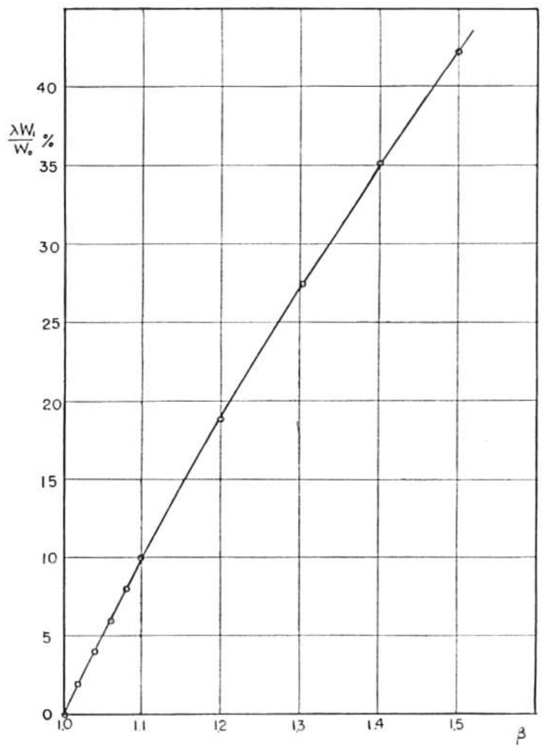

FIG. 2

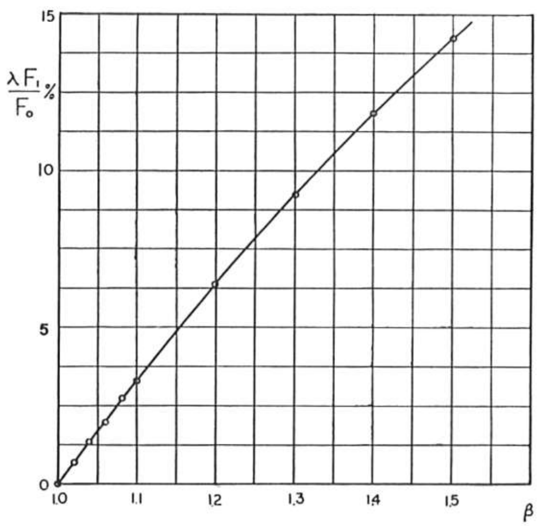

FIG. 3

ally, the method derived can be applied to the concave slider as well, the only difference being in the sign of λ. It is negative in the concave case.

REFERENCE

"Lubrication," by A. E. Norton, McGraw-Hill Book Company, Inc., New York, New York, 1942.

Discussion

F. OSTERLE.[6] In this paper the unperturbed solution is based on

TABLE 1

β	λL^2	$\frac{\lambda W_1}{W_0}$, per cent	$W = W_0 + \lambda W_1$ in $\frac{6\mu UB^5}{h_0^2}$
1	0	0	0.01130
1.02	0.219	1.91	0.01109
1.04	0.470	4.10	0.01082
1.06	0.700	6.10	0.01060
1.08	0.924	8.05	0.01037
1.10	1.142	9.96	0.00965
1.20	2.19	19.10	0.00914
1.30	3.15	27.4	0.00820
1.40	4.03	35.2	0.00732
1.50	4.86	42.3	0.00652

TABLE 2

β	λL^2	$\frac{\lambda F_1}{F_0}$, per cent	$F = F_0 + \lambda F_1$ in $\frac{6\mu UB^2}{h_0}$
1.0	0	0	0.1259
1.02	0.219	0.644	0.1250
1.04	0.470	1.388	0.1240
1.06	0.700	2.07	0.1231
1.08	0.924	2.73	0.1225
1.10	1.142	3.36	0.1216
1.20	2.19	6.44	0.1180
1.30	3.15	9.26	0.1141
1.40	4.03	11.90	0.1110
1.50	4.86	14.35	0.1074

the assumption that the slider is not plane but is curved exponentially in the direction of motion. This curvature is small so that, as was shown in the authors' earlier paper,[7] in most cases little disagreement exists between results obtained for plane sliders by the Michell solution and those obtained for exponential sliders by the authors' solution. However, the authors' use of the perturbation technique to put in slider curvature in the direction transverse to motion suggests the possibility that, if it ever becomes necessary to do so, the same technique could be used to take out slider curvature in the direction of motion. The exponential film thickness given by

$$h = ae^{bx} = a\left(1 + bx + \frac{b^2x^2}{2} + \ldots\right)$$

is, in most cases, adequately represented by the first three terms of the series. To perturb the film thickness into the linear case it would be necessary to subtract the term $b^2x^2/2$.

In the authors' investigation of the range of transverse curvatures over which the perturbation technique can be applied the criterion is employed that as long as the amount by which the load or friction force is corrected is less than 10 per cent of the original value of the load or friction force the method yields acceptable results. The writer wonders why 10 per cent is used as the criterion. A possible reason is that if the first correction term is 10 per cent of the original and the assumption is made that the second correction term will be on the order of 10 per cent of the first correction term and so on, an accuracy of roughly 1 per cent could be claimed.

A. A. RAIMONDI.[8] The authors once again have demonstrated the versatility of depicting film shapes of rectangular slider bearings by exponential formulas. This powerful method can no doubt be applied to many more problems and it is hoped that the authors will be encouraged to continue along these lines.

In attempting to interpret the data given with consideration to practical significance, it can be assumed that increasing values of the parameter β would mean increasing values of the amount of deflection of an originally flat slider, or pad. This deflection is interpreted to occur (in the practical case of a pivoted-pad thrust bearing) in the radial direction. The authors have shown that for a radial deflection of the order of 150 per cent of the minimum film thickness ($\beta = 1.50$) a decrease in load-carrying capacity of about 42 per cent should be expected.

[6] Mechanical Engineering Department, Carnegie Institute of Technology Pittsburgh, Pa. Jun. ASME.

[7] Authors' reference 5.

[8] Research Engineer, Westinghouse Electric Company, East Pittsburgh, Pa. Jun. ASME.

It would have been interesting if the authors had also shown the effect of increasing values of β on the location of the center of pressure, that is, the pivot position. It is the writer's estimate that due to increased side leakage (and the accompanying alteration in the pressure distribution) with increasing β, the center of pressure would retreat toward the trailing edge of the slider. This leads to the interesting fact that sliders deformed in this manner would not tend to operate as well as flat sliders when the pivot is placed midway between the leading and trailing edge, that is, centrally located. This conclusion is reached on the premise that the main reason a slider bearing operates satisfactorily with its pivot centrally located is due to the decrease in viscosity of the lubricating liquid as it passes across the slider. This seems to be the most popular explanation at the present time although it has been observed that Fogg's thermal-wedge effect may contribute to the part played by variable viscosity when a liquid lubricant is used. Boswall[9] has shown that rounding the pad entrance has the same effect.

It also has been stated in the literature that an air-lubricated bearing with the pivot centrally located will operate satisfactorily. Since the viscosity of air increases with temperature the variable-viscosity theory will not explain the satisfactory performance. Shaw[10] shows that Fogg's thermal-wedge effect will not explain it either. Hence there is some unknown factor which plays an important role in explaining the satisfactory operation of centrally pivoted tilting-pad thrust bearings.

A factor which may well be important and which has not received much consideration as yet is the shape or configuration of the pad itself. In practical applications, the pads also may deform about the pivot point in the longitudinal direction, that is, in the direction of motion, as well as in the radial direction which this paper implies. If this deformation is such that a diverging oil film exists over some region of the pad near the trailing edge, the oil film will rupture in this region and the center of pressure will move toward the entrance end. The amount of advance of the center of pressure depends upon the nature and extent of this diverging region. In fact, calculations made by the writer's company with an electrical resistance network have shown that it is possible for the center of pressure to lie well in advance of the central position when the deformed slider has a spherical, or convex, configuration.

Central pivot-position operation, chamfering of entrance and exit sections, and pad shape are subjects which have intrigued the writer's associates. Much time and effort have been and are being devoted to their study. To further this study special equipment already has been built for producing accurately desired degrees of pad flatness, convexity, or concavity and for performance-testing these pads at different pivot positions. Some test data have been obtained and considerable time has been devoted to a mathematical evaluation. It is intended to publish these findings in the future.

[9] "The Theory of Film Lubrication," by R. O. Boswall, Longmans, Green & Company, Inc., New York, N. Y., 1928.

[10] "An Analysis of the Parallel-Surface Thrust Bearing," by M. C. Shaw, Trans. ASME, vol. 69, 1947, p. 387.

Authors' Closure

The suggestion of Dr. Osterle that the perturbation technique be used to obtain a better approximation to the plane slider from the solution for the exponential slider is an interesting one. This could certainly be done if closer agreement were desired between the two solutions. However, in view of the accuracy of the approximation as it now stands, it does not seem worth the effort.

In the present paper a value of 10 per cent was chosen arbitrarily since in application of perturbation methods to corresponding problems in other fields this is roughly the limit for good accuracy. It is usually quite difficult to establish exact bounds to the error.

Mr. Raimondi raises some very important and basic questions. The authors hope to show soon the effect of several of the variables on the location of the center of pressure as well as the effect of β on it. The latter can be calculated from the development in the present paper. It will be of great interest to the authors to study the results obtained by Mr. Raimondi and his associates in evaluating the relative importance of the various factors. The authors hope that this work will appear soon.