April 15th, 1915.

THE MICHELL THRUST BEARING.

(By J. A. TAYLOR.)

The subject of these few notes is one which the author hopes may be of interest to members.

The Michell Thrust Bearing is the invention of Mr. A. G. M. Michell, of Melbourne, and was first constructed in 1905. It is only in the last few years, however, that it has come into prominence, and its rise and the development of its field of usefulness have been very rapid.

Based initially upon the results of one of the most able investigators, it has been the subject of much research, both practical and theoretical, in this country and in the United Kingdom.

Mr. H. T. Newbigin, of Newcastle-on-Tyne, has carried out many interesting and valuable tests upon actual bearings, the results of which tests are given in his paper before the Institution of Civil Engineers (see Minutes of Proceedings, Vol. CXCVI., Session 1913-1914, Part 11), to which members are referred for a more exhaustive treatment of the whole subject than is attempted in this paper.

It has long been recognised that the problem of efficiently lubricating the collars of an ordinary thrust block is one of great difficulty, and in the best-designed blocks water-cooling is always used for the collars, of which there are usually a considerable number, and an elaborate system of oil grooves in the faces has to be made so as to give the lubricant every chance to get on to the surface when it is required.

In the Michell Block, however, these troubles disappear; pressures up to 500lbs. per sq. inch can be easily carried, which results in a more compact block, and as the co-efficient of friction is about 1/10, that of the ordinary type of bearing, a considerable saving in fuel can be effected.

Before describing the Michell Bearing, it may be of interest to briefly review the various researches which have been carried out from time to time on the general problem of the lubrication of bearings and the pressure which can safely be imposed on the various types of bearing.

In 1885 Beauchamp Tower carried out a classical series of experiments for the Institution of Mechanical Engineers and thoroughly investigated the conditions governing the running of bearings of both the journal and collar type. He found that whilst a journal bearing could carry a load of between 500 and 600lbs. per sq. inch, with a co-efficient of friction of 0.003, provided the lubrication was ample, a collar bearing could only carry from 50-60lbs. per square inch with a co-efficient of friction of 0.03—in other words, the friction of an ordinary collar bearing is about ten times as much as that of a journal bearing, whilst at the same time about ten times as much area must be provided to carry the same load.

The explanation of this was given by Osborne Reynolds, who proved that the better results of journal bearings were due to the fact that no journal ever runs exactly concentric with its bearing. Reynolds demonstrated mathematically that when two inclined surfaces are moving relatively to one another, a pressure is induced in the oil film between the two surfaces, and this oil pressure is enough to support the one surface clear of the other.

In this way a journal when running is actually supported from its bearing by a film of oil. In the case of two parallel surfaces, however, a pressure cannot be induced in the oil film, with the result that the lubricant is squeezed out and the surfaces come into direct contact, and if the pressure between the surfaces is at all high, rapid wear results.

The case of parallel surfaces is, of course, the case of the collar bearing and thrust bearing. Osborne Reynolds not only worked out the above explanation, but also gave detailed calculations as to the best angle at which to incline the surfaces so as to ensure the best results.

It is on Reynolds' results that the Michell Bearing is based. The problem which confronted the inventor was to produce in a thrust or collar bearing the same conditions as prevail in a journal bearing, namely, to introduce a film of oil between the two surfaces. If this could be done, then there appeared no reason why pressures as great as carried by journal bearings could not be carried on thrust bearings. By applying Osborne Reynolds' results and arranging that the two surfaces should be inclined, the desired conditions were obtained.

The Michell Bearing consists of a moving collar which bears against a series of pivotted segmental blocks, which transmit the thrust to the fixed portion of the bearing. The arrangement is shown diagramatically in Fig. 1, "P" being the moving, and "P1" the lxed portion. The segmental block "S" is pivotted so that the pressure due to the load "P" acting on the surface of "S" causes the block to automatically take a slight tilt, thus establishing the condition necessary for automatic lubrication.

It should be clearly understood that Fig. 1 is only a diagram illustrating the principle of the Michell bearing. In an actual bearing "P" is a collar fixed to the shaft and turned and scraped up true to a surface plate, so that the face which bears against the blocks is quite smooth and exactly at right angles to the axis of the shaft.

The blocks "S" are usually three or four in number, though in marine thrust blocks there sometimes are eight. They are equally spaced round the fixed portion of the bearing, and the spaces between them are filled up with spacing pieces. The exact shape of the blocks in practice is slightly different to that shown in Fig. 1. The bot-

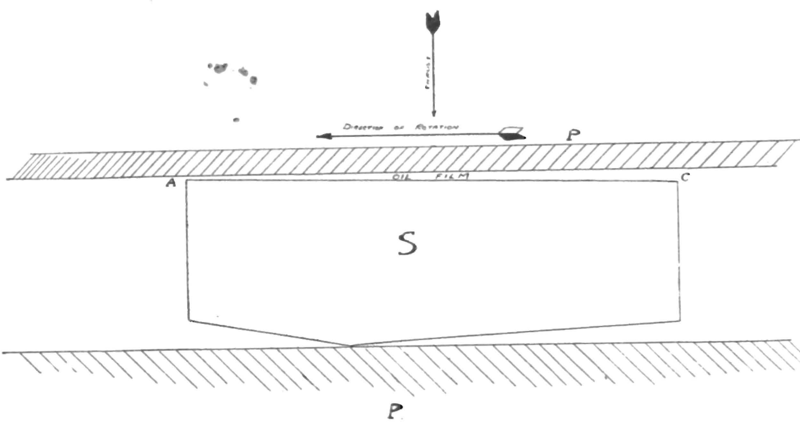


Diagram shewing Principle of Michell Bearing

Fig. 1.

tom side is usually paralled with the top for one-third of its length, and is then cut away. In cases where thrust has to be taken in both directions there are two sets of blocks—one on each side of the moving collar. The collar, in this case, is accurately laced up on both sides. The exact construction of the whole bearing will be better understood by referring to the illustration of actual bearings given later in the paper.

The angle through which the block has to tilt is extremely small, being only about 1 part in 3000. The result of this tilting action is that a wedge of oil is introduced into the space "AC," and, as has been shown by Osborne Reynolds, so long as the flow of oil is steady the wedge will support pressure. In fact, the resistance to shearing of the oil film is transformed into hydrostatic pressure. In practice the blocks are so cut that the resultant pressure on each passes through a point one-third the width of the block from the trailing edge. Under these conditions the block takes a tilt, so that the space between it and the opposing surface is about twice as great at the leading edge as at the trailing edge, this being the condition necessary to ensure the most satisfactory lubrication.

The point about which the blocks tilt can be varied slightly, and the best proportions of the blocks and the most efficient pivotting point can be calculated for each case. The result of this tilt is that the pressure is actually transmitted from surface to surface through a film of oil, and the conditions are analagous to those of a journal bearing.

Extraordinary results have been obtained with this type of bearing, and it is rapidly displacing the ordinary multiple collar type thrust bearing. The need for a more efficient type of thrust bearing had long been recognised, but the lack of such a bearing did not become marked until the advent of the steam turbine—especially the geared marine steam turbine.

The reason that the geared marine turbine brought this question of thrust bearings into prominence, is as follows: In the case of a direct coupled marine turbine the axial clearance between fixed and moving blades is considerable, and slight axial movement is permissible. Also, the end thrust of the turbine is opposed to the thrust of the propeller, so that the two may be made to partially neutralise one another, and the result is that the thrust block can be made smaller than would be otherwise necessary. Now, in the case of the geared turbine the speed of the turbine is high, and the axial clearance between fixed and moving blades is small, so that axial movement is restricted from this cause alone. But more important than this is the fact that, owing to the extreme accuracy required in the gearing, side play is absolutely out of the question in the gears, and should any thrust happen to be borne by the gears the results would be disastrous. The nett result of this is that not only must there be no thrust on the gears either from turbine or propeller, but the whole thrust of the propeller must be taken on the propeller shaft.

In the case of a reciprocating engine, the thrust varies slightly with the position of the crank or cranks, so that at certain periods the pressure between the fixed and moving parts is lessened and oil can find its way between the surfaces and assist the lubrication.

In the case of a steam turbine, however, the thrust is constant, and the lubrication of ordinary thrust bearings became very difficult, and they had to be made with very ample surfaces. With the Michell Thrust Bearing this trouble disappears. Fig. 2 shows a marine thrust bearing for a geared turbine, which transmits 2600-h.p. at 260 r.p.m. On test the oil temperature did not rise above 148 degrees F., with an engine-room temperature of 90 degrees F. The pressure in this case was 300lbs. per square inch, which is low for a Michell Thrust, although about six times that permissible in an ordinary thrust bearing. It may be mentioned that in the trial referred to, the oil was not water-cooled, as is commonly the practice in marine work.

The intensity of pressure which can be carried by a Michell Bearing is dependent on the speed and the viscosity of the oil used. To get the best results the oil used should be the thinnest which will prevent metallic

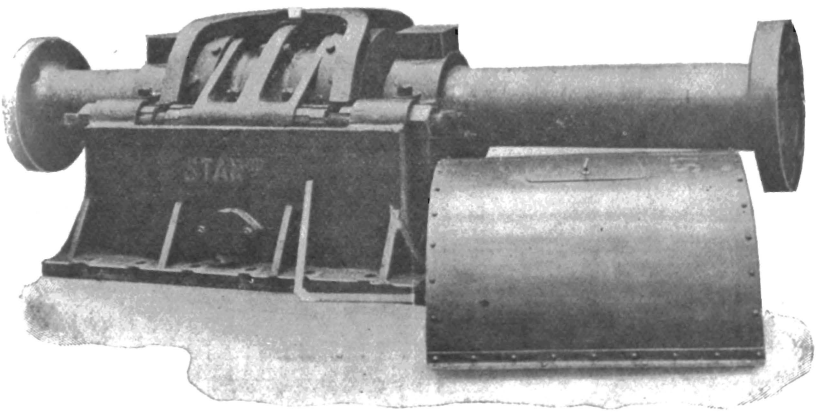


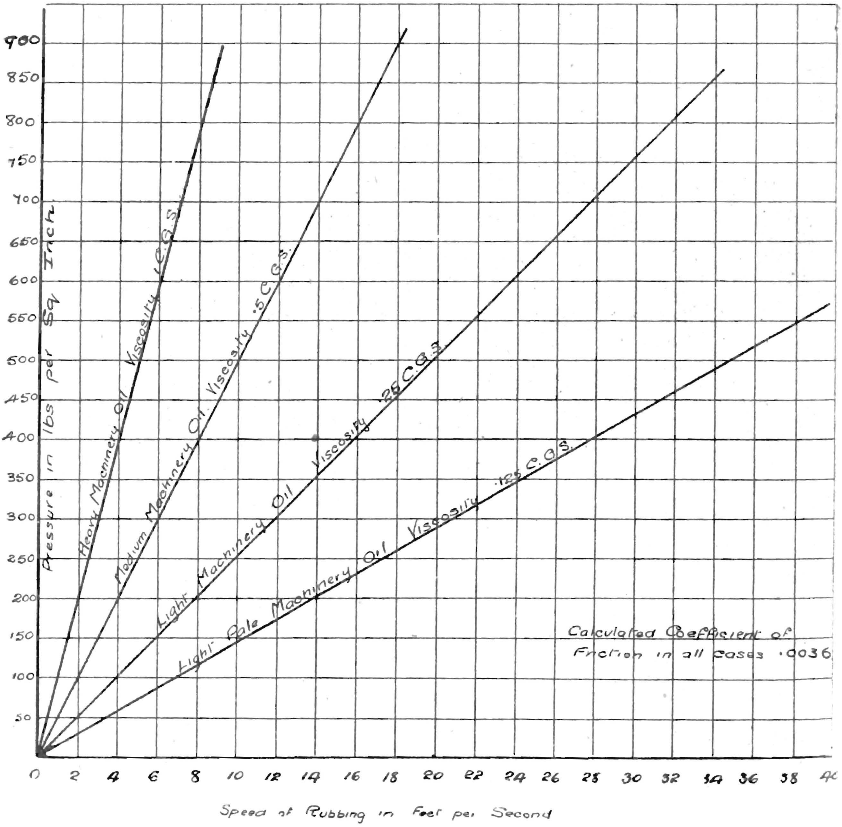
Fig. 2.

contact at the speed. Fig. 3 shows the relation between speeds and pressure for oils of various classes and varying viscoscities. The coefficient of friction is calculated at .0036 in all cases. It will be noticed that pressures up to 600lbs. per square inch are easily carried, and in recent tests 800lbs. per square inch has been carried, the bearing acting as its own oil-pump.

In some recent experiments on the relative coefficients of friction of various types of thrust bearings, the following results were obtained:—

Ordinary Collar Bearing .... .0418

Michell Bearing, average coefficient from starting at full speed	.0078
Michell Bearing at full speed	.0048
Ball Thrust Bearing	.0075



MICHELL BEARING DIAGRAM OF SPEEDS & PRESSURES
WITH OIL OF VARYING THICKNESS

Fig. 3.

Thus the Michell bearing shows a great saving over the ordinary collar bearing, and has as low a coefficient friction as a ball bearing, without the risk of a failure from crushed or broken balls. It is also, by reason of its simplicity, eminently suitable for carrying the heavier classes of load for which a ball bearing is not suitable. In the case of thrust bearings for turbine work or for large pumps, the risk of a cracked ball or a faulty ball-race cannot be taken, owing to the disastrous consequences of any failure of a bearing in these situations. The saving due to the use of ball bearings is due to their low static friction rather than to their low running friction, and in the case of thrust bearings, low starting friction is of less importance than reliability and simplicity.

The advantages of a Michell Thrust Bearing over the usual collar type are many; the fact that the area required to take up the thrust is only about one-fifth or less of that of a collar bearing, enables a very neat design of bearing to be used, and has the additional advantage in marine work of saving valuable space. The ordinary thrust bearing requires careful adjustment, and should the adjustment be inaccurate the load will be taken by one or two of the collars, and the result will be that these collars will heat up and cause serious trouble. It is the usual practice to provide water-cooling for the marine thrust block—there is no necessity for this with the Michell Bearing, since it has been proved that such a bearing will run cool under a pressure which is sufficient to cause the white metal of a bearing to begin to flow. The Michell Bearing needs only two collars—one for ahead and one for astern thrust, and there is no adjustment needed after once the bearing is set up. The automatic tilting action of the blocks renders the bearing self-lubricating, and provided that oil is supplied in sufficient quantity, there is no need for any further attention.

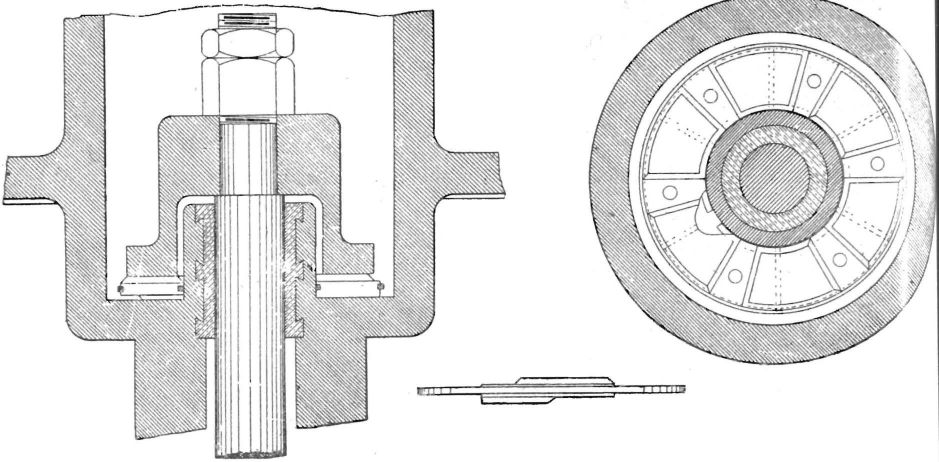


Fig. 4

Figure 4 shows the general construction of a footstep bearing on the Michell principle. Fig. 5 is a similar bearing, used to suspend the vertical shaft of a 24in. Francis water turbine. The step bearing is here combined with

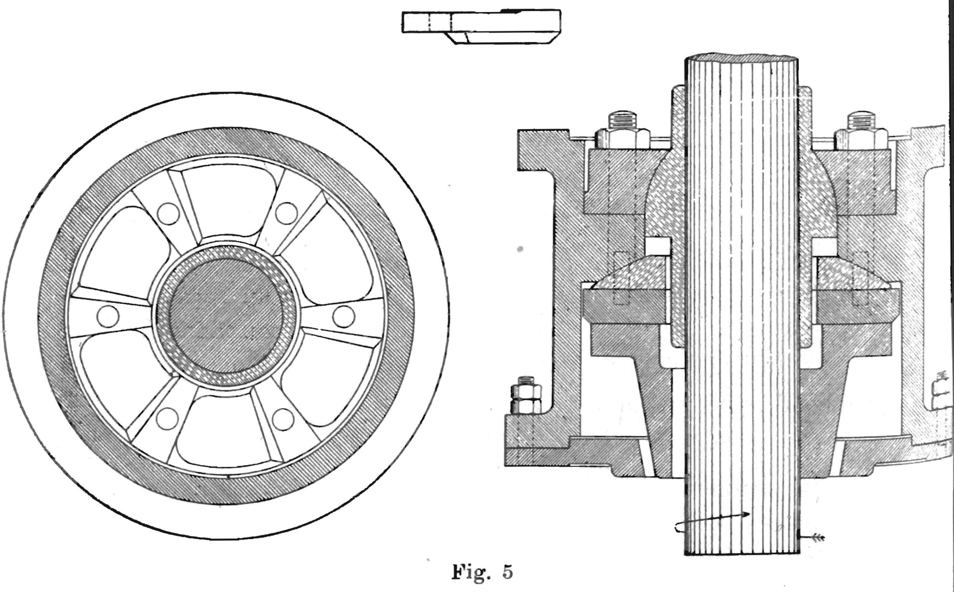


Fig. 5

a spherical seated journal bearing, so that the thrust bearing blocks are themselves supported on a spherical seating.

The thrust bearing in Fig. 6 is designed to take the thrust of a steam turbine and to carry a normal load of 8000 lbs., with occasional loads of 12,000 lbs., the speed being 1200 r.p.m. This gives a pressure on the blocks of 400 lbs. per square inch under normal conditions. The coefficient of friction with oil having a viscosity of 0.125 c.g.s. at working temperature, is 0.0037. It is interesting to note that this bearing is mounted on a gimbal ring, so as to permit of slight adjustments.

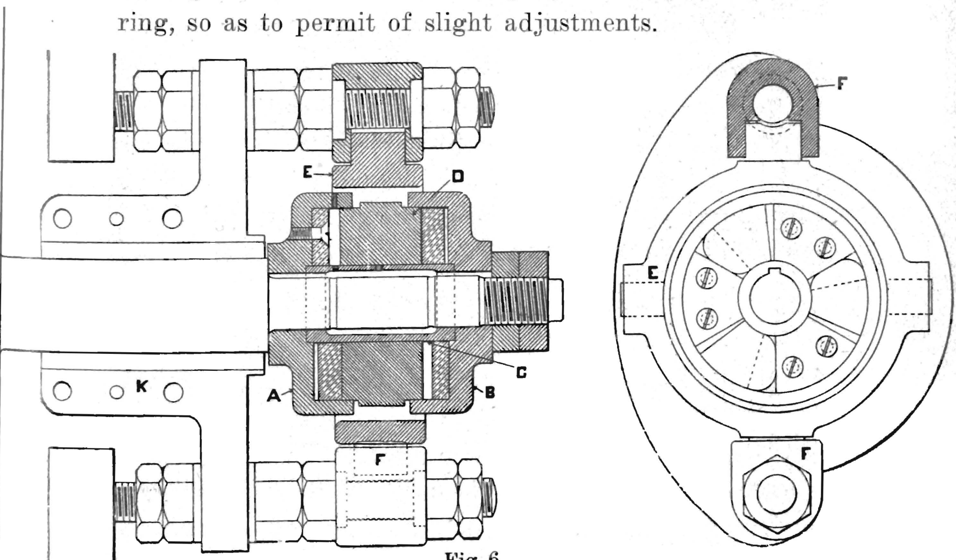


Fig. 6

The bearing on the table has been constructed to Mr. Michell's design for the Metropolitan Board of Water Supply and Sewerage. It is for taking the end thrust of a large centrifugal pump, and will sustain a pressure of 1000lbs. at a speed of 1780 r.p.m. Only the thrust collar and pivotted blocks are shown—the casing of the bearing and the fixed portion into which the blocks fit being part of the pump framing.

This type of bearing is rapidly coming into use in England. The British Admiralty already have six warships fitted with Michell Thrust Bearings, and there are many more privately owned vessels also fitted.

Messrs. C. A. Parsons & Co., Ltd., have standardised this bearing as a part of their turbine to take up end thrust, and have abandoned the collar type of bearing. The large turbo generators now being built for the Melbourne Suburban Electrification by Messrs. Parsons, each 15,000-b.h.p., are all fitted with Michell Thrusts. Many other well-known turbine builders are also adopting it—one firm alone having about seventy machines so fitted.

In conclusion, it may be said that the field before this particular type of bearing is an exceptionally large one. It is cheap to construct, compact, the wear is negligible, and provided the lubrication is attended to regularly it should run for long periods without the necessity for examination.

It is hoped that these few remarks may have proved of interest to the members of the Association, as describing an appliance which is comparatively new to Australia. The author wishes to express his thanks to Mr. A. G. M. Michell for very kindly providing him with a quantity of most interesting and useful information on this subject.

Discussion.

The President: Gentlemen, the paper is now open for discussion. It is an extremely interesting paper, and I am sure you will agree with me that it has been very lucidly put before us. There is a secondary reason why we should be very glad to have such a paper as this—apart altogether from the merits of the paper and the subject itself—and that is that we in Australia hear very little about Mr. Michell. Probably, in Melbourne, one hears more of him,