Roundness in Shafts

By Arthur C. Carter

IT is quite a common thing to meet capable engineers who will assert that it is possible to take pieces of ground bar which, when measured, give a constant diameter and which are not truly round, and every engineer knows of cases in which a shaft which has been measured by micrometers or verniers will prove to be stiff in a hole which has been carefully reamered to a plug gauge. This experience has been responsible for the introduction of the more frequent use of ring gauges and also for the assertion that shapes which give a constant diameter need not be round, which is, of course, a very false supposition.

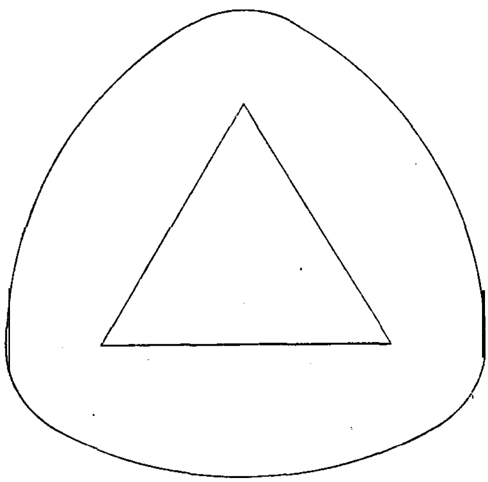

Fig. 1. A figure with a constant measurement across-

The definition in Euclid of a circle is " a plane figure contained by one line which is called the diameter, and is such that all straight lines drawn from a certain point within the figure to the circumference are equal; this point is called the centre of the circle." A diameter is " a straight line drawn through the centre and terminated both ways by the circumference." Fig. 1 is an exaggerated example of a shape which, when measured by micrometers or verniers, will give a constant reading; it is also the type of shape which sometimes results from centreless grinding. It is formed upon an isosceles triangle, and in Fig. 2 it is proved that the diameters-that is, any two lines through the centre of the figure, which is obviously the centre of the isosceles triangle-are not necessarily equal.

In Fig. 2, ABC is an isosceles triangle. 0 is its centre. Short arcs are subtended on A, B and C as centres with the same radius (r). With a long radius (R), these centres are joined up by arcs subtended from A, B and C. 0 is then the centre of the resultant figure. DOE and XOY are drawn as diameters. DA and EA are joined.

We are going to prove that these diameters, DOE and XOE, are unequal.

PROOF

XOY = XA + AY = r + R.

Now, DA = r, and AE = R.

Therefore DA + AE = r + R = XA + AY = XOY.

Now DAE is a triangle.

Therefore DA + AE is greater than DOE.

But DA + AE = XOY.

Therefore XOY is greater than DOE.

Therefore these two diameters are not equal.

Therefore the diameters of this figure are not constant.

As this certainly proves that the diameters are not equal, it will be necessary to find out why this figure gives a constant reading when measured by micrometers or vernier calipers.

Now, when we measure with micrometers or vernier calipers, the two faces with which we measure are parallel and flat. They must, then, always touch any figure tangentially. In Fig. 3, we see that any two parallel faces touching the figure subtend two normals to the centre of the arcs which they touch, and that these two normals form a straight line which is always a constant length, but which does not necessarily go through the centre of the figure and form a diameter.

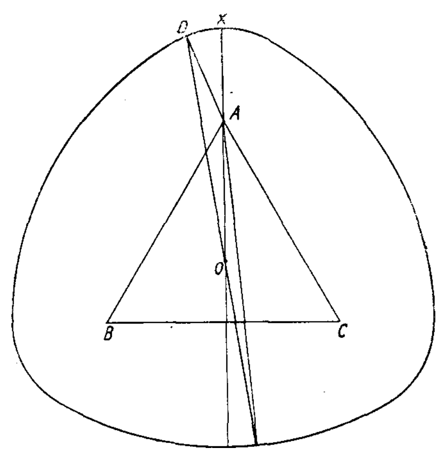

Fig. 2.

in Fig. 3, ABC is an isosceles triangle. 0 is the centre. LX and MY are parallel tangents at X and Y, respectively. X and Y are joined.

Now, since LX is a tangent to the arc centre A, radius r, the normal from X must go through A.

Also, since MY is a tangent to the arc centre A, radius R, the normal must go through A.

Now, since LX is parallel to MY, and LXA =

90" = MYA, XAY must be a straight line; that is, it must coincide with XY.

But XA = r, and YA = R.

Therefore XAY = XY = r + R.

Now this applies to all parallel tangents to the figure whose normals must always form a straight line = r + R.

Therefore, all measurements of the figure between parallel tangential faces must be equal to r + R and constant.

With these two differences before us it is obvious that we must be more careful in our usage of diameter as an expression meaning the measurement across a shaft; because, as we have seen, sections can be obtained which give a constant cross-reading but which have certainly not got constant diameters.

The obvious remaining course is to distrust measurements of shaft or round bar taken with micrometers or vernier calipers, because these do not give any indication of true roundness; and although the theoretical geometry just shown seems to be rather hair-splitting, its implications in practical work are enormous, and full realisation of the theoretical side is essential to clear thinking in manufacture.

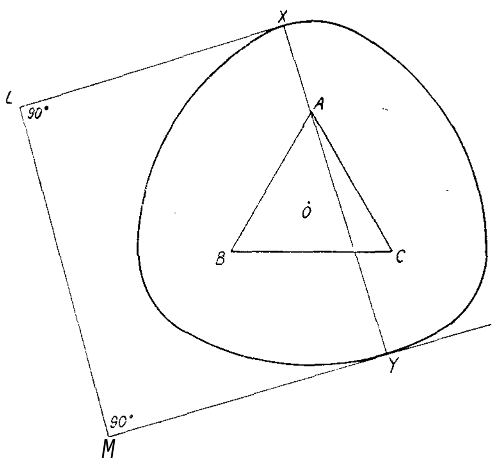

Fig. 3.

We all come across a very carefully reamered hole made to suit ground bar to the manufacturer's tolerances, and are surprised to find undue tightness. Our usual course is to measure the shaft with micrometers, and, on finding it to be correct, to assume that our hole is, perhaps, not quite right, and then we resort to emery paper or an expanding reamer to open it out. The obvious result is that in use the shaft hammers the hole a size bigger, and we have wear on our hands which is usually put down to the strains and wear and tear of the machine on the metal. The only sure course is to use a plug gauge on the hole, and, if it is correct, to scrap the bar as being not truly round. Another case which can lead to serious trouble is in the use of ground bar in valves, etc., when a bar which fits into its gland will still leak unless it is absolutely true.

There are really only two methods of testing bars for roundness without much difficulty; one is to mount it on a vee-block, as in Fig. 4, and gauge it with a comperator; the other is to measure it carefully with micrometers and then to make sure that it fits into the appropriate ring gauge-the second being the much more reliable and easiest to carry out.

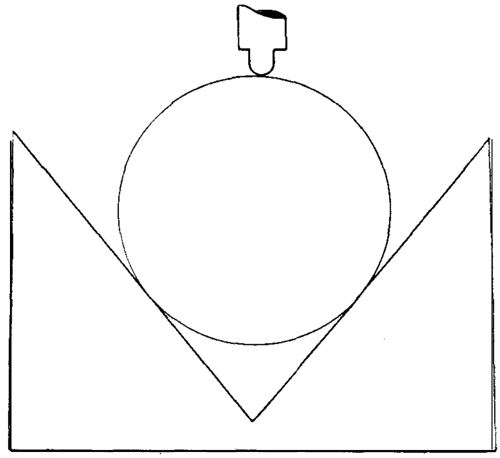

Fig. 4.

It can easily be seen how important this matter is, the rather subtle difference between constant diameter and constant measurement in round bar seems very much like one of those things with which the theoretical man alone worries himself, yet it is a thing which must be fully grasped by every practical engineer if he is to be sure that his work will be true and reliable. It is one of the points which are least understood and causes, incidentally, in big engineering works, a distrust of standards and inspection routine, encouraging a resort to expanding reamers and the consequent doubtful work.

Let us remember, then, that everything with a constant diameter is round, but that sections which have a constant measurement need not have a constant diameter and may be very far from round.