Provisional report on cooperative work on the dynamic cutting coefficient carried out at Eindhoven

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Provisional report on cooperative work on the dynamic cutting coefficient carried out at Eindhoven

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samenvatting

This report contains results of experiments on "susceptibility to chatter of materials". The experiments form part of the cooperative work on the dynamic cutting coefficient of the C.I.R.P.-Ma Group.
Cutting tests using the Vanherck-Peters stand are carried out to establish the limit of width of cut as a function of the parameters: workmaterial, cutting speed, chip thickness and tool geometry.

prognose

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NOTATION

α = clearence angle
γ = rake angle
ζ = damping ratio
K = cutting-edge angle
b_{lim} = critical depth of cut
s = chip thickness
v = cutting speed
x = displacement
f = frequency
F = alternating force
R_+ = maximum positive real part of the Nyquist diagram
R_- = maximum negative real part of the Nyquist diagram
WM = work material

PROVISIONAL REPORT ON COOPERATIVE WORK ON THE DYNAMIC CUTTING COEFFICIENT CARRIED OUT AT EINDHOVEN

INTRODUCTION

This report contains results of experiments on the dynamic coefficient on the cutting force. The experiments form part of the cooperative work of the C.I.R.P.-Ma Group as suggested at the meeting of a special committee of the C.I.R.P.-Ma Group held at Prague from 28th to 30th May 1968.

The results of this report relate directly to item A-a of the report of the meeting of the special committee containing:

- cutting test using basically the Vanherck-Peters stand and establishing the limit of width of cut (b_{lim}) as a function of the parameters (WM, v, s, α, γ).

The values of the parameters concerning feed, cutting-speed and compliance of the test-rig, used in this work have been adjusted to those which are applied by Peters and Vanherck at the University of Louvain.

(1) WORK MATERIAL

The test has been carried out with steels received from:

1. Louvain,
2. Prague,
3. Birmingham,

and with steel from Eindhoven (S.M.-steel, C 45 N)

The workpieces have been supported between a self-centering chuck and a tailstock with a live centre.

Before the experiments started, the bars had been turned down once on the test-lathe in order to become well-centered workpieces.

The feed rate during experiments was 0.072 mm/rev.

(2) THE "TEST-RIG"

The natural frequency was found at 157 Hz.
The vibration of the "Vanherck-Peters Test-Rig" is measured by strain-gauges which are mounted on the leaf springs of the test-rig. So a good reproduction is ensured.
On the test-rig an inductive displacement transducer is also mounted perpendicularly to the springs on the side farthest from the workpiece By measuring the compliance, results obtained by the latter method are different from those acquired by means of the strain-gauges(Figs. 1 and 2).
Notably the ratio between the positive real part and the negative real part of the Nyquist diagram showed a larger deviation from a single-degree-of-freedom system when the inductive transducer was used. In the inductive transducer method the deviation was 25% compared with about 8% when using the strain-gauges.
As the electronic equipment was the same for both measurements, and the transducer had been mounted very rigidly, it is doubtless that the deviation is due to torsional vibrations of the test-rig.
Now it is to be expected that torsional vibrations will influence the results in a larger degree than is assumed in general, the more so as the distance from the tip of the tool to the axis of the rig is still greater than that from the transducer to the axis.
According to the tests carried out at Louvain the absolute compliance of the test-rig in the main direction (perpendicular to the springs) had been adjusted to 0.205 $\frac{\mu m}{N}$ (Fig. 1).
In the direction parallel to the springs the absolute compliance was 0.017 $\frac{\mu m}{N}$ for 344 Hz, and parallel to the axis of the tool 0,060 $\frac{\mu m}{N}$ for 328 Hz.

The latter value is quite high and is probably due to the torsional movement of the rig as mentioned before. The movement in the direction parallel to the tool-axis, however, has no effect on the modulation of the chip thickness when a tool with $K = 90^\circ$ is used.
The compliance of the mounted workpiece with respect to the carriage has been measured in three directions. In reference to the horizontal and the vertical direction perpendicular to the workpiece-axis the compliance is shown in Figs. 3 and 4. In both cases the natural frequency of the mounted workpiece lies so far from the natural frequency of the rig that only a negligible influence on the results need be expected.
In axial direction the compliance, viz. 0.003 $\frac{\mu m}{N}$, is to be neglected.
During the determination of the transfer functions the dynamic force has been checked for constancy.
It turned out that although the electric current remained constant, the dynamic force on the excited system depended on the way of fitting and lining up the exciter. Fig. 12 shows the possible changes in value and phase angle introduced by bad mounting.

(3) THE TOOL

Standard throw-away type carbide tool-tips were used.
Tool geometry: $\alpha = 6^\circ$, $\gamma = 6^\circ$, $K = 90^\circ$.
The tips were changed every time the cutting speed altered.

(4) ELECTRONIC EQUIPMENT

The displacement of the tool was measured by strain-gauges mounted on the springs of the test-rig (Fig. 13).

The strain-gauges are connected to a strain-gauge amplifier (Hottinger).
After being led through a differentiator the output signal of the amplifier is connected to a wave-analyser.
The bandwidth of the filter of the wave-analyser is adjusted to 125 Hz.
By way of a AC/DC converter the mean value of the vibration was recorded mechanically.

(5) DISCUSSION OF THE RESULTS

When the critical depth of cut is reached, the amplitude of the vibration increases suddenly to high values well exceeding 10 mm/s. So the critical depth of cut is to be taken at the bending point of the curve.
Fig. 6 shows the results of a repeated experiment.
Comparison of the results of Fig. 5 and Fig. 6 reveals that except for the steel from Birmingham the results are reproductive.
The standard deviation determined from a series of three measurements is 0.25 mm.
The diagrams of Fig. 7, 8, 9, and 10 describe the critical depth of cut b_{lim} as a function of the cutting speed for the several kinds of steel.
To ascertain the form of the curve, allowance has been made for the standard deviation.
The test has been carried out for a series of cutting-speeds of 20 m/min up to 120 m/min.
Looking at Fig. 11 we can notice that

- the four workpiece materials represent a minimum;
- for all the workpiece materials the differential of b_{lim} increases as it approaches the minimum;
- all the minima appear at the cutting-speed of about 80 m/min;

- at increasing cutting-speed up to 105 m/min the critical depth of cut is about twice its lowest value.

Comparing the test results with those obtained at Louvain one can conclude that

- the relative position of the critical depth of cut is the same for three work materials;
- with the exception of the steel from Eindhoven the values of the results of b_{lim} are about twice those of Peters and Vanherck;
- proportionately a remarkable difference is to be seen in the results concerning the steel from Eindhoven;
- the minimum values of b_{lim} are equal to those which have been obtained at Louvain. However, the minima mentioned arise at higher cutting-speeds;
- according to the conclusion of Peters and Vanherck: The dynamic cutting coefficient is dependent on the cutting-speed and the work material. Comparing the dynamic performances of a machine tool on the basis of cutting tests, it is necessary to make allowance for the influence of the cutting-speed.

NOTES:

During experiments it was found that the values for b_{lim} increase with growing wear of the tool.
The experiments have been carried out on a LANGE 10 kW lathe. To acquire the most constant feed rate the screw-spindle has been used to move the carriage. According to experiments carried out at Eindhoven formerly, it is known that the deviations in the feed rate are about 1% if the screw-spindle is used. If the sliding-spindle is used the deviation which can be expected is about 7%.

It may be assumed that the way of driving the carriage affects the results.

(6) CONCLUSION

Although the above results show great similarity with those obtained at Louvain, especially with regard to the values of the cutting-speed at which the critical depth of cut attains a minimum, there is a remarkable difference.

Further conclusions cannot be made before results from the other cooperating laboratories are known.

H.J.J.Kals.

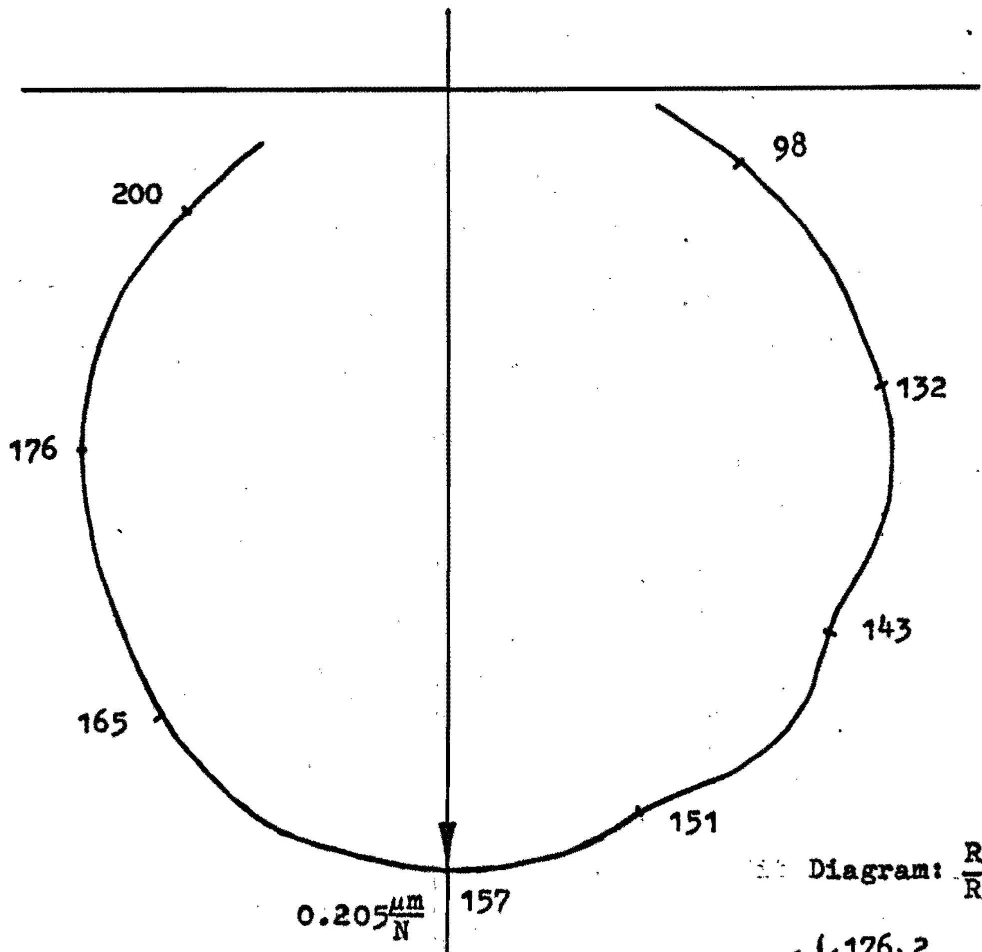

Diagram: $\frac{R_+}{R_-} = 1,20$

$$\zeta = \frac{1}{2}\left\{\left(\frac{176}{157}\right)^2 - 1\right\} = 0,13$$

$$\frac{R_+}{R_-} = \frac{1+\zeta}{1-\zeta} = \frac{1,13}{0,87} = 1,30$$

FIG.1: COMPLIANCE OF THE TEST-RIG IN THE MAIN DIRECTION

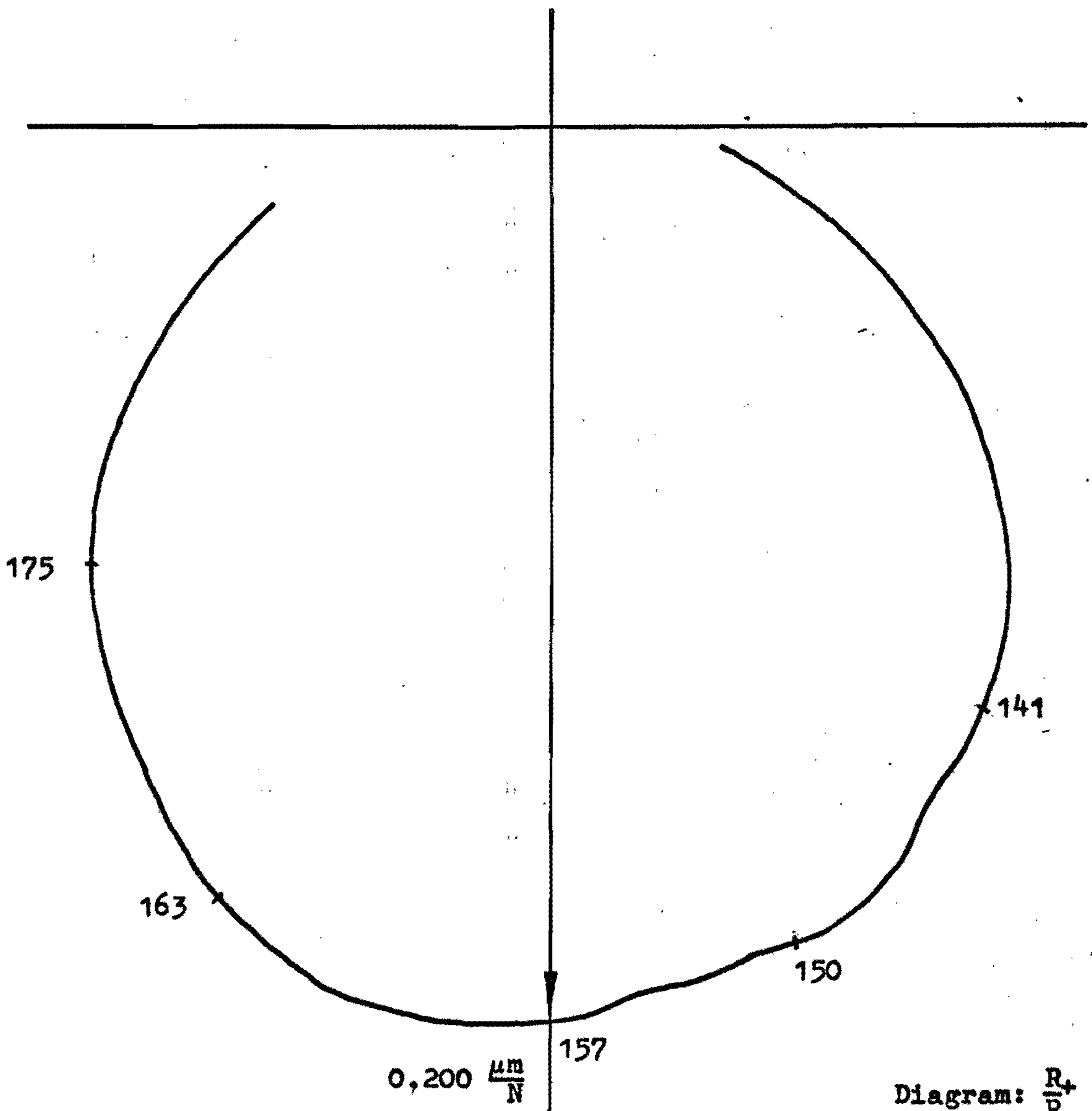

Diagram: $\frac{R_+}{R_-} = 1,00$

$$\zeta = \frac{1}{2}\left\{\left(\frac{175}{157}\right)^2 - 1\right\} = 0,12$$

$$\frac{R_+}{R_-} = \frac{1,12}{0,88} = 1,27$$

FIG.2: TORSIONAL INFLUENCE ON THE COMPLIANCE OF THE TEST-RIG IN THE MAIN DIRECTION.

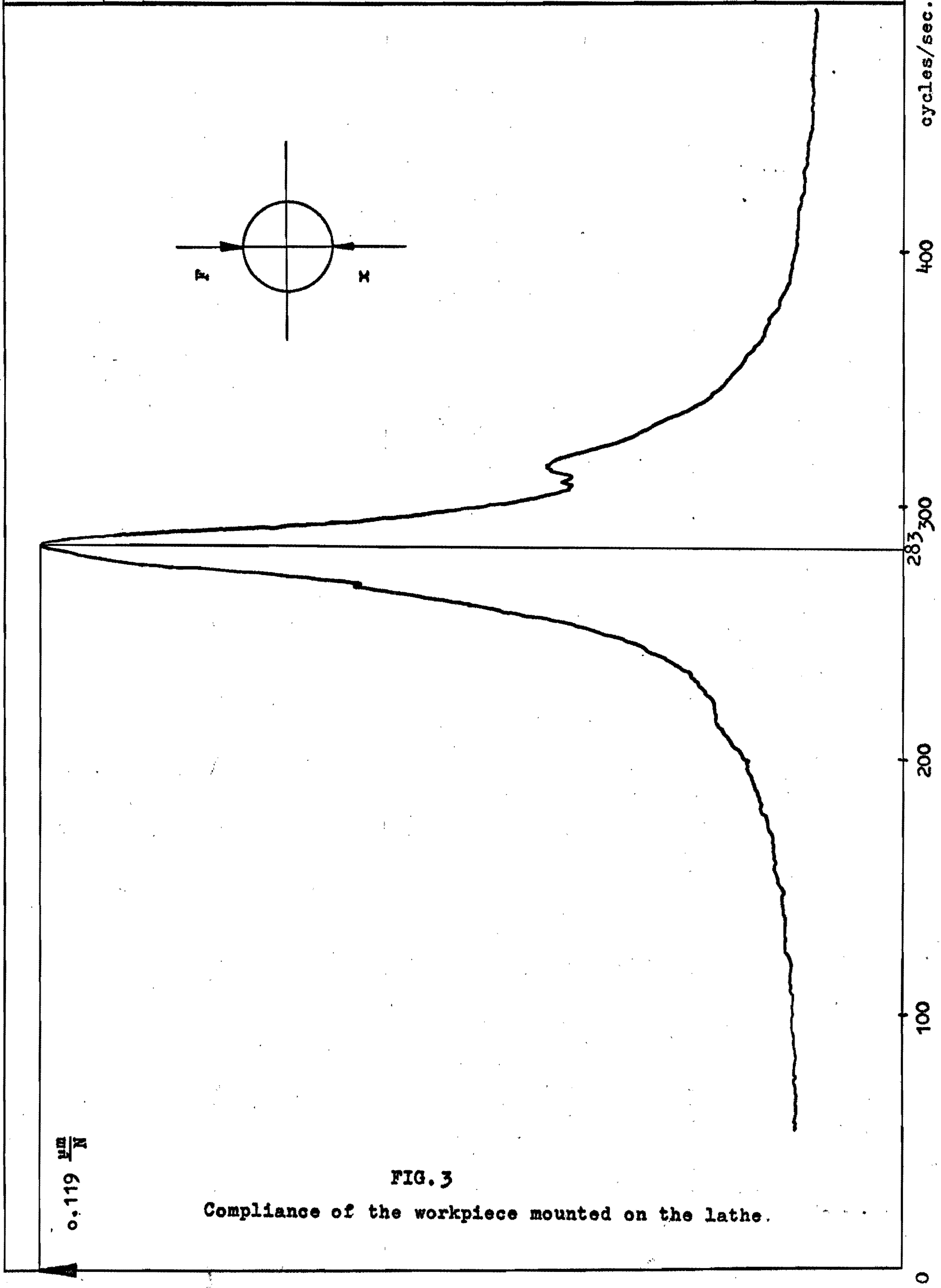

FIG. 3

Compliance of the workpiece mounted on the lathe.

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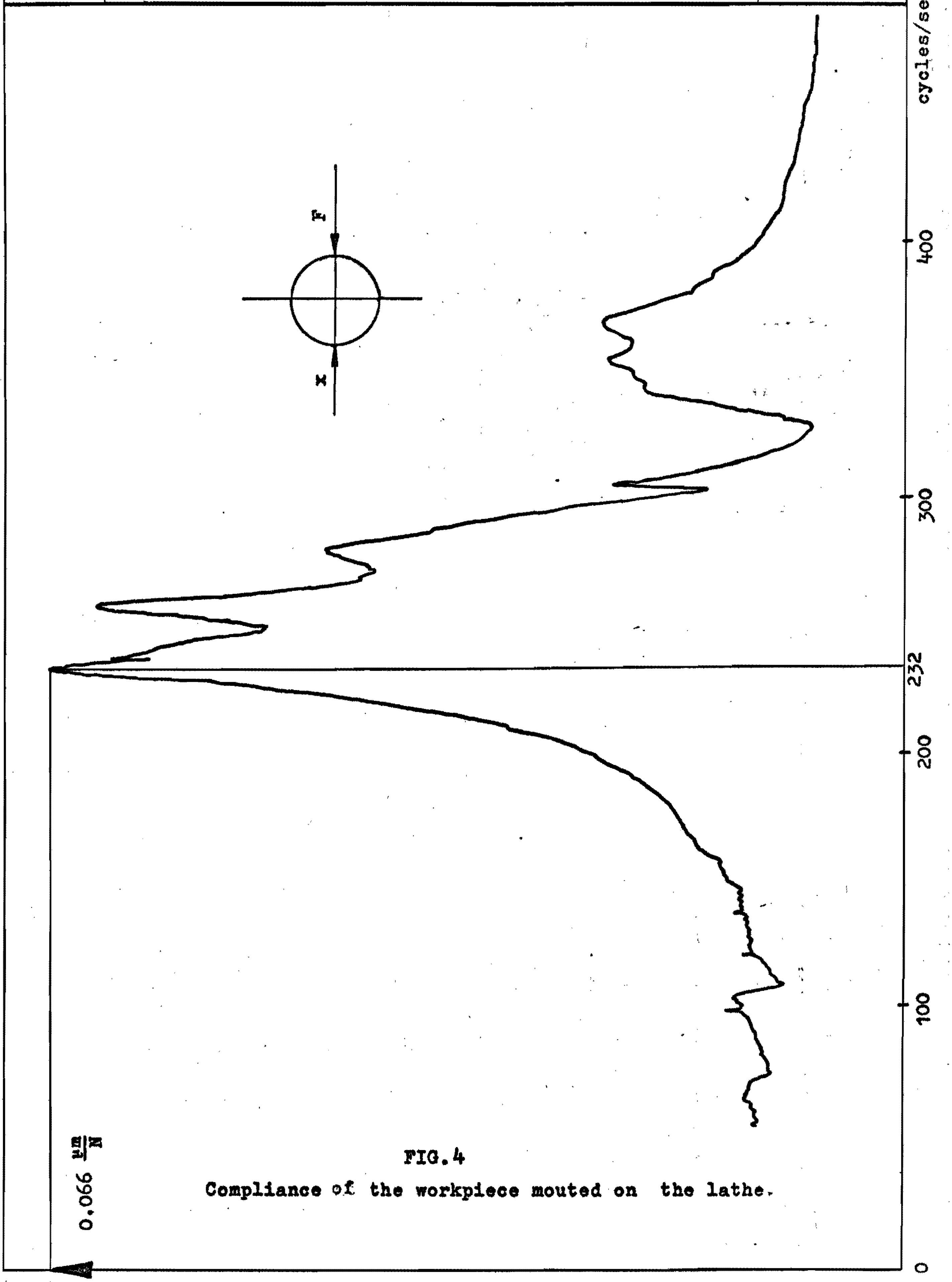


FIG.4

Compliance of the workpiece mouted on the lathe.

FIG.5: VIBRATION AMPLITUDE VERSUS DEPTH OF CUT

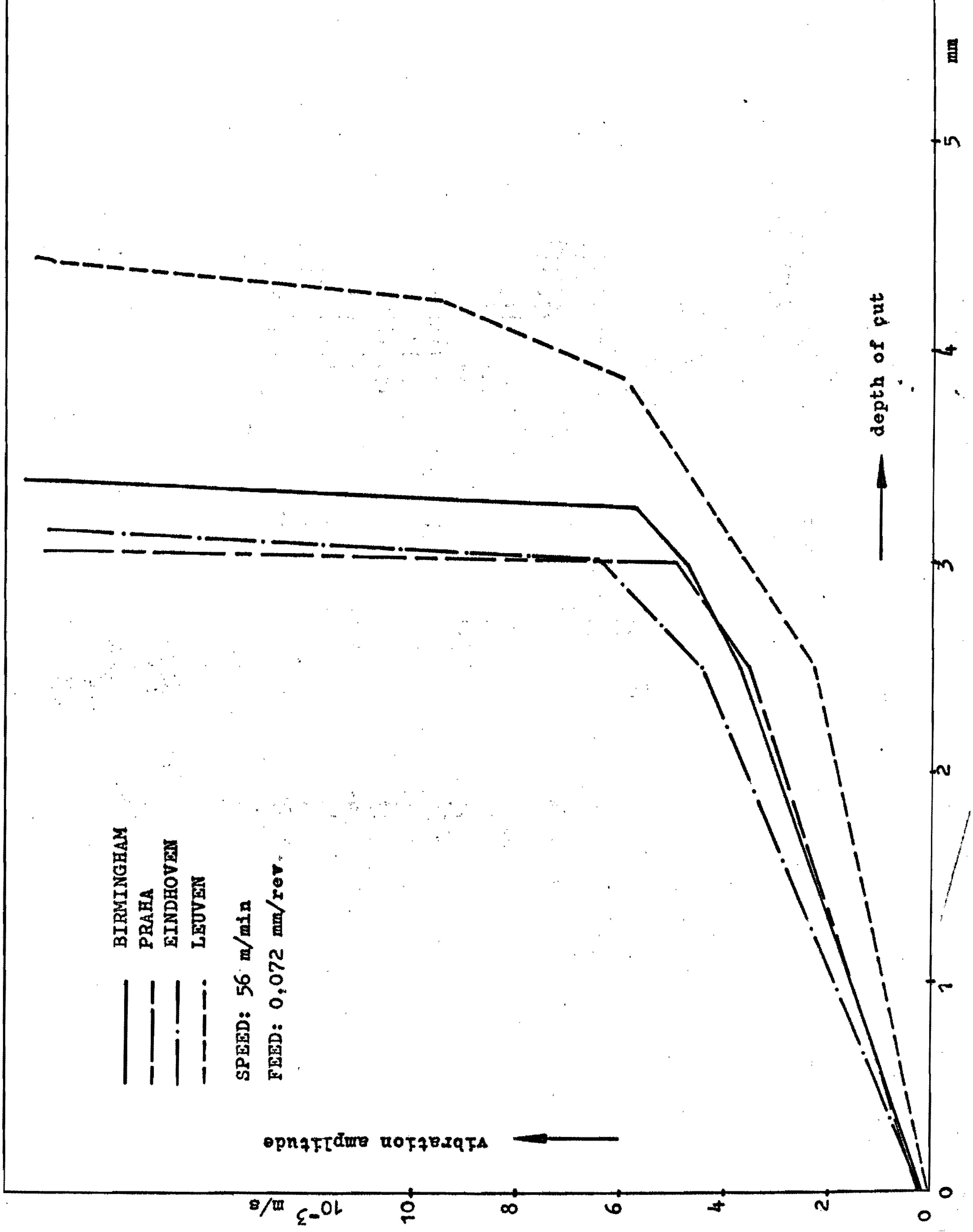


FIG.6: VIBRATION AMPLITUDE VERSUS DEPTH OF CUT

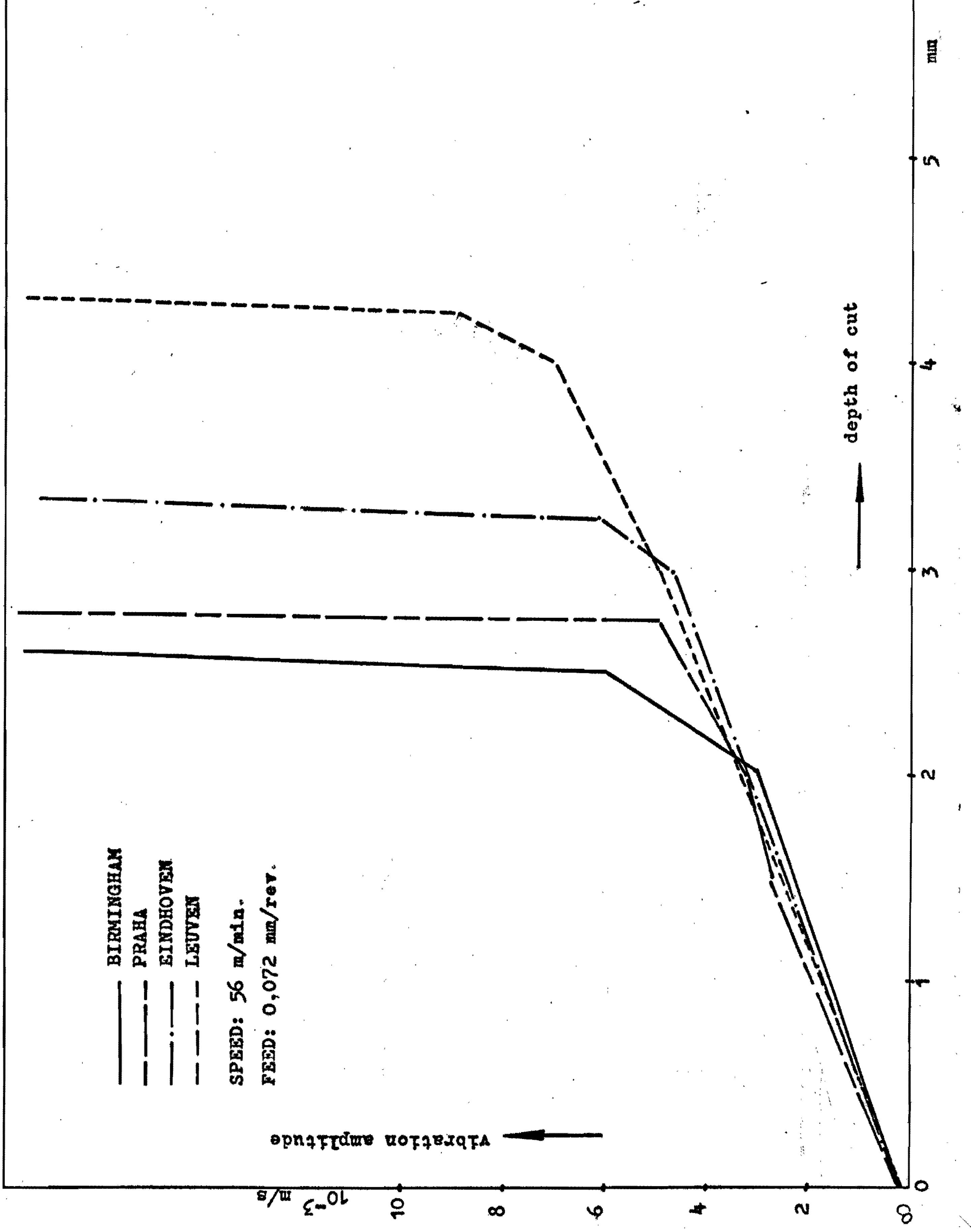


FIG.7: CRITICAL DEPTH OF CUT VERSUS CUTTING SPEED

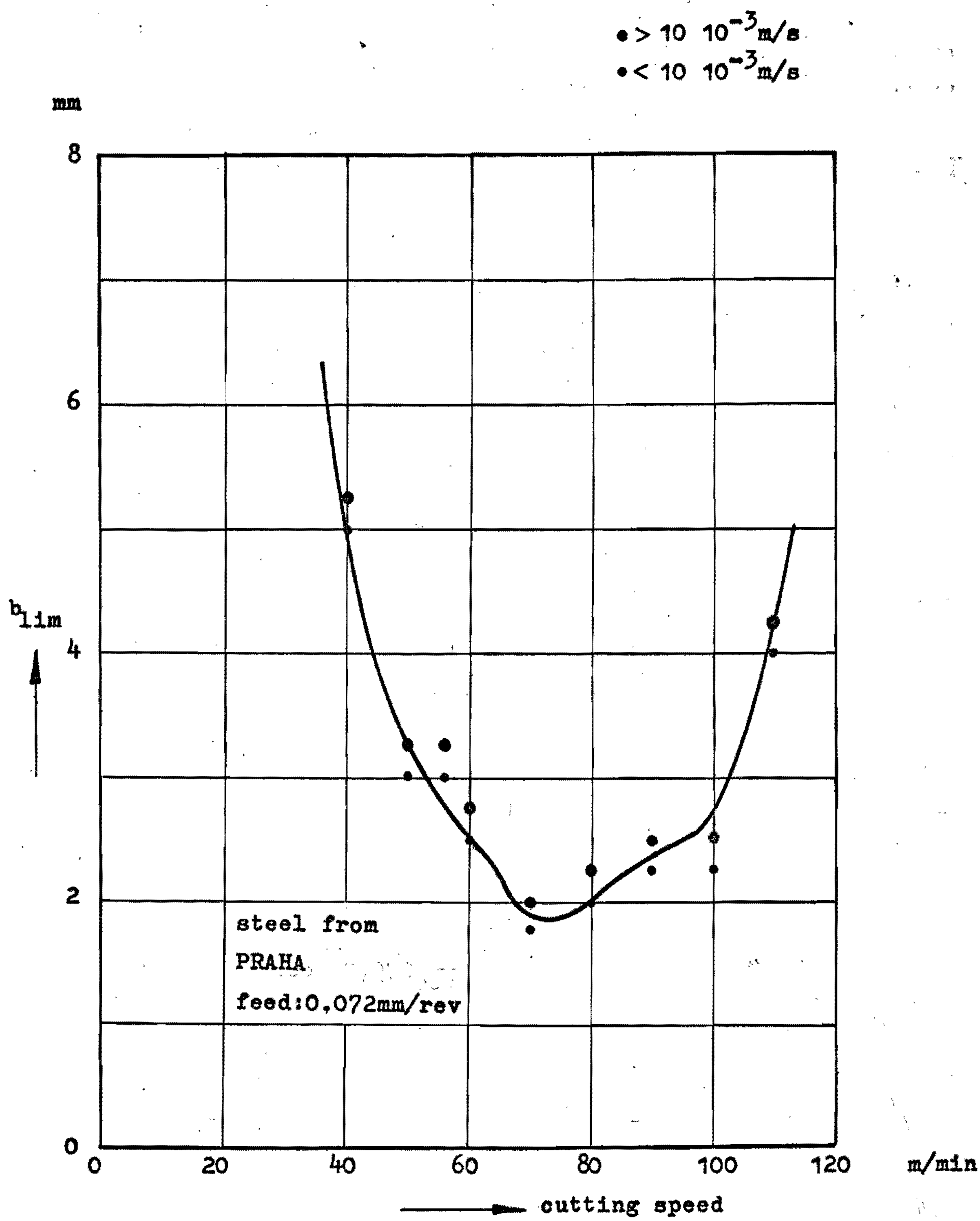


FIG.8: CRITICAL DEPTH OF CUT VERSUS CUTTING SPEED

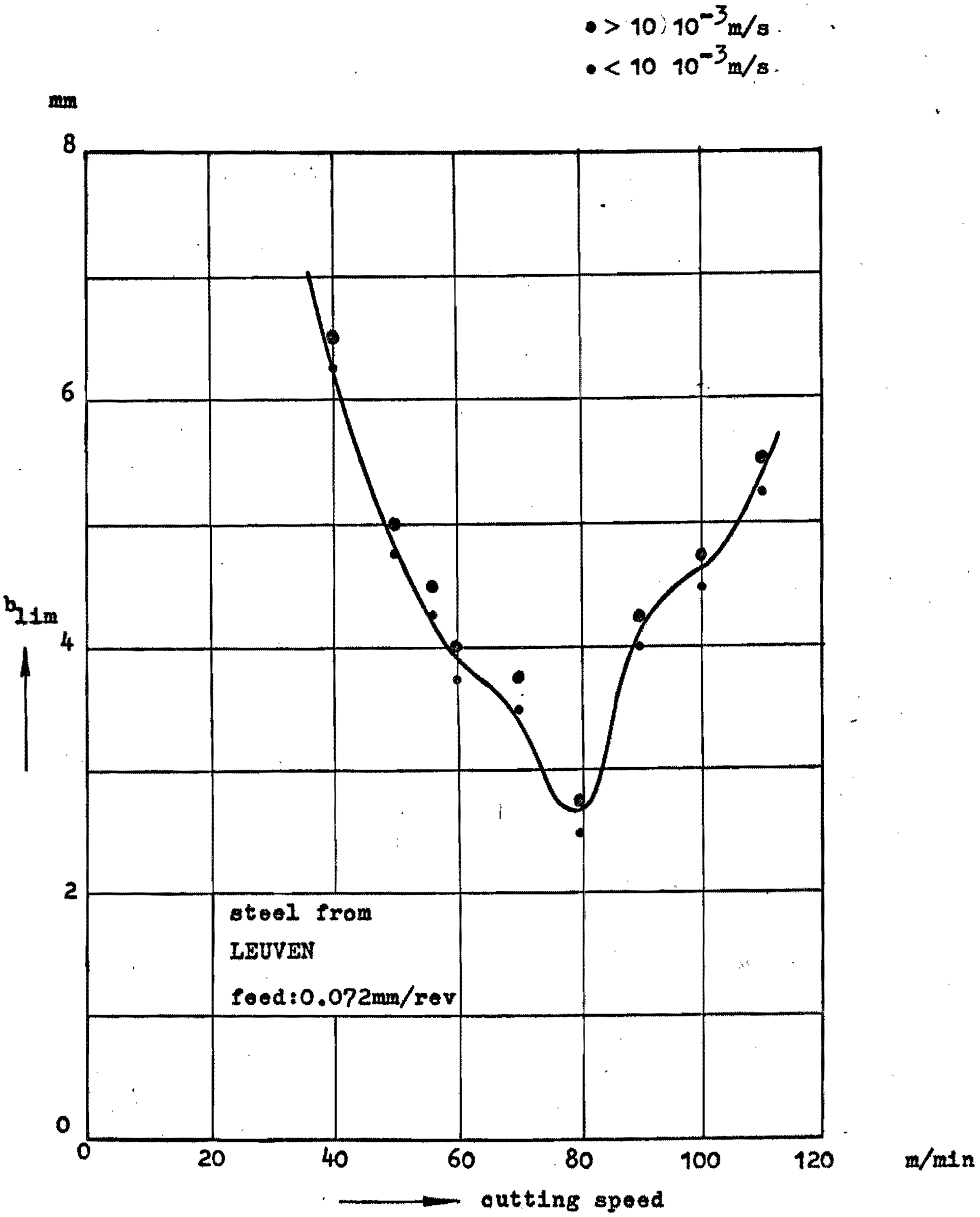


FIG.9: CRITICAL DEPTH OF CUT VERSUS CUTTING SPEED

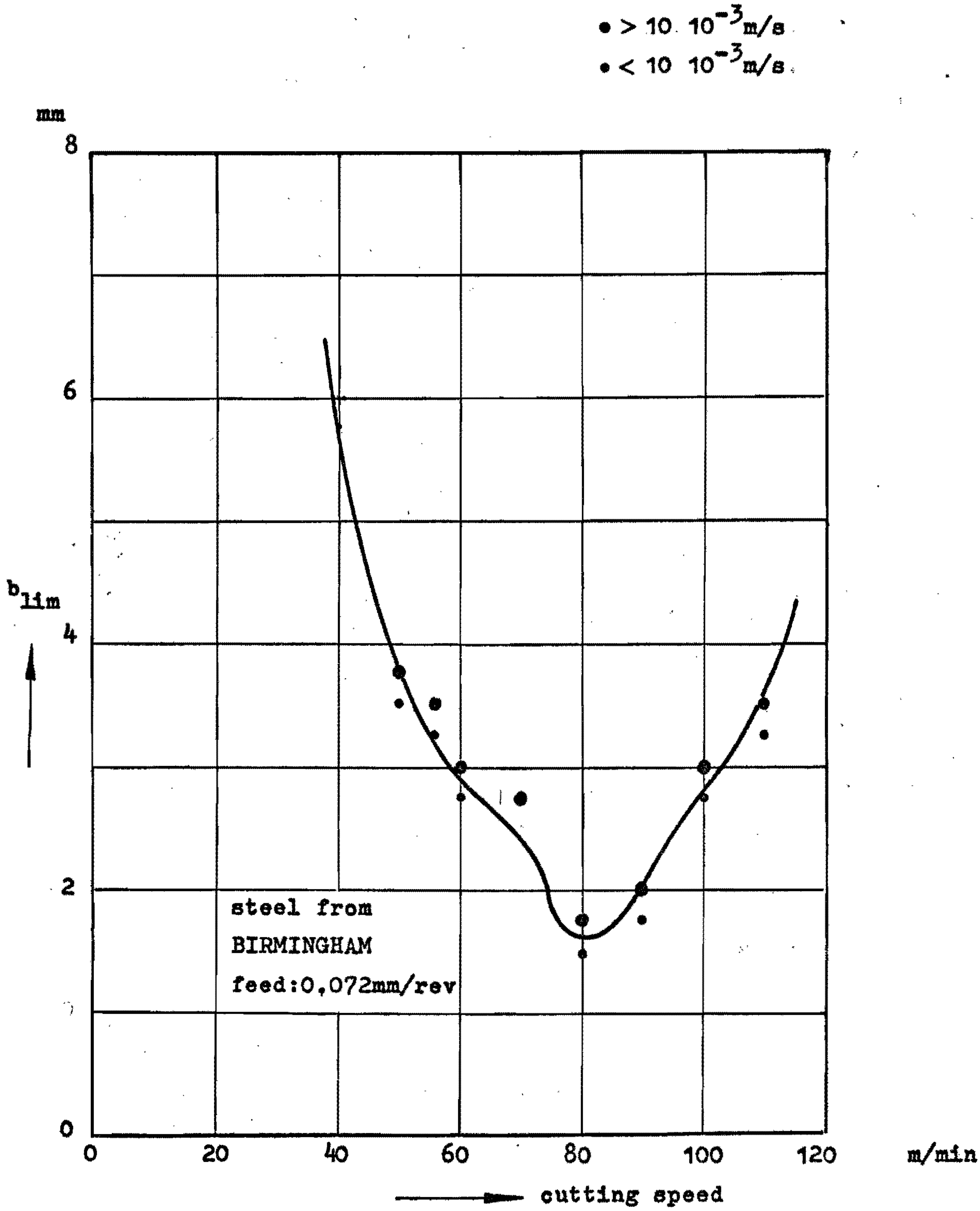


FIG.10: CRITICAL DEPTH OF CUT VERSUS CUTTING SPEED

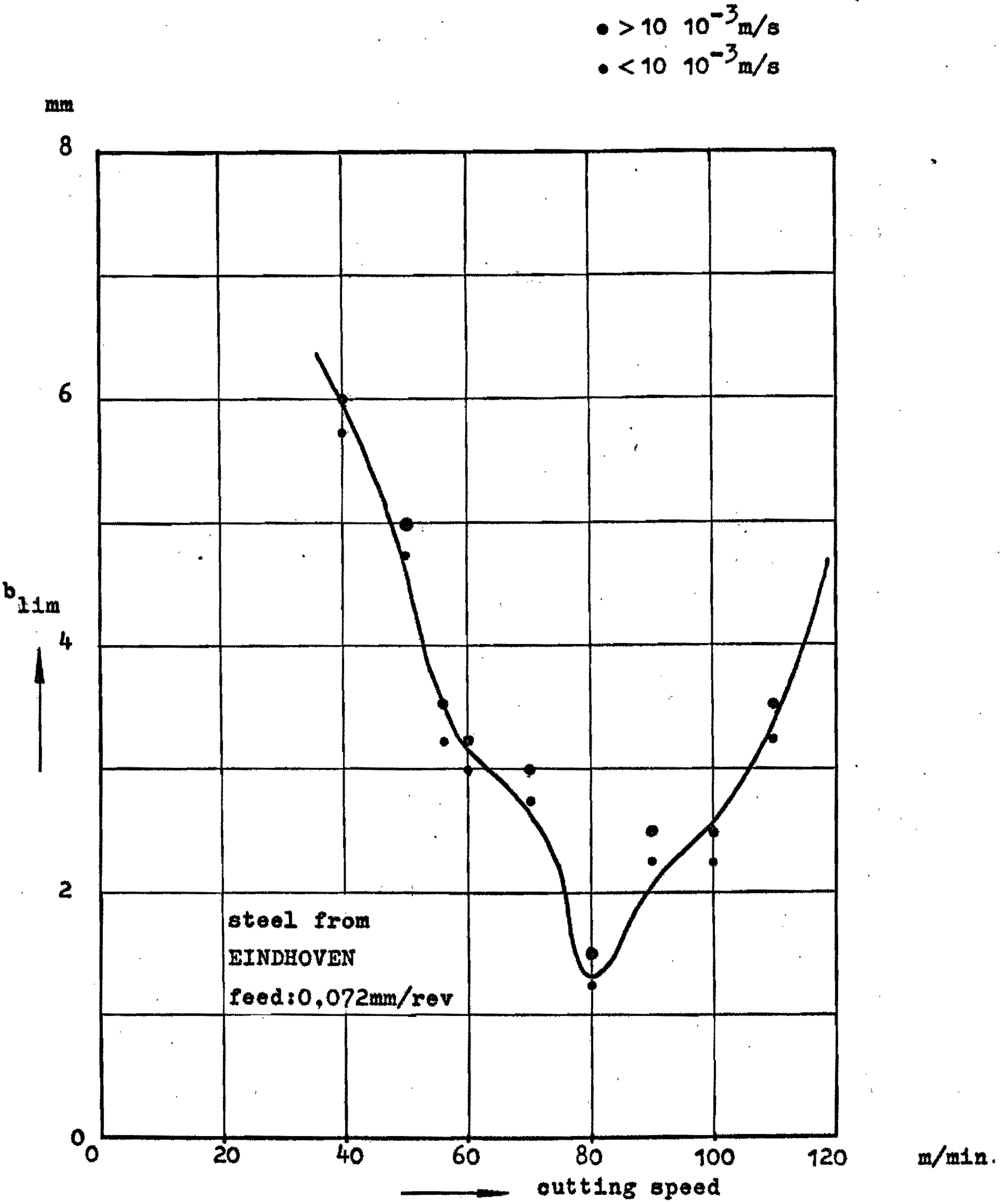
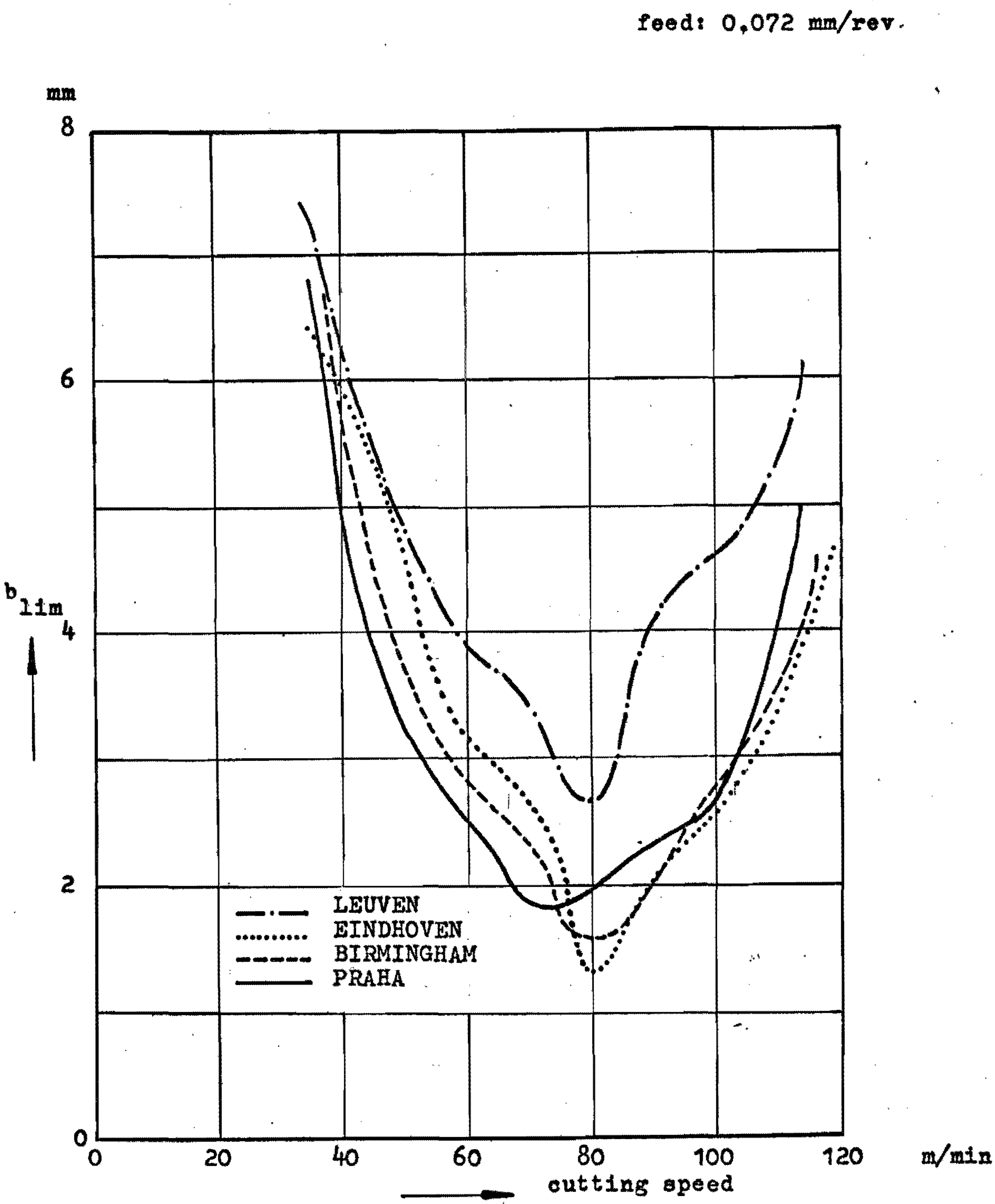


FIG.11: CRITICAL DEPTH OF CUT VERSUS CUTTING SPEED



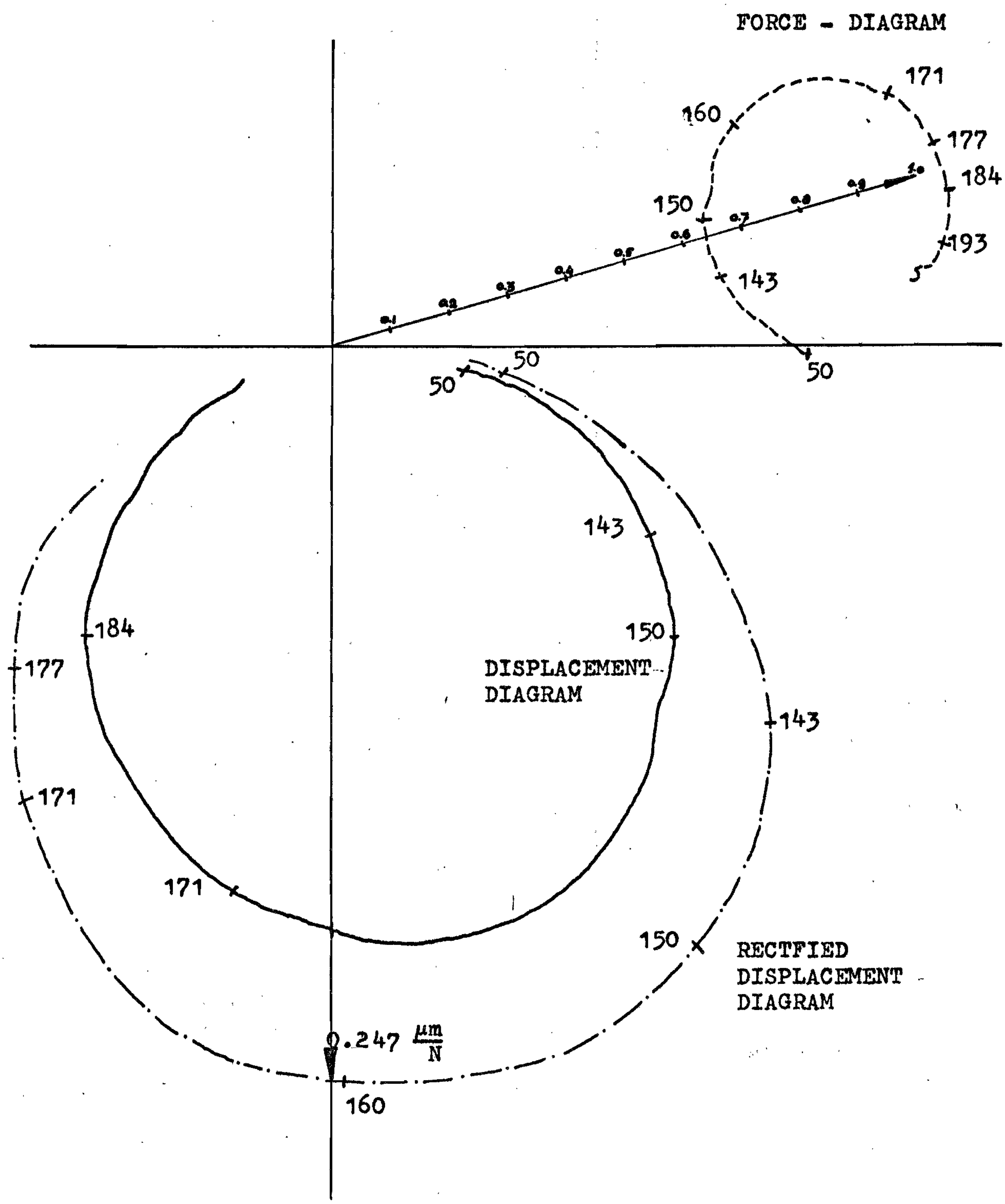


FIG.12
THE INFLUENCE OF BAD MOUNTING
OF THE EXCITER.

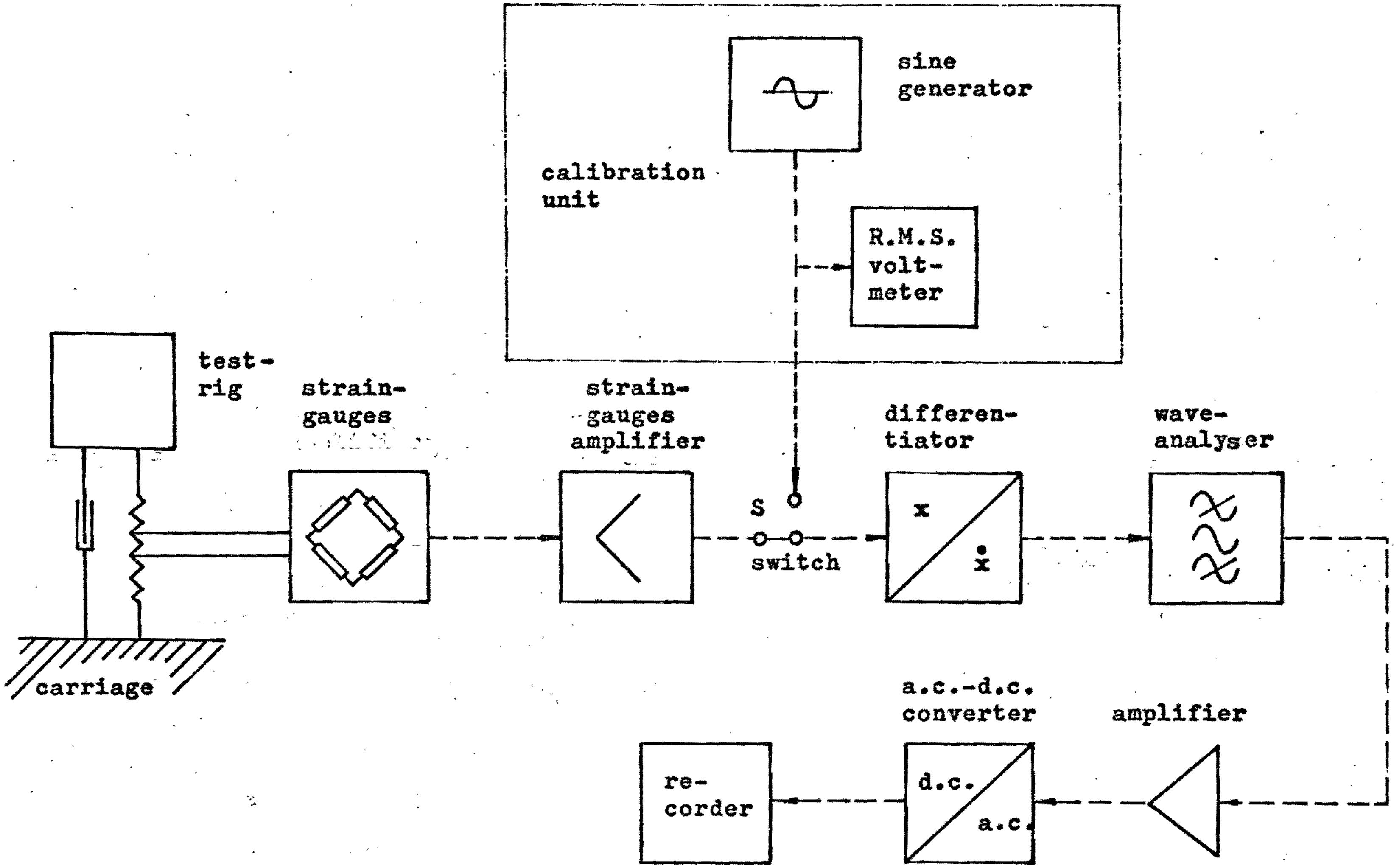


FIG.13: THE ELECTRONIC EQUIPMENT