DYNAMIC BEHAVIOUR OF MILLING MACHINE STRUCTURE

BY

PROF.DR. A.A. NASSER(1) , PROF.DR. H.R. EL-SAYED(2)
DR. S.M. SERAG(3) AND ENG. S.M. SAMAK(4)

1 - SUMMARY:

Prediction of the dynamic behaviour of a machine tool structure enables the designer to study the different alternative designs and make the necessary corrections. In this way the overall dynamic characteristics of the machine could be improved early before the production stage. For such purposes, experimentation on scaled models and/or the use of the mathematical models are recommended.

In this work, the dynamic behaviour of the structure of a horizontal knee-type milling machine is studied. The study includes the prediction of the structure behaviour using mathematical models based on the classical beam theory. Moreover experimental determination of the structure behaviour is also carried out on perspex models. Two quarter-scale perspex models are constructed and tested. The theoretical and experimental results are compared and justified.

The presented study shows the suitability of both techniques for predicting and improving the structure characteristics, and hence the considered machine.

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(1) Abdel-Hady Abdel-Bary Nasser, Prof. Dr., Head of Production Engineering & Machine Design Department, Faculty of Engineering & Technology, Menoufia University.

(2) Hassan Ragab El-Sayed, Prof. Dr. Faculty of Engineering, Alexandria University.

(3) Soad Mohamed Serag, B.Sc., Ph.D., Lecturer, Production Engineering & Machine Design Department, Faculty of Engineering & Technology, Menoufia University.

(4) Salem M. Samak, B.Sc., Demonstrator, Faculty of Engineering & Technology, Menoufia University.

2 - INTRODUCTION:

The model technique is considered as one of the most acceptable and reliable techniques that could be used for predicting the static and dynamic behaviour of machine tool structures. It has been applied with considerable success to almost all types of machine tool structures. Moreover it has been adopted by many firms as an almost standard technique preceding the final design stage. The work published by E. Bodart and other authors presents typical examples of the application of this technique (1-6).

In this work, the model technique is used to investigate the dynamic behaviour of the structure of the horizontal knee-type milling machine. The behaviour of the considered structure is also theoretically predicted. In this way the reliability of the considered mathematical technique could be evaluated.

3 - DERIVATION OF THE MATHEMATICAL MODEL:

The main dimensions and main parts of the considered milling machine as well as the derivation of the mathematical model and the dynamic behaviour governing equations were presented by the author in a separate paper (6). The theoretical results of the basic model of the machine, Fig. (1), and the second modification, Fig. (2), will be included in this work for the purpose of comparison. These are given in tables (1) and (2).

4 - THE TEST ARRANGEMENT:

The elements of the test arrangement is shown diagramatically in Fig. (3). It is composed of the test model, the exciter and the measuring system. A photograph of the test arrangement is shown in Fig. (4).

The models were made from prespex, having the same dimensions as those shown in Figs (1) and (2). In the course of the experiments, they are securely bolted to the heavy table of a radial drilling machine as shown in Figs (3) and (4).

Provisions for measurements were provided by attaching the three prespex strips 1, 2 and 3 shown in Figs (5) and (6). The strips were of 3 mm thickness and 15 mm width. On each strip equal pitched holes were drilled and tapped. In this way the acceleration pick-up could be firmly fixed to the model at the selected measuring points as shown in Fig. (6).

A knocking pin was fixed at the top of the model column using the upper hole of the back strip as shown in Figs (5) and (6). The construction of this pin is shown in Fig. (7), it insures the rotation of the ball and in the same time its ability to slide back to eliminate the effect of excessive engagement which may take place between the knocking pin and the exciter.

To conduct the necessary tests, a mechanical exciter was designed and constructed, making use of the facilities provided by the stepless drive mechanism of the spindle of a radial drilling machine. In this way the drilling spindle and its driving mechanism constituted two main elements of the designed mechanical exciter. The third main element was the knocking disc attachement, Figs (8) and (9). A diagrammatic sketch of the designed mechanical exciter and photograph picture are shown in Figs (10) and (11).

The exciting frequency was measured with the aid of the r.p.m. indicating counter of the radial drilling machine, which is graduated from 0 to 2000 r.p.m. Accordingly, the exiting frequency will be 10/60 of the indicated r.p.m. The reading of this counter was calibrated using a speedometer and the calibration curve is shown in Fig. (12).

The deflection at each measuring point was determined using the measuring system shown in Figs (3). The system consisted of an acceleration pik-up, and amplifier and a digital displacement meter.

5 - THE EXPERIMENTAL RESULTS:

The experimentally determined results are presented in Figs (13) to (18). For the basic model, the deflections of the different preselected measuring points on the column, table and overarm are plotted against the exciting frequency as shown in Figs (13) to (15). In the same way the deflections of the similar measuring points on the main parts of the second model are plotted in Figs. (16) to (18).

Examining Figs (13) to (15), it could be seen that the column, table and overarm of the basic model exhibit a common resonance peak at approximatelly 210 C/S. The exciting frequency (210 C/S) giving this common resonance peak will be considered as the first natural frequency of that model.

Applying the same procedure on Fig. (16) to (18) the common resonance peak is found approximately at 190 C/S, which gives the first natural frequency of that model.

6 - DISCUSSION OF THE RESULTS:

Fig. (19) shows a comparison between the predicted and measured results. The comparison shows a distinct deviation from the theoretically predicted values, for both modeform and natural frequency, However, this deviation could be justified by the following sources of inaccuracy inherent to the experimental work:

1. The theoretical work was based on the fact that each of the model main parts forms an integral unit whilst in the expierimental work each unit was composed by jointing several plates of perspex.

2. In the theoretical work, the column is assumed rigidly connected to the base which is considered as infinitly rigid member. In the experimental the base is bolted to the work table of the machine which gives the base a definite and not infinite rigidity.

3. The theoretically predicted deflections are those of the centrelines of the different main parts of the model, whilst the experimentally measured deflections are those of points located on the upper surfaces of each part.

4. Due to the lack of measuring instruments, a simple measuring circuit was utilized. In the course of experimental work the accelerometer was shifted from one measuring point to another, instead of simultaneous measuring and recording the deflections of the different measuring points.

7 - THE MAIN CONCLUSIONS:

From the presented results and discussion, the following could be concluded:-

1. The classical beam theory is a suitable mathematical technique that can be used for predicting and improving the dynamic behaviour of machine tool structures.

2. The structure behaviour could be improved by altering its configuration, when its mass, main dimensions and wall thickness are kept constant.

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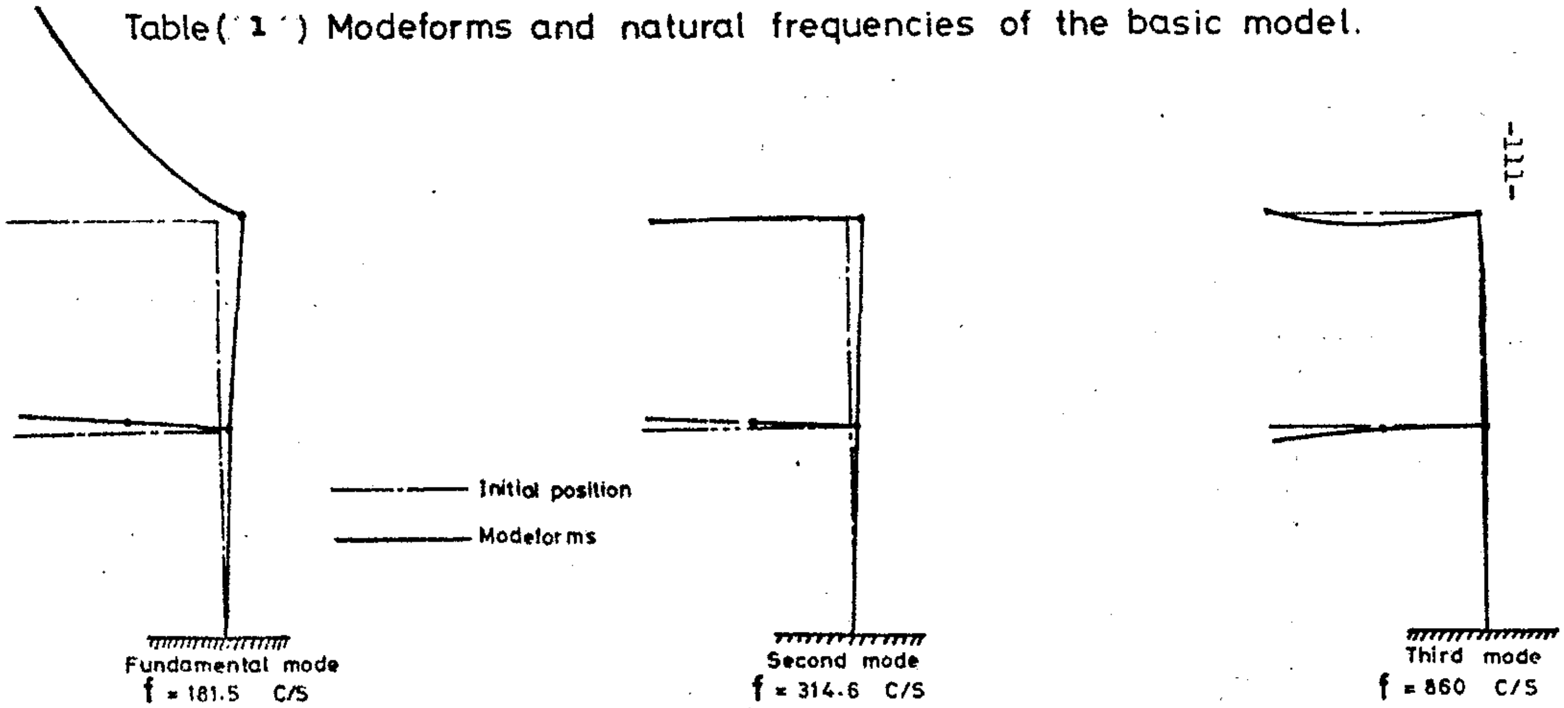
5. A. Cowley, "Analysis of machine tool structure by computing techniques", Proc. Inter. M.T.D.R. Conference, 1967, pp. 119-137.

6. "Mathematical simulation of machine tool structures" under pulbication. Prof.Dr. A.A. Nasser, Prof. Dr. H.R. El-Sayed, Dr. S.M. Serag, Eng. S. samak.

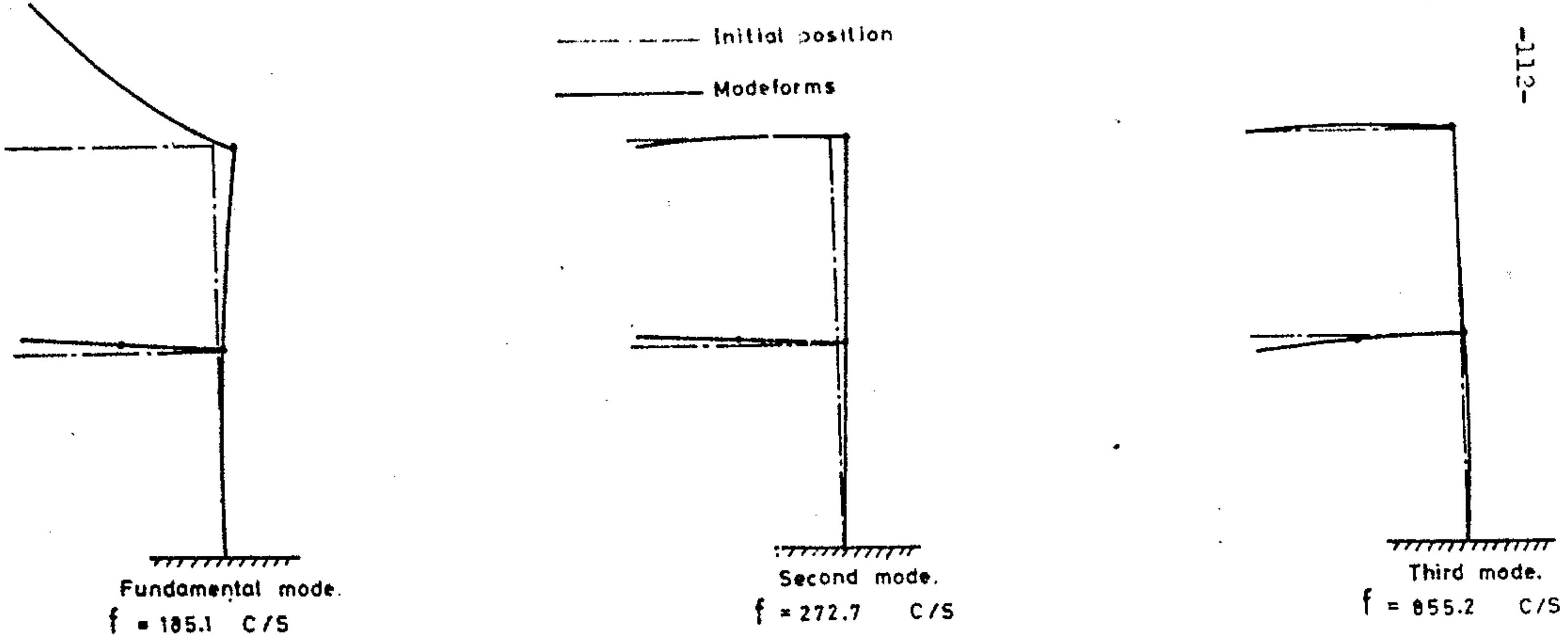
Mode no.	z_1	f c/s	Deflections																								
			Beam 1					Beam 2					Beam 3					Beam 4					Beam 5				
			X_1/L_1					X_2/L_2					X_3/L_3					X_4/L_4					X_5/L_5				
			0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1
1st	0.79	181.5	0	0.09	0.34	0.74	1.28	1.28	1.93	2.68	3.35	4.48	0	0.3	0.61	0.92	1.23	1.23	1.54	1.87	2.18	2.5	0	4.51	14.22	26.67	39.98
2nd	1.04	314.6	0	0.08	0.28	0.59	0.96	0.96	1.34	1.72	2.08	2.42	0	0.2	0.41	0.63	0.85	0.85	1.08	1.31	1.55	1.79	0	0.18	0.09	-0.17	-0.51
3rd	1.72	860.5	0	0.11	0.35	0.56	0.59	059	0.51	0.41	0.28	0.12	0	-0.1	-0.31	-0.59	-0.94	-0.94	-1.34	-1.8	-2.29	-2.79	0	-1.02	-2.08	-1.56	0.38

Table(1) Modeforms and natural frequencies of the basic model.



Mode no.	Z_1	f c/s	Deflections																								
			Beam 1					Beam 2					Beam 3					Beam 4					Beam 5				
			X_1/L_1					X_2/L_2					X_3/L_3					X_4/L_4					X_5/L_5				
			0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.75	0.5	0.75	1	0	0.25	0.5	0.75	1	0	0.25	0.5	0.75	1
1^{st}	0.83	185.1	0	0.09	0.35	0.76	1.31	1.31	1.96	2.72	3.57	4.53	0	0.28	0.57	0.86	1.16	1.16	1.45	1.75	2.04	2.34	0	3.55	10.79	19.95	29.7
2^{nd}	1.09	272.7	0	0.08	0.29	0.6	0.97	0.97	1.34	1.69	2.02	2.32	0	0.18	0.37	0.56	0.75	0.75	0.95	1.15	1.35	1.55	0	0.06	-0.25	-0.76	-1.34
3^{rd}	1.93	855.2	0	0.14	0.42	0.63	0.57	0.57	0.35	0.19	0.06	-0.03	0	-0.17	-0.43	-0.76	-1.15	-1.15	-1.59	-2.08	-2.59	-3.11	0	0.34	0.78	0.26	-0.28

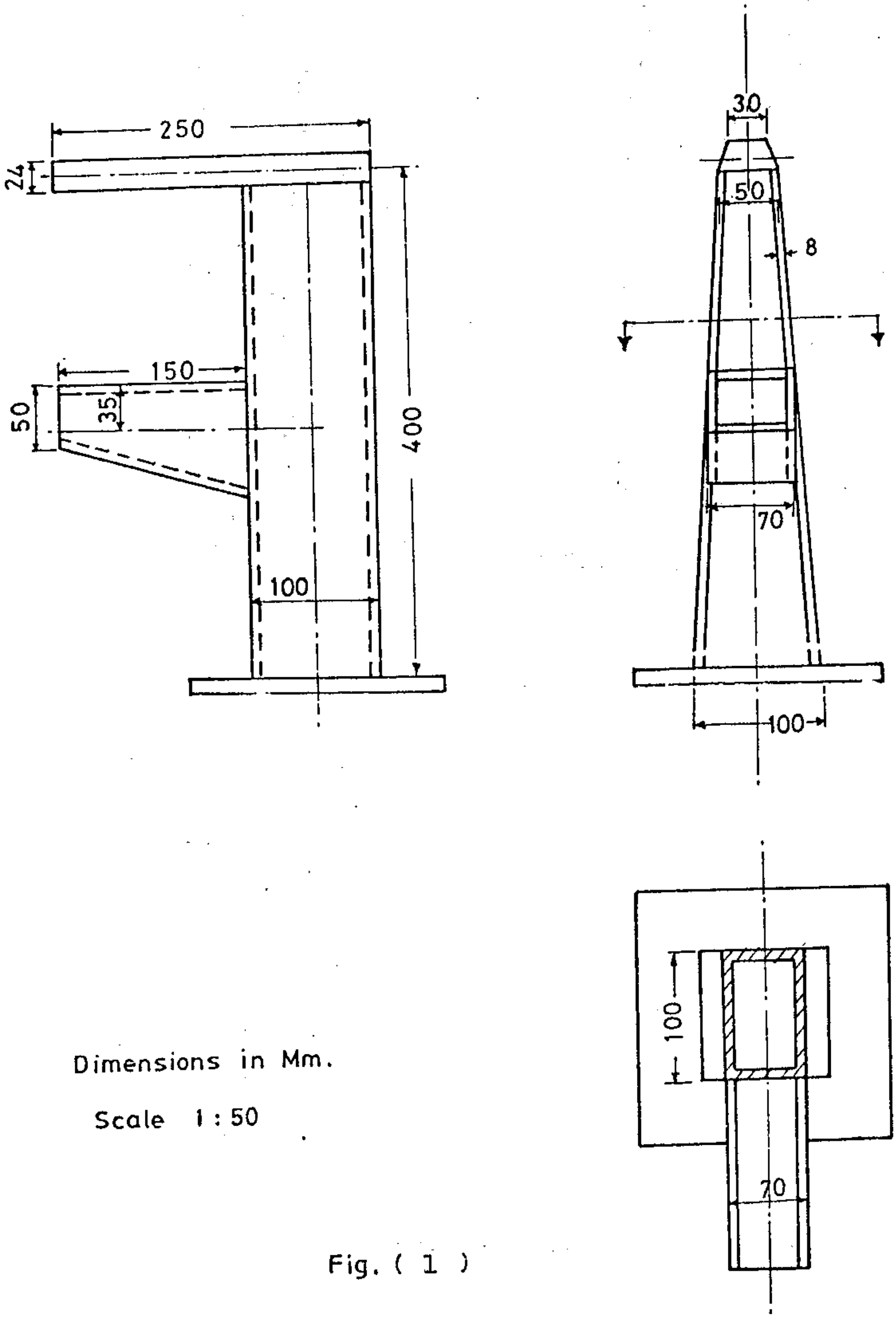
Table (2) Modeforms and natural frequencies of the first modification



Fundamental mode.
f = 185.1 C/S

Second mode.
f = 272.7 C/S

Third mode.
f = 855.2 C/S



Dimensions in Mm.

Scale 1 : 50

Fig. (1)

The basic model of the machine.

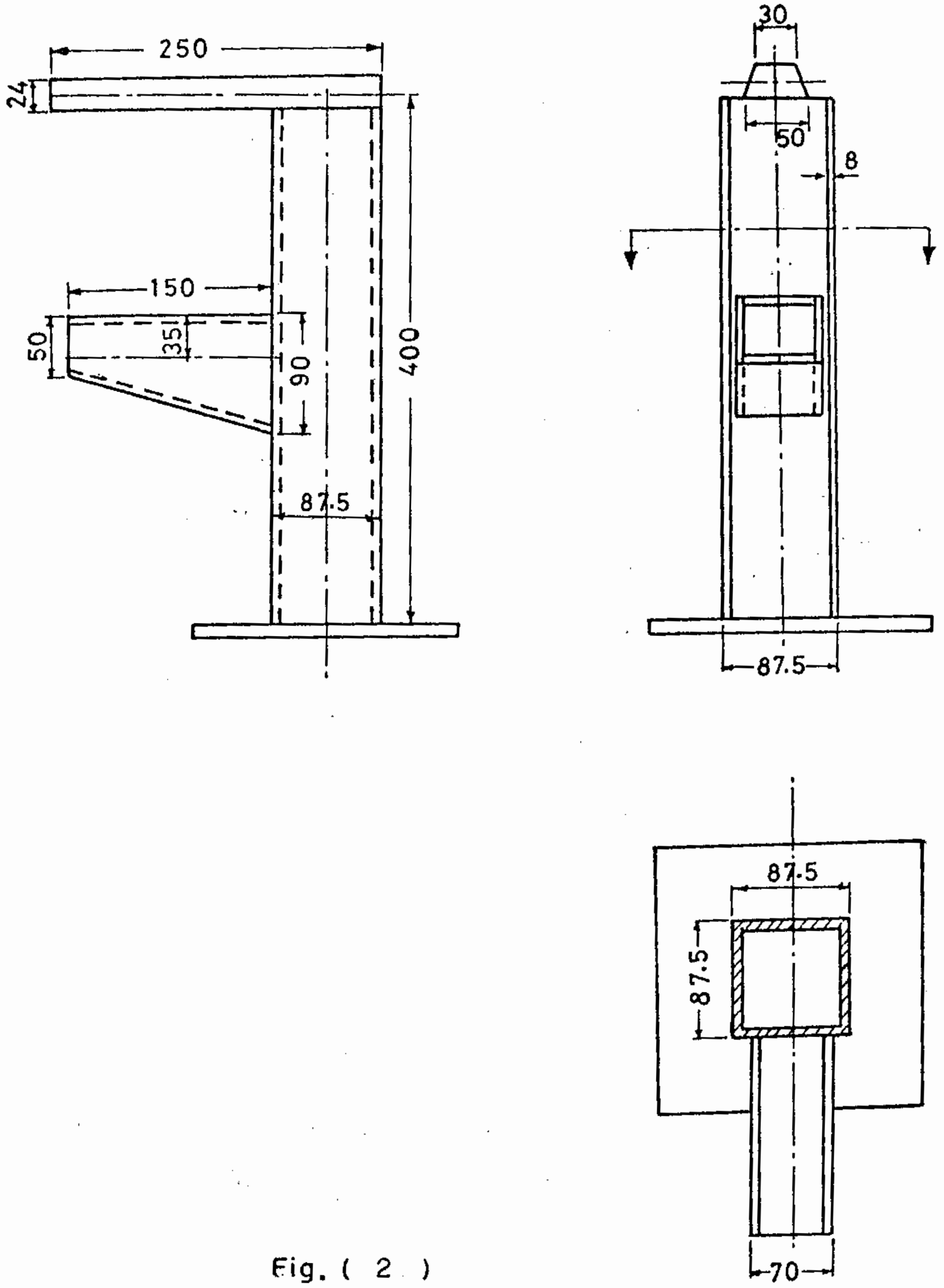


Fig. (2)

Model of the second modification

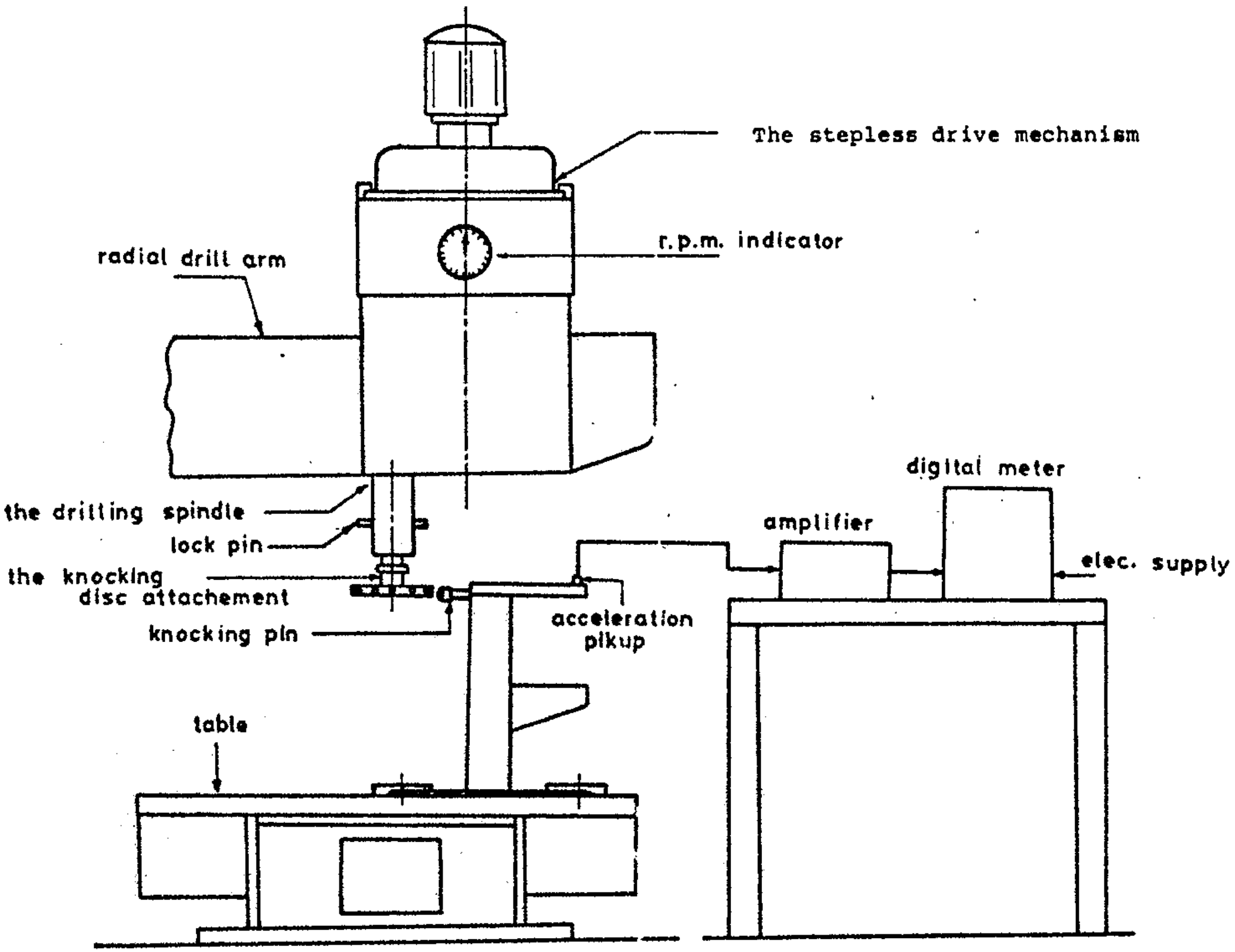


Fig. (3) Diagram of the test arrangement.

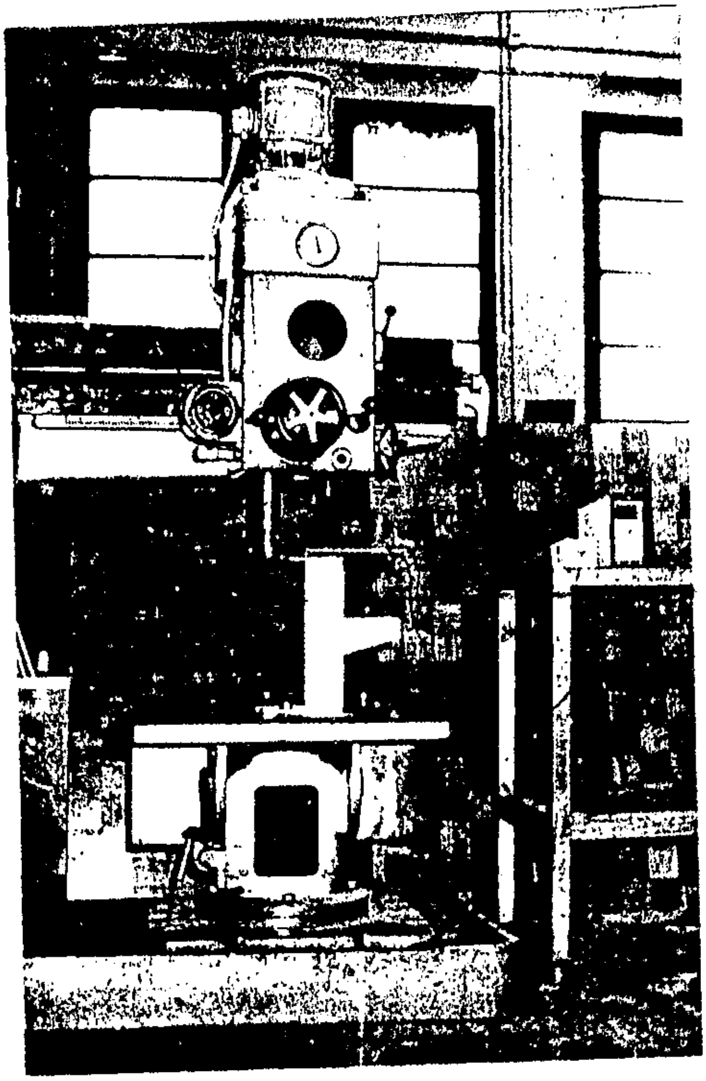


Fig (4)

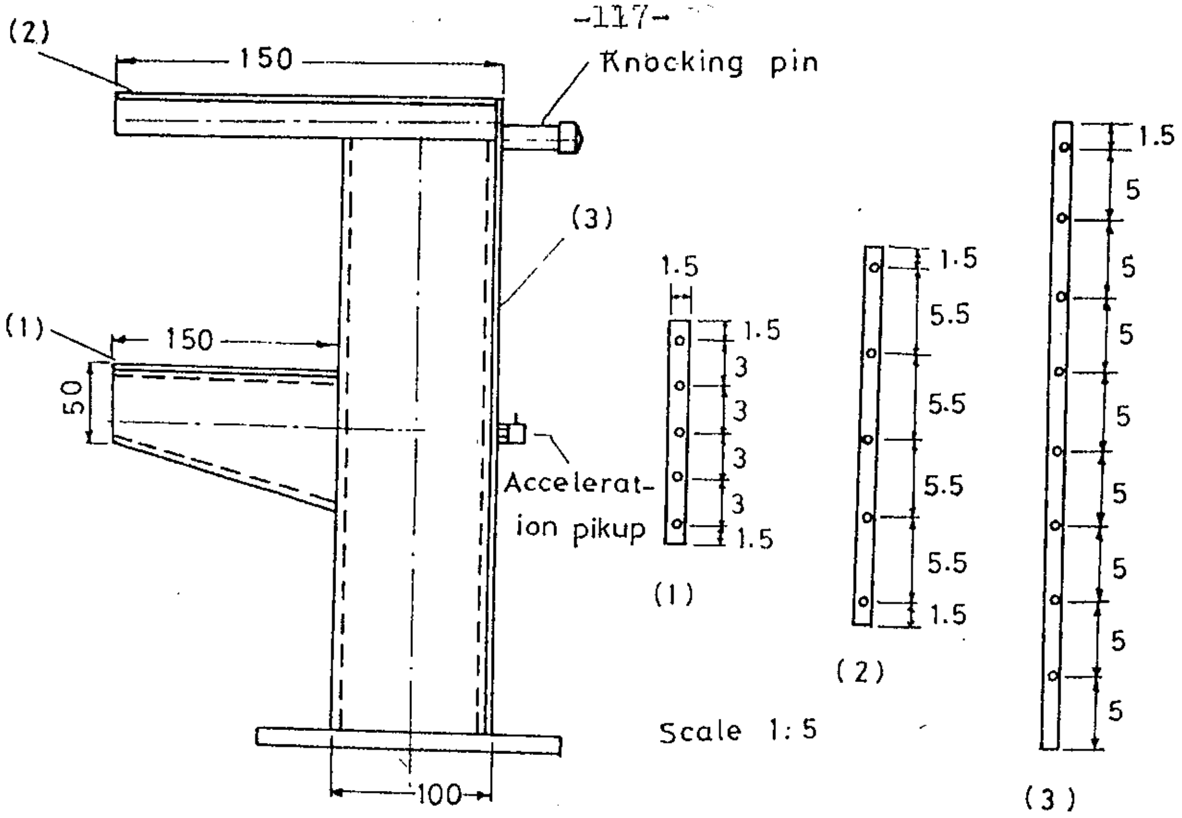


Fig. (5) The test model and strips.

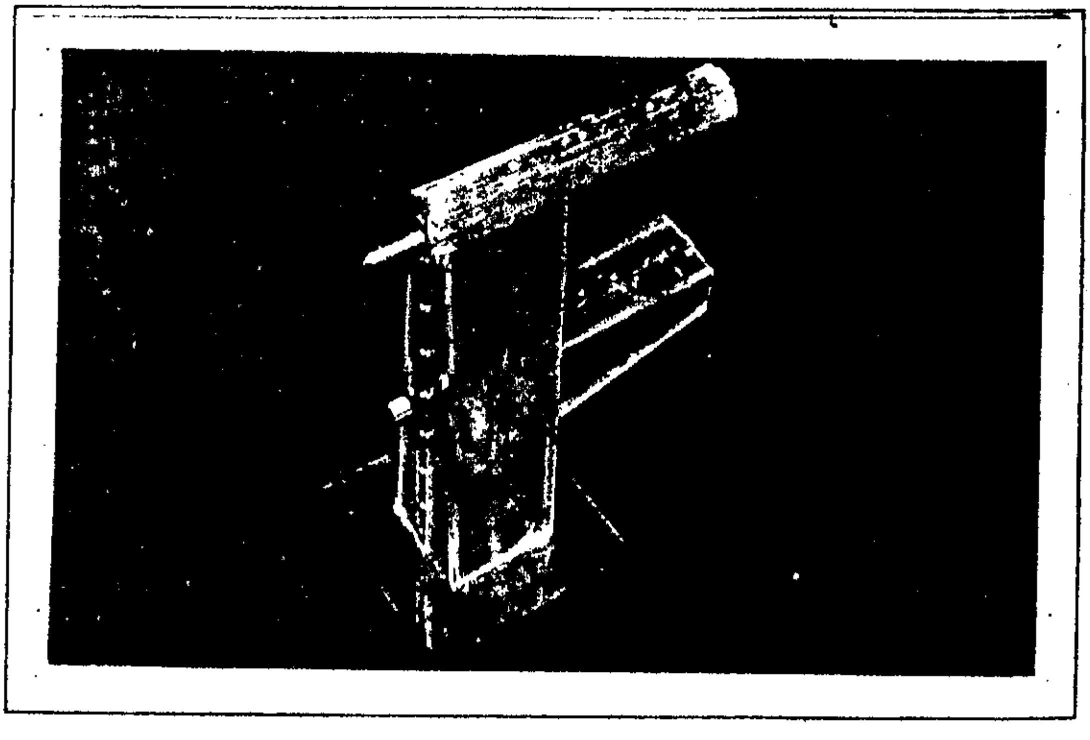
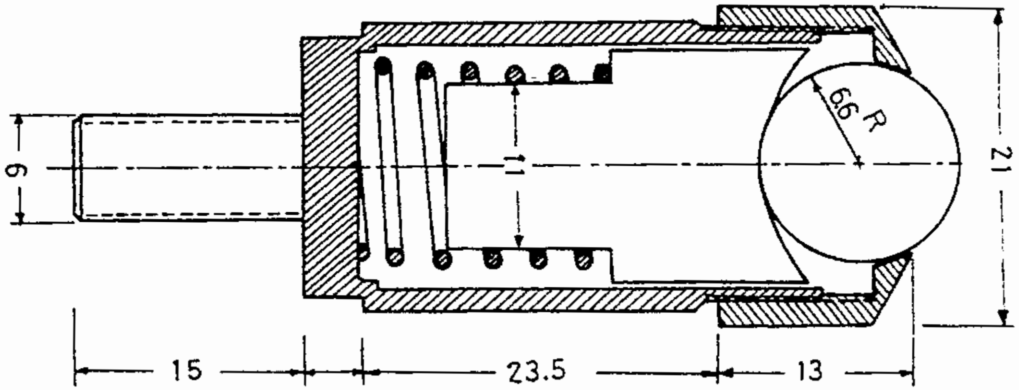


Fig. (6)



Scale 2:1
Dimension in Mm.

Fig (7) The knocking pin

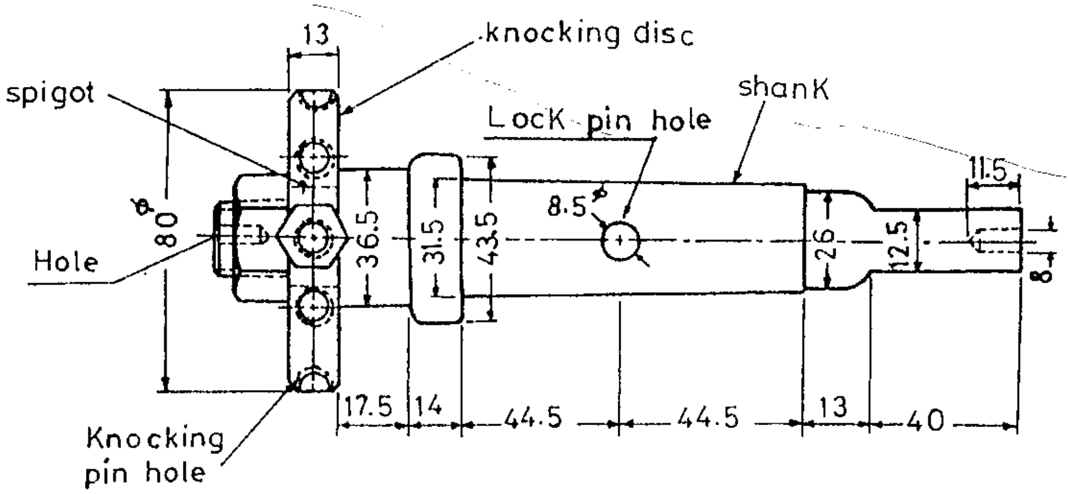


Fig (8) The knocking disc attachement Scale 1:2

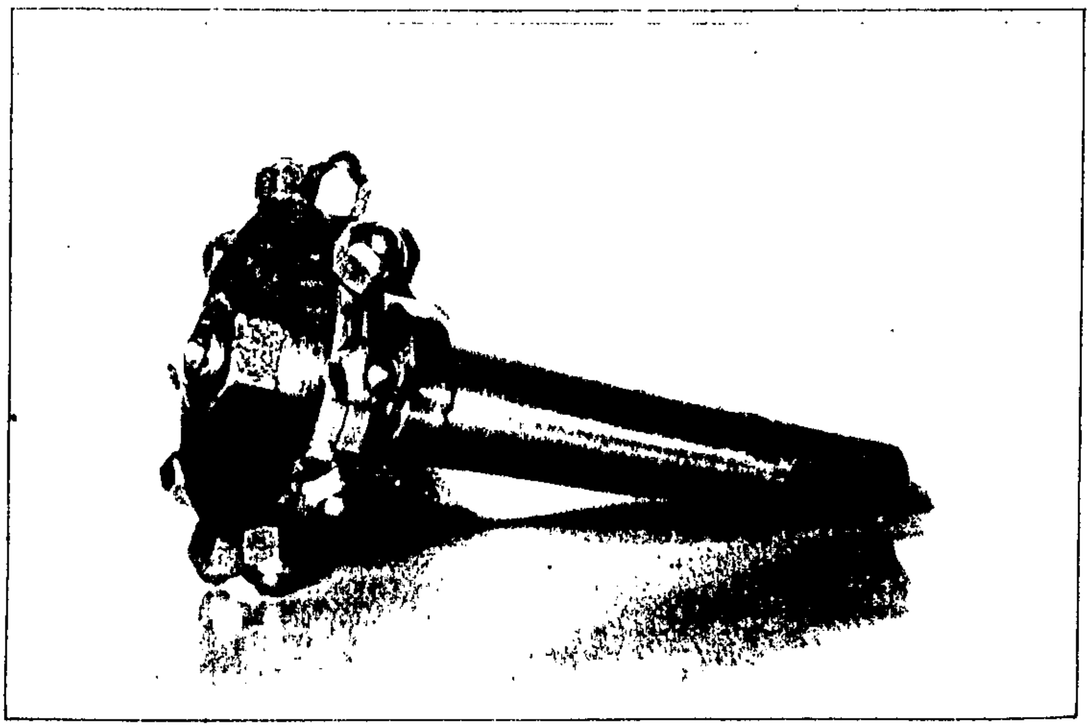


Fig.(9)

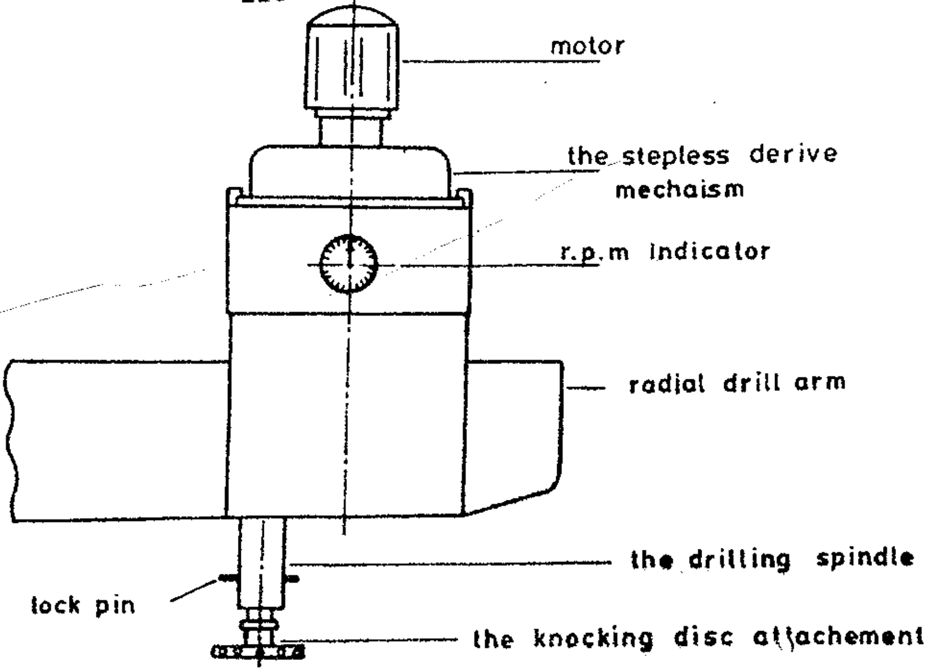


Fig.(10.) Mechanical exciter

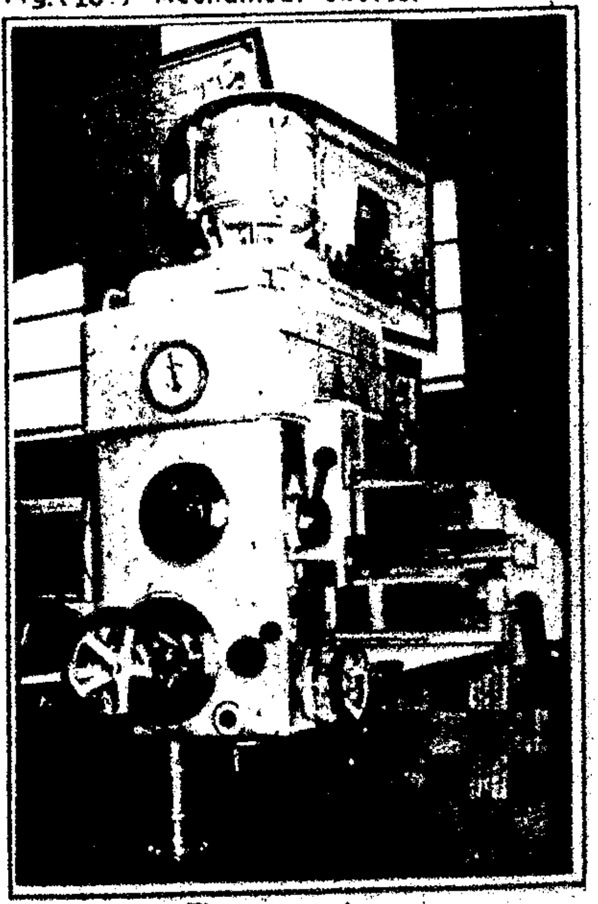


Fig. (11)

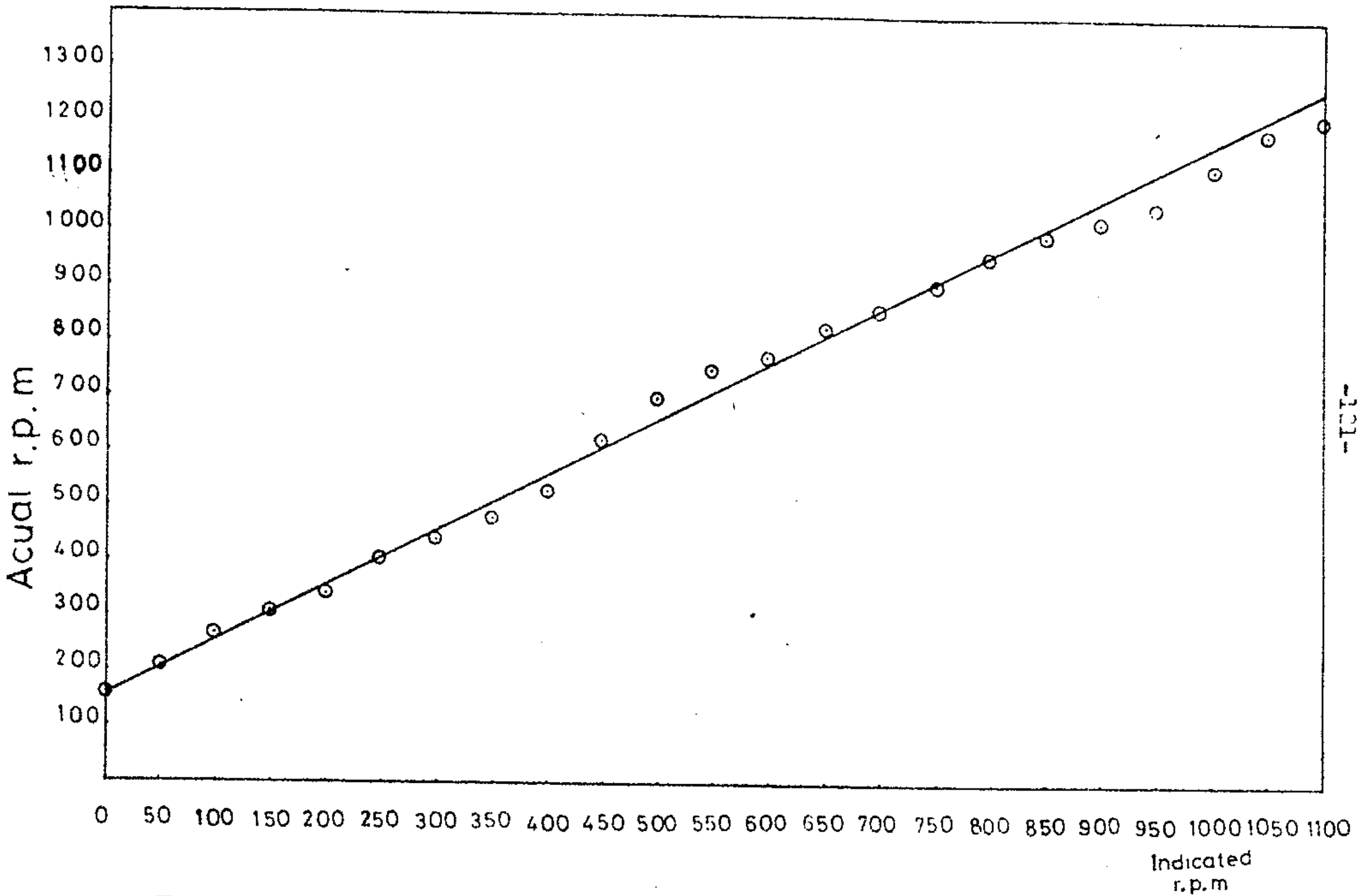


Fig. (12) Calibration curve of the r.p.m indicating Counter

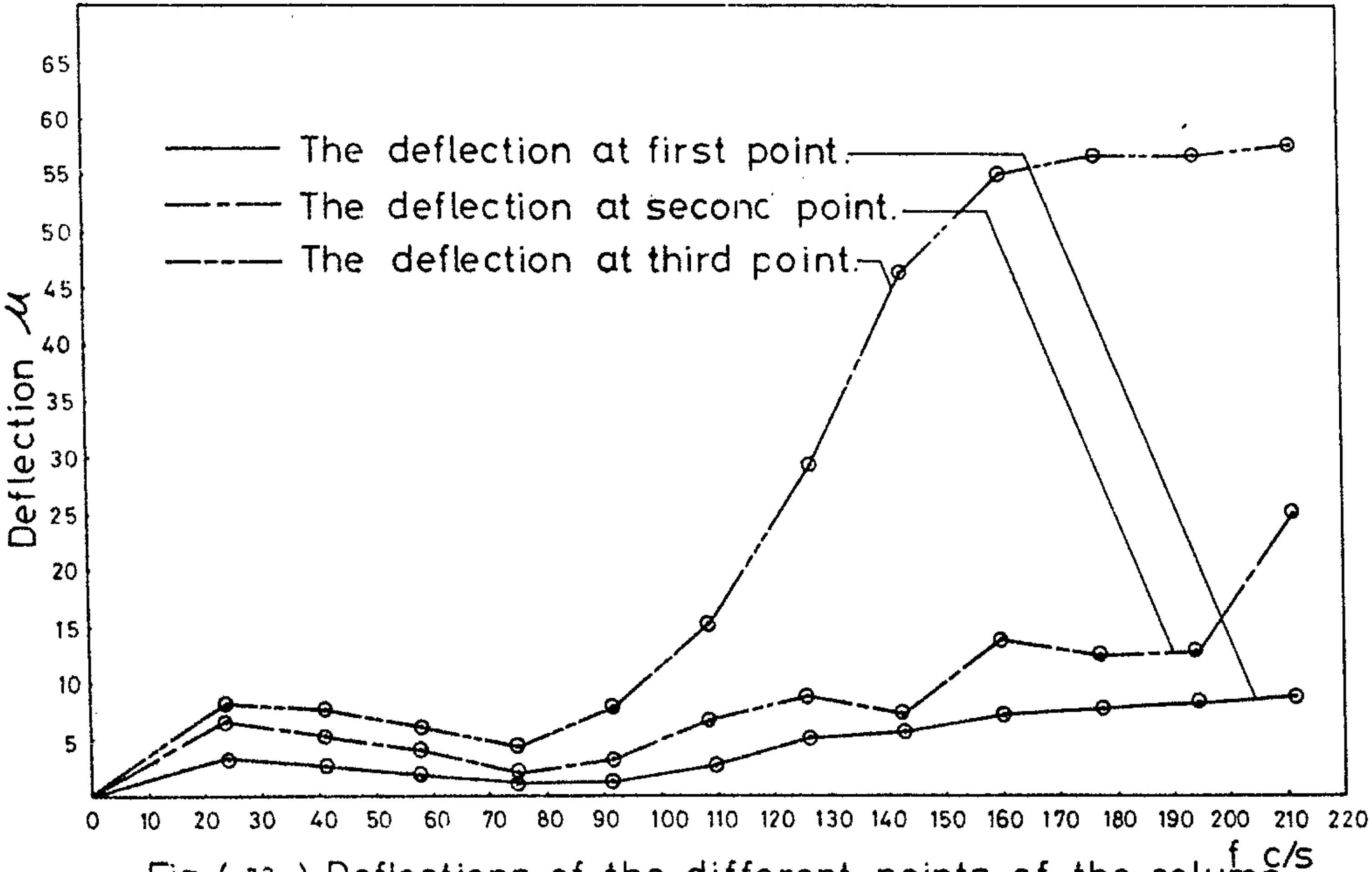


Fig. (13) Deflections of the different points of the column.
(Basic model)

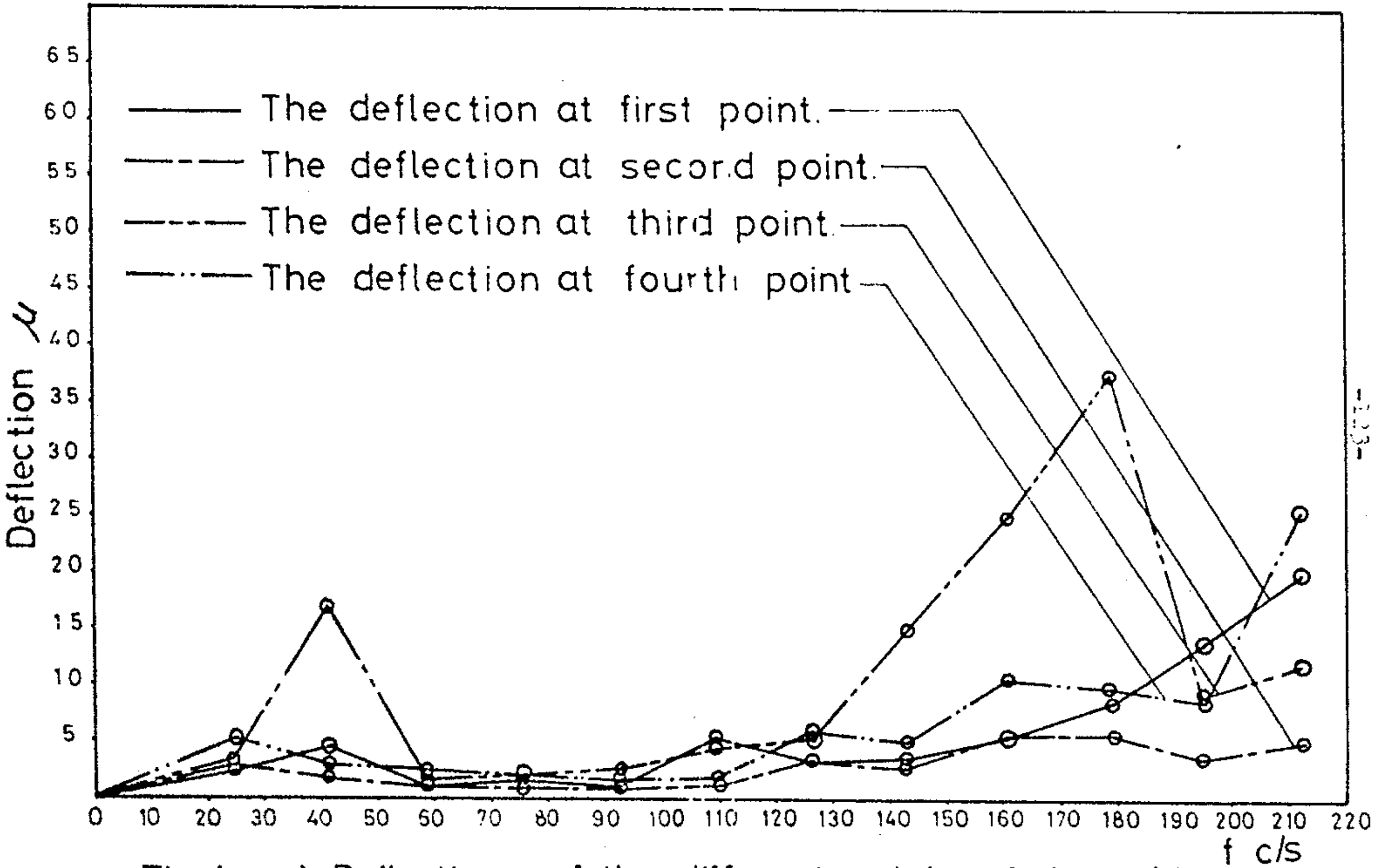


Fig (14) Deflections of the different points of the table
(Basic model)

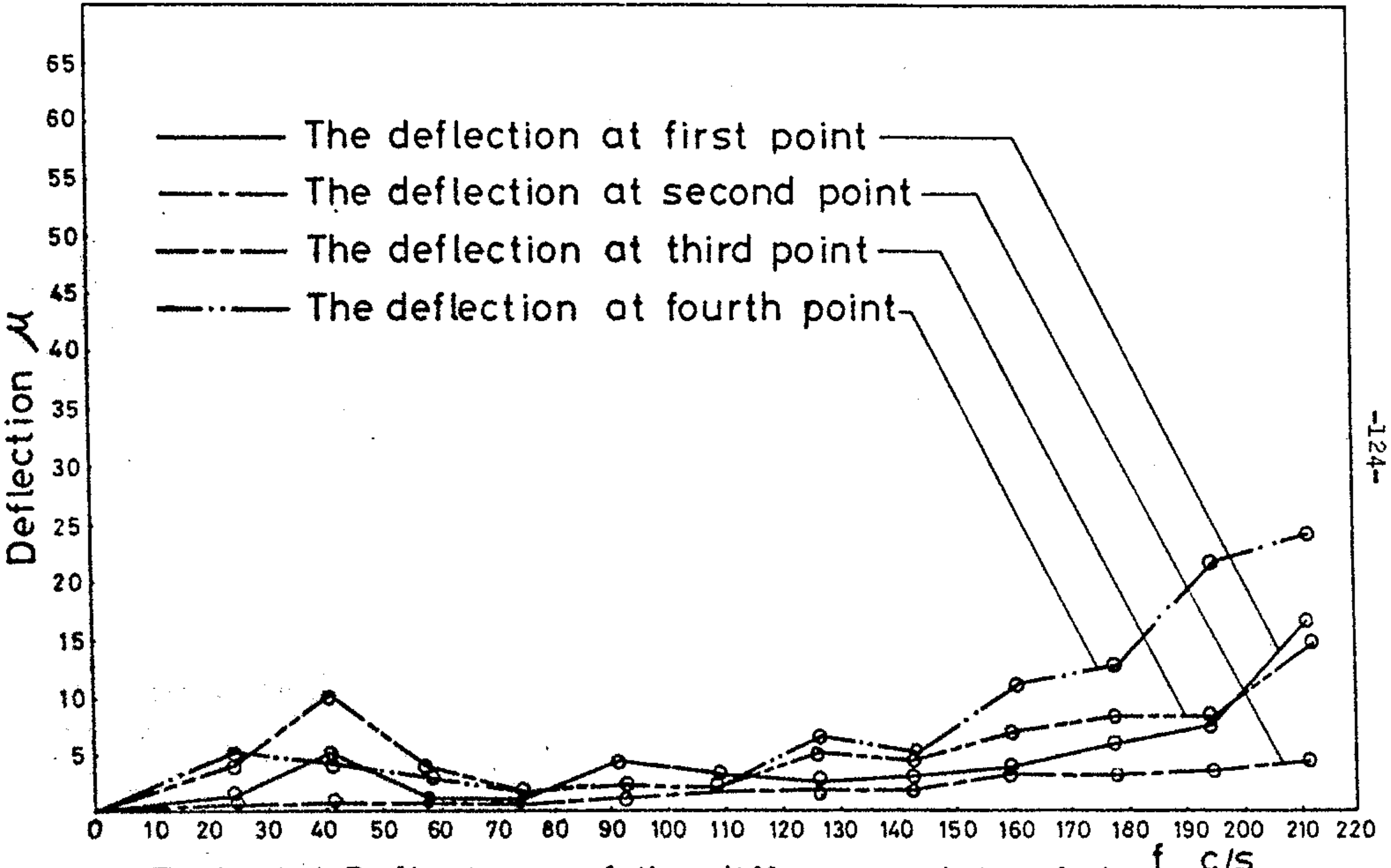


Fig.(3 15) Deflections of the different points of the overarm
(Basic model)

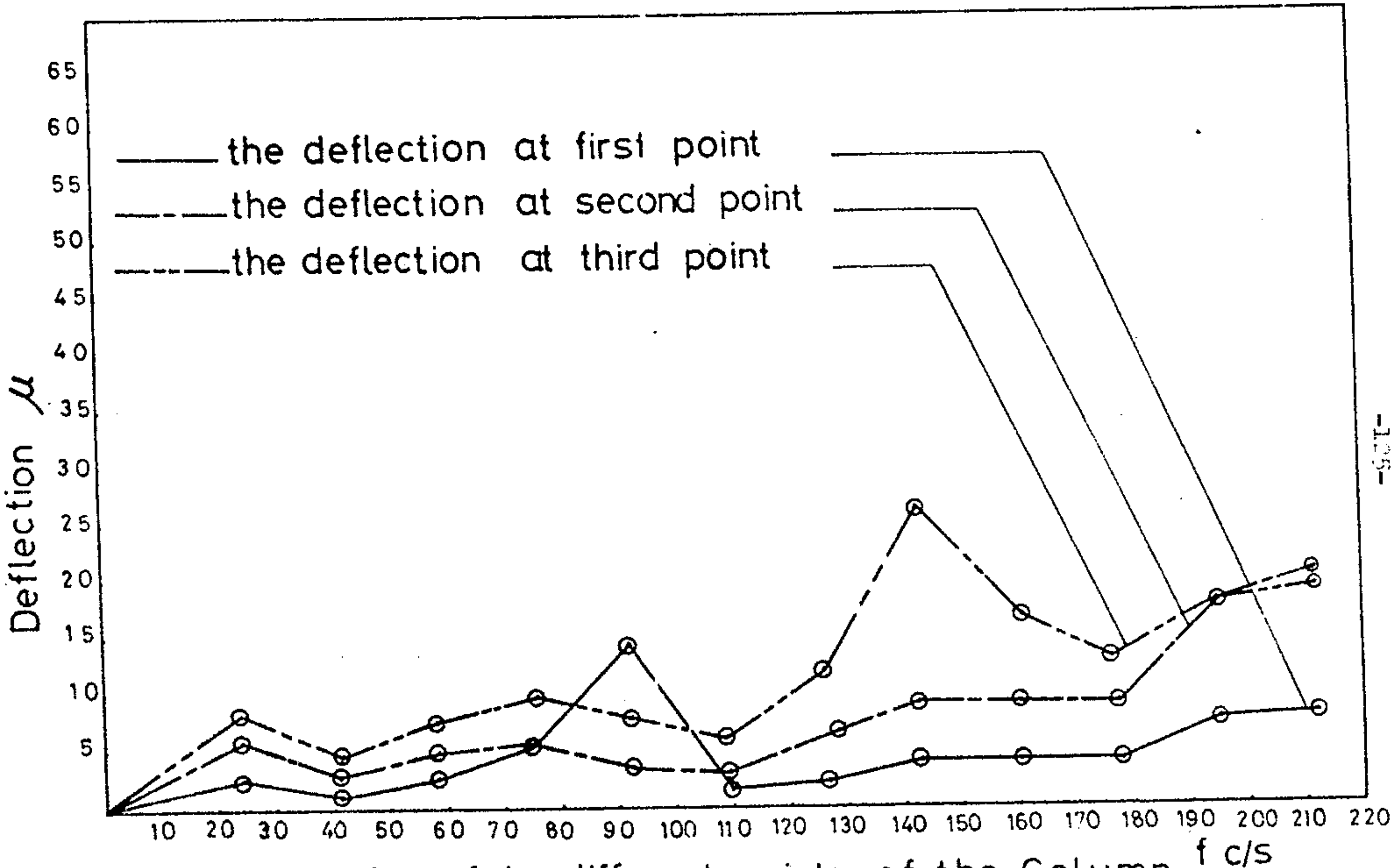


Fig (. 16) Deflection of the different points of the Column
(Second modification)

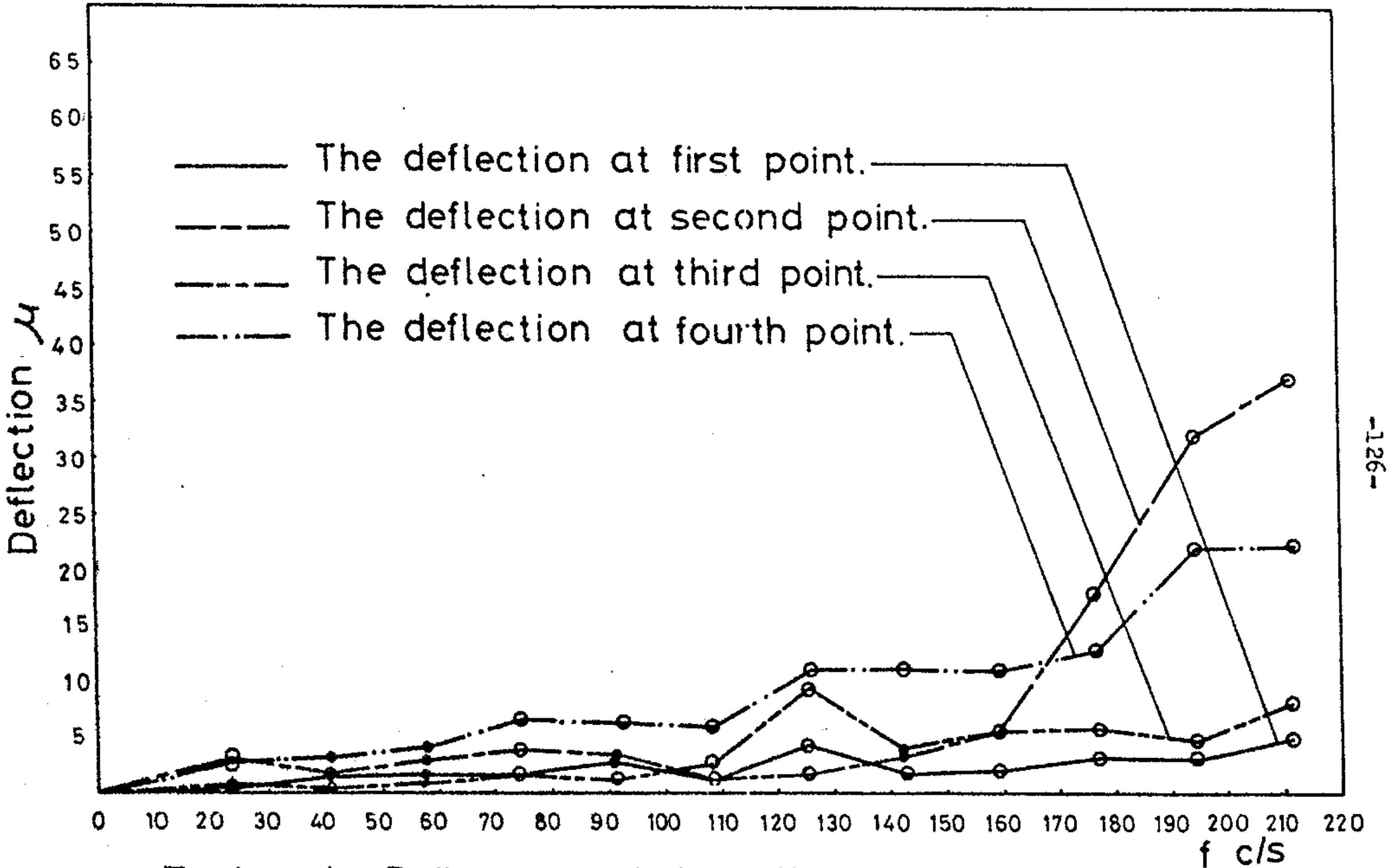


Fig.(17) Deflections of the different points of the table
(Second modification)

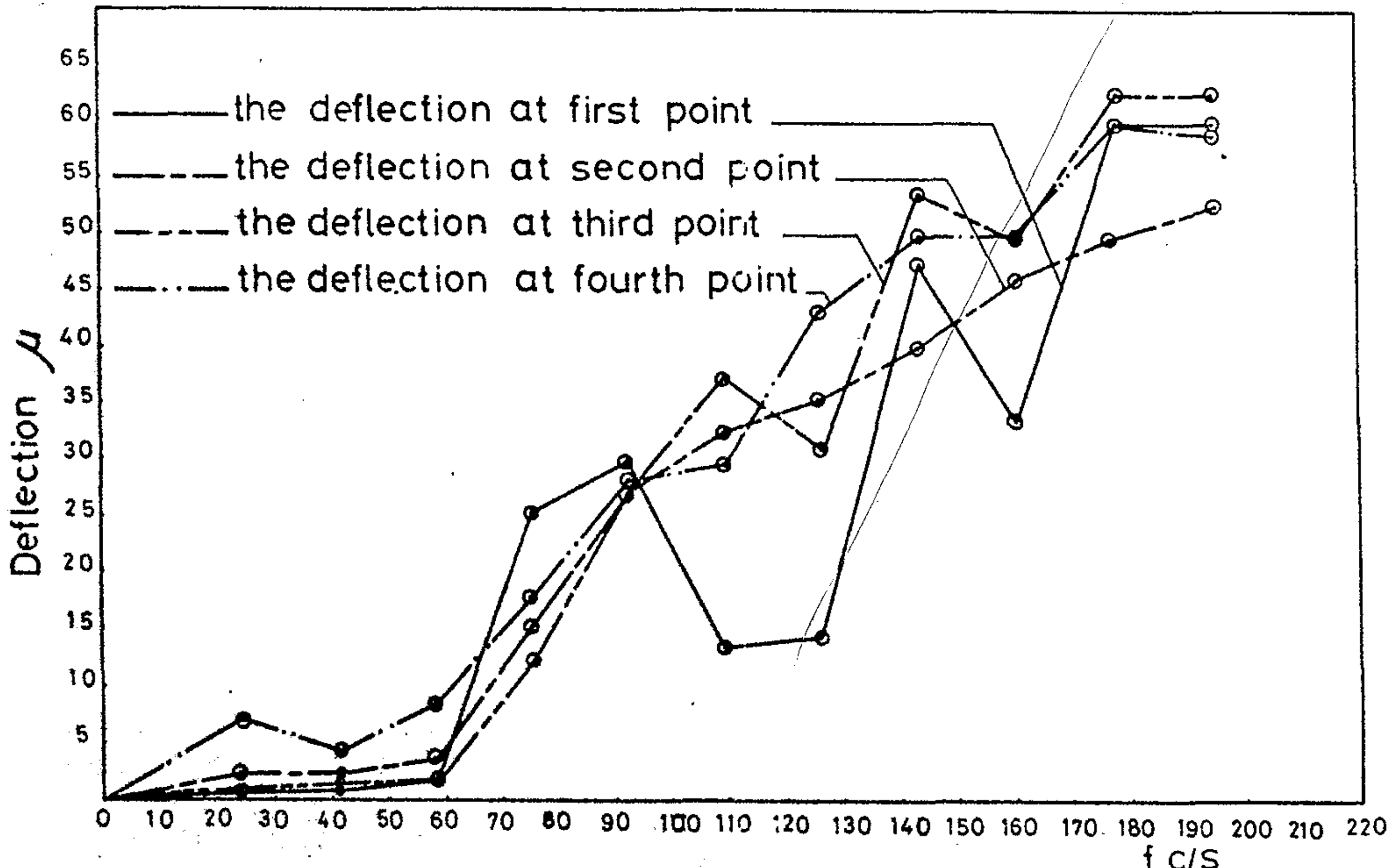
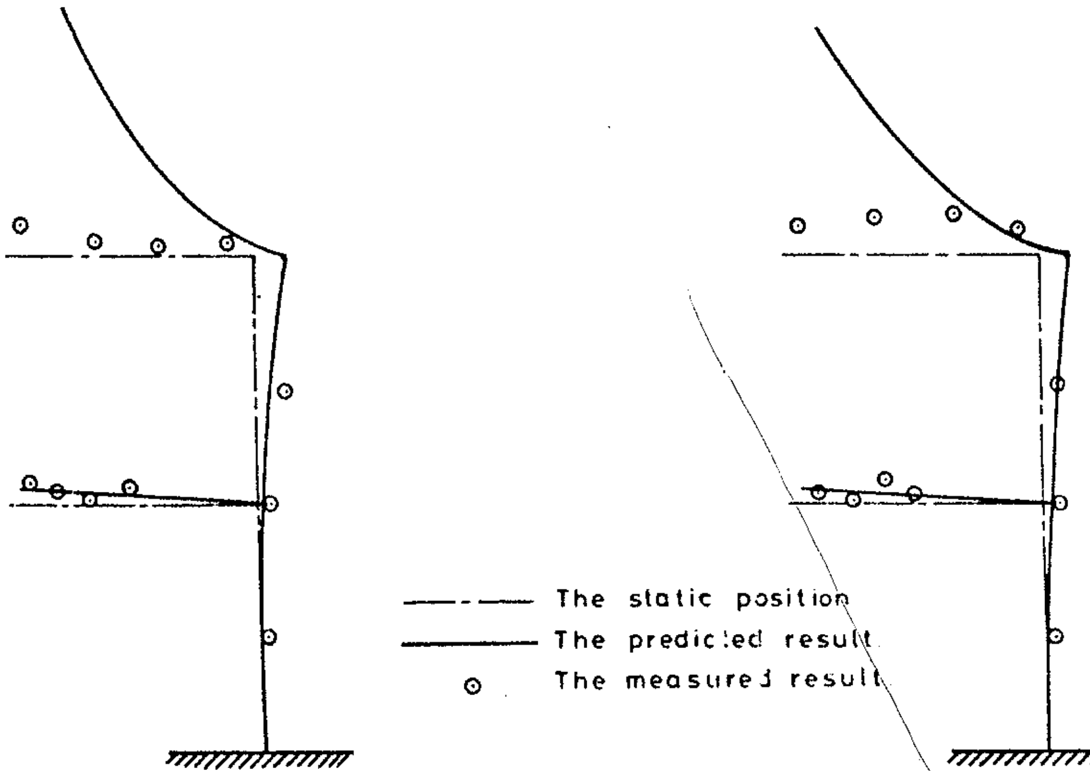


Fig (18) Deflection of the different points of the overarm

(Second modification)



a) The basic model

f (perdiction) = 181.5 C/S

f (measured) = 210 C/S

b) The second modification

f (perdiction) = 171.9 C/S

f (measured) = 190 C/S

Fig. (19) Comparison between the predicted and measured results.

DYNAMIC BEHAVIOUR OF MILLING MACHINE STRUCTURE.

الحالة الديناميكة لهيكل ماكينة التفريز

أستاذ دكتور / عبدالهادى ناصر • أستاذ دكتور / حسن رجب السيد
دكتوره / سعاد محمد سراج • مهندس / سالم سمك

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الدراسة المقدمة بينت قابلية كلا من الطريقتين " النظرية والعملية " لتوقع وتحسين خصائص الهيكل وبالتالى الماكينة •