.55	-7.00
-49.94	79.36	28.83	6.87	5.77	-3.97
-34.37	28.83	19.84	2.50	3.97	-1.44
-40.40	15.16	23.32	1.31	4.66	-0.76
-25.49	0.00	14.71	0.00	2.94	0.00
0.00	147.15	0.00	-7.36	0.00	-12.74
22.74	139.95	39.38	-7.00	4.55	-12.12
28.83	79.36	49.94	-3.97	5.77	-6.87
19.84	28.83	34.37	-1.44	3.97	-2.50
23.32	15.16	40.40	-0.76	4.66	-1.31
24.53	0.00	42.48	0.00	4.91	0.00
0.00	147.15	0.00	-12.74	0.00	-7.36
39.38	139.95	22.74	-12.12	4.55	-7.00
49.94	79.36	28.83	-6.87	5.77	-3.97
34.37	28.83	19.84	-2.50	3.97	-1.44
40.40	15.16	23.32	-1.31	4.66	-0.76
42.48	0.00	24.52	0.00	4.91	0.00
0.00	**196.20**	**0.00**	**0.00**	**0.00**	**19.62**
-4.62	**97.99**	**0.00**	**0.00**	**0.00**	**11.36**
-9.23	**195.98**	**0.00**	**0.00**	**0.00**	**22.71**
-18.41	**195.33**	**0.00**	**0.00**	**0.00**	**25.75**
-27.46	**194.27**	**0.00**	**0.00**	**0.00**	**28.69**
-36.34	**192.81**	**0.00**	**0.00**	**0.00**	**31.54**
-54.40	**289.21**	**0.00**	**0.00**	**0.00**	**47.32**
-44.99	**190.97**	**0.00**	**0.00**	**0.00**	**34.28**
-67.48	**286.46**	**0.00**	**0.00**	**0.00**	**51.42**
0.00	**294.30**	**0.00**	**0.00**	**0.00**	**29.43**
-13.85	**293.97**	**0.00**	**0.00**	**0.00**	**34.07**
-27.61	**293.00**	**0.00**	**0.00**	**0.00**	**38.62**
-41.19	**291.40**	**0.00**	**0.00**	**0.00**	**43.04**

Note : the values printed in **bold characters** correspond to the **13** tests used for predictions

Fx(N)	Fy(N)	Fz(N)	Mx(Nm)	My(Nm)	Mz(Nm)
86.49	119.05	0.00	0.00	0.00	0.00
0.00	279.90	90.94	0.00	0.00	0.00
49.05	0.00	-84.96	0.00	0.00	0.00
0.00	490.50	0.00	-16.99	0.00	9.81
0.00	490.50	0.00	-16.99	0.00	9.81
-11.54	489.96	-19.99	-23.72	0.00	13.69
-23.01	488.34	-39.85	-30.37	0.00	17.53
-34.32	485.67	-59.45	-36.89	0.00	21.30
23.01	488.34	39.85	-3.47	0.00	2.00
27.25	289.21	47.20	5.91	0.00	-3.41
-28.61	181.63	68.47	6.21	2.33	-3.59
-19.14	177.21	82.01	10.94	4.11	-6.32
-85.60	279.59	33.43	-13.54	-5.08	7.81
-92.22	278.66	21.36	-17.33	-6.50	10.00
-98.58	277.14	9.35	-21.05	-7.90	12.15
87.23	116.99	18.90	-2.39	2.01	-1.38
92.09	114.56	6.95	-5.50	4.61	-3.17
81.48	118.52	31.10	0.84	-0.71	0.49
99.87	158.73	57.66	5.50	-4.61	3.17
95.15	158.55	65.59	7.68	-6.44	4.43
90.23	158.03	73.35	9.83	-8.24	5.67
85.16	157.17	80.87	11.94	-10.01	6.89
-97.16	0.00	-17.12	0.68	7.77	-3.84
-92.72	0.00	-33.73	1.33	7.42	-3.66
-85.45	0.00	-49.31	1.95	6.84	-3.38
-75.60	0.00	-63.39	2.50	6.05	-2.99
-63.45	0.00	-75.55	2.98	5.08	-2.51
-49.37	0.00	-85.42	3.37	3.95	-1.95
-33.80	0.00	-92.69	3.66	2.70	-1.34
-17.20	0.00	-97.15	3.84	1.38	-0.68
-97.16	0.00	17.12	-0.68	7.77	-3.84
-92.72	0.00	33.73	-1.33	7.32	-3.66
-85.45	0.00	49.31	-1.95	6.75	-3.38
-75.60	0.00	63.39	-2.50	5.97	-2.99
-63.45	0.00	75.55	-2.98	5.01	-2.51
-49.37	0.00	85.42	-3.37	3.90	-1.95
-97.16	0.00	-17.12	0.68	-9.72	-3.84
-92.72	0.00	-33.73	1.33	-9.27	-3.66
-85.45	0.00	-49.31	1.95	-8.55	-3.38
-75.60	0.00	-63.40	2.50	-7.56	-2.99
-63.45	0.00	-75.55	2.98	-6.35	-2.51
-49.37	0.00	-85.42	3.37	-4.94	-1.95
-33.80	0.00	-92.69	3.66	-3.38	-1.34
-97.16	0.00	17.12	-0.68	-9.72	-3.84
-92.72	0.00	33.73	-1.33	-9.27	-3.66
-85.45	0.00	49.31	-1.95	-8.55	-3.38
-75.60	0.00	63.40	-2.50	-7.56	-2.99
-63.45	0.00	75.55	-2.98	-6.35	-2.51

Fx(N)	Fy(N)	Fz(N)	Mx(Nm)	My(Nm)	Mz(Nm)
-49.37	0.00	85.42	-3.37	-4.94	-1.95
-33.80	0.00	92.69	-3.66	-3.38	-1.34
-17.20	0.00	97.15	-3.84	-1.72	-0.68
0.00	98.66	0.00	-12.06	0.00	12.07
0.00	147.83	0.00	-18.08	0.00	18.09
0.00	98.66	0.00	-8.53	0.00	14.78
0.00	147.83	0.00	-12.78	0.00	22.15
-145.58	0.00	-25.66	1.01	-7.28	-5.75
-138.92	0.00	-50.54	2.00	-6.95	-5.49
-128.04	0.00	-73.88	2.92	-6.40	-5.06
-113.28	0.00	-94.98	3.75	-5.66	-4.47
-95.07	0.00	-113.20	4.47	-4.75	-3.76
-73.98	0.00	-127.98	5.06	-3.70	-2.92
-145.58	0.00	25.66	-1.01	-7.28	-5.75
-138.92	0.00	50.54	-2.00	-6.95	-5.49
-128.04	0.00	73.88	-2.92	-6.40	-5.06
-113.28	0.00	94.98	-3.75	-5.66	-4.47
-95.07	0.00	113.20	-4.47	-4.75	-3.76
-73.98	0.00	127.98	-5.06	-3.70	-2.92
-50.65	0.00	138.88	-5.49	-2.53	-2.00
-25.77	0.00	145.56	-5.75	-1.29	-1.02
-97.16	0.00	-17.12	0.68	-4.86	-3.84
-92.72	0.00	-33.73	1.33	-4.64	-3.66

2) Output signal data (116 tests)

SFx (mV)	SFy (mV)	SFz (mV)	SMx (mV)	SMy (mV)	SMz (mV)
9.0	-36.0	-12.0	2.0	-3.0	-225.0
7.0	-4.0	74.0	6.0	-302.5	2.5
-4.0	-32.0	0.0	-217.5	1.0	-199.0
-29.0	-35.0	50.0	-203.0	-238.0	-189.5
-25.0	-16.5	46.5	-82.5	-225.0	-80.0
-32.5	-12.0	64.5	-59.5	-304.0	-58.0
-38.0	-8.0	78.0	-28.0	-360.0	-30.0
-42.5	-4.0	84.0	12.0	-377.5	2.0
-6.0	-22.0	-1.0	-59.0	7.0	-50.0
-16.0	-21.0	24.0	-53.0	-51.0	-47.0
-29.0	-19.0	47.0	-44.0	-101.0	-40.0
-19.0	-8.0	33.0	-16.0	-71.0	-15.0
-22.0	-4.0	39.0	-8.0	-88.0	-7.0
-22.5	-1.5	41.0	0.0	-92.5	0.0
-4.0	-32.0	2.0	-148.5	5.5	-42.0
-39.0	-30.5	25.0	-138.0	-83.5	-39.5
-47.5	-18.5	28.0	-77.5	-108.0	-23.0
-32.0	-8.0	20.5	-28.0	-76.0	-8.0
-37.5	-5.0	23.0	-14.5	-90.0	-4.0
-23.5	-1.5	13.5	0.0	-57.5	0.0
5.5	-37.5	-7.5	81.5	2.0	-73.0
28.0	-36.5	31.5	79.5	-83.0	-69.5

SFx (mV)	SFy (mV)	SFz (mV)	SMx (mV)	SMy (mV)	SMz (mV)
32.0	-20.0	44.0	46.0	-107.0	-38.0
22.0	-8.0	30.5	17.0	-74.0	-13.5
26.0	-4.0	38.0	10.0	-87.5	-6.0
26.0	-1.0	40.5	1.0	-93.0	0.0
8.0	-40.5	-7.5	144.0	2.0	-42.0
46.0	-39.0	16.0	140.0	-84.0	-39.0
56.0	-23.0	24.5	80.0	-107.0	-21.0
37.0	-8.0	17.0	29.0	-74.5	-6.5
43.0	-5.0	22.0	15.5	-88.0	-3.0
45.5	-0.5	23.0	1.0	-93.5	0.0
2.1	-55.0	5.5	-3.3	-7.3	113.7
-4.5	-28.8	2.7	-2.3	-4.3	65.9
-8.1	-57.0	5.6	-3.6	-8.8	132.2
-15.6	-57.7	7.2	-3.2	-10.0	150.9
-25.6	-58.1	7.0	-3.2	-12.2	167.7
-39.0	-57.5	4.6	-2.7	-15.8	182.5
-54.5	-86.0	8.9	-4.2	-22.4	274.0
-41.0	-58.3	9.8	-3.2	-14.6	200.0
-61.0	-86.5	15.4	-3.7	-21.7	299.0
2.5	-84.4	9.6	0.8	-11.8	173.3
-10.4	-85.9	10.9	1.7	-14.1	199.4
-24.0	-88.0	13.5	3.6	-13.7	230.0
-37.4	-88.7	14.2	3.0	-15.2	251.0
84.0	-30.0	-0.8	-0.3	-0.4	1.6
0.0	-71.9	82.0	-0.5	1.6	0.8
52.7	0.6	-81.4	-5.1	-1.0	1.4
11.4	-136.0	-3.0	193.2	-13.6	63.7
11.2	-133.6	-2.3	193.2	-13.2	63.3
2.0	-137.0	-20.8	266.0	-17.7	86.0
-7.2	-140.2	-40.1	342.0	-22.0	108.0
-17.7	-142.2	-58.6	416.0	-26.0	130.0
29.4	-126.1	36.6	37.1	-2.6	17.6
26.6	-71.3	44.6	-69.8	4.5	-16.8
-26.3	-44.9	66.6	-71.2	-41.1	-19.7
-19.0	-41.6	80.8	-125.0	-73.0	-36.2
-77.6	-77.8	30.0	155.0	90.6	46.9
-82.6	-79.4	17.5	198.6	115.5	60.0
-89.1	-80.5	5.8	241.0	140.0	72.8
87.3	-30.4	17.4	27.9	-40.0	-7.6
94.4	-30.7	5.2	63.2	-90.4	-18.1
79.1	-28.6	29.5	-8.8	12.5	3.6
94.1	-37.4	55.5	-62.2	90.1	20.4
87.4	-36.0	63.8	-85.6	123.6	27.2
81.6	-35.5	71.4	-109.0	160.6	35.1
75.0	-34.1	78.8	-133.0	195.5	42.1
-93.4	-0.5	-14.4	-9.1	-153.7	-25.3
-88.5	0.7	-31.7	-18.2	-145.0	-23.9

SFx (mV)	SFy (mV)	SFz (mV)	SMx (mV)	SMy (mV)	SMz (mV)
-82.4	-0.8	-47.2	-25.6	-132.7	-22.2
-72.0	0.3	-62.3	-33.2	-117.0	-19.3
-60.7	0.0	-72.9	-38.1	-99.2	-16.3
-48.3	-0.8	-81.2	-42.9	-78.7	-12.9
-32.5	0.4	-88.6	-46.3	-52.5	-8.7
-17.7	1.1	-92.1	-48.2	-30.4	-5.1
-94.0	-3.1	19.2	8.3	-151.6	-24.9
-88.5	-2.7	34.5	16.7	-143.3	-23.7
-82.9	-3.0	47.6	23.6	-133.5	-21.6
-72.8	-3.1	62.3	31.2	-116.4	-18.9
-61.8	-2.5	71.9	36.4	-100.0	-16.0
-47.7	-2.8	81.0	41.9	-77.9	-12.4
-95.7	1.9	-20.0	-7.4	189.5	-25.7
-92.0	6.0	-37.0	-16.4	184.0	-24.0
-86.0	5.0	-49.0	-23.0	171.5	-22.0
-77.5	3.0	-62.0	-30.5	154.5	-20.0
-65.5	2.0	-73.0	-37.0	132.0	-17.0
-54.0	3.0	-81.0	-41.0	107.0	-14.0
-38.0	1.0	-89.0	-45.0	75.5	-9.5
-94.0	2.0	13.5	10.5	189.0	-24.5
-91.0	1.0	28.5	18.5	180.5	-23.0
-83.0	1.0	44.0	25.0	165.0	-21.0
-74.5	0.0	57.0	32.0	146.5	-19.0
-64.5	0.0	68.5	37.5	125.0	-15.0
-49.5	0.0	77.5	42.0	97.0	-12.0
-32.5	0.0	87.5	46.0	65.0	-7.5
-16.5	1.0	92.0	48.0	32.0	-3.0
0.5	-33.0	6.0	137.0	-6.0	73.0
0.0	-50.0	9.5	206.0	-8.0	110.0
0.0	-33.0	6.5	93.0	-2.5	90.0
0.0	-49.5	10.5	139.0	-2.5	135.0
-145.5	0.0	-25.5	-10.5	144.0	-37.0
-138.0	1.0	-49.0	-23.0	139.5	-35.0
-130.0	2.0	-71.0	-35.0	130.0	-33.0
-116.0	2.0	-91.0	-45.5	118.0	-30.0
-102.5	1.5	-105.0	-53.5	103.5	-26.0
-78.0	2.0	-122.0	-61.0	79.0	-19.0
-143.0	1.0	23.0	13.0	145.0	-37.0
-136.0	0.5	48.0	26.5	137.0	-35.0
-125.5	0.0	69.0	37.0	124.5	-32.0
-108.5	0.0	90.5	49.5	112.5	-28.0
-91.5	-1.5	106.5	58.0	95.5	-23.0
-72.5	-1.0	120.0	64.5	75.5	-19.0
-47.5	-2.0	132.0	71.0	50.0	-11.0
-24.0	-3.0	138.0	74.0	25.0	-6.0
-96.0	1.0	-16.0	-7.0	96.0	-25.0
-93.0	1.0	-32.0	-16.0	94.0	-23.0

3) Statistical information for sensitivity coefficients

For SFx

Predictor	Coef	Stdev	t-ratio	p-value
Fx	0.984619	0.003964	248.42	0.000
Mx	-0.26660	0.03101	-8.60	0.000
My	0.34497	0.04083	8.45	0.000
FxFy	-0.00015876	0.00004366	-3.64	0.000
FyFy	0.00003231	0.00000482	6.70	0.000
FzMy	-0.0018103	0.0006960	-2.60	0.011
MxMz	0.005236	0.001835	2.85	0.005
MyMy	0.013170	0.003881	3.39	0.001

For SFy

Predictor	Coef	Stdev	t-ratio	p-value
Fx	0.014122	0.001657	8.52	0.000
Fy	-0.257068	0.000761	-337.84	0.000
Mx	0.32744	0.01708	19.17	0.000
My	-0.27306	0.02279	-11.98	0.000
Mz	-0.29449	0.01786	-16.49	0.000
FxMy	-0.0006237	0.0003094	-2.02	0.047
MyMy	0.004642	0.001514	3.07	0.003
MzMz	0.0012282	0.0005296	2.32	0.023

For SFz

Predictor	Coef	Stdev	t-ratio	p-value
Fz	0.955973	0.003161	302.38	0.000
Mz	0.40173	0.02920	13.76	0.000
FxFx	0.00018030	0.00003467	5.20	0.000
FxMy	-0.0023212	0.0004164	-5.57	0.000
FyFz	-0.00013170	0.00003317	-3.97	0.000
FyMx	0.00097447	0.00008272	11.78	0.000
FzMy	0.0030993	0.0005916	5.24	0.000
MyMy	-0.012548	0.003825	-3.28	0.001
MzMz	0.0061589	0.0009062	6.80	0.000

For SMx

Predictor	Coef	Stdev	t-ratio	p-value
Fy	-0.015129	0.001847	-8.19	0.000
Fz	0.055128	0.004466	12.34	0.000
Mx	-11.2408	0.0452	-248.56	0.000
My	-0.15477	0.03167	-4.89	0.000
FxFz	-0.00016533	0.00007093	-2.33	0.022
FxMx	-0.005960	0.001806	-3.30	0.001
FyMx	-0.0011643	0.0002199	-5.29	0.000
FyMy	-0.003887	0.001257	-3.09	0.003
FyMz	-0.0007944	0.0001408	-5.64	0.000
FzMx	-0.0011414	0.0005434	-2.10	0.038
MxMx	0.006739	0.001976	3.41	0.001
MyMy	0.014944	0.002175	6.87	0.000
MyMz	-0.023657	0.005045	-4.69	0.000

For SMy

Predictor	Coef	Stdev	t-ratio	p-value
Fy	0.024780	0.007442	3.33	0.001
My	-19.6427	0.0802	-244.98	0.000
FyFy	-0.00011974	0.00001854	-6.46	0.000
FzMy	0.005630	0.001262	4.46	0.000

For SMz

Predictor	Coef	Stdev	t-ratio	p-value
Fx	0.017709	0.002413	7.34	0.000
Fy	0.011298	0.002073	5.45	0.000
Mx	-0.16548	0.02364	-7.00	0.000
My	0.04785	0.01422	3.37	0.001
Mz	5.79002	0.04209	137.56	0.000
FxFx	-0.00009720	0.00002002	-4.86	0.000
FxFy	-0.00008819	0.00002111	-4.18	0.000
FyFy	0.00001610	0.00000495	3.25	0.002
FyFz	-0.00012154	0.00003214	-3.78	0.000
FyMx	0.0013708	0.0002014	6.81	0.000
FyMz	0.0013144	0.0003061	4.29	0.000
MxMz	0.006331	0.001098	5.76	0.000
MyMy	0.005128	0.001226	4.18	0.000
MyMz	0.004528	0.001995	2.27	0.026
MzMz	0.0059219	0.0007908	7.49	0.000

4) Statistical information for exploitation coefficients

For Fx

Predictor	Coef	Stdev	t-ratio	p-value
SFx	1.02040	0.00335	305.02	0.000
SMx	-0.026193	0.002721	-9.63	0.000
SMy	0.017001	0.001768	9.61	0.000
SFySFy	-0.00046095	0.00006995	-6.59	0.000
SMxSMy	-0.00011101	0.00002716	-4.09	0.000
SMxSMz	0.00008793	0.00002836	3.10	0.003

For Fy

Predictor	Coef	Stdev	t-ratio	p-value
SFx	0.057678	0.006087	9.48	0.000
SFy	-3.89463	0.01453	-268.03	0.000
SMx	-0.119161	0.005733	-20.78	0.000
SMy	0.043819	0.003091	14.18	0.000
SMz	-0.204242	0.009121	-22.39	0.000
SMxSMx	0.00005752	0.00002457	2.34	0.021

For Fz

Predictor	Coef	Stdev	t-ratio	p-value
SFz	1.05012	0.00371	283.19	0.000
SMz	-0.067163	0.005726	-11.73	0.000
SFxSFx	-0.00017865	0.00004212	-4.24	0.000
SFxSMy	-0.00012772	0.00002653	-4.81	0.000
SFySMx	-0.00027248	0.00002842	-9.59	0.000
SFzSMy	0.00016003	0.00003656	4.38	0.000
SMySMy	0.00003089	0.00001182	2.61	0.010
SMzSMz	-0.00018650	0.00003167	-5.89	0.000

For Mx

Predictor	Coef	Stdev	t-ratio	p-value
SFy	0.0056940	0.0009618	5.92	0.000
SFz	0.0045758	0.0002787	16.42	0.000
SMx	-0.0884900	0.0003743	-236.42	0.000
SMy	0.0005229	0.0001152	4.54	0.000
SFySFy	0.00002306	0.00001143	2.02	0.046
SFySMx	-0.00003182	0.00000637	-4.99	0.000
SFySMx	0.00005636	0.00000875	6.44	0.000
SFzSMx	0.00001107	0.00000397	2.78	0.007
SMySMy	0.00000374	0.00000051	7.38	0.000
SMySMz	0.00001095	0.00000270	4.05	0.000

For My

Predictor	Coef	Stdev	t-ratio	p-value
SFy	-0.004751	0.001268	-3.75	0.000
SMy	-0.0507832	0.0001831	-277.34	0.000
SFxSFx	0.00000675	0.00000273	2.47	0.015
SFxSMx	0.00005146	0.00001627	3.16	0.002
SFySFy	-0.00005511	0.00001323	-4.17	0.000
SFySMy	-0.00007394	0.00003616	-2.04	0.044
SFySMz	0.00002326	0.00000934	2.49	0.015
SFzSMy	-0.00001408	0.00000268	-5.26	0.000
SFzSMz	-0.00008181	0.00003115	-2.63	0.010
SMxSMy	-0.00000676	0.00000267	-2.54	0.013
SMxSMz	-0.00000890	0.00000239	-3.73	0.000

For Mz

Predictor	Coef	Stdev	t-ratio	p-value
SFx	-0.0012514	0.0003195	-3.92	0.000
SFy	0.009572	0.001231	7.78	0.000
SMy	0.0004578	0.0001148	3.99	0.000
SMz	0.167562	0.000455	368.21	0.000
SFxSFx	0.00001542	0.00000301	5.12	0.000
SFySFz	-0.00006453	0.00002387	-2.70	0.008
SFySMx	-0.00001651	0.00000630	-2.62	0.010
SMxSMz	0.00001464	0.00000258	5.68	0.000
SMzSMz	-0.00002182	0.00000302	-7.22	0.000

Appendix XII: A new suggested approach for the combined study of prosthetic alignment and loading

XII.1 Introduction

The thorough and systematic investigation of the influence that prosthetic alignment has on the loading of lower limb prostheses requires a proper mathematical framework.

As discussed in chapter 2, former studies in this field investigated the effect of certain alignment changes on a number of kinetic parameters, in order to establish criteria for the achievement of optimum alignment configurations. Despite the undoubted importance of these contributions, the need for a theoretical and experimental framework which would globally cover the field has not still been met.

In this appendix the author suggests a mathematical framework that could provide the research team the ability to investigate individual as well as interaction effects of prosthetic alignment changes on any kinetic parameters chosen. The new suggested approach involves the well established method of factorial experimentation and is presented in the following discussion.

The presentation of the new approach commences with the description of the equipment and methods available at the moment in the Bioengineering Unit.

XII.2 Prerequisite Equipment and Methods

For studies combining prosthetic loading and alignment there are two major prerequisites : a system to measure prosthetic loading and a method to assess prosthetic alignment.

XII.2.1 The Pylon Transducer

The short pylon transducer of the Bioengineering Unit or any future version of it can be used for data acquisition regarding the prosthetic loading during amputee locomotion.

Furthermore the portable system developed by Pashalides (1989) and improved and currently used by Ainscough (1991) allows the acquisition of data from outdoor tests. This system is a free-range system and can provide data acquired in the external environment.

The processing of the data can be performed by the software developed by Karagiannopoulos (1991). Thus, the loads acting at all levels of the prosthesis as well as a set of temporal parameters can be known and used for further analysis.

Future development of the software could provide the calculation of any other chosen kinetic parameters. Such parameters can be of differential (slopes of loading patterns) or integral (impulses of load components) character. In the context of factorial experimentation all these quantities will constitute the quantities on which the effect of alignment is to studied.

The use of a powerful micro-computer would result in a fast data processing and adequate data storage.

XII.2.2 The Assessment of Alignment

In chapters 7 and 8 of this thesis a new method for the fast (in fact immediate) assessment of the prosthetic alignment is presented. In chapter 9 a series of improvements further needed regarding this method is reported. However, this method can virtually constitute the method of alignment assessment in the context of factorial experimentation.

The mathematical framework suggested in this chapter involves factorial experimentation and therefore a considerable amount of replicated tests. The assessment of alignment between tests must, thus, be as fast as possible. The fact that the method presented in chapters 7 and 8 immediately provides the current values of the alignment parameters is considered a good qualification and constitutes a good reason for any further improvements on this method.

In the context of factorial experimentation the alignment parameters or the absolute values of the corresponding alignment changes will constitute the quantities the effect of which is to be studied.

Having presented the equipment and methods available in the Bioengineering Unit, a discussion follows on the factorial experimentation.

XII.3 The Factorial Experimentation

In a factorial experiment the effects of a number of different parameters, over several quantities under study, are investigated simultaneously. The aim of this type of experiment is to to reveal all quantitative and qualitative (individual or interactive) effects of the parameters to be tested over the quantities under study.

The parameters, the effect of which is to be studied, are referred to as f a c t o r s and the combinations of all factors that can be formed consist what is referred to as t r e a t m e n t s. Each factor will appear in the treatments by different values called the l e v e l s o f t h e f a c t o r. The number of times a measurement is repeated are called r e p l i c a t i o n s.

For complicated experimental procedures the analysis of the acquired data is carried out by statistical software. According to the chosen levels, the statistically significant effects are pointed out and the experimenters can draw their conclusions.

XII.4 General Considerations on the Experimental Design

XII.4.1 Introduction

The design of the experimental procedure is of high importance. To draw reliable inferences out of the results, both the factors and the quantities chosen to be studied have to be carefully decided, according to the application that the results are supposed to serve in long run.

The variability in results is very typical in most of the experiments. Thus, the problem of drawing conclusions from the results is a problem in induction from the s a m p l e to the p o p u l a t i o n. The statistical theories of estimation and testing of different hypotheses provide solutions to this problem in the form of definite statements that have a known and controllable probability of being correct. If for instance, it is required to estimate the t r u e v a l u e of a quantity (say the maximum axial force acting on the foot, as a percentage of the body weight) having the e x p e r i m e n t a l d a t a from a sample (say the corresponding values from thirty steps of an amputee's walking session), then it is possible to find limits that are almost certain to enclose the true figure, where the degree of certainty as measured by the probability, can be chosen by the experimenter. It is known that these limits are called c o n f i d e n c e l i m i t s and the probability associated with them is called the c o n f i d e n c e p r o b a b i l i t y.

The experimental design is the necessary procedure, which, when properly carried out, ensures the highest possible quality of the inferences drawn.

Before starting any experimental work the following must be done :

1) a statement of objectives and

2) a description of the undertaken experiment covering such matters as the experimental treatments, the size of the experimental work and the kind of the material to be used.

XII.4.2 The Objectives

The objectives should be in the form of questions to be answered, hypotheses on the significance of various factors to be tested, or effects to be estimated. Objectives could be of the following form : How does plantar/dorsi flexion of two different types of prosthetic feet change the temporal characteristics of the axial load ?

A step-by-step approach may be adopted in the description of the objectives in order to assure not only success, but also a good basis for further future work.

On the other hand, the statement of objectives should include an account of the area over which generalisations are to be made, or in other words, of the population about which it is hoped to make inferences.

XII.4.3 The Experimental Treatments

In the selection of treatments it is very important to define clearly each treatment and to understand the role that each treatment will play in reaching the objectives of the experimental work.

Confusion may be caused by failure to distinguish whether the object is merely to "spot the winner" among the different treatments, or whether, in addition, we desire to find some clues as to why the treatments behave as they do. Is ,for instance, the achievement of an optimum alignment configuration, if any, the only task or , in addition to this, more global explanations are sought ?

Although there are occasions when it is sufficient simply to discover which is the best of the treatments, experience suggests that even in strictly applied research progress is faster, if experiments supply fundamental knowledge. Similarly, the criticism that certain treatment should be omited , because it would not be used in practice, is valid if the aim is to find the best of the "practical" treatments, but it is not valid if the "impractical" treatments will supply some needed information about the behaviour of the other treatments in the experiment.

Another important issue in the decisions regarding the experimental treatments is that of the conditions under which the treatments are to be compared. Testing on a particular walking surface under different conditions (wet and dry) , for example, may cause comparative problems. In any case the decision must be guided by the objectives of the experiment.

The feasibility of various treatments is also important. In some cases, it becomes apparent that the treatments that can be tested in practice are not those or the only ones, that one would like to test. Thus, the experimenters have to face the issues of how best to use the resources available and whether the experiment, as it can be done, is worth doing.

Finally, discussion may arise as the need for a c o n t r o l , this term being used rather loosely for the treatment in which the research team is not particularly interested, but which may be needed in order to reveal, by comparison, the effect of the other treatments. Such a control is strongly advised for cases where there is not any single clue for the effect of treatments. In these cases a knowledge of the conditions under which the various treatments are tested are provided by the control treatment.

XII.5 Specific Considerations on the Experimental Design

XII.5.1 The Amputee Population

The population of the amputees that the results and conclusions will apply to, and the sample will be taken from must be well defined. The term sample denotes the number and kind of amputees to be tested and the term population denotes the particular kind of patients that conclusions and generalisations will be applicable to. The decision about this issue can be based on age, activity level, length or age of stump, sex etc.

XII.5.2 The Quantities under study and the Factors

The quantities chosen to be studied must be these which are considered as sufficiently describing the prosthetic loading patterns. As such could be considered local or global maxima or minima, time intervals and durations, derivatives (gradient of load graphs) or integrals (chart area bounded by the load graphs).

The factors could be the alignment parameters, the walking surface characteristics (slope, material etc), as well as other parameters like the type of prosthetic foot or socket etc.

XII.5.3 The Experimental Procedure

In order to define the kind and number of treatments needed it is important to decide on the number of different levels that every factor will be tested at. One must bear in mind that the number of levels causes a considerable increase to the total number of treatments , as shown by the following expression :

$$\text{Number of treatments} = l_1 \circ l_2 \circ l_3 \circ \ldots \circ l_n$$

where : l_i is the number of levels for the i-th factor.

A good balance should be achieved between the number of treatments providing information directly related to the objectives and the total number of treatments in order to avoid excessive and purposeless work but also to allow for some control treatments to be introduced.

Since not all statistically interesting treatments will be functionally accepted by the amputees, the experimenters should think on these restrictions as well. The experimental procedure may be quite long and the amputees' discomfort should, in any case, be avoided.

It is also statistically important to provide every treatment the same chance to exhibit its effect. Some sort of randomisation should be designed in the succession of treatments and also the number of replications should be the same between the treatments. In other words, when testing the amputee it is necessary to follow a mixed sequence of treatments and record data over about the same time with the same walking speed. When the processing stage is reached then the same number of steps (ie. the replications of the particular measurement) should be taken into account.

XII.6 Summary

This appendix presented an outline of the mathematical framework suggested for combined studies on prosthetic loading and alignment. This framework is the theory of the factorial experimentation.

The equipment used for loading data acquisition will be the pylon transducer system and the alignment may be assessed using the method described in chapters 7 and 8 of this thesis.

The research team must initially specify which alignment parameters will be considered as factors and which kinetic or temporal quantities will be chosen to be studied. They may also consider other factors of qualitative character. It is very important to decide since the beginning which particular amputee population is meant to correspond both to the work and the conclusions drawn from its results.

Then the team must define their objectives and plan the experimental procedure so as to reach the desired tasks by the best of ways.

Finally the experimenters must process the data acquired by the pylon transducer, derive all the quantities chosen to be studied and perform their analysis using a statistical package.

The analysis of variance that the package will carry out will reveal a certain number of significant main or interaction effects. In any case, however, all results that the statistical analysis will provide will only be based on the confidence levels that the team will have set in advance and the reliability of any conclusions will depend upon the quality of the experimental procedure. Furthermore, once having decided about the significant effects of various factors (alignment parameters and others) on the kinetic or temporal quantities under study, the research team may even attempt to build multiple regression models, able to perform certain predictions.

Appendix XIII : Listings of the developed programs

All programs are written in the Fortran language of the main frame VAX computer of the University of Strathclyde. The programs are :

1) INSTRON.FOR (chapter 5)
2) KNEE.FOR (chapter 10)
3) ALIGNMENT. FOR (chapter 8)
4) RIGALIGN.FOR (chapter 8)
5) INITIAL.FOR

The last program is an auxilliary program related to the subject of chapters 7 and 8. In case the matrices of all frames of Initial Reference Position (IRP) is required then this auxilliary program calculates them using the rig data file.

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```
C     ***************************************************
C
C                   INSTRON - PYLON   TESTS
C                   ----------------------
C                    PROGRAM : INSTRON.FOR
C                    ---------------------
C
C     THIS PROGRAM CALCULATES :
C     THE LOADS THAT THE  INSTRON  APPLIES ONTO THE PYLON
C     AS WELL AS  THE LOADS THAT THE  PYLON  DETECTS  AND
C     COMPARES THEM , FOR EVERY GEOMETRICAL CONFIGURATION
C     TESTED,
C
C     I M P O R T A N T :  THE  USER  SHOULD  CONSULT THE
C     PROGRAM IN ADVANCE TO FIND OUT WHICH IS THE MAXIMUM
C     LOAD LIMIT FOR THE  VARIOUS  CONFIGURATIONS  TO  BE
C     TESTED !!!!!!!!!!
C
C     ***************************************************
C
C     File where results will be stored
      CHARACTER *20,OUTFILE
C
C     Value PI = 3.14
      REAL PI
C
C     Applied Instron load in kg
      REAL L
C
C     Load L expressed in the pylon frame in terms of the
C     six components
      REAL FXI,FYI,FZI,MXI,MYI,MZI
C
C     Pylon transducer output signals
      REAL SFX,SFY,SFZ,SMX,SMY,SMZ
C
C     Pylon detected loads N and Nm
      REAL FXP,FYP,FZP,MXP,MYP,MZP
C
C     Percentages of difference between
C     applied and detected loads
      REAL DFX,DFY,DFZ,DMX,DMY,DMZ
C
C     Parameters specifying the pylon frame
C     with respect to the Instron frame
      REAL Rx,THy,THx
C
C     Direction cosines of pylon frame axes
      REAL LX,MX,NX,LY,MY,NY,LZ,MZ,NZ
C
C     Allowed loads for each channel for each particular
C     geometrical configuration
      REAL ALLOWED(6)
C
C     Program parameters
      INTEGER OPTION1,OPTION2,OPTION3,OPTION4
C
```

```
C     Loop counter
      INTEGER I
C
C     ***************************************************
C
      PI=4*ATAN(1.0)
C
C     ***************************************************
C
C
C     Output file
C
      PRINT *,'*****************************'
      PRINT *,'GIVE OUTFILE NAME FOR RESULTS'
      READ  *,OUTFILE
      OPEN (3,FILE=OUTFILE,STATUS='NEW')
C
C
C     Detecting whether the geometrical position
C     to be tested ,is the one just run or not
C
1000  PRINT *,'*****************************'
      PRINT *,'   NEW POSITION FOR PYLON ? '
      PRINT *,'        YES(1) NO(0)        '
      READ  *, OPTION1
      IF (OPTION1 .EQ. 1) THEN
          GO TO 10
      ELSE
          GO TO 20
      END IF
C
C     Reading in the parameters defining
C     the  new geometrical configuration
C
10    PRINT *,'*****************************'
      PRINT *,' GIVE POSITION PARAMETERS   :'
      PRINT *,' Rx(mm) AND THy,THx(degrees)'
      READ *,Rx,THy,THx
C
C     Writing the new parameters in the output file
C
      WRITE (3,15)  Rx,THy,THx
C
C     Calculation of the values to be used
C     (meters and radians) ; Rx being the opposite of
C     the given value
C
      Rx  = -Rx/1000
      THx = -THx*PI/180
      THy = THy*PI/180
C
C     Calculation of the pylon axes' direction cosines
C
      LX=COS(THy)
      MX=SIN(THx)*SIN(THy)
      NX=-SIN(THy)*COS(THx)
C
```

```
      LY=0.0
      MY=COS(THx)
      NY=SIN(THx)
C
      LZ=SIN(THy)
      MZ=-COS(THy)*SIN(THx)
      NZ=COS(THx)*COS(THy)
C
C     Calculation of the limit Instron loads for
C     each channel for the particular configuration;
C     considered 1000 kg for null angular displacements
C     ONLY THE MINIMUM OF THESE LOADS IS ALLOWED
C
      IF (MX .EQ. 0.0) THEN
          ALLOWED(1)=1000.0
      ELSE
          ALLOWED(1)=ABS(100/9.81/MX)
      END IF
C
      IF (MY .EQ. 0.0) THEN
          ALLOWED(2)=1000.0
      ELSE
          ALLOWED(2)=ABS(1000/9.81/MY)
      END IF
C
      IF (MZ .EQ. 0.0) THEN
          ALLOWED(3)=1000.0
      ELSE
          ALLOWED(3)=ABS(100/9.81/MZ)
      END IF
C
      IF ( (Rx*NX) .EQ. 0.0) THEN
          ALLOWED(4)=1000.0
      ELSE
          ALLOWED(4)=ABS(100/9.81/(Rx*NX))
      END IF
C
      IF ( (Rx*NY) .EQ. 0.0) THEN
          ALLOWED(5)=1000.0
      ELSE
          ALLOWED(5)=ABS(30/9.81/(Rx*NY))
      END IF
C
      IF ( (Rx*NZ) .EQ. 0.0) THEN
          ALLOWED(6)=1000.0
      ELSE
          ALLOWED(6)=ABS(100/9.81/(Rx*NZ))
      END IF
C
C     Printing the limit Instron loads on the screen
C
20    PRINT *,'******************************'
      PRINT *,'ALLOWED  kgs FOR EACH CHANNEL'
      DO 30 I=1,6
      IF (ALLOWED(I) .GE. 1000.0) THEN
          PRINT *,'   1000.0'
      ELSE
```

```
            PRINT *, ALLOWED(I)
        END IF
30      CONTINUE
C
C       In case this is the first time this configuration
C       is run , these limit values are written in the
C       output file
C
        IF (OPTION1 .EQ. 1) THEN
            WRITE (3,25)
            DO 40 I=1,6
                IF (ALLOWED(I) .GT. 1000.0) THEN
                    WRITE (3,35)
                ELSE
                    WRITE (3,45) ALLOWED(I)
                END IF
40          CONTINUE
        ELSE
        END IF
C
C       In case an Instron load is to be "applied" by the
C       program , the program proceeds asking the load
C
        PRINT *,'*****************************'
        PRINT *,'DO YOU WANT  TO APPLY A  LOAD '
        PRINT *,'  JUST NOW ? YES(1)  NO(0)'
        READ *,OPTION2
C
        IF (OPTION2 .EQ. 0) THEN
            GO TO 50
        ELSE
            PRINT *,'******************************'
            PRINT *,'  GIVE  INSTRON LOAD IN kg '
            PRINT *,'  MUST BE  LESS  OR  EQUAL '
            PRINT *,'  THAN THE  LOWEST ALLOWED '
            READ *,L
            WRITE (3,55) L
        END IF
C
C       Calculation of the components of the Instron load
C       in the pylon transducer frame
C       ( I stands for Instron )
C
        FXI=L*MX*9.81
        FYI=L*MY*9.81
        FZI=L*MZ*9.81
        MXI=L*Rx*NX*9.81
        MYI=L*Rx*NY*9.81
        MZI=L*Rx*NZ*9.81
C
C       Printing these loads on the screen and
C       writing these loads in the output file
C
        PRINT *,'*****************************'
        PRINT *,' '
        WRITE (*,65) FXI,FYI,FZI
        WRITE (*,75) MXI,MYI,MZI
```

```
      WRITE (3,65) FXI,FYI,FZI
      WRITE (3,75) MXI,MYI,MZI
C
C
C     In case this configuration has already been tested
C     on the Instron , pylon  output signals  can be fed
C     into the program and detected loads can be derived
C
50    PRINT *,'*****************************'
      PRINT *,'DO YOU KNOW THE  PYLON OUTPUT'
      PRINT *,'   SIGNALS AT THIS STAGE?'
      PRINT *,'        YES (1) NO (0)'
      READ *,OPTION3
C
      IF (OPTION3 .EQ. 0) THEN
          GO TO 60
      ELSE IF (OPTION3 . EQ. 1) THEN
C
          PRINT *,'*****************************'
          PRINT *,'  GIVE THESE SIGNALS IN mV'
          PRINT *,'ORDER:SFX SFY SFZ SMX SMY SMZ'
          READ  *,SFX,SFY,SFZ,SMX,SMY,SMZ
      END IF
C
C     Calculation of the loads detected by the pylon
C     during the application of the Instron load
C     ( P stands for Pylon )
C
      FXP = 1.02*SFX + 0.02*SFY - 0.03*SFZ - 0.02*SMX
     &      + 0.03*SMY
      FYP =-3.96*SFY - 0.05*SFZ + 0.02*SMY
      FZP = 1.06*SFZ + 0.02*SMX + 0.03*SMY - 0.06*SMZ
      MXP =-0.09*SMX
      MYP =-0.05*SMY
      MZP = 0.19*SMZ
C
C     Printing these loads on the screen and
C     writing these loads in the output file
C
      PRINT *,'*****************************'
      PRINT *,' '
      WRITE (*,85) FXP,FYP,FZP
      WRITE (*,95) MXP,MYP,MZP
      WRITE (3,85) FXP,FYP,FZP
      WRITE (3,95) MXP,MYP,MZP
C
C     Calculation of the observed differences
C
      DFX=ABS(FXP-FXI)
      DFY=ABS(FYP-FYI)
      DFZ=ABS(FZP-FZI)
      DMX=ABS(MXP-MXI)
      DMY=ABS(MYP-MYI)
      DMZ=ABS(MZP-MZI)
C
C     Printing the differences on the screen and
C     writing the differences in the output file
```

```
C
      PRINT *,'*****************************'
      PRINT *,' THE ABSOLUTE DIFFERENCES'
      PRINT *,'    FOR EACH CHANNEL IS :'
      PRINT *,      DFX,DFY,DFZ
      PRINT *,      DMX,DMY,DMZ
      WRITE (3,105) DFX,DFY,DFZ,DMX,DMY,DMZ
C
C     Run-again option
C
60    PRINT *,'*****************************'
      PRINT *,'    RUN THE PROGRAM AGAIN ?'
      PRINT *,'          YES(1) NO(0)'
      READ *,OPTION4
      IF (OPTION4 .EQ. 1) THEN
          GO TO 1000
      ELSE
          GO TO 2000
      END IF
C
C     Close the output file
C
2000  CLOSE (3)
C
C
C     Format commands
C
15    FORMAT (/,/,/,10X,'*******************************',
     &/,10X,'POSITION PARAMETERS :',/,10X,'Rx =',F6.1,
     &' mm THy =',
     &F5.1,' deg THx =',F5.1,' deg',
     &/,10X,'*****************************************'
     &,/,/)
25    FORMAT (10X,'ALLOWED LOAD FOR EACH CHANNEL',
     &' IN LOAD CELL kg',/)
35    FORMAT (10X,'    1000.0',' kg')
45    FORMAT (10X,F10.2,' kg')
55    FORMAT (/,/,10X,'INSTRON APPLIED LOAD          = ',
     &F7.2,' kg',/)
65    FORMAT (10X,'INSTRON APPLIED FORCES (N)    = ',
     &3(F7.2,3X),/)
75    FORMAT (10X,'INSTRON APPLIED MOMENTS (Nm) = ',
     &3(F7.2,3X),/)
85    FORMAT (10X,'PYLON  DETECTED FORCES (N)    = ',
     &3(F7.2,3X),/)
95    FORMAT (10X,'PYLON  DETECTED MOMENTS (Nm) = ',
     &3(F7.2,3X),/)
105   FORMAT (10X,'ABSOLUTE DIFFERENCE OF LOAD FOR'
     &' EACH CHANNEL',/,
     &/,10X,6(F7.2,3X),/,/)
C
C     ***************************************************
C
      END
```

```
C     ***************************************************
C
C                        KNEELING TESTS
C                        --------------
C                      PROGRAM:KNEE.FOR
C                    --------------------
C      THIS  PROGRAM CALCULATES THE LOADS APPLIED  ON THE
C     FORCE PLATES  BY THE TOES AND KNEE AREA ,AS WELL AS
C     THE COMPONENTS  OF THEIR  REACTION ON  THE  LEG ,AT
C     A FRAME PARALLEL TO THE PYLON FRAME.
C
C      PYLON LOADS  ARE ALSO CALCULATED.
C
C      THE LOADS APPLIED ON THE PROSTHESIS,AT THE VARIOUS
C     POINTS UNDER STUDY (FREE BODY DIAGRAM)  ARE DERIVED
C     AS WELL AS THE NUTCRACKER MOMENT,
C
C
C     ***************************************************
C
C     Input data files and file with results.
      CHARACTER PARAMETERS*20,DATA*20,RESULTS*20
C
C     The mass and weight of the subject
      REAL  M , W
C
C     Input data for channels 1 to 6 (force plate 1)
      REAL C1(3000),C2(3000),C3(3000),C4(3000),C5(3000),
     &     C6(3000)
C
C     Input data for channels 7 to 12 (force plate 2)
      REAL C7(3000),C8(3000),C9(3000),C10(3000),
     &     C11(3000),C12(3000)
C
C     Input data for channels 13 to 18 (pylon transducer)
      REAL C13(3000),C14(3000),C15(3000),C16(3000),
     &     C17(3000),C18(3000)

C     Maximum vertical reaction on force plate 1
C     Algebraically is a minimum
      REAL FY1MINI
C
C     Total number of frames (and duration)
      INTEGER NUMBER
      REAL DURATION
C
C     Order of camera frame where FY1MINI occurs
C     and corresponding time moment
      INTEGER ORDER
      REAL TIME
C
C     Force plate loads for the ORDERth frame
      REAL FX1,FY1,FZ1,MX1,MY1,MZ1
      REAL FX2,FY2,FZ2,MX2,MY2,MZ2
C
C     Force plate coordinates for centres of pressure
C     and force plates geometry constants
```

```
      REAL XF1,XF2,ZF1,ZF2
      REAL XX,ZZ
C     Distance between the two centres of pressure
      REAL F1F2
C     Related angular position of the shank (rad)
      REAL A
C
C     Weight leverarm at the position under study
      REAL WLEVER
C
C     Percentage of body weigtht supported by
C     the prosthesis
      REAL WEIGHT
C
C     Pylon detected loads for the ORDERth frame
      REAL FXP,FYP,FZP,MXP,MYP,MZP
C
C     Prosthesis parameters
      REAL P1,P2,P3,P4,P5,P6,P7,P8
C
C     Frame { FVL } parameters
      REAL FVL
      REAL LF,MF,NF
      REAL VER
      REAL LV,MV,NV
      REAL LAT
      REAL LL,ML,NL
C
C     Elements of matrix R = [ Rij ]
      REAL R11,R12,R13,R21,R22,R23,R31,R32,R33
C
C     Components of the force plate loads
C     expressed in prosthesis frames {F1},{F2}
      REAL R1,R2,R3,R4,R5,R6
C
C     Results obtained by force plate data
      REAL S1F,S2F,SF,K1F,K2F,KF,MNF
C
C     Results obtained by pylon transducer data
      REAL S1P,S2P,SP,K1P,K2P,KP,MNP
C
C     Results from the comparison of the above
      REAL DIFF1,DIFF2,DIFF3,DIFF4,DIFF5,DIFF6
C
C     Evaluation of pylon trasducer results
C     REAL EVAL1,EVAL2,EVAL3
C
C     Radians-to-degrees conversion constant
      REAL RD
C
C     Degrees-to-radians conversion constant
      REAL DR
C
C     Constant of the prosthesis
      REAL TANB
C
C     Programming parameters
```

```
C     Decision parameters
      INTEGER OPTION1,OPTION2,OPTION3
C     Loop counter
      INTEGER I

C     ***************************************************

      RD = 180.0 / (ATAN(1.0)*4)
C
      DR = 1 / RD
C
      TANB = TAN ( 11 * DR )
C
C     Reading of the data ********************************
C
C
      PRINT *,' GIVE SUBJECT MASS IN Kg'
      READ  *, M
      W = M * 9.81
C
 10   PRINT *,'                                   '
      PRINT *,' GIVE THE NAME OF PARAMETERS FILE '
      PRINT *,'                                   '
C
      READ  *,PARAMETERS
C
      OPEN (3,FILE=PARAMETERS,STATUS='OLD')
C
      READ (3,*) P1,P2,P3,P4,P5,P6,P7,P8
C
      CLOSE (3)
C
      PRINT *,'                                '
      PRINT *,' GIVE THE NAME OF THE DATA FILE'
      PRINT *,'                                '
C
      READ  *,DATA
C
      DO 20 I=1,3000
        C1(I)=0
        C2(I)=0
        C3(I)=0
        C4(I)=0
        C5(I)=0
        C6(I)=0
        C7(I)=0
        C8(I)=0
        C9(I)=0
        C10(I)=0
        C11(I)=0
        C12(I)=0
        C13(I)=0
        C14(I)=0
        C15(I)=0
        C16(I)=0
        C17(I)=0
        C18(I)=0
```

```
C
 20    CONTINUE
C
       OPEN (3,FILE=DATA,STATUS='OLD')
C
       DO 30 I=1,3000
C
         NUMBER=I
         READ (3,*,END=40)
     &   C1(I),C2(I),C3(I),C4(I),C5(I),C6(I),
     &   C7(I),C8(I),C9(I),C10(I),C11(I),C12(I),
     &   C13(I),C14(I),C15(I),C16(I),C17(I),C18(I)
C
 30    CONTINUE
C
 40     CLOSE (3)
C
       NUMBER=NUMBER-1
       DURATION=NUMBER/50.0
C
C      Calculation of all loads **************************
C
       DO 50 I=1,NUMBER
C
         C1(I) = ( C1(I)-1973.1) *(-0.3554)
         C2(I) = ( C2(I)-1972.7) *(-1.2415)
         C3(I) = ( C3(I)-1970.6) *(+0.15025)
         C4(I) = ( C4(I)-1969.6) *(-0.25875)
         C5(I) = ( C5(I)-1923.5) *(-0.041125)
         C6(I) = ( C6(I)-1969.7) *(+0.2585)
         C7(I) = ( C7(I)-1965.4) *(+0.3316)
         C8(I) = ( C8(I)-1974.9) *(-1.2534)
         C9(I) = ( C9(I)-1964.0) *(-0.1531)
         C10(I)= (C10(I)-1973.0) *(+0.25875)
         C11(I)= (C11(I)-1965.3) *(-0.041125)
         C12(I)= (C12(I)-1971.3) *(-0.2646)
C
         C13(I)= (C13(I)-1987.2) /1625*1000
         C14(I)= (C14(I)-1978.9) /1625*1000
         C15(I)= (C15(I)-1990.0) /1625*1000
         C16(I)= (C16(I)-1980.1) /1625*1000
         C17(I)= (C17(I)-1994.6) /1625*1000
         C18(I)= (C18(I)-1984.2) /1625*1000
C
         C13(I)= 1.02*C13(I)+0.014*C14(I)-0.027*C15(I)
     &           -0.019*C16(I)+0.026*C17(I)+0.005*C18(I)
C
         C14(I)=-3.961*C14(I)-0.0046*C15(I)-0.132*C16(I)
     &           + 0.018*C17(I)+0.003*C18(I)
C
         C15(I)=-0.004*C13(I)-0.003*C14(I)+1.064*C15(I)
     &           + 0.018*C16(I) + 0.026*C17(I)
     &           -0.055*C18(I)
C
         C16(I)= 0.003*C15(I)-0.094*C16(I)
         C17(I)=-0.002*C13(I)-0.003*C15(I)-0.001*C16(I)
     &           -0.054*C17(I)-0.001*C18(I)
```

```
      C18(I)=-0.003*C13(I)+0.002*C14(I)+0.001*C16(I)
     &            +0.187*C18(I)
C
 50   CONTINUE
C
C     Identification of FY1MINI *************************
C
      FY1MINI = 0.0
C
      DO 60 I=(NUMBER-100),NUMBER
         IF ( C2(I) .LT. FY1MINI ) THEN
            FY1MINI=C2(I)
         ELSE
            FY1MINI=FY1MINI
         END IF
C
 60   CONTINUE
C
C     Identification of ORDER ***************************

      DO 70 I=(NUMBER-100),NUMBER
C
         ORDER=I
         IF ( C2(I) .EQ. FY1MINI ) THEN
           GO TO 80
         ELSE
           GO TO 70
         END IF
C
 70   CONTINUE
C
C     Loads for the moment under study *****************
C     This moment is given the name TIME(sec) ***********
C
 80   TIME = ORDER / 50.0
C
      FX1 =  -C1(ORDER)
      FY1 =  -C2(ORDER)
      FZ1 =  -C3(ORDER)
      MX1 =  -C4(ORDER)
      MY1 =  -C5(ORDER)
      MZ1 =  -C6(ORDER)
C
      FX2 =  -C7(ORDER)
      FY2 =  -C8(ORDER)
      FZ2 =  -C9(ORDER)
      MX2 = -C10(ORDER)
      MY2 = -C11(ORDER)
      MZ2 = -C12(ORDER)
C
      FXP = C13(ORDER)
      FYP = C14(ORDER)
      FZP = C15(ORDER)
      MXP = C16(ORDER)
      MYP = C17(ORDER)
      MZP = C18(ORDER)
C
```

```
C     Main calculations starting point *****************
C
      XF1 = (  MZ1 + FX1 * 0.04 ) / FY1
      XF2 = (  MZ2 + FX2 * 0.04 ) / FY2
      ZF1 = ( -MX1 + FZ1 * 0.04 ) / FY1
      ZF2 = ( -MX2 + FZ2 * 0.04 ) / FY2
C
      XX= 0.605
      ZZ= 0.216
C
      F1F2 = SQRT( (ZZ+ZF2-ZF1)**2 + (XX+XF2-XF1)**2 )
C
      A = ATAN ( (ZZ+ZF2-ZF1) / (XX+XF2-XF1) )
C
      WLEVER  = (FY1 / (FY1+FY2) ) * (F1F2)
      WLEVER  = (WLEVER/F1F2) * 100
      WEIGHT  = (FY1+FY2) / W * 100
C
      FOR = (  (P2-P1)**2 + P4**2 + P3**2 ) ** (0.5)
      VER = (  (P2-P1)**2 + P4**2         ) ** (0.5)
      LAT = (  (P4**2 + (P2-P1)**2) ** 2
     &        +(P3*P4) ** 2
     &        +(P3*(P2-P1)) ** 2          ) ** (0.5)
C
C
      LF = (P2-P1)    / FOR
      MF =  P4        / FOR
      NF = -P3        / FOR
      LV = -P4            / VER
      MV = (P2-P1)        / VER
      NV =  0.0           / VER
      LL =  P3*(P2-P1)        / LAT
      ML =  P3*P4             / LAT
      NL = (P4**2+(P2-P1)**2) / LAT
C
      R11 = LF*COS(A) - LL*SIN(A)
      R12 = LV
      R13 = LF*SIN(A) + LL*COS(A)
      R21 = MF*COS(A) - ML*SIN(A)
      R22 = MV
      R23 = MF*SIN(A) + ML*COS(A)
      R31 = NF*COS(A) - NL*SIN(A)
      R32 = NV
      R33 = NF*SIN(A) + NL*COS(A)
C
      R1  = R11*FX1 + R12*FY1 + R13*FZ1
      R2  = R21*FX1 + R22*FY1 + R23*FZ1
      R3  = R31*FX1 + R32*FY1 + R33*FZ1
      R4  = R11*FX2 + R12*FY2 + R13*FZ2
      R5  = R21*FX2 + R22*FY2 + R23*FZ2
      R6  = R31*FX2 + R32*FY2 + R33*FZ2
C
      S2F = -(R1*P8+R2*P1+R4*(P8-P4)+R5*P2) /
     &               (P8-P7+P5*TANB)
C
      S1F = S2F * TANB
C
```

```
      SF = (S1F**2+S2F**2)**(0.5)
C
      K1F = S1F - R2 - R5
C
      K2F = S2F + R1 + R4
C
      KF = (K1F**2+K2F**2)**(0.5)
C
      MNF = R1*P7 + R2*P1
C
C
      S2P = -(R4*(P8-P4)+R5*P2+FXP*(P8-P6)+MZP) /
     &              (P8-P7+P5*TANB)
C
      S1P = S2P * TANB
C
      SP = (S1P**2+S2P**2)**(0.5)
C
      K1P = S1P - FYP - R5
C
      K2P = S2P + FXP + R4
C
      KP = (K1P**2+K2P**2)**(0.5)
C
      MNP = FXP*(P7-P6) + MZP
C
C
      DIFF1 = R1 - FXP
      DIFF2 = R2 - FYP
      DIFF3 = R3 - FZP
      DIFF4 = (-R2*P3 - R3*P6) - MXP
      DIFF5 = ( R1*P3 - R3*P1) - MYP
      DIFF6 = ( R1*P6 + R2*P1) - MZP
C
      EVAL1 = FXP*P6 + FYP*P1 - MZP
      EVAL2 = FYP*P3 + FZP*P6 + MXP
      EVAL3 = FXP*P3 - FZP*P1 - MYP
C
C     Print out on screen ********************************
C
      WRITE (*,101) WLEVER,WEIGHT,MNF,MNP,SF,SP,KF,KP
C
C     Print out in a file ********************************
C
      PRINT *,'                                      '
      PRINT *,'GIVE FILENAME FOR RESULTS TO BE STORED'
      PRINT *,'                                      '
C
      READ *,RESULTS
C
      OPEN  (3,FILE=RESULTS,STATUS='NEW')
      WRITE (3,102) RESULTS,DATA,DURATION,FY1MINI,TIME
C
      WRITE (3,103) FX1,FX2,FXP,
     &              FY1,FY2,FYP,
     &              FZ1,FZ2,FZP,
     &              MX1,MX2,MXP,
```

```
     &                MY1,MY2,MYP,
     &                MZ1,MZ2,MZP
C
      WRITE (3,104) XF1,ZF1,XF2,ZF2
C
      WRITE (3,105) R1,R2,R3,R4,R5,R6
C
      WRITE (3,101) WLEVER,WEIGHT,MNF,MNP,SF,SP,KF,KP
C
      WRITE (3,106) DIFF1,DIFF2,DIFF3,DIFF4,DIFF5,DIFF6,
     &              EVAL1,EVAL2,EVAL3
C
      CLOSE (3)
C
C     Run-again option ***********************************
C
      PRINT *,'                                        '
      PRINT *,'YOU WANT TO RUN THE PROGRAM AGAIN ?'
      PRINT *,'GIVE :   YES (1)   OR   NO (0)          '
      PRINT *,'                                        '
C
      READ *,OPTION1
C
      IF (OPTION1 .EQ. 1) THEN
      GO TO 10
      ELSE
      GO TO 90
      END IF
C
C     Format commands ************************************
C
101   FORMAT (5X,'WEIGHT LEVERARM % = ',F5.1,'  %',/,
     &        5X,'WEIGHT PERCENTAGE%= ',F5.1,'  %',/,/,
     &  30X,' BY FPs',3X,' BY PT ',/,
     &   5X,'NUTCRACKER MOMENT (Nm)',3X,F7.1,3X,F7.1,/,
     &   5X,'SHIN LOAD  (N)        ',3X,F7.1,3X,F7.1,/,
     &   5X,'KNEE LOAD  (N)        ',3X,F7.1,3X,F7.1,/)
C
102   FORMAT (5X,'THIS IS FILE           ',A20,/,/,
     &        5X,'WITH RESULTS OF TEST ',A20,/,/,
     &        5X,'                     ',/,
     &        5X,'DURATION (sec)       ',F5.2,/,
     &        5X,'MAX.REACTION FY1     ',F6.1,' N',/,
     &        5X,'OCCURING AT TIME     ',F5.2,' sec',/,/)
C
103   FORMAT (/,5X,'LOADS',/,/,
     &        5X,'ON FP1','          ON FP2',10X,
     &                       ' ON PT',/,
     &       5X,3(F6.1,10X),'N ',/,5X,3(F6.1,10X),'N ',/,
     &       5X,3(F6.1,10X),'N ',/,5X,3(F6.1,10X),'Nm',/,
     &       5X,3(F6.1,10X),'Nm',/,5X,3(F6.1,10X),'Nm',/)
C
104   FORMAT (5X,'CENTRES OF PRESSURE ON FPs 1 and 2',/
     &       ,5X,'XF1 = ',F6.3,5X,'ZF1 = ',F6.3,'   m',/
     &       ,5X,'XF2 = ',F6.3,5X,'ZF2 = ',F6.3,'   m',/)
C
105   FORMAT (/,5X,'LOADS APPLIED FROM THE F/PLATES',
```

```
     &           ' TO THE SHANK',/,
     &        5X,'EXPRESSED IN THE PT FRAME ',/,
     &        5X,'R1 =',F6.1,'  R2 =',F6.1,
     &           '  R3 =',F6.1,'   N',/,
     &        5X,'R4 =',F6.1,'  R5 =',F6.1,
     &           '  R6 =',F6.1,'   N',/,/)
C
106   FORMAT (5x,'COMPARISON RESULTS'
     &     ,/,5X,'DIFF1 = ',F6.1,' N'
     &     ,/,5X,'DIFF2 = ',F6.1,' N'
     &     ,/,5X,'DIFF3 = ',F6.1,' N'
     &     ,/,5X,'DIFF4 = ',F6.1,' Nm'
     &     ,/,5X,'DIFF5 = ',F6.1,' Nm'
     &     ,/,5X,'DIFF6 = ',F6.1,' Nm'
     &     ,/
     &     ,/,5X,'EVAL1 = ',F6.1,' Nm'
     &     ,/,5X,'EVAL2 = ',F6.1,' Nm'
     &     ,/,5X,'EVAL3 = ',F6.1,' Nm')
C
C
C
 90   END
```

```
C       ***************************************************
C
C                      NEW ALIGNMENT METHOD
C                      --------------------
C                     PROGRAM: ALIGNMENT.FOR
C                     ----------------------
C
C       THIS PROGRAM  CALCULATES  THE  ALIGNMENT PARAMETERS
C       OF AN  ABOVE - KNEE OTTO BOCK PROSTHESIS  ACCORDING
C       TO THE  ANGULAR  ADJUSTMENTS  MADE  AT THE ADAPTORS
C       OF THE PROSTHESIS
C
C       INITIALLY  READS-IN THE RIG DATA  OF THE PROSTHESIS
C       AND AT THE END  STORES  THE WHOLE ALIGNMENT SESSION
C       IN A FILE .
C
C       THIS PROGRAM  MUST  BE  RUN  DURING  THE  ALIGNMENT
C       SESSION AND  SUPPLIED WITH THE PARAMETERS SPECIFIED
C       IN THE NEW ALIGNMENT METHOD !!!
C
C       ***************************************************
C
C       Input and output files
        CHARACTER *20 LEGIN,LEGOUT
C
C       Parameters related to the set up on the rig;
C       in fact the distances Hc and t1 mentioned at the
C       paragraph regarding the calibration of the adaptors
C       They are both falling along the y-axis
        REAL Hc , t1
C
C       Coordinates x,y,z of the necessary socket landmarks
C       (PL stands for proximal lateral )
C       (PM    "     "      "    medial   )
C       (PA    "     "      "    anterior)
C       (DL    "     "  distal   lateral )
C       (DM    "     "      "    medial   )
        REAL XPL,YPL,ZPL,XPM,YPM,ZPM,XDL,YDL,ZDL,
     &      XDM,YDM,ZDM,XPA,YPA,ZPA
C
C       Coordinates x,y,z of the distal (K2)
C       the proximal (K1) knee adaptors as well as of
C       the knee centre (K)
        REAL XK2,YK2,ZK2,XK,YK,ZK,XK1,YK1,ZK1
        REAL XRS,YRS,ZRS
C
C       The initial values of flexion angles at
C       the knee unit (1 for proximal and 2 for distal)
        REAL DWAP1,DWAP2
C
C       Intersept and slope (gradient) of the calibration
C       models of the adaptors ...
        REAL WI,WG
C
C       ... and their various values
        REAL WIANAP,WGANAP,WIANML,WGANML
        REAL WIDKAP,WGDKAP,WIDKML,WGDKML
```

```
      REAL WIPKAP,WGPKAP,WIPKML,WGPKML
C
C     Initial frames for all landmarks
      REAL UNIV(4,4),FOOT(4,4),ISHANK(4,4),IDKNEE(4,4),
     &  IKNEE(4,4),IPKNEE(4,4),ISOROT(4,4),ISOCKT(4,4)
C
C     Final coordinates x,y,z  of the points defining the
C     socket frame ( top:H1 , bottom:H2 ) and three other
C     parameters which are:the distance between H2 and H1
C     and  the z-coordinate of  H1 corrected according to
C     conventions and the side of amputation and the
C     distance between H1 and the proximal anterior mark
      REAL XH1,YH1,ZH1,XH2,YH2,ZH2,H2H1,H1Z,H1ANT
C
C     Current frames for all landmarks
C     These frames start from their initial configuration
C     and change continuously depending on the alignment
C     changes during the actual session
      REAL CSHANK(4,4),
     &CDKNEE(4,4),CKNEE(4,4),CPKNEE(4,4),
     &CSOROT(4,4),CSOCKT(4,4)
C
C     Translated frames for all landmarks
C     These frames are the current frames but translated
C     to the origin of the axis of rotation of each
C     angular adjustment
      REAL TSHANK(4,4),
     &     TDKNEE(4,4),TKNEE(4,4),TPKNEE(4,4),
     &     TSOROT(4,4),TSOCKT(4,4)
C
C     Auxiliary matrix used for the rotations of frames
      REAL ROT(4,4)
C
C     Auxiliary frames used in matrices operations
C     In fact they are the rotated versions of the
C     translated frames
      REAL RSHANK(4,4),RDKNEE(4,4),RKNEE(4,4),
     &RPKNEE(4,4),RSOROT(4,4),RSOCKT(4,4)
C
C     Parameters used at the determination of angular
C     displacements ( see matrix ROT ) and the new
C     current frames( see matrix UNIROT )
      REAL KX,KY,KZ,PKX,PKY,PKZ
C
C     The general angle w .......
      REAL W
C
C     The screw lenghts needed for determination of the
C     corresponding angular adjustment ( Before and
C     After the angular adjustment is made)
      REAL LB,LA
C
C     Alignment parameters
      REAL KAPS,KH,KMLS,KMLT,KR
      REAL SAPS,SH,SMLS,SAPT,SMLT,SR
C
C     Socket rotation defining angles
```

```
      REAL RSF1,RSF2
C
C     Parameter related to the side of amputation :
C     it is +1 for right side prostheses and
C     it is -1 for left  side prostheses
      REAL KIND
C
C     Pi = 3.14
      REAL PI
C
C
C     Menu option parameter
      INTEGER OPTION
C
C     Loop counters
      INTEGER I,J
C
C     Day-Month-Year
      INTEGER DD,MM,YY
C
C     Session number for the particular day
      INTEGER SS
C
C     ****************************************************
C
C      Rig measurement values are input
C
      PRINT *,'***************************************'
      PRINT *,'GIVE THE NAME OF FILE FOR THE RIG DATA'
      PRINT *,'***************************************'
      READ *,LEGIN
      OPEN(3,FILE=LEGIN,STATUS='OLD')
C
      READ(3,*) Hc , t1 ,
     &XK2,YK2,ZK2,XK,YK,ZK,XK1,YK1,ZK1,
     &XRS,YRS,ZRS,
     &XPL,YPL,ZPL,XPM,YPM,ZPM,XDL,YDL,ZDL,
     &XDM,YDM,ZDM,XPA,YPA,ZPA,
     &DWAP1,DWAP2,
     &WIANAP,WGANAP,WIANML,WGANML,
     &WIDKAP,WGDKAP,WIDKML,WGDKML,
     &WIPKAP,WGPKAP,WIPKML,WGPKML,
     &KIND
C
      CLOSE (3)
C
C     Preparation of output file
      PRINT *,'  '
      PRINT *,'******************************************'
      PRINT *,'GIVE NAME FOR FILE WHERE PROCEDURE AND '
      PRINT *,'     RESULTS  WILL BE SAVED INTO'
      PRINT *,'******************************************'
C
      READ *,LEGOUT
C
      OPEN(3,FILE=LEGOUT,STATUS='NEW')
C
```

```
      PRINT *,' '
      PRINT *,'*******************************************'
      PRINT *,'WHAT IS THE DATE TODAY ?'
      PRINT *,'IN THE FORM : DD MM YY'
      PRINT *,'*******************************************'
      READ *,DD,MM,YY
C
      PRINT *,' '
      PRINT *,'*******************************************'
      PRINT *,'SESSION NUMBER,FOR THIS PATIENT,FOR TODAY'
      PRINT *,'*******************************************'
      READ *,SS
C
      WRITE (3,1000) LEGOUT,DD,MM,YY,SS,LEGIN
      WRITE (3,1001)
C
C     ***************************************************
C
C     Initial frame matrices are created with respect to
C            the universal frame of reference
C
      PI=4*ATAN(1.0)
C
C
      DO 10 I=1,4
         DO 11 J=1,4
            IF (I.EQ.J) THEN
               UNIV(I,J)=1
               FOOT(I,J)=1
               ISHANK(I,J)=1
               IDKNEE(I,J)=1
               IKNEE(I,J)=1
               IPKNEE(I,J)=1
               ISOROT(I,J)=1
               ISOCKT(I,J)=1
               GO TO 11
            ELSE IF (I.NE.J) THEN
               UNIV(I,J)=0
               FOOT(I,J)=0
               ISHANK(I,J)=0
               IDKNEE(I,J)=0
               IKNEE(I,J)=0
               IPKNEE(I,J)=0
               ISOROT(I,J)=0
               ISOCKT(I,J)=0
            END IF
11       CONTINUE
10    CONTINUE
C
      FOOT(2,4)= Hc + t1
C
      IDKNEE(1,1)=1*COS(DWAP2/180*PI)
      IDKNEE(2,1)=1*SIN(DWAP2/180*PI)
      IDKNEE(1,2)=-1*SIN(DWAP2/180*PI)
      IDKNEE(2,2)=1*COS(DWAP2/180*PI)
      IDKNEE(1,4)=XK2
      IDKNEE(2,4)=YK2+Hc
```

```
      IDKNEE(3,4)=ZK2
C
      IKNEE(1,4)=XK
      IKNEE(2,4)=YK+Hc
      IKNEE(3,4)=ZK
C
      IPKNEE(1,1)=1*COS(DWAP1/180*PI)
      IPKNEE(2,1)=1*SIN(DWAP1/180*PI)
      IPKNEE(1,2)=-1*SIN(DWAP1/180*PI)
      IPKNEE(2,2)=1*COS(DWAP1/180*PI)
      IPKNEE(1,4)=XK1
      IPKNEE(2,4)=YK1+Hc
      IPKNEE(3,4)=ZK1
C
      ISOROT(1,1)=1*COS(DWAP1/180*PI)
      ISOROT(2,1)=1*SIN(DWAP1/180*PI)
      ISOROT(1,2)=-1*SIN(DWAP1/180*PI)
      ISOROT(2,2)=1*COS(DWAP1/180*PI)
      ISOROT(1,4)=XRS
      ISOROT(2,4)=YRS+Hc
      ISOROT(3,4)=ZRS
C
C
      XH1=(XPL+XPM)/2
      YH1=(YPL+YPM)/2+Hc
      ZH1=(ZPL+ZPM)/2
      XH2=(XDL+XDM)/2
      YH2=(YDL+YDM)/2+Hc
      ZH2=(ZDL+ZDM)/2
      H2H1=(SQRT((XH2-XH1)**2+(YH2-YH1)**2+(ZH2-ZH1)**2))
      H1ANT=(SQRT((XH1-XPA)**2+(YH1-(YPA+Hc))**2+
     &       (ZH1-ZPA)**2))
C
      IF (KIND.EQ.(1.0)) THEN
         H1Z=(SQRT((XH1-XPL)**2+(YH1-(YPL+Hc))**2+
     &        (ZH1-ZPL)**2))
      ELSE IF (KIND.EQ.(-1.0)) THEN
         H1Z=(SQRT((XH1-XPM)**2+(YH1-(YPM+Hc))**2+
     &        (ZH1-ZPM)**2))
      END IF
C
C
      ISOCKT(1,1)=(XPA-XH1)/H1ANT
      ISOCKT(2,1)=((YPA+Hc)-YH1)/H1ANT
      ISOCKT(3,1)=(ZPA-ZH1)/H1ANT
      ISOCKT(1,2)=(XH1-XH2)/H2H1
      ISOCKT(2,2)=(YH1-YH2)/H2H1
      ISOCKT(3,2)=(ZH1-ZH2)/H2H1
C
      IF (KIND.EQ.(1.0)) THEN
         ISOCKT(1,3)=(XPL-XH1)/H1Z
         ISOCKT(2,3)=((YPL+Hc)-YH1)/H1Z
         ISOCKT(3,3)=(ZPL-ZH1)/H1Z
      ELSE IF (KIND.EQ.(-1.0)) THEN
         ISOCKT(1,3)=(XPM-XH1)/H1Z
         ISOCKT(2,3)=((YPM+Hc)-YH1)/H1Z
         ISOCKT(3,3)=(ZPM-ZH1)/H1Z
```

```
      END IF
C
      ISOCKT(1,4)=XH1
      ISOCKT(2,4)=YH1
      ISOCKT(3,4)=ZH1
C
C
C     ***************************************************
C     First current frame matrices are created
C
      DO 12 I=1,4
         DO 13 J=1,4
            CSHANK(I,J)=ISHANK(I,J)
            CDKNEE(I,J)=IDKNEE(I,J)
            CKNEE(I,J) =IKNEE(I,J)
            CPKNEE(I,J)=IPKNEE(I,J)
            CSOROT(I,J)=ISOROT(I,J)
            CSOCKT(I,J)=ISOCKT(I,J)
13       CONTINUE
12    CONTINUE
C
      GO TO 500
C
C     ***************************************************
C     Menu is presented and
C     Alignment changes are considered
C
 100  PRINT *,' --------------------------------------'
      PRINT *,' CHOOSE THE OPTION CORRESPONDING TO THE '
      PRINT *,'  ADJUSTMENT, WHICH IS TO BE MADE NOW   '
      PRINT *,' --------------------------------------'
      PRINT *,' OPTION 1 :FOOT ADAPTOR A/P CHANGES'
      PRINT *,' OPTION 2 :........... M/L .......'
      PRINT *,' OPTION 3 :DISTAL KNEE ADAPTOR A/P CHANGES'
      PRINT *,' OPTION 4 :.................. M/L .......'
      PRINT *,' OPTION 5 :PROXIM KNEE ADAPTOR A/P CHANGES'
      PRINT *,' OPTION 6 :.................. M/L .......'
      PRINT *,' OPTION 7 :ROTATION ABOUT SHANK ADAPTOR'
      PRINT *,' OPTION 8 :......... ... SOCKET ADAPTOR'
      PRINT *,' GIVE THE OPTION NUMBER (ZERO IF FINISHED)'
C
C
      READ *,OPTION
C
      IF (OPTION.EQ.0) THEN
         GO TO 600
C
C     Provide the angular adjustment if known
C
      ELSE IF (OPTION.EQ.7) THEN
         WRITE (3,1014)
         WRITE (*,1101)
         READ *,W
         WRITE (3,1015)W
         W = W * (PI/180.0)
         GO TO 20
C
```

```
      ELSE IF (OPTION.EQ.8) THEN
         WRITE (3,1016)
         WRITE (*,1101)
         READ *,W
         WRITE (3,1015)W
         W = W * (PI/180.0)
         GO TO 20
C
      END IF

C     Calculation of the angular adjustment
C
      IF (OPTION.EQ.1) THEN
         WRITE (3,1002)
         WRITE (*,1100)
         READ *,LB,LA
         WI=WIANAP
         WG=WGANAP
C
      ELSE IF (OPTION.EQ.2) THEN
         WRITE (3,1003)
         WRITE (*,1100)
         READ *,LB,LA
         WI=WIANML
         WG=WGANML
C
      ELSE IF (OPTION.EQ.3) THEN
         WRITE (3,1004)
         WRITE (*,1100)
         READ *,LB,LA
         WI=WIDKAP
         WG=WGDKAP
C
      ELSE IF (OPTION.EQ.4) THEN
         WRITE (3,1005)
         WRITE (*,1100)
         READ *,LB,LA
         WI=WIDKML
         WG=WGDKML
C
      ELSE IF (OPTION.EQ.5) THEN
         WRITE (3,1006)
         WRITE (*,1100)
         READ *,LB,LA
         WI=WIPKAP
         WG=WGPKAP
C
      ELSE IF (OPTION.EQ.6) THEN
         WRITE (3,1007)
         WRITE (*,1100)
         READ *,LB,LA
         WI=WIPKML
         WG=WGPKML
C
      END IF
C
      CALL ANGLE (WI,WG,LB,LA,W)
```

```
      W = KIND*W
      WRITE (3,1010) LB,LA,W
      W = W*PI/180
C
C
C
C     Determination of the axis(direction cosines K x,y,z)
C     about which the angular adjustment is performed , as
C     well as of the origin of this axis (PK x,y,z)
C
20    IF (OPTION.EQ.1) THEN
          KX=0.0
          KY=0.0
          KZ=1.0
         PKX=0.0
         PKY=0.0
         PKZ=0.0
C
      ELSE IF (OPTION.EQ.2) THEN
          KX=1.0
          KY=0.0
          KZ=0.0
         PKX=0.0
         PKY=0.0
         PKZ=0.0
C
      ELSE IF (OPTION.EQ.3) THEN
          KX=CDKNEE(1,3)
          KY=CDKNEE(2,3)
          KZ=CDKNEE(3,3)
         PKX=CDKNEE(1,4)
         PKY=CDKNEE(2,4)
         PKZ=CDKNEE(3,4)
C
      ELSE IF (OPTION.EQ.4) THEN
          KX=CDKNEE(1,1)
          KY=CDKNEE(2,1)
          KZ=CDKNEE(3,1)
         PKX=CDKNEE(1,4)
         PKY=CDKNEE(2,4)
         PKZ=CDKNEE(3,4)
C
      ELSE IF (OPTION.EQ.5) THEN
          KX=CPKNEE(1,3)
          KY=CPKNEE(2,3)
          KZ=CPKNEE(3,3)
         PKX=CPKNEE(1,4)
         PKY=CPKNEE(2,4)
         PKZ=CPKNEE(3,4)
C
      ELSE IF (OPTION.EQ.6) THEN
          KX=CPKNEE(1,1)
          KY=CPKNEE(2,1)
          KZ=CPKNEE(3,1)
         PKX=CPKNEE(1,4)
         PKY=CPKNEE(2,4)
         PKZ=CPKNEE(3,4)
```

```
C
      ELSE IF (OPTION.EQ.7) THEN
          KX=CSHANK(1,2)
          KY=CSHANK(2,2)
          KZ=CSHANK(3,2)
         PKX=0.0
         PKY=0.0
         PKZ=0.0
C
      ELSE IF (OPTION.EQ.8) THEN
          KX=CSOROT(1,2)
          KY=CSOROT(2,2)
          KZ=CSOROT(3,2)
         PKX=CSOROT(1,4)
         PKY=CSOROT(2,4)
         PKZ=CSOROT(3,4)
C
      END IF
C
C
C     Calculation of the matrix representing
C     the rotational effect of the angular
C     adjustment ( matrix [ROT] )
C
      CALL ROTMAT (KX,KY,KZ,W,ROT)
C
C
C     Calculation of the new position and orientation
C     of all frames affected by the angular adjustment
C     made
C
C     From labels 21 to 24 the operations performed on
C     the frames are as follows :
C     firstly each frame is translated to the origin of
C     the axis of rotation, then the resulting frame is
C     rotated by multiplication with matrix [ROT]   and
C     finally is translated back to its initial origin.
C
      IF (OPTION.EQ.1) THEN
         GO TO 21
      ELSE IF (OPTION.EQ.2) THEN
         GO TO 21
      ELSE IF (OPTION.EQ.3) THEN
         GO TO 22
      ELSE IF (OPTION.EQ.4) THEN
         GO TO 22
      ELSE IF (OPTION.EQ.5) THEN
         GO TO 23
      ELSE IF (OPTION.EQ.6) THEN
         GO TO 23
      ELSE IF (OPTION.EQ.7) THEN
         GO TO 22
      ELSE IF (OPTION.EQ.8) THEN
         GO TO 24
      END IF
C
C
```

```
C        Find New CSHANK
C        ---------------
C
21      CALL TRANSL1(PKX,PKY,PKZ,CSHANK,TSHANK)
        CALL MATMULT(ROT,TSHANK,RSHANK)
        CALL TRANSL2(PKX,PKY,PKZ,RSHANK,CSHANK)
C
C
C        Find New CDKNEE
C        ---------------
C
22      CALL TRANSL1(PKX,PKY,PKZ,CDKNEE,TDKNEE)
        CALL MATMULT(ROT,TDKNEE,RDKNEE)
        CALL TRANSL2(PKX,PKY,PKZ,RDKNEE,CDKNEE)
C
C        Find New CKNEE
C        --------------
C
        CALL TRANSL1(PKX,PKY,PKZ,CKNEE,TKNEE)
        CALL MATMULT(ROT,TKNEE,RKNEE)
        CALL TRANSL2(PKX,PKY,PKZ,RKNEE,CKNEE)
C
C        Find New CPKNEE
C        ---------------
C
        CALL TRANSL1(PKX,PKY,PKZ,CPKNEE,TPKNEE)
        CALL MATMULT(ROT,TPKNEE,RPKNEE)
        CALL TRANSL2(PKX,PKY,PKZ,RPKNEE,CPKNEE)
C
C        Find New CSOROT
C        ---------------
C
23      CALL TRANSL1(PKX,PKY,PKZ,CSOROT,TSOROT)
        CALL MATMULT(ROT,TSOROT,RSOROT)
        CALL TRANSL2(PKX,PKY,PKZ,RSOROT,CSOROT)
C
C        Find New CSOCKT
C        ---------------
C
24      CALL TRANSL1(PKX,PKY,PKZ,CSOCKT,TSOCKT)
        CALL MATMULT(ROT,TSOCKT,RSOCKT)
        CALL TRANSL2(PKX,PKY,PKZ,RSOCKT,CSOCKT)
C
C
C
       IF (OPTION.EQ.1) THEN
          PRINT *,'***** OPTION 1 IS OVER *******'
       ELSE IF (OPTION.EQ.2) THEN
          PRINT *,'***** OPTION 2 IS OVER *******'
       ELSE IF (OPTION.EQ.3) THEN
          PRINT *,'***** OPTION 3 IS OVER *******'
       ELSE IF (OPTION.EQ.4) THEN
          PRINT *,'***** OPTION 4 IS OVER *******'
       ELSE IF (OPTION.EQ.5) THEN
          PRINT *,'***** OPTION 5 IS OVER *******'
       ELSE IF (OPTION.EQ.6) THEN
          PRINT *,'***** OPTION 6 IS OVER *******'
```

```
      ELSE IF (OPTION.EQ.7) THEN
         PRINT *,'***** OPTION 7 IS OVER *******'
      ELSE IF (OPTION.EQ.8) THEN
         PRINT *,'***** OPTION 8 IS OVER *******'
      END IF
C
         GO TO 501
C
C     ********************************************
C
C     Alignment parameters for the change performed
C
 500  PRINT *,' '
      PRINT *,' '
      PRINT *,' '
      PRINT *,'**** INITIAL ALIGNMENT ****'
      PRINT *,' '
      WRITE (3,1018)
C
      GO TO 502
C
 501  WRITE (*,1019) OPTION
C
 502  KAPS=CKNEE(1,4)
      KH=CKNEE(2,4)-Hc-t1
      KMLS=(KIND)*CKNEE(3,4)
      KMLT=(KIND)*ATAN(-CKNEE(2,3)/CKNEE(3,3))*180.0/PI
      KR=(KIND)*ATAN(CKNEE(1,3)/CKNEE(3,3))*180.0/PI
C
      SAPS=CSOCKT(1,4)
      SH=CSOCKT(2,4)-Hc-t1
      SMLS=(KIND)*CSOCKT(3,4)
      SAPT=ATAN(-CSOCKT(1,2)/CSOCKT(2,2))*180.0/PI
      SMLT=(KIND)*ATAN(CSOCKT(3,2)/CSOCKT(2,2))*180.0/PI
           RSF1=ATAN(CKNEE(1,3)/CKNEE(3,3))
           RSF2=ATAN(CSOCKT(1,3)/CSOCKT(3,3))
      SR=(KIND)*(RSF2-RSF1)*180.0/PI
C
C     ***********************************************
C     The current results are stored
C
      WRITE (*,1020) KAPS,KMLS,KH
      WRITE (3,1020) KAPS,KMLS,KH
      WRITE (*,1022) KMLT,KR
      WRITE (3,1022) KMLT,KR
      WRITE (*,1024) SAPS,SMLS,SH
      WRITE (3,1024) SAPS,SMLS,SH
      WRITE (*,1026) SAPT,SMLT,SR
      WRITE (3,1026) SAPT,SMLT,SR
      PRINT *,'******************************************'
      WRITE (3,1028)
C
      GO TO 100
C
 600  CLOSE (3)
C
      GO TO 601
```

```
C
C
C     ************************************************
C
C     Format commands
C
1000  FORMAT (1X,'THIS IS FILE : ',1X,A20,/,/,1X,
     &'DATE OF THE SESSION: ',I2,'-',
     &I2,'-',I2,/,/,1X,'ORDER NUMBER OF THIS SESSION : '
     &,I2,
     &/,/,1X,'FILE OF THE PROSTHESIS DATA : ',1X,A20,/,/,
     &'***********************************************
     &********************',/,/,/,/)
C
1001  FORMAT  (1X,'WHAT THE OPTIONS ARE : ',/,/,
     &1X,'OPTION 1 :FOOT ADAPTOR A/P CHANGES',/,
     &1X,'OPTION 2 :........... M/L .......',/,
     &1X,'OPTION 3 :DISTAL KNEE ADAPTOR A/P CHANGES',/,
     &1X,'OPTION 4 :.....  ........... M/L .......',/,
     &1X,'OPTION 5 :PROX.  KNEE ADAPTOR A/P CHANGES',/,
     &1X,'OPTION 6 :.................. M/L .......',/,
     &1X,'OPTION 7 :ROTATION ABOUT SHANK ADAPTOR',/)
C
1002  FORMAT (/,/,1X,'THEN OPTION 1 WAS FOLLOWED',/)
C
1003  FORMAT (/,/,1X,'THEN OPTION 2 WAS FOLLOWED',/)
C
1004  FORMAT (/,/,1X,'THEN OPTION 3 WAS FOLLOWED',/)
C
1005  FORMAT (/,/,1X,'THEN OPTION 4 WAS FOLLOWED',/)
C
1006  FORMAT (/,/,1X,'THEN OPTION 5 WAS FOLLOWED',/)
C
1007  FORMAT (/,/,1X,'THEN OPTION 6 WAS FOLLOWED',/)
C
1010  FORMAT(/,1X,'ADJUSTMENT MADE :',
     &/,1X,'LATERAL SCREW LENGTH BEFORE = ',F10.5,' mm',
     &/,1X,'LATERAL SCREW LENGTH AFTER  = ',F10.5,' mm',
     &/,1X,'THE ANGULAR CHANGE IMPOSED  = ',F10.5,' deg',
     &/)
C
1014  FORMAT (/,/,1X,'THEN OPTION 7 WAS FOLLOWED',/)
C
1015  FORMAT(/,1X,'THE ANGULAR CHANGE IS =',F10.5,' deg',/)
C
1016  FORMAT (/,/,1X,'THEN OPTION 8 WAS FOLLOWED',/)
C
1017  FORMAT(/,1X,'THE ANGULAR CHANGE IS =',F10.5,' deg')
C
1018  FORMAT (/,/,/,/,/,1X,'THE ALIGNMENT PROCEDURE',
     &'FOLLOWED :',/,
     &1X,'-----------------------------------',/,/,/,/,
     &1X,'THE INITIAL ALIGNMENT WAS : ',/,
     &1X,'---------------------------')
C
1019  FORMAT(1X,'THIS IS ALIGNMENT FOR OPTION ',I1,/)
C
```

```
1020  FORMAT(1X,'KAPS=',F7.2,' mm',2X,'KMLS=',F7.2,' mm',2X,
     &'KH=',F7.2,' mm')
C
1022  FORMAT(1X,'KMLT=',F6.2,' deg',2X,'KR=',F6.2,' deg')
C
1024  FORMAT(1X,'SAPS=',F7.2,' mm',2X,'SMLS=',F7.2,' mm',
     &2X,'SH=',F7.2,' mm')
C
1026  FORMAT(1X,'SAPT=',F6.2,' deg',2X,'SMLT=',F6.2,
     &' deg',2X,'SR=',F6.2,' deg')
C
C
1028  FORMAT(/,1X,'****************************************')
C
1100  FORMAT(/,1X,'SCREW LENGTH BEFORE AND AFTER ADJUSTMENT')
C
1101  FORMAT(/,1X,'GIVE THE ROTATION ANGLE IN DEGREES')
C
C
 601     END
C
C
C     ************************************************
C
C     Subroutines
C
C     For the matrix of rotation (see appendix V in thesis)
C
      SUBROUTINE ROTMAT(A,B,C,TH,R)
      REAL   A,B,C,TH,R(4,4)
      R(1,1)=A*A*(1-COS(TH))+COS(TH)
      R(1,2)=A*B*(1-COS(TH))-C*SIN(TH)
      R(1,3)=A*C*(1-COS(TH))+B*SIN(TH)
      R(1,4)=0.0
      R(2,1)=B*A*(1-COS(TH))+C*SIN(TH)
      R(2,2)=B*B*(1-COS(TH))+COS(TH)
      R(2,3)=B*C*(1-COS(TH))-A*SIN(TH)
      R(2,4)=0.0
      R(3,1)=C*A*(1-COS(TH))-B*SIN(TH)
      R(3,2)=C*B*(1-COS(TH))+A*SIN(TH)
      R(3,3)=C*C*(1-COS(TH))+COS(TH)
      R(3,4)=0.0
      R(4,1)=0.0
      R(4,2)=0.0
      R(4,3)=0.0
      R(4,4)=1.0
      RETURN
      END
C
C
C     For matrices multiplication ( [AM]*[BM]=[CM] )
C
      SUBROUTINE MATMULT(AM,BM,CM)
      INTEGER IM,JM,KM
      REAL AM(4,4),BM(4,4),CM(4,4),SUM
      DO 200 IM=1,4
      DO 201 JM=1,4
```

```
      SUM=0.0
      DO 202 KM=1,4
      SUM=SUM+(AM(IM,KM)*BM(KM,JM))
202   CONTINUE
      CM(IM,JM)=SUM
201   CONTINUE
200   CONTINUE
      RETURN
      END
C
C     For the translation of frames to the origin of
C     the axis of rotation (see appendix V in thesis
C     for the general case of rotation)
C
      SUBROUTINE TRANSL1 (A,B,C,BN,CN)
      REAL A,B,C,BN(4,4),CN(4,4)
      INTEGER IN,JN
      DO 300 IN=1,4
      DO 301 JN=1,4
         CN(IN,JN)=BN(IN,JN)
301   CONTINUE
300   CONTINUE
         CN(1,4)=BN(1,4)-A
         CN(2,4)=BN(2,4)-B
         CN(3,4)=BN(3,4)-C
      RETURN
      END
C
C     For the translation of frames back to
C     their initial origin (see appendix V in thesis
C     for general case of rotation)
C
      SUBROUTINE TRANSL2 (A,B,C,BN,CN)
      REAL A,B,C,BN(4,4),CN(4,4)
      INTEGER IN,JN
      DO 400 IN=1,4
      DO 401 JN=1,4
         CN(IN,JN)=BN(IN,JN)
401   CONTINUE
400   CONTINUE
         CN(1,4)=BN(1,4)+A
         CN(2,4)=BN(2,4)+B
         CN(3,4)=BN(3,4)+C
      RETURN
      END
C
C     For the determination of the angular adjustment
C     from the screw lenght before and after it
C
      SUBROUTINE ANGLE(WINTER,WGRAD,LENGTH0,LENGTH1,WNET)
      REAL WINTER,WGRAD,LENGTH0,LENGTH1,WPRE,WPOST,WNET
      WPRE=WINTER-WGRAD*LENGTH0
      WPOST=WINTER-WGRAD*LENGTH1
      WNET=WPOST-WPRE
      RETURN
      END
```

```
C     ****************************************************
C             ALIGNMENT ASSESSMENT USING THE RIG
C             ----------------------------------
C                   PROGRAM:RIGALIGN.FOR
C                   --------------------
C     THIS PROGRAM CALCULATES THE ALIGNMENT PARAMETERS
C           OF AN ABOVE-KNEE OTTO BOCK PROSTHESIS
C      ACCORDING TO THE FINAL RIG MEASUREMENTS AT THE
C             KNEE AND SOCKET OF THE PROSTHESIS
C
C     ****************************************************
C
C     Coordinates x,y,z of the necessary socket landmarks
C     (PL stands for proximal lateral)
C     (PM    "    "     "     medial )
C     (DL    "    "  distal   lateral)
C     (DM    "    "     "     medial )
      REAL XPL,YPL,ZPL,XPM,YPM,ZPM,XDL,YDL,ZDL,
     &     XDM,YDM,ZDM
C
C     Coordinates x,y,z of the medial and lateral points
C     at the knee, defined  by using the associated pins
C     and the distances between them and knee centre
      REAL XKM,YKM,ZKM,XKL,YKL,ZKL,KML,A,B
C
C     Final coordinates x,y,z  of the points defining the
C     socket  frame ( top:H1 , bottom:H2 ) and  two other
C     parameters which are:the distance between H2 and H1
C     and  the z-coordinate of  H1 corrected according to
C     conventions and the side of amputation
      REAL XH1,YH1,ZH1,XH2,YH2,ZH2,H2H1,H1Z
C
C     Parameter related to the set up on the rig; it is
C     in fact the distance between ankle frame origin and
C     rig origin
      REAL DY2
C
C     Matrices representing knee and  socket  frames  and
C     the associated alignment parameters
      REAL CKNEE(3,4),CSOCKT(3,4)
      REAL KAPS,KH,KMLS,KMLT,KR
      REAL SAPS,SH,SMLS,SAPT,SMLT,SR
C
C     Socket rotation defining angles
      REAL RSF1,RSF2
C
C     Pi = 3.14
      REAL PI
C
C     Parameter related to the side of amputation :
C     it is +1 for right side prostheses and
C     it is -1 for left  side prostheses
      REAL KIND
C
C     ****************************************************
C
      PI= 4*ATAN(1.0)
```

```
C
C     Rig measurement values are input
C
      PRINT *,'GIVE  :  X,Y,Z OF PL,PM,DL,DM,KL,KM  AND'
      PRINT *,' DISTANCES A,B OF KM,KL FROM KCENTRE AND'
      PRINT *,' DISTANCE DY2 OF ANKLE FROM RIG-BASE'
      PRINT *,'           KIND   OF LEG.'
C
      READ *,XPL,YPL,ZPL,XPM,YPM,ZPM,XDL,YDL,ZDL,
     &XDM,YDM,ZDM,XKL,YKL,ZKL,XKM,YKM,ZKM,A,B,DY2,KIND
C
C
C     Calculation of knee frame origin and dir. cosines
C
      CKNEE(1,4)=XKM+(XKL-XKM)*A/(A+B)
      CKNEE(2,4)=YKM+(YKL-YKM)*A/(A+B)
      CKNEE(3,4)=ZKM+(ZKL-ZKM)*A/(A+B)
      KML=A+B
C
      IF (KIND.EQ.(1.0)) THEN
      CKNEE(1,3)=(XKL-XKM)/KML
      CKNEE(2,3)=(YKL-YKM)/KML
      CKNEE(3,3)=(ZKL-ZKM)/KML
      ELSE IF (KIND.EQ.(-1.0)) THEN
      CKNEE(1,3)=(XKM-XKL)/KML
      CKNEE(2,3)=(YKM-YKL)/KML
      CKNEE(3,3)=(ZKM-ZKL)/KML
      END IF
C
C
C     Calculation of socket frame origin and dir. cosines
C
      XH1=(XPL+XPM)/2
      YH1=(YPL+YPM)/2
      ZH1=(ZPL+ZPM)/2
      XH2=(XDL+XDM)/2
      YH2=(YDL+YDM)/2
      ZH2=(ZDL+ZDM)/2
      H2H1=(SQRT((XH2-XH1)**2+(YH2-YH1)**2+(ZH2-ZH1)**2))

      IF (KIND.EQ.(1.0)) THEN
      H1Z=(SQRT((XH1-XPL)**2+(YH1-YPL)**2+(ZH1-ZPL)**2))
      ELSE IF (KIND.EQ.(-1.0)) THEN
      H1Z=(SQRT((XH1-XPM)**2+(YH1-YPM)**2+(ZH1-ZPM)**2))
      END IF
C
      CSOCKT(1,2)=(XH1-XH2)/H2H1
      CSOCKT(2,2)=(YH1-YH2)/H2H1
      CSOCKT(3,2)=(ZH1-ZH2)/H2H1
C
      IF (KIND.EQ.(1.0)) THEN
      CSOCKT(1,3)=(XPL-XH1)/H1Z
      CSOCKT(2,3)=(YPL-YH1)/H1Z
      CSOCKT(3,3)=(ZPL-ZH1)/H1Z
      ELSE IF (KIND.EQ.(-1.0)) THEN
      CSOCKT(1,3)=(XPM-XH1)/H1Z
      CSOCKT(2,3)=(YPM-YH1)/H1Z
```

```
      CSOCKT(3,3)=(ZPM-ZH1)/H1Z
      END IF
C
      CSOCKT(1,4)=XH1
      CSOCKT(2,4)=YH1
      CSOCKT(3,4)=ZH1
C
C
C     Calculation of alignment parameters
C
      KAPS=CKNEE(1,4)
      KH=CKNEE(2,4)-DY2
C
      KMLS=(KIND)*CKNEE(3,4)
      KMLT=(KIND)*ATAN(-CKNEE(2,3)/CKNEE(3,3))*180.0/PI
      KR=(KIND)*ATAN(CKNEE(1,3)/CKNEE(3,3))*180.0/PI
C
      SAPS=CSOCKT(1,4)
      SH=CSOCKT(2,4)-DY2
C
      SMLS=(KIND)*CSOCKT(3,4)
      SAPT=ATAN(-CSOCKT(1,2)/CSOCKT(2,2))*180.0/PI
      SMLT=(KIND)*ATAN(CSOCKT(3,2)/CSOCKT(2,2))*180.0/PI
       RSF1=ATAN(CKNEE(1,3)/CKNEE(3,3))
       RSF2=ATAN(CSOCKT(1,3)/CSOCKT(3,3))
      SR=(KIND)*(RSF2-RSF1)*180.0/PI
C
C     ***************************************************
C
C     Printing results on the screen
C
      WRITE (*,10) KAPS,KMLS,KH
10    FORMAT(1X,'KAPS=',F7.2,' MM',2X,'KMLS=',F7.2,' MM',
     &2X,'KH=',F7.2,' MM')
      WRITE (*,11) KMLT,KR
11    FORMAT(1X,'KMLT=',F6.2,' DEG',2X,'KR=',F6.2,' DEG')
      WRITE (*,12) SAPS,SMLS,SH
12    FORMAT(1X,'SAPS=',F7.2,' MM',2X,'SMLS=',F7.2,' MM',
     &2X,'SH=',F7.2,' MM')
      WRITE (*,13) SAPT,SMLT,SR
13    FORMAT(1X,'SAPT=',F6.2,' DEG',2X,'SMLT=',F6.2,
     &' DEG',2X,'SR=',F6.2,' DEG')
      PRINT *,'*******************************************'
C
C
      END




C     ***************************************************
```

```
C
C                    PROGRAM: INITIAL.FOR
C
C               THIS PROGRAM PRODUCES A FILE
C     WITH  ALL  THE  INITIAL  FRAMES  OF  A PROSTHESIS
C     USING  DATA  DERIVED BY  RIG MEASUREMENTS FOR THE
C     INITIAL  REFERENCE  POSITION  OF  THE  PROSTHESIS
C     AS   DESCRIBED   IN   THE  NEW  ALIGNMENT  METHOD
C        (all notations are the same with the ones
C           in the associated program ALIGN.FOR)
C
C     THIS PROGRAM SHOULD BE RUN IN CASE ONLY THE INITIAL
C     FRAME CONFIGURATION IS REQUIRED !!!!
C     FOR  A  COMPLETE  ALIGNMENT  SESSION  THE  PROGRAM
C     ALIGNMENT.FOR  SHOULD BE RUN !!!!!!!
C
C     ***************************************************
C
      CHARACTER *20 LEGIN,INITIALOUT
      REAL Hc,t1,
     &XK2,YK2,ZK2,XK,YK,ZK,XK1,YK1,ZK1,
     &XRS,YRS,ZRS
      REAL XPL,YPL,ZPL,XPM,YPM,ZPM,XDL,YDL,ZDL,
     &XDM,YDM,ZDM
      REAL XPA,YPA,ZPA
      REAL DWAP1,DWAP2
      REAL WIANAP,WGANAP,WIANML,WGANML
      REAL WIDKAP,WGDKAP,WIDKML,WGDKML
      REAL WIPKAP,WGPKAP,WIPKML,WGPKML
      REAL*8 UNIV(4,4),FOOT(4,4),ISHANK(4,4),
     &IDKNEE(4,4),IKNEE(4,4),
     &IPKNEE(4,4),ISOROT(4,4),ISOCKT(4,4)
      REAL*8 XH1,YH1,ZH1,XH2,YH2,ZH2,H2H1,H1ANT,H1Z
      REAL*8 CSHANK(4,4),CDKNEE(4,4),CKNEE(4,4),
     &CPKNEE(4,4),CSOROT(4,4),
     &CSOCKT(4,4),UNIROT(4,4),CFOOT(4,4)
      REAL*8 PI
      INTEGER I,J
      REAL KIND
C
C     ***************************************************
C
C     Rig measurement values are input
C
      PRINT *,'****************************************'
      PRINT *,'GIVE THE NAME OF FILE FOR THE RIG DATA'
      PRINT *,'****************************************'
      READ *,LEGIN
      OPEN(3,FILE=LEGIN,STATUS='OLD')
      READ(3,*)Hc,t1,
     &XK2,YK2,ZK2,XK,YK,ZK,XK1,YK1,ZK1,
     &XRS,YRS,ZRS,
     &XPL,YPL,ZPL,XPM,YPM,ZPM,XDL,YDL,ZDL,XDM,YDM,ZDM,
     &XPA,YPA,ZPA,
     &DWAP1,DWAP2,
     &WIANAP,WGANAP,WIANML,WGANML,WIDKAP,WGDKAP,
     &WIDKML,WGDKML,WIPKAP,WGPKAP,WIPKML,WGPKML,
```

```
     &KIND
C
      CLOSE (3)
      PRINT *,'  '
C
C     Initial UNIT matrices are created with respect to
C              the universal frame of reference
C
      PI=4*ATAN(1.0)
C
C
      DO 10 I=1,4
         DO 11 J=1,4
            IF (I.EQ.J) THEN
                UNIV(I,J)=1
                FOOT(I,J)=1
                ISHANK(I,J)=1
                IDKNEE(I,J)=1
                IKNEE(I,J)=1
                IPKNEE(I,J)=1
                ISOROT(I,J)=1
                ISOCKT(I,J)=1
                GO TO 11
            ELSE IF (I.NE.J) THEN
                UNIV(I,J)=0
                FOOT(I,J)=0
                ISHANK(I,J)=0
                IDKNEE(I,J)=0
                IKNEE(I,J)=0
                IPKNEE(I,J)=0
                ISOROT(I,J)=0
                ISOCKT(I,J)=0
            END IF
11       CONTINUE
10    CONTINUE
C
C     Initial FRAME matrices are created according to the
C     measurements on the rig
C
      FOOT(2,4)  = Hc + t1
C
      IDKNEE(1,1)=1*COS(DWAP2/180*PI)
      IDKNEE(2,1)=1*SIN(DWAP2/180*PI)
      IDKNEE(1,2)=-1*SIN(DWAP2/180*PI)
      IDKNEE(2,2)=1*COS(DWAP2/180*PI)
      IDKNEE(1,4)=XK2
      IDKNEE(2,4)=YK2+Hc
      IDKNEE(3,4)=ZK2
C
      IKNEE(1,4)=XK
      IKNEE(2,4)=YK+Hc
      IKNEE(3,4)=ZK
C
      IPKNEE(1,1)=1*COS(DWAP1/180*PI)
      IPKNEE(2,1)=1*SIN(DWAP1/180*PI)
      IPKNEE(1,2)=-1*SIN(DWAP1/180*PI)
      IPKNEE(2,2)=1*COS(DWAP1/180*PI)
```

```
      IPKNEE(1,4)=XK1
      IPKNEE(2,4)=YK1+Hc
      IPKNEE(3,4)=ZK1
C
      ISOROT(1,1)=1*COS(DWAP1/180*PI)
      ISOROT(2,1)=1*SIN(DWAP1/180*PI)
      ISOROT(1,2)=-1*SIN(DWAP1/180*PI)
      ISOROT(2,2)=1*COS(DWAP1/180*PI)
      ISOROT(1,4)=XRS
      ISOROT(2,4)=YRS+Hc
      ISOROT(3,4)=ZRS
C
C     Determination of the socket frame
      XH1=(XPL+XPM)/2
      YH1=(YPL+YPM)/2+Hc
      ZH1=(ZPL+ZPM)/2
      XH2=(XDL+XDM)/2
      YH2=(YDL+YDM)/2+Hc
      ZH2=(ZDL+ZDM)/2
      H2H1=(SQRT((XH2-XH1)**2+(YH2-YH1)**2+
     &(ZH2-ZH1)**2))
      H1ANT=(SQRT((XH1-XPA)**2+(YH1-(YPA+Hc))**2
     &+(ZH1-ZPA)**2))
C
      IF (KIND.EQ.(1.0)) THEN
      H1Z=(SQRT((XH1-XPL)**2+(YH1-(YPL+Hc))**2
     &+(ZH1-ZPL)**2))
      ELSE IF (KIND.EQ.(-1.0)) THEN
      H1Z=(SQRT((XH1-XPM)**2+(YH1-(YPM+Hc))**2
     &+(ZH1-ZPM)**2))
      END IF
C
      ISOCKT(1,1)=(XPA-XH1)/H1ANT
      ISOCKT(2,1)=((YPA+Hc)-YH1)/H1ANT
      ISOCKT(3,1)=(ZPA-ZH1)/H1ANT
C
      ISOCKT(1,2)=(XH1-XH2)/H2H1
      ISOCKT(2,2)=(YH1-YH2)/H2H1
      ISOCKT(3,2)=(ZH1-ZH2)/H2H1
C
C     Side of amputation is taken into account for
C     the correct conventions of z-coordinate
      IF (KIND.EQ.(1.0)) THEN
         ISOCKT(1,3)=(XPL-XH1)/H1Z
         ISOCKT(2,3)=((YPL+Hc)-YH1)/H1Z
         ISOCKT(3,3)=(ZPL-ZH1)/H1Z
      ELSE IF (KIND.EQ.(-1.0)) THEN
         ISOCKT(1,3)=(XPM-XH1)/H1Z
         ISOCKT(2,3)=((YPM+Hc)-YH1)/H1Z
         ISOCKT(3,3)=(ZPM-ZH1)/H1Z
      END IF
C
      ISOCKT(1,4)=XH1
      ISOCKT(2,4)=YH1
      ISOCKT(3,4)=ZH1
C
C     ***************************************************
```

```
C
      PRINT *,'GIVE OUTPUT FILENAME'
      READ *,INITIALOUT
C     File to store the data is opened
      OPEN(13,FILE=INITIALOUT,STATUS='NEW')
C
      WRITE (13,100)LEGIN
C
C     Initial frames given the prefix "C" because in fact
C     they are the first current frames for an alignment
C     session (see new alignment method)
      DO 200 I=1,4
         DO 201 J=1,4
            CFOOT(I,J)=FOOT(I,J)
            CDKNEE(I,J)=IDKNEE(I,J)
            CKNEE(I,J)=IKNEE(I,J)
            WRITE (13,101)I,J,CFOOT(I,J),
     &                           CDKNEE(I,J),CKNEE(I,J)
C
201      CONTINUE
200   CONTINUE
C
C     The initial frames are stored in the file
C
      WRITE (13,102)
C
      DO 202 I=1,4
         DO 203 J=1,4
            CPKNEE(I,J)=IPKNEE(I,J)
            CSOROT(I,J)=ISOROT(I,J)
            CSOCKT(I,J)=ISOCKT(I,J)
            WRITE (13,103)I,J,CPKNEE(I,J),
     &                           CSOROT(I,J),CSOCKT(I,J)
203      CONTINUE
202   CONTINUE
C
      CLOSE(13)
C
C     Format commands
C
100   FORMAT (1X,'INITIAL FRAMES FOR PROSTHESIS',2X,A20,
     &2X,/,/,
     &1X,'REFERENCE IS THE FRAME OF THE ANKLE SPHERE',/,
     &/,/,1X,'IJ',2X,'        FOOT ',2X,
     &'                DKNEE',2X,
     &'                 KNEE ',/)
C
101   FORMAT(1X,I1,I1,2X,D20.10,2X,D20.10,2X,D20.10,/)
C
102   FORMAT (/,/,/,1X,'IJ',2X,'          PKNEE',2X,
     &'                SOROT',2X,
     &'                 SOCKT',/)
C
103   FORMAT (1X,I1,I1,2X,D20.10,2X,D20.10,2X,D20.10,/)
C
      END
```