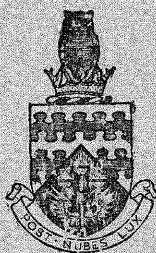


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THRUST AND STIFFNESS NOMOGRAMS
FOR HYDROSTATIC BEARING CALCULATIONS
by

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DEPARTMENT OF PRODUCTION AND INDUSTRIAL ADMINISTRATION

Thrust and stiffness nomograms for hydrostatic bearing calculations

- by -

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Contents

	<u>Page No.</u>
Introduction	1
The thrust nomogram	1
The stiffness nomogram	3
References	3
Figures	

Introduction

The application of hydrostatic lubrication to slideways is now becoming common practice in the machine tool industry. The theoretical basis for determining design parameters for hydrostatic lubrication is well established (Refs. 1 and 2) but one of the practical problems facing the machine tool designer wishing to use this technique is the tedious computation involved in arriving at suitable design parameters.

Two of the most important parameters relating to hydrostatic bearings are the thrust (T) developed by the bearing and its stiffness (S). These may be expressed as follows:

$$T = \frac{P_s A_e}{1 + h^3/h_o^3} \quad \text{lbs.}$$

and

$$S = \frac{3 A_e P_s h^2/h_o^3}{(1 + h^3/h_o^3)^2} \quad \text{lb/in.}$$

where P_s = oil supply pressure

A_e = effective pad area (see Fig. 2)

h = bearing gap

h_o = equivalent gap (when the resistance of the capillary equals the resistance of the land).

It is suggested that the presentation of these formulae in the form of nomograms will assist the designer in arriving at a satisfactory solution to the design problems posed in hydrostatic lubrication more easily and efficiently.

The thrust nomogram

The thrust nomogram is shown in Fig. 1 and can be utilised in the following manner:

1. Determine the operating bearing gap (h). This may be taken as being approximately four times the attainable machining accuracy of the component under consideration. This scale on the nomogram should be adhered to when determining the thrust at discrete points within the operating gap.
2. For the optimum operating conditions, the thrust which the bearing is designed to carry should be produced when the land resistance is equal to

the capillary resistance, i.e. when $1 + \frac{h^3}{h_o^3} = 2$. Using this value a combination of oil pressures and effective areas are available from the nomogram which will produce the design thrust.

3. If, as is usually the case, a specific oil supply pressure is chosen then the required effective pad area may be determined from the nomogram. The actual effective pad area (see Fig. 2) must then be equal to or greater than this value. If the slideway configuration does not permit a pad of the required effective area then the supply pressure must be modified accordingly.
4. Once the effective area has been decided upon then the thrust can be read off the nomogram at discrete intervals within the operating gap and hence the thrust gap characteristics determined.

Example

Determine the size of a rectangular, single-acting hydrostatic bearing with square cut corners, to support an average load of 2,000 lbs., and draw up the thrust-gap characteristics. Assume the maximum variation in straightness and flatness of the bearing components to be 0.00025 in.

The operating gap is, therefore, $4 \times 0.00025 = 0.001$ in. say.
From the thrust nomogram at a thrust of 2,000 lbs. and at $1 + \frac{h^3}{h_o^3} = 2$ a series of effective areas and pressures are available.

Choose, say, a pressure of 500 p.s.i. then an effective area of 7.5 sq.in. is required.

From Fig. 2, $A_e = (a+b)c + ab$

make	$a = 5$ in. say	}	assuming that these figures are
	$b = 1$ in. say		acceptable to the slideway
	$c = \frac{1}{2}$ in. say		configuration.

$$A_e = (5 + 1) \frac{1}{2} + 5 \times 1 = 8 \text{ sq. in.}$$

$$8 \text{ sq. in.} > 7\frac{1}{2} \text{ sq.in.}$$

Therefore, this figure can be accepted.

Using the nomogram, the thrust-gap characteristics can now be drawn for different values of 'h' at an operating gap of 0.001 in. and this can be seen in Fig. 3.

The stiffness nomogram

The stiffness nomogram is shown in Fig. 4 and can be utilised in the following manner.

1. Using the oil supply pressure and effective area determined from the thrust nomogram, the stiffness of the bearing at discrete values of 'h' may be read off. The same operating gap scale as was used in the thrust nomogram must be used in establishing the bearing stiffness.
2. The stiffness gap characteristics may now be plotted.

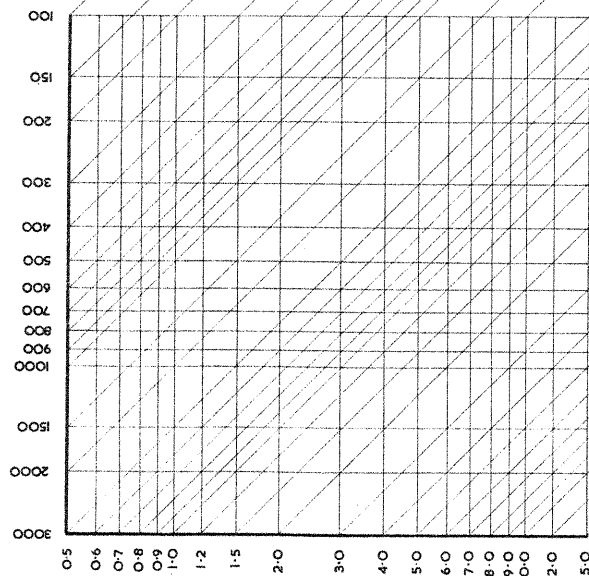
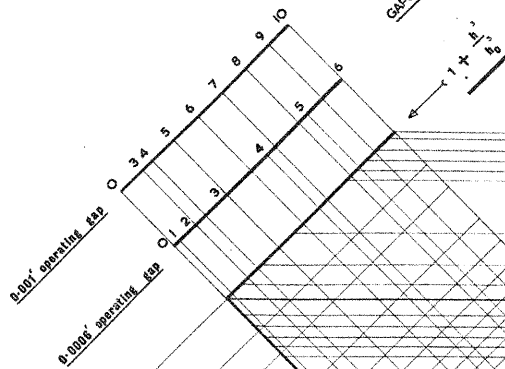
Example

Determine the stiffness/gap curves for the previous example. From the stiffness nomogram; at a pressure of 500 p.s.i., an effective area of 8 sq.in. and using an operating gap scale on the nomogram of 0.001 in., the stiffness can be read off directly, and can be seen on Fig. 5.

References

1. Loxham, J., and Hemp. J. 'The Application of Hydrostatic Bearings to High Precision Machine Tools'. Journal of the Institution of Production Engineers. Vol. 43, No. 11, 1964.
2. 'Hydrostatic Bearing System Design and its Application to Machine Tools'. Pera Report No. 134.

OIL SUPPLY PRESSURE, LBS PER SQ. IN., P_s



BEARING OPERATING
GAPS $b = 10^{-4}$ in

$$T = \frac{A_s P_s}{1 + \frac{A_s}{N_b}}$$

$$T = \frac{A_s P_s}{1 + \frac{A_s}{N_b}}$$

BEARING THRUST IN LBS., T

FIG. 1 THRUST NOMOGRAM

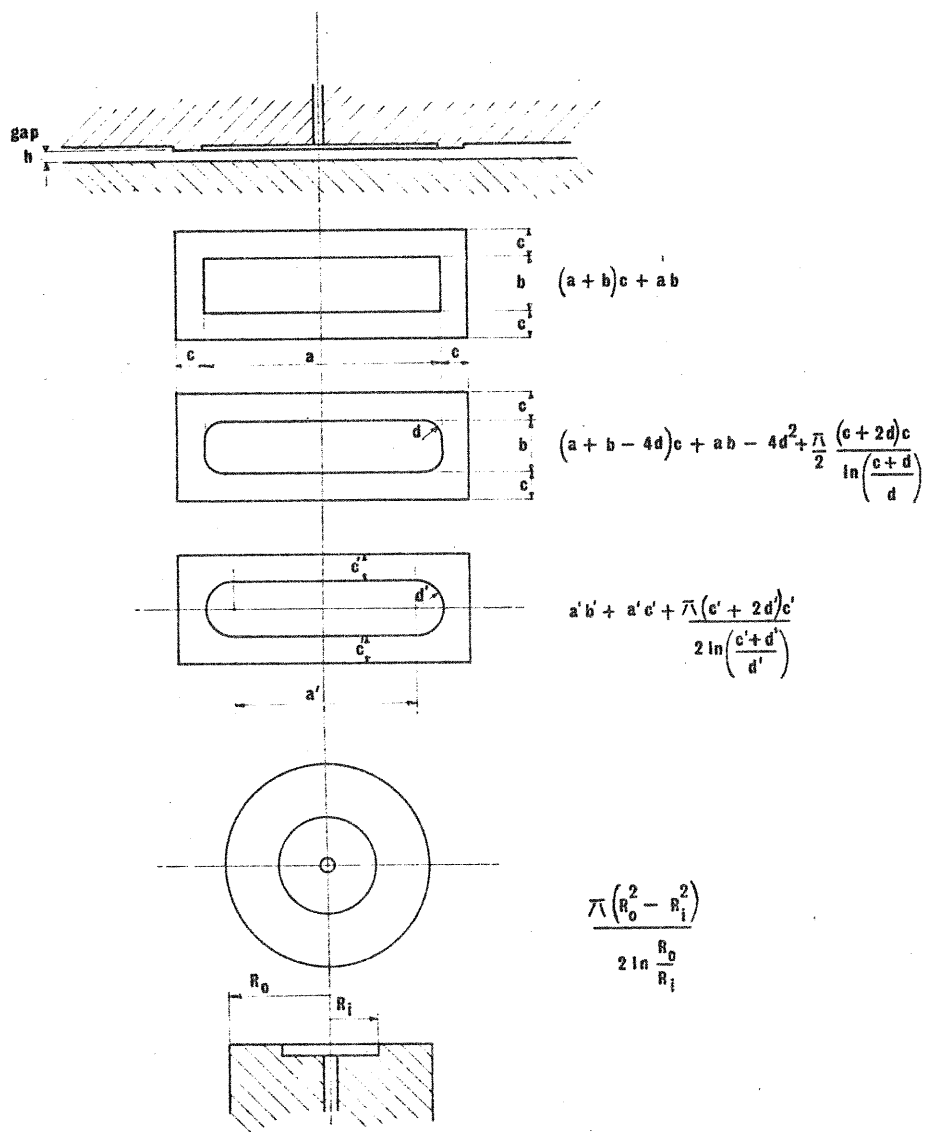


FIG. 2 DIFFERENT PAD CONFIGURATIONS AND THEIR EFFECTIVE AREAS

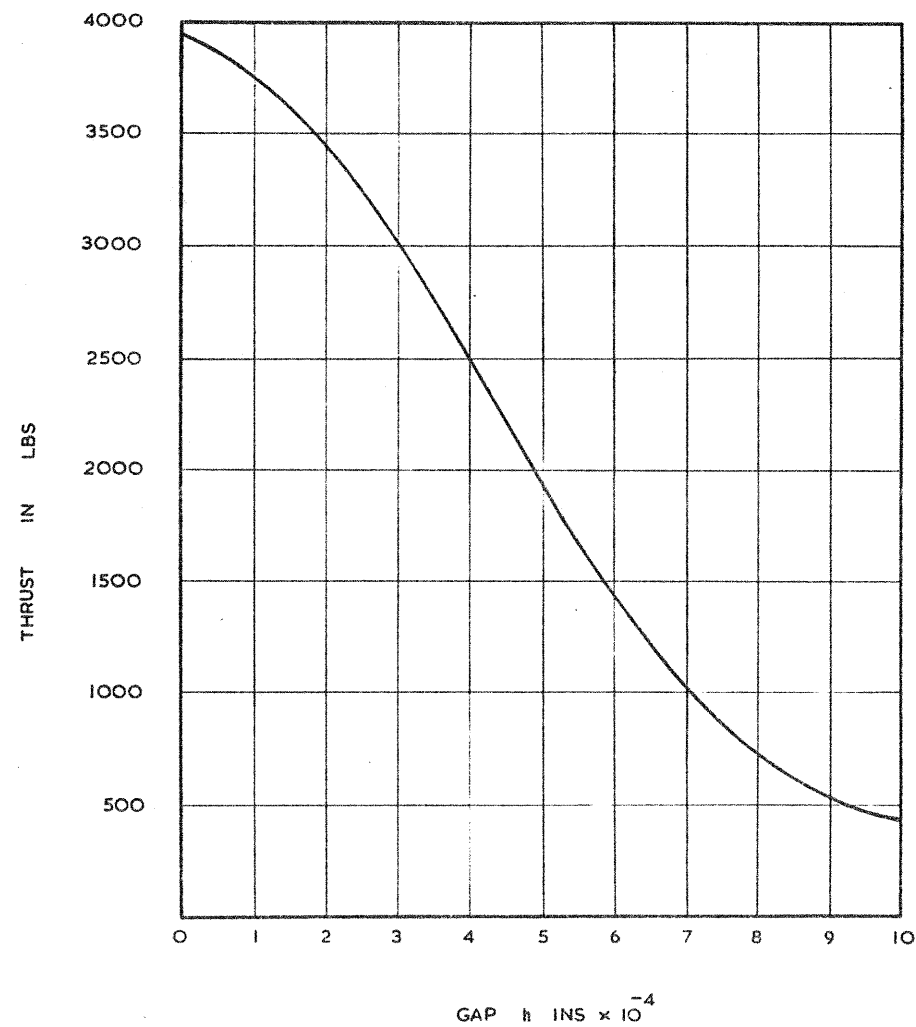


FIG. 3 THRUST-GAP CURVE OBTAINED FROM NOMOGRAM



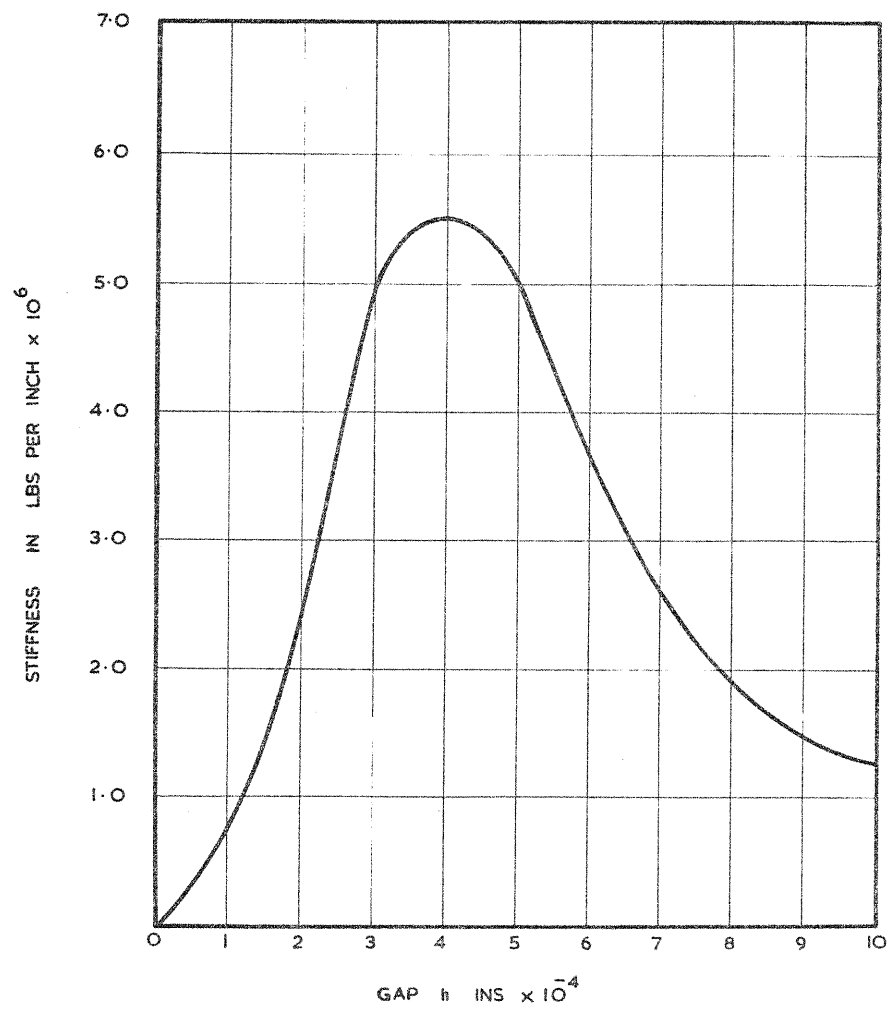


FIG. 5 STIFFNESS-GAP CURVE OBTAINED FROM NOMOGRAM