CHAPTER VI.

BEARINGS.

§ 103.

DESIGN AND PROPORTION.

The mechanical devices by which the journals of shafts and axles are carried are called bearings. A complete bearing may be divided into three portions: 1, the box or frame; 2, the body or casing; 3, the connecting parts.

The various forms may be divided according to their use into the two main classes:

A. Bearings for lateral journals or Lateral Bearings.
B. Bearings for end or line pressure or Thrust Bearings.

Under these classes the principal distinction is to be made as to the side on which the bearing is to be supported. If we suppose the journal to be included in a cube 1.2 . . . 8, Figs. 291 and 292, we have for lateral bearings:

A Pillow Block, when the base lies in 1, 2, 3.
A Wall Bearing, " " " " " " 4-8 or 2-8.
A Front Bearing, " " " " 4-6 or 4-7,
A Hanger, " " " " 5-7.

For Thrust Bearings we may have Foot Step Bearings, Wall Step Bearings, or Hanging Step Bearings.

Special care is to be taken for the equalization of wear and for efficient lubrication, and these points affect mainly the boxes.

The examples which follow have only been selected from the vast number of forms to show typical cases.

The dimensions are based upon a proportional scale. As the unit for the thickness of the boxes we have $e = 0.07 d + 0.15''$, $d$ being the bore of the box, and values of $e$ are given in the second column of the table in § 91. The modulus for the body of the bearing is $d_f = 1.15 d + 0.4''$.

§ 104.

LATERAL BEARINGS

Pillow Block

In Fig. 293 is shown a form of pillow block suitable for journals from 1 1/8'' to 8 1/4''. The proportions of the body and cap are based on the modulus $d_f$ (see 107), with the exception of the oil cup on the cap, which would then be rather too large for small bearings, in which it is made in length equal to the width of the cap, and in width equal to 0.7 $d$.

The length of the boxes is dependent upon the length of the journal, which, as discussed in § 90, may be 1.5 $d$, 2 $d$, etc. For the form shown a good proportion is $l = 1.15 d$, the projecting portion of the boxes being governed by the proportion of length to diameter adopted.

The bolts for the base plate are made somewhat heavier than those for the cap, as they are screwed up much tighter, and they are often made with special heads to fit a separate sole plate as shown in Fig. 294. The ends of the base are given a bevel in order to permit the use of side keys. The coring out of the sole plate reduces its weight and also simplifies the machine work. The spaces between the cap and the body of the bearing are filled with slips of wood so that the cap bolts may be tightened without binding the shaft. In cases where the load is great, the pressure alternating, the joint is closely fitted without spaces, and if wear in the journal is to be taken up the surfaces are filed down.

§ 105.

PROPORTIONAL SCALE FOR PILLOW BLOCKS.

The proportional scale may be used to great advantage in the construction of bearings, and the following example will show its use:

The poles $O, O_1, O_2$, Fig. 294, are used for the journal diameter $d_1$; the poles $P, P_1$, and $P_2$, for those dimensions which depend on the modulus $d_f = 1.15 d + 0.4''$. This gives $d_1 = O$.

When $d = \left(\frac{d_1}{d'}\right) = 0.34''$, hence $P$ must be placed when the vertical space between the rays $O_1$ and $O_2$ is equal to $0.34''$. The intersection of the rays from $O$ and from $P$ by the ordinates $1, 2, 3$, etc., give the dimensions of the corresponding sizes. The dimensions of the boxes must be obtained from another pole, as they depend upon another modulus. This modulus is $e = 0.07 d + 0.15''$ and becomes $O$, when $d = 0.125$;

vertical line on which the distance $a' b'$ equals 1.78''. For the oil cup in the cap the width is:

\[
0.25 d_f + 0.4'' = 0.4'' + 0.25 (0.4'' + 1.15 d) = 0.25 d + 0.25'' = 0.18 (0.07 d + 0.15'') = 0.18 e.
\]

Hence $E$ is also the pole for the oil cup.

* The firm of Eicher, Wyss & Co., in Zurich, have used the proportional scale very well for designing bearings, both in determining the geometrical proportions throughout and also by the excellent method of a single pole.
§ 106.

VARIOUS FORMS OF JOURNAL BOXES.

It is often found convenient to give the boxes of a pillow-block other forms than those of the preceding illustrations, as for example octagonal, as in Fig. 295, or cylindrical, as in Figs. 296 and 297. The last two forms are suitable for bearings in lathe headstocks, and in such cases the boxes are kept from slipping out of place by the flanges whose width is 2c, as shown in Fig. 296, or by projecting pins, Fig. 297, fitting into recesses in the base and cap. Each of these forms has its advantages and objection, and it is hardly possible to decide which form is the most desirable, special conditions being generally present. The modifications in the base and cap to admit the forms shown in Figs. 296 and 297 are readily made without requiring detailed instructions.

Boxes in which white metal or similar compositions are used require special construction, since these materials are not strong enough to resist the stresses with the same security as solid bronze boxes; for such bearings a cast-iron or bronze shell is made, in which a lining of the softer metal can be poured, as in Fig. 298. In such cases the shell should be cleaned with acid and tinned before pouring the lining metal.

Boxes of lignum vitreum (see § § 97-117) must be made of simple shape. A convenient shape is shown in Fig. 299, which the general form of the bearing may be made.

In America examples are often found of bearings in which the soft metal is run directly into recesses in the base and cap. Fig. 300 shows such a bearing as made for the journals of fan-blowers and shafting, by Sturtevant, of Boston. The base is hollowed out to serve as an oil chamber, and the oil is fed to the journal by a wick. The details are shown in Fig. 301. These journals are made very long (7 9/16), and hence the superficial pressure is small.

§ 107.

NARROW BASE BEARINGS. LARGE PILLOW BLOCKS.

It is often desirable, when space is limited, to make bearings with narrow bases, and this may be done by making the cap-bolts with collars as shown in Fig. 302, and also Fig. 312. This permits the holding down bolts to be dispensed with, and space saved. Such collared bolts are also used for pillow blocks, which are subjected to both upward and downward stresses, since the boxes are firmly bound together (see § 88). Fig. 302 shows a form of pillow block for journals of 8 to 12 inches in diameter. It is made with four cap-bolts and four base bolts, by which it is secured to the base plate. The base bolts are of the form shown in Fig. 294; § 105, so that the base may be removed from the base plate when necessary without disturbing the solidity of the latter. The body of the pillow block is cored out to a greater extent than in the previous form, and when the journal is used for a crank shaft, or is subjected to jarring strains, the cap-bolts should be provided with jam nuts, or some of the other forms of security, such as is shown in § 88.

§ 108.

PILLOW BLOCK WITH ADJUSTABLE BEARING.

In many cases it is only necessary to adjust the height of pillow blocks from time to time by inserting liners beneath the base, but in some situations it is desirable to provide a special means of obtaining such an adjustment. In Fig. 303 is shown such an adjustable bearing for use in screw propeller shafts. The body of the bearing is not bolted down, but rests solely by its weight upon the wedge system, by means of which it can be raised or lowered as may be found necessary. The upper box is provided with flanges through which the cap bolts (omitted in the illustration) pass. The lower box is lined with white metal, which is poured into the recessed bearing.
Adjustable Pillow Blocks.

Many attempts have been made to arrange the boxes in a pillow block so that they may be self-adjusting and so adapt themselves to various positions, which the journals may assume and secure for it at all times a full bearing and support. For this purpose, among other methods, the plan has been adopted of making the boxes with central spherical portion fitting into corresponding recesses in the body of the pillow block. This form of bearing has been widely introduced in America by Messrs. Wm. Sellers & Co., and adapted to a great variety of positions.

Sellers has always urged the desirability of the principle of keeping the pressure between journal and bearing at a minimum. This practice permits the use of cast iron boxes, for which a pressure of not more than 15 pounds per square inch is used.

The use of moderate superficial pressures is most practicable in the case of bearings for line shafting in which the proportions may be made such as to give but light pressure. This advantage will be seen on reference to Fig. 304.

Fig. 304 shows Sellers' form of pillow block. The cast iron boxes are made with a spherical enlargement in the middle, which is held between corresponding recesses in the cap and base. The boxes are prevented from revolving by the hollows in the sides which receive the bodies of the cap bolts. Three openings are made for oil or grease and two drip cups, which are cast on the base plate, serve to receive the superfluous oil.

The modulus upon which the proportions of this bearing are based, is not that given in (107), but the following:

\[ D = \frac{3}{4} (d^2 + \alpha^2) \]  

The length of the boxes is 4\( \alpha \). The shape adopted by Sellers shows the care in modelling which is characteristic of the American designs of crammers. The Sellers bearings have been used to a considerable extent in Germany.

---

Another form of adjustable pillow block is shown in Fig. 305. This is used by Sturtevant in some of his fan blowers. In this case the ratio of \( d \) to \( t \) is very great (see example 4, § 91). The adjustability is obtained by pivoting the bearing \( A \) upon a cross bolt \( B \), which passes through the cheeks of the pedestal also, the latter being adjustable about the axis \( BC \). The bearing is lined with white metal, and the end thrust is taken up by a block of lignum vitae. If an adjustment in the direction \( AA \) is required, the bolt \( C \) may be loosened and the required movement made. The provision for lubrication is especially noteworthy both in the manner of supply and in the collection of the overflow.

Bearings with Three-Part Boxes.

In horizontal steam engines and in similar services, the pressure upon the journal is thrown first on one side and then on the other, while at the same time there is a constant vertical pressure, such as the weight of a fly wheel. Attempts to remedy the tendency to overwear by making the boxes inclined, have proved but a partial remedy, and the best method of constriction in such cases is to make the box in three parts, one of which receives the constant vertical pressure, while the other two provide for the backward and forward thrust. Such a bearing is shown in Fig. 306. The modulus \( d = \frac{3 \times 15 \times d + 0.47}{2} \). The bottom box rests on two wedges which are tapped with screw threads and can be adjusted and locked at any desired point by the bolts shown. The side boxes are each held up by two steel set screws, a wrought iron plate being interposed between the screws and the boxes. If it be-
comes necessary to remove the side boxes the cap is first taken off, and the iron plates taken out, when the boxes can be separated far enough from the shaft to permit their removal without interference with the shaft. The body of the bearing is increased in width in order to provide for the increased lateral pressure.

Another three-part bearing* is shown in Fig. 307. In this case there is no vertical adjustment to the lower box—and it necessary it must be raised by packing underneath. The side boxes are set up by wedges which are adjusted by set screws through the cap. Each wedge carries a screw on its upper end, and the nuts for these screws are fitted so as to revolve in the cap, being turned by a wrench on the hexagonal head, and then clamped in position by the thin jam nut shown. The heavy inclined ribs stiffen the body of the bearing to resist the shock and thrust of the piston. It is often convenient (as in the case of the original of the figure) to cast the body of the bearing in one piece with the bed plate of the engine.

A third, and simple form of three-part bearing (by Schults Brothers in Mayence) is shown in Fig. 308. It is suitable for those cases in which an alternating up and down pressure is combined with a constant lateral pressure. The latter would not be provided for in an ordinary pillow block, but here it is taken up by the small side box. This form is suited for small vertical engines in which the pull of the belt is toward one side.

§ 111.

PESDENTAL BEARINGS.

Bearings which are not placed directly upon a base plate, but are raised upon feet or pedestal are called pedestal bearings.

That shown in Fig. 306 is similar to the one in Fig. 293, placed upon a pedestal. Such pedestals vary greatly both in form and height. The width of the foot is made equal to the height of the journal in the form shown, which gives the base and the legs a sufficiently slender appearance.

§ 112.

WALL BEARINGS.

The wall bearing shown in Fig. 299 is the same as shown in Fig. 293, with the addition of the bracket. The base here is placed at right angles to the joint in the boxes and parallel to the axis of the bearing, the whole being made in the bracket form shown.

The cap and the boxes are of the same size and proportions as for a pillow block for the same size journal. The bolts may either be tapped into the body of the bearing, or made as stud bolts, using the forms shown in Figs. 225 and 226 § 83, with key.

For larger sizes the opening in the plate should be surrounded with a rib of a thickness 0.44, and width — 0.44, the latter being measured in the direction of the axis of the journal.

Fig. 312 shows an adjustable wall bearing by Sellers. In this case the cast iron boxes are somewhat lighter than for pillow blocks and are made with a cylindrical cross piece in the middle, in which the spherical seats are placed. The special feature is the method by which the vertical adjustment is made. The two plugs which support the boxes have cast upon them a very shallow screw thread, and the nuts in the sockets have also their threads cast in them. The thread only extends along

*From a steam engine by the Soc. Fives-Taille in Paris.
THE CONSTRUCTOR.

a portion of the length of the plugs as shown, in order to permit securing them in position. This is done by the two self screws which clamp them firmly in their places.

The opening through the upper plug gives access for the tube of a lubricator.

By removing the cap, the wedge and the block can be easily removed and the shaft moved sideways to a sufficient extent to permit the removal of the boxes. The cap bolts are provided with collars forged upon them and serve also to fasten the bearing in place. The modulus for the dimensions is the same as (117), \( d = 1.15 d + 0.4''/\)°.

FIG. 310.

The projection from the wall \( s \) is made constant for bearings for journals 3" to 4" in diameter and equals 6''. The elegance of the form is noticeable in the principal elevation and also in the horizontal section.

\section*{§ 113.

VOKE BEARINGS.

The bearings used on vertical shafts may be considered as a variety of wall bearings. In situations where the space is limited the forms shown are not always convenient, the first, because it is not symmetrically disposed about the parting of the boxes, and the second, because of the space it requires. For this service a compact, symmetrical bearing, whose base is at right angles to the parting of the boxes, is often very desirable. Such a construction is shown in Fig. 312, and may be called a Voke Bearing. In this case the cap and body together form a rectangular yoke, in which the bronze boxes are placed in a transverse direction. In the illustration the wear can only be taken up in one direction, but if it is desired in both directions the cast iron block on the right may be replaced by a wedge as shown on the left.

\section*{§ 114.

WALL BRACKETS.

* In Fig. 313 is shown a form of bearing similar to Fig. 302, which may be called a wall bracket bearing. The cap bolts are inserted from below, which permits their ready removal and replacement. If only two bolts are used in the wall plate, it is desirable that it should be held from lateral motion between wedges, and should also be firmly secured against vertical mo-

\* For such a Voke Bearing, see Engineers' and Machinists' Assistant, London, 1894, Fig. 1.
tions by some of the methods given in the following chapter. Where it is not practicable to secure it in this manner, four bolts should be used.

![Figure 314](image)

Another form of wall bracket is shown in Fig. 314. It is similar to the Yoke Bearing, and can often be of service, as for example in Fig. 350, § 126, although it is not of as general application as the preceding form. The bolts for the cap are made with heads, of the ordinary cap screw form.

Various other wall and bracket bearings may be made by combination of a wall plate and pillow block in different positions, and these may be grouped in the general class of Arm Bearings, each form being governed by the conditions of the special case under consideration.

115.

HANGERS.

According to the definition in § 109 a pillow block by inversion becomes a hanger, the pressure of the journal falling upon the cap box. If the journal is one of wrought iron proportioned to bear the load given in § 91, the bolts for the cap and base plate will not be strong enough if determined from the same unit of proportion as already given for such bearings. This is also true for the cap and feet of the base.

For this service, good dimensions may be obtained by using for the boxes the previous modulus \( E' = 1.75 \times d + 0.4" \), and also \( E \) as before, and for all other portions the special modulus,

\[
D'' = 1.75 \times d + 0.4"
\]

If a pillow block is to be used as a hanger for a neck journal, the cap bolts should be increased to such size as would be given by the use of formula (109), in which \( d \) is the diameter of the neck journal corresponding to an equivalent end journal.

Example: A load of 17,000 lbs would give, according to the table in § 11 for a wrought iron journal, a diameter of about 4 inches. If this load is carried on the cap of the bearing we use the modulus,

\[
D'' = 1.75 \times d + 0.4" = 1.75 \times 4" + 0.4" = 7.4"
\]

This gives for the diameter of the cap bolts \( 7.4 \times 0.2 = 1.48" \) say 1 1/8". A neck journal of 6 1/2" diameter to bear the same load would have for its normal unit \( d = 1.15 \times 0.75 + 0.4 = 8.75" \), which is greater than the preceding value and hence may be used safely, even though the full load be carried by the cap.

Sellers makes a short hanger which resembles in form and dimensions the corresponding size pillow block, with the boxes turned 180° and the drip caps cast on the cap instead of the base. In most cases, however, a greater distance is required between the shaft and the base plate for hangers than is given in pillow blocks, for which reason they are best considered as a separate form of construction.

The hanger shown in Fig. 315 is called, from its form, a Ribbed Hanger. The boxes are carried in the hook-shaped portion below, their form being the same as we have already shown. The cap is secured with a key and clamped in the desired position by the bolt shown.

For journals of less than 2 inches diameter, but one bolt need be used in each foot, and in such case their diameter is \( 0.3 d \), the bosses on the plate be altered to correspond.

![Figure 315](image)

In the Post Hanger, Fig. 316, the general arrangement is the same as in the preceding form, the principal difference being in the frame. The column is made hollow and its internal diameter = 0.55 \( d \). For the larger sizes, four bolt holes are made in the base plate, as shown in Fig. 315.

Hangers are not generally bolted directly to the ceiling beams, but to strong pieces, or intermediate timbers, and by

![Figure 316](image)

varying the thickness of these pieces any desired amount of drop may be obtained. If the variation is too great to be secured in this manner a different depth hanger must be used.

![Figure 317](image)

If the building is of so-called fire-proof construction, with
ceilings of iron beams and brick arches, the form of the base of the hanger must be correspondingly modified. A practical method is shown in Fig. 317, in which hook bolts are used. The bolts, which are four in number, pass through sockets cast in the base of the hanger, and their method of attachment avoids weakening the beam. The base of the hanger is made with ledges which fit over the edge of the beam and permit the use of wedges on each side.

The form shown in Fig. 318, which is due to Fairbairn, is intended to bring the shaft parallel to the beam, while the previous form carries the shaft at right angles to the beams. The attachment of the hanger bolts to the beam and the arch makes a very secure fastening, but the inaccessibility of the bolt head is an objection. In this case also the beam is not weakened by drilling, hook bolts and keys being used, as in the previous case.

The drop, or distance from base to centre of shaft, \( d = \frac{3.5}{d} \) in the illustration, but in some cases it must be made greater. These hangers, like all of Sellers' bearings, show very careful modeling and proportioning, which the small size of the illustrations can only imperfectly show.

In Fig. 320 is shown Sellers' countershaft hanger. In this form the shaft is put in place from the side, and the amount of wear in the boxes is so slight that they are made solid, instead of in halves. The cap—which is secured by a bolt, holds the box in place, and the drip cup is cast in one piece with the body of the hanger and provision is made for a drip cock to remove the waste oil.

The illustration shows also the arm for carrying the belt shifter.

Sturtevant uses ball and socket hangers also for the counter-shaft of his fan blowers. These are somewhat different from the preceding. Fig. 321 shows the boxes in perspective and in cross section. The section shows the white metal lining and also the arrangement of double oil chambers, which, by means of wicking, keep the journal lubricated. The outer ends of the box casting are formed into drip channels, and also receive the shoulders on the shaft. These shoulders, as shown in Fig. 322, run freely in the boxes without contact. The journal as shown is on the end of the shaft, and the pressure is so small that the wear is unappreciable.

§ 117.

**Special Forms of Bearings.**

In propeller shafts where the screw is arranged to be lifted it is necessary to design bearings which are to be entirely immersed in water. Penn's practice is to line such bearings with lead, which has proved especially satisfactory. In Fig. 323, is given an illustration of such a bearing as constructed by Ravenhill & Hodgson, the diameter of the shaft being about 1 5 inches. The body of the bearing is of bronze, the boxes are of cylindrical section fitted with strips of lignum vitae set in a special lining metal. The pin, projecting from the bottom, enters into a corresponding recess in the stern frame, when the screw is lowered into place.

On the Russian State Railway there have recently been adopted two standard forms of bearings for use under cars—one form being for bronze, the other for white metal boxes. In
kept in position by three dowel pins. A wrought yoke holds the lower portion up to the body of the bearing by means of the bolt shown, the head being secured by the internal hexagonal socket shown.

The white metal lining is cast in the body of the box by being poured upon the journal. The inner end of the journal is provided with a wooden dust guard packed with a ring of felt. As will be seen, lubrication is provided both above and below. The upper chamber contains wicking and affords a means of prompt and copious lubrication in case the journal grows hot. The principal source of lubrication, however, is from below, the oil being wiped upon the journal by a brush, which is fed with oil by a wick reaching into the chamber below. The oil brush is shown, with its spring holder in the lower right-hand corner of the illustration.

In order to permit the boxes to adjust themselves to the journal when the axle assumes an inclined position with regard to the bearing a certain amount of play is given, as is shown in the plan view, where the ledge cast upon the bearing are made parallel for a short distance and then diverge from below upward from a width of 54 mm. to 42 mm.

All the dimensions in Fig. 324 are in millimeters, as this is a standard Prussian railway journal box.

This construction is undoubtedly well adapted to meet the requirements, but it is a question whether the results might not be attained by simpler means.

The second form of standard bearing of the Prussian Railways differs from the first mainly in the boxes. These are cast of bronze with semi-cylindrical projections on the track, which enter into corresponding recesses in the bearing, and permit the boxes to adjust themselves to the journal.

The guides for the bearing are given an amount of play similar to the previous form, and there is no change in the details of the lower portion.

Fig. 325 shows a form of American axle bearing. This is similar to the older pattern designed by Lightner. It is only arranged for lubrication from below and is designed so as to permit a box to be removed and replaced in the shortest possible time. The body is of very simple form and is cast in one piece and a large opening and lid renders it readily accessible from without. The box is made of bronze, and between it and the body of the bearing is a filling block, somewhat similar to that used in the bearing shown in Fig. 312, arranged so that its removal facilitates the changing of boxes.

This filling block, which is sometimes rounded on top to provide adjustment, is held between two small projections, but can easily be removed when the pressure is removed by use of a lifting jack. The change of boxes can be effected in a few minutes.

A brush or pad for distributing the oil is not used, but instead the vacant space in the bearing is packed with waste, which feeds the oil to the journal. This form of journal box has proved very efficacious in service.

§ 118.

**STEEP BEARINGS.**

In Fig. 326 is shown a form of steep bearing for vertical shaft. The bearing piece or steep proper is made with very obtuse point on the under side in order that it may be able to adjust itself to the shaft. In order to provide for adjustment in the position of the bearing the bolt holes in the base plate are elongated length-wise, thus permitting adjustment in any direction.

§ 119.

**WALL STEEP BEARINGS.**

The following is a modified form of steep bearings, and is intended to be used with the wall plate supported on a key beneath its lower edge; this key may be made 0.3 1/2 deep, so

*This section of railway journal boxes is an instructive example of the importance of constructive simplicity to machine elements. Since in the very early Prussian there were few engine axles or cast-iron boxes. The cost of these represents an investment upon which every penny economized in construction has an important total.*

*See Henninger, Schmierstoffkasten (Lubrication), Winzau, 1864, p. 31.
that by its removal the bearing may be taken from under the journal, without removing the shaft from its place.

Fig. 327.

The recess in the step plate serves as an oil chamber; end wear may be taken up very conveniently by the adjustment provided by the set screw.

§ 128.

INDEPENDENT STEP BEARINGS.

In many cases, as in examples by Belgian designers, the lower bearing of a vertical shaft is divided into two independent parts, a pure lateral bearing and a pure thrust bearing. For the lateral bearing may be used a pillow block or yoke bearing consisting of one of the forms already described, while the vertical thrust is taken by a simple step quite close to the preceding bearing. This makes the step bearing readily accessible and also readily adjustable in the direction of wear.

The following example is selected from among a number of such bearings.

Fig. 328.

The step itself is made of bronze. This is carried on the bluntly coned head of the strut set screw, a steel plate being interposed, while the prismatic form of the screw head prevents rotation of the step. The screw itself is kept from moving by Penn's method within the bearing, and the whole is bolted down to a base plate. The modules for the dimensions is the same as before. An application of this form is shown in § 129.

§ 129.

THRUST BEARINGS WITH WOODEN SURFACES.

For bearings which are operated wet, the use of Lignum Vitae has been found to give the best results. The wood is inserted in a similar manner to that shown in § 117, the pieces being made in the form of plugs. In Fig. 329 is shown the step of a screw propeller shaft of this type. The plugs are inserted in bronze plate, and the end of the shaft faced with bronze.

A bearing of this form on the "Orontes" had 37 plugs each 1 1/8" diameter, and on 50 H. P. nominal English gunboats the thrust plates have 7 plugs each 2 1/4" diameter. Both these examples are by James Watt & Co.

Collar bearings with surfaces of wooden are often made; these should be always worked under water. Penn, to whom the introduction of such wooden bearing surfaces is mainly due, has especially used them in various bearings in the length of a screw propeller shaft, the lower half of the shaft running in a water trough. The usual construction of the thrust ring between the hub of the screw propeller and the stern post is shown in Fig. 330. A is the shaft with a bronze sleeve fitting into the wooden lining of the hole through the stern tube; B is the hub of the screw pro-

Fig. 329.

pellor; C, the thrust ring with its wooden plugs; D is the nozzle on the end of the stern tube showing the stiffening ribs which assist in receiving the thrust. The parts B, C, D and E are of bronze.

Fig. 330.

Fig. 331 shows a form of thrust ring used on the imperial steamships "Kaiser," "Friedrich Karl," "Preussen," "Viktoria," "Freya," "Ariadne," "Nautilus" and "Cyklon." The ring is made in halves, and can readily be removed and replaced.

Fig. 331.
The two axial projections enter into recesses in the flange on the end of the tube, and prevent the thrust ring from revolving. The dimensions of the wooden bearing surfaces on the various ships are approximately as given in the following table:

<table>
<thead>
<tr>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>D'</td>
</tr>
<tr>
<td>b</td>
</tr>
<tr>
<td>5'0&quot;</td>
</tr>
<tr>
<td>6'0&quot;</td>
</tr>
<tr>
<td>6'3&quot;</td>
</tr>
<tr>
<td>6'6&quot;</td>
</tr>
<tr>
<td>6'9&quot;</td>
</tr>
<tr>
<td>7'2&quot;</td>
</tr>
<tr>
<td>7'5&quot;</td>
</tr>
<tr>
<td>7'8&quot;</td>
</tr>
<tr>
<td>8'1&quot;</td>
</tr>
<tr>
<td>8'4&quot;</td>
</tr>
<tr>
<td>8'7&quot;</td>
</tr>
<tr>
<td>8'10&quot;</td>
</tr>
<tr>
<td>9'3&quot;</td>
</tr>
<tr>
<td>9'6&quot;</td>
</tr>
<tr>
<td>9'9&quot;</td>
</tr>
<tr>
<td>10'2&quot;</td>
</tr>
<tr>
<td>10'5&quot;</td>
</tr>
<tr>
<td>10'8&quot;</td>
</tr>
<tr>
<td>11'1&quot;</td>
</tr>
<tr>
<td>11'4&quot;</td>
</tr>
<tr>
<td>11'7&quot;</td>
</tr>
<tr>
<td>12'0&quot;</td>
</tr>
</tbody>
</table>

In the "Wasp" the thrust ring is made with 5 sectors of 3,185 sq. ft. surface, in the "Leopold" there are 40 small sectors with a total surface of 2,412 sq. ft. The use of such thrust rings filled with blocks of lignum vitae has been most successful in vessels of the German navy, and the wear on the wood has been so slight that renewal is rarely necessary.

§ 122.
MULTIPLE COLLAR BEARINGS.

For thrust bearings which are subjected to heavy service, the multiple collar bearing is most valuable. These are generally used to receive the thrust of screw propellers, but are also used in other situations, as, for example, large turbines, also centrifugal machines of great size and weight, such as are used in sugar refineries. The forms which may be given to these bearings are quite varied, but in every case the most important consideration is the pressure to which the various surfaces are subjected.

For pillow blocks in which the shaft is made with several collars, the boxes may be cast in bronze with internal collars

![Figure 332](image)

as shown in Fig. 332. For larger dimensions, the boxes may be strengthened by ring shaped ribs, let into recesses in the cap and body of the bearing.

Example.—The thrust bearing on the "City of Richmond," built by Todd & MacGregor, of Glasgow, from the designs of Telford, has 17 rings, inside diameter, 77"; outside diameter, 37"; total length of the bearing, 25 ft. 8 in.; the boxes are strengthened by three ribs of depth 2", while the engine indicates 2,500 H. P., and the speed of the vessel is about 11 knots per minute.

James Watt & Co. make the boxes free in the bearing, and support them by set screws at the ends, as shown in Fig. 333.

On the "Mediterranean" and "Adriatic" four set screws are used in each flange, the shaft being 72" diameter, with eight rings. In the "Jason," by the same firm, there are six set screws in each flange, the shaft being 72" diameter, with eight rings.

Some boxes of cast iron lined with white metal are sometimes used by various makers, as, for example, in the "Mooltan," by Day & Co., in which the shaft is 13¼" diameter, and has twelve rings. The design shown in Fig. 334, which is a French pattern, uses an adjustable bearing lined with white metal.

In Fig. 335 is shown a form of thrust bearing in which the rings are made of bronze separately, and fitted to the body and cap. This form is the design of Ravenhill & Hodgson. Especially to be noted is the arrangement of bolts. These are in two sets, the first securing the body of the bearing to the sole plate, and the second being the cap bolts. The wedge or tongue which is let into the sole plate is arranged with a space as shown on the left, in which a key is fitted to provide for the take-up of the wear upon the rings. The cross section in upper right hand portion of the illustration shows the construction and application of the bronze rings. The arrangement provides for a constant distribution of grease, thus preventing the rusting of the journal by the application of water for cooling.

In Figs. 336 and 337 is shown a thrust bearing by Penn, as used on the "Kaiser." Here the bearing surfaces are made in separate rings of still simpler form than the preceding. These rings, which are made of bronze, are in halves for convenience of construction. In the "Kaiser" d' is equal to 18½", and there are eight rings on the shaft and in the bearing. The six bolts

![Figure 335](image)

are arranged so as to act both as cap bolts and fastenings for the bearing. The adjustment for wear is similar to the preceding case. The dimensions are based on the same modulus as already given, viz.: d' = 1.13 d + 0.4".

A most noticeable form of thrust bearing is that of Maudslay,
shown in Figs. 338 to 340, as used on the "Elizabeth." For each collar on the shaft there is provided a separate ring and support, with means for ample lubrication. The bearing rings are made of iron, shoe form, and are of cast iron lined with white metal. The collars on the shaft dip into an oil trough. They are also provided with oil cups above, so that as in the case of the car axle box previously described, lubrication is supplied both above and below. Each ring may be adjusted by its own set screws, or all can be adjusted together. The proportions are all based upon the previous modules, $d = 175 \text{ d} + 0.4\text{"}$, and the shape and dimensions give an excellent appearance. In the "Elizabeth" the shaft is $13\frac{3}{4}\text{"}$ diameter.

FIG. 337.

EXAMPLES OF THRUST BEARINGS.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Armored Frigate König Wilhelm</td>
<td>Mandalay &amp; Sons, London.</td>
<td>2,313</td>
<td>1,243</td>
<td>18''</td>
<td>5</td>
<td>Anti-monoy</td>
<td>6,367</td>
<td>10''</td>
<td>Wetable</td>
<td>Selft</td>
<td>Run warm before thrust ring was applied.</td>
<td>Ditto</td>
</tr>
<tr>
<td>2</td>
<td>Armored Frigate Kaiser</td>
<td>John Ferm &amp; Sons, Greenwich.</td>
<td>5802</td>
<td>1,800</td>
<td>18''</td>
<td>5</td>
<td>Bronze</td>
<td>7,800</td>
<td>20''</td>
<td>Ditto</td>
<td>Selft</td>
<td>Run warm before thrust ring was applied.</td>
<td>Ditto</td>
</tr>
<tr>
<td>3</td>
<td>Armored Frigate Friedrich Karl</td>
<td>Société des Forges et</td>
<td>3092</td>
<td>1,288</td>
<td>15''</td>
<td>13-13\frac{1}{2}''</td>
<td>White Metal.</td>
<td>8,000</td>
<td>15\frac{1}{4}''</td>
<td>Selft</td>
<td>Selft</td>
<td>Mode without thrust ring and run warm. Since its application works well.</td>
<td>Ditto</td>
</tr>
<tr>
<td>4</td>
<td>Armored Frigate Preussen</td>
<td>Aktingesellschaft Vulkan</td>
<td>2,880</td>
<td>1,988</td>
<td>16''</td>
<td>8</td>
<td>Bronze</td>
<td>5,780</td>
<td>15\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>Run warm before thrust ring was applied.</td>
<td>Ditto</td>
</tr>
<tr>
<td>5</td>
<td>Decked Corvette Leipzig</td>
<td>Ditto</td>
<td>2,375</td>
<td>1,435</td>
<td>16''</td>
<td>8</td>
<td>Bronze</td>
<td>4,500</td>
<td>15\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>Run warm before thrust ring was applied.</td>
<td>Ditto</td>
</tr>
<tr>
<td>6</td>
<td>Decked Corvette Vicenza</td>
<td>Ditto</td>
<td>1,255</td>
<td>1,200</td>
<td>16''</td>
<td>8</td>
<td>Bronze</td>
<td>4,500</td>
<td>15\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>Run warm before thrust ring was applied.</td>
<td>Ditto</td>
</tr>
<tr>
<td>7</td>
<td>Decked Corvette Prusa</td>
<td>Ditto</td>
<td>1,955</td>
<td>1,554</td>
<td>16''</td>
<td>8</td>
<td>Bronze</td>
<td>2,950</td>
<td>15\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>Run warm before thrust ring was applied.</td>
<td>Ditto</td>
</tr>
<tr>
<td>8</td>
<td>Decked Corvette Ariesche</td>
<td>Ditto</td>
<td>1,799</td>
<td>1,000</td>
<td>15''</td>
<td>8</td>
<td>Bronze</td>
<td>3,950</td>
<td>15\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>Run warm before thrust ring was applied.</td>
<td>Ditto</td>
</tr>
<tr>
<td>9</td>
<td>Decked Corvette Augusta</td>
<td>Marti &amp; Co., Halle.</td>
<td>1,397</td>
<td>1,305</td>
<td>11''</td>
<td>12</td>
<td>Anti-monoy</td>
<td>5,177</td>
<td>14\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>No thrust ring in stern post.</td>
<td>Ditto</td>
</tr>
<tr>
<td>10</td>
<td>Gunboat Nautilus</td>
<td>Müller &amp; Hulberg in Grubow</td>
<td>1,004</td>
<td>1,047</td>
<td>15''</td>
<td>10</td>
<td>Anti-monoy</td>
<td>1,535</td>
<td>7\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>No thrust ring in stern post.</td>
<td>Ditto</td>
</tr>
<tr>
<td>11</td>
<td>Gunboat Cylop</td>
<td>Stettiner Maschinenbau, Aktingesellschaft Vulkan in Bredow bei Sielt.</td>
<td>845</td>
<td>858</td>
<td>96''</td>
<td>4</td>
<td>Lignum Vitae</td>
<td>0,495</td>
<td>7\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>No thrust ring in stern post.</td>
<td>Ditto</td>
</tr>
<tr>
<td>12</td>
<td>Armored Gunboat Wespe</td>
<td>Aktingesellschaft, Wespe in Bremen</td>
<td>299</td>
<td>2,650</td>
<td>72''</td>
<td>12</td>
<td>Bronze</td>
<td>1,750</td>
<td>7\frac{1}{2}''</td>
<td>Selft</td>
<td>Selft</td>
<td>No thrust ring in stern post.</td>
<td>Ditto</td>
</tr>
</tbody>
</table>

FIG. 339.

in § 100, the maximum pressure upon the thrust bearing surface. It is important to observe that in only two cases out of the twelve was a thrust ring used between the stern post and propeller hub. The elasticity of the hull of the ship may sometimes cause the entire force to be thrown on the thrust bearing, and at other times much may be taken by the thrust ring. The data given in the table will also be found valuable for other purposes.