Chapter XII.—EXAMPLES IN LATHE WORK.

TECHNICAL TERMS USED WITH REFERENCE TO LATHE WORK.—Work held between the lathe centres is said to run true, when a fixed point set to touch its perimeter will have an equal degree of contact all around the circumference, and at any part of the length of the same when the work is cylindrical and is rotated. When such a fixed point has contact at one part more than at another of the work circumference, it is said to run "out of true," "out of truth," or not to run true.

Radial or side faces (as they are sometimes called) also run true when a fixed point has equal contact (at all parts of the revolution) with the work surface.

Work that is held in chucks is said to be set true when it is adjusted in the intended position.

To true up is to take off the work a cut of sufficient depth to cause a fixed point to touch the work surface equally at each point in the revolution.

To clean work up is to take off it a cut sufficiently deep to cause it to run true, and at the same time removes the rough surface or scale from the metal.

Roughing out work is taking off a cut which reduces it to nearly the finishing size, leaving sufficient metal to take a finishing cut, and reduce it to the proper size.

Facing a piece of work is taking a cut off its radial face.

When a radial face or surface is convex, it is said to be *rounding* or *round*, and when it is concave it is said to be *hollow*.

When a radial face is at a right angle to a cylindrical parallel surface, it is said to be *square*; but in taper work, it is said to be *square* when it is at a right angle to the axis of the taper.

Outside work includes all operations performed on a piece of work except those executed within the bores of holes or recesses, which is termed inside or internal work.

Jarring or *chattering* is the term applied to a condition in which the tool does not cut the work smooth, but leaves a succession of elevations and depressions on it, these forming sometimes a regular pattern on the work. In this case the projections only will have contact with the measuring tools, or with the enveloped or enveloping work surface, when the two pieces are put together.

Jarring or chattering more commonly occurs in the bores of holes or upon radial surfaces, than upon plain cylindrical surfaces, unless the latter be very long and slender. It occurs more also upon brass than upon iron work, and more upon cast than upon wrought iron or steel. It is caused mainly by vibrations of either the work or the tool.

It is induced by weakness (or want of support) in the work, by weakness in the tool, or by its being improperly formed for the duty. Thus, if a tool have too broad a cutting surface it will jar; if it be held out far from the tool post it may jar; if it have too keen a top face for the conditions it will jar.

Jarring may almost always be remedied on brass work by reducing the keenness of the top face, giving it if necessary negative rake, as shown in Fig. 964. On iron or steel work it may be avoided by using as stiff a cutting tool as possible, holding its cutting edge as close to the tool post as convenient, and reducing the length of cutting edge to a minimum.

It may be prevented sometimes by simply placing the finger or a weight upon the tool, or by applying oil to the work, but if this be done it should be supplied continuously throughout the cut, as a tool will cut to a different depth when dry from what it will when lubricated.

In using hand tools such as scrapers, too thin a tool may cause jarring, which may be obviated by keeping the tool rest as close to the work as possible, and placing a piece of leather between the work and the rest.

EXAMPLES IN LATHE WORK.—The simplest class of lathe work is that cut from rods or short lengths of rod metal, which may be turned by being held in a small chuck, or between the lathe centres.

Such work is usually of small diameter and short length, and is therefore difficult to get at if turned between the lathe centres, because the dog that drives it, the lathe face plate, and the dead centre are in the way; such work may be more conveniently driven by a small chuck.

It is usually made of round wire or rod, cut into lengths to suit the conditions; thus if the lathe have a hollow spindle, the rod lengths may be so long as to pass entirely through the spindle, otherwise the lengths may be passed through the chuck, and as far as possible into the live spindle centre hole.

In any event it is desirable to let the rod project so far out from the chuck as to enable its being finished and cut off, without removal from or moving it in the chuck, because such chucks are apt in course of time to wear, so that the jaws do not grip the work quite concentric to the line of centres; hence, if the work be moved in the chuck after having been turned, it is apt to run out of true.

Sometimes, however, the existence of a collar on the work prevents it from being trued for fit at both ends without being cut off from the rod, in which case, if it requires correction after being cut off, it must be rechucked, and it may be necessary at this rechucking to grip it in several successive positions (partly rotating it in the chuck at each trial) before it will run true.

Sometimes the length of work that may advantageously be driven by such a chuck is so great as to render the use of the dead centre to support one end necessary, in which case the rod should be removed from the chuck before each piece is turned, so as to centre drill the dead centre end.

There is one special advantage in driving small work in a chuck of this kind, inasmuch as the work can be tried for fit without removing it from the lathe, while in some cases operations can be performed on it which would otherwise require its removal to the vice; suppose, for example, a thread of very small diameter and pitch requires to be cut on the work end, then a pair of dies or a screw plate may be placed on it, and the lathe pulled round by the belt; after the dies have commenced to start the thread, they may be released and allowed to rotate with the lathe, which will show if they are starting the thread true upon the work.

In cases also where the end of the work requires fitting to a seat, or where it requires turning to a conical point, there is the advantage that the work can be tried to the seat, or turned to the point without taking from the lathe, or without any subsequent operations, whereas in the case of a conical point, the existence of a work centre would necessitate turning the cone some distance from the end, and cutting off the work centre.

As the size of the work increases, the form of the chuck is varied to make it more powerful and strong to resist the strains, but when the size of the chuck becomes so large that it is as much in the way as the face place would be, it is better to turn the work between the lathe centres.

For work to be turned between the lathe centres, it is essential that those centres run true, and be axially in line, and that both centres be turned to the same degree of angle or cone, which is usually for small lathes an angle of 60°, and for lathes of about 30 inches swing and over an angle of about 70°. Both centres should be of an equal angle, for the following reasons.

It is obvious that the work centres wear to fit the dead centre, because of the friction between the two. Now in order to turn a piece of work from end to end, it is necessary to reverse it in the lathe, because at the first turning one end is covered by the carrier or driver driving it. At the first turning one work centre only will have worn to fit the lathe centre; hence when at the second, the other work centre wears to fit the dead centre and in the process of such wearing moves (as it always does to some degree) its location, the part first turned will no longer run true. To obviate this difficulty it is proper at the first turning to cut the work down to nearly the finished size, and then reverse it in the lathe and turn up the other end. At this second turning the work will have had both work centres worn to fit the dead centre, hence if it be of the same angle as the live centre, the work will properly bed to both centres, otherwise it will plainly not bed well to the live centre, and in consequence will be apt to run in some degree out of true at the live centre end.

The lathe centres should, for parallel work, stand axially true one with the other, and this can only be the case when the live centre runs true. If the live centre does not run true the following difficulties are met with.

If one end only of the work requires to be turned and it can be completely finished without moving the work driver, the work will be true (assuming the live spindle to run true in its bearings and to fit the same). It will also run true if the work be taken from the lathe and replaced without moving the driver or carrier, providing that the driver be so placed as to receive the driving pressure at the same end as it did when the work was driven; and it is therefore desirable, on this account alone, to always so place the work in the lathe that the driver is driven by its tail end, and not from the screw or screw head. But if the work be turned end for end it will not run true, because the work centre at the unturned end of the work will not be true or central to the turned part of the work.

It is obvious then that lathe centres should run true. But this will not be the case unless the holes into which they fit in the lathe are axially true one with the other and with the lathe spindles. If these holes are true, and the centres are turned true and properly cleaned before insertion, the centres may be put into their places without any adjustment of position. Otherwise, however, a centre punch mark is made on the radial or end face of the live spindle, and another is made on the live centre, so that both for turning up and for subsequent use the centre will run true when these centre punch marks are exactly opposite to each other.

The best way to true lathe centres is with an emery-wheel. In some lathes there are special fixtures for emery grinding, while in others an attachment to go in the tool post is used. Fig. 1156 shows such an attachment.

In the figure A is a frame to be fastened in the slide rest tool post at the stem A′. It affords journal bearing to the hand wheel B, to the shaft of which is attached the gear-wheel C, which drives a pinion D, on a shaft carrying the emery-wheel E, the operation being obviously to rotate wheel B, and drive the emery-wheel E, through the medium of the multiplying gear-wheels C, D.

The emery-wheel is fed to its depth of cut on the lathe centre P, by the cross feed screw of the lathe, and is traversed by pulling or pushing the knob F, the construction of this part of the device being as follows: G and H are two bushes, a sliding fit in the arms of frame A, but having on top flat places I and J, against which touch the ends of the two set-screws *k*, *l*, to prevent them from rotating. The emery-wheel and gear pinion D are fast together, and a pin passes through and holds G and H together. Hence the knob F pushes or pulls, as the case may be, the bushes through the bearings G, H, in the frame A, the pinion and emery-wheel traversing with them. Hence pinion D is traversed to and fro by hand, and it is to admit of this traverse that it requires its great length. The stem A is at such an angle that, if it be placed true with the line of cross feed, the lathe centre will be ground to the proper angle.

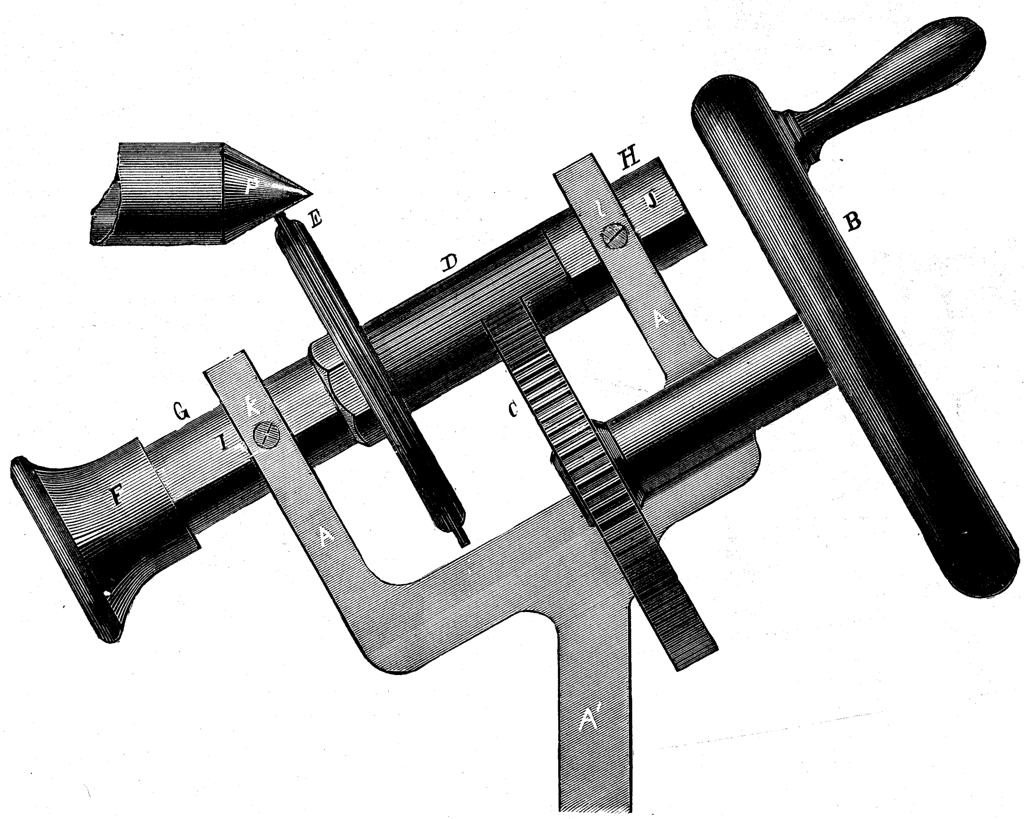


Fig. 1156.

Fig. 1157 represents a centre grinding attachment by Trump Brothers, of Wilmington, Delaware. In this device the emery-wheel is driven by belt power as follows. A driving wheel A is bolted to the lathe face plate, and a stand carries at its top the over-head belt pulleys, and at its base the emery-wheel and spindle. This stand at C sets over the tool post, and is secured by a bar passing through C and through the tool post, whose set-screw therefore holds the stand in position. On the end of the emery-wheel spindle is a feed lever, by means of which the emery-wheel may be fed along the lathe centre. Cup piece B is for enabling wheel A to be readily set true on the lathe face plate, one end of B fitting the hub of A, while the other receives the dead centre which is screwed up so that B will hold A in place, while it is bolted to the lathe face plate, and at the same time will hold it true.

In the absence of a centre grinding attachment, lathe centres may be turned true with a cutting tool, and finished with water applied to the tool so as to leave a bright and true surface. They should not, for the finest of work, be finished by filing, even though the file be a dead smooth one, because the file marks cause undue wear both to the lathe centres and the work centres.

The dead centres should be hardened to a straw color, and the live centre to a blue; the former so as to have sufficient strength to resist the strain, and enough hardness to resist abrasion, and the latter to enable it to be trued up without softening it.

When, after turning them up, the centres are put into their places, the tailstock may be moved up the bed so that the dead centre projects but very little from the tailstock, and is yet close to the live centre, and the lathe should be run at

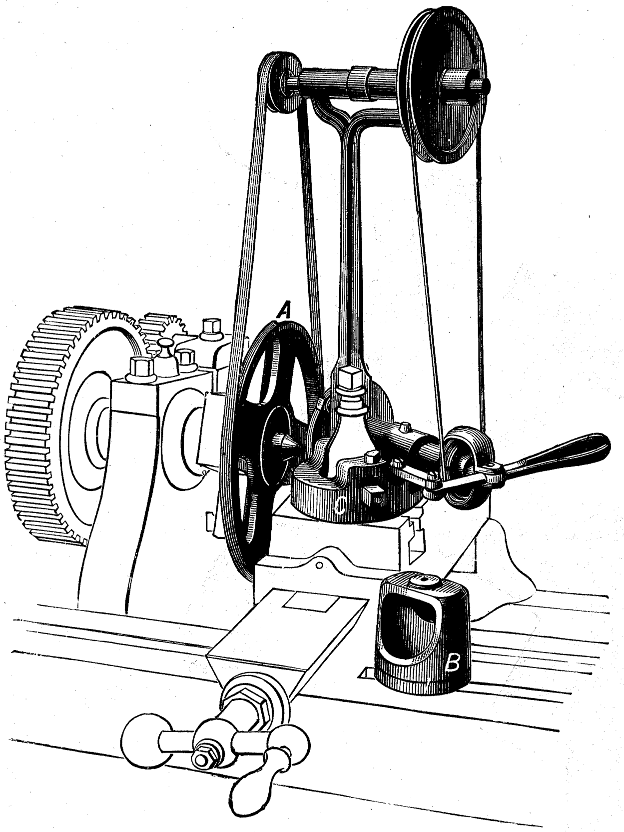


Fig. 1157.

its fastest speed to enable the eye to perceive if the live centre runs true, and whether the dead centre is in line with the live one, and the process repeated so that both centres may be tested.

A more correct test, however, may be made with the centre indicator.

Centre Indicators.—On account of the difficulty of ascertaining when a centre runs quite true, or when a very small hole

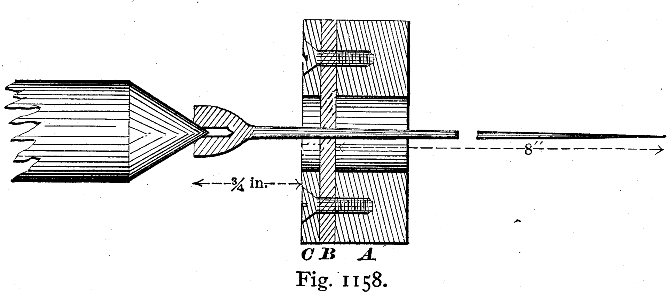


Fig. 1158.

or fine cone as a centre punch mark runs true when chucked in a lathe, the centre indicator is used to make such tests, its object being to magnify any error, and locate its direction. Fig. 1158, from *The American Machinist*, represents a simple form of this tool, designed by Mr. G. B. Foote, for testing lathe centres. A is a piece of iron about 8 inches long to fit the lathe tool post, B is a leather disk secured to A by a plate C, and serving to act as a holding fulcrum to the indicator needle, which has freedom of movement on account of the elasticity of the leather washer, and on account of the hole shown to pass through A. It is obvious

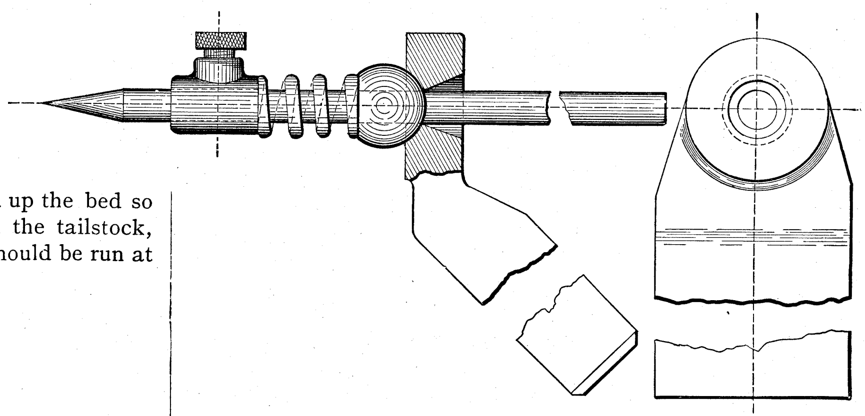


Fig. 1159.

that if the countersunk end of the needle does not run true, the pointed end will magnify the error by as many times as the distance from the needle point to the leather washer is greater than that from the leather washer to the countersunk end of the needle. It is necessary to make several tests with the indicator, rotating the lathe centre a quarter turn in its socket for each test, so as to prove that the centre runs true in any position in the lathe spindle. If it does not run true the error should be corrected, or the centre and the lathe spindle end may be marked by a centre punch done to show in what position the centre must stand to run true.

The tension of the leather washer serves to keep the countersunk against the lathe centre without a very minute end adjustment. Or the same end may be attained by the means shown in Fig. 1159, which is a design communicated by Mr. C. E. Simonds to *The American Machinist*. The holder is cupped on one side to receive a ball as shown, and has a countersink on the other to permit a free vibration of the needle. The ball is fitted to slide easily upon the needle, and between the ball and a fixed collar is

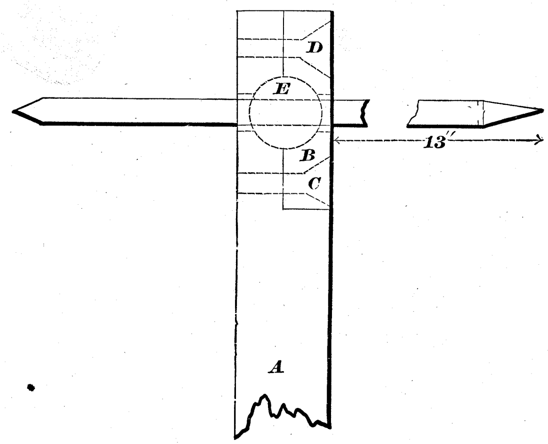


Fig. 1160.

a spiral spring that keeps the ball in contact with its seat in the holder.

One end of the needle is pointed for very small holes or conical recesses, while the other is countersunk for pointed work, as lathe centres. The countersink of the needle may be made less acute than the lathe centre, so that the contact will be at the very point of the lathe centre, the needle not being centre-drilled. The end of the needle that is placed against the work should be as near to the ball or fulcrum as convenient, so as to multiply the errors of work truth as much as possible.

In some forms of centre indicators the ball is pivoted, so that the needle only needs to be removed to reverse it end for end, or for adjusting its distance, it being made a close sliding fit through the ball. Thus, in Fig. 1160 the ball E is held in a bearing cut half in the holder A, and half in cap B, which is screwed to A by screws C D.

Or the ball may be held in a universal joint, and thus work more frictionless. Thus, in Fig. 1161 it is held by the conical points of two screws diametrically opposite in a ring which is held by the conical points of two screws threading through an outer ring, these latter screws being at a right angle to those in the inner ring.

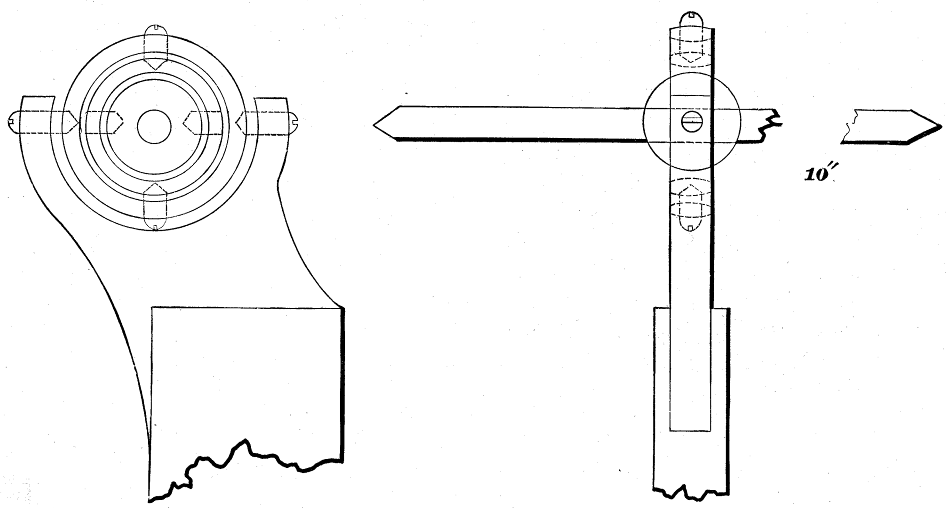


Fig. 1161.

The outer ring is held to the holder by the conical points of two screws, all the conical points seating in conical recesses.

It is obvious that the contact of the point of the needle and the work may be more delicately made when there is some elasticity provided, as is the case with the spiral spring in Fig. 1159.

Indicators of this class may be used to test the truth of cylindrical work: thus, in Fig. 1162 is an application to a piece of work between the lathe centres, there being fitted to one end of the needle a fork *a* that may be removed at pleasure.

One of the difficulties in turning up a lathe centre to run true arises from the difference in cutting speed at the point and at the full diameter of the cone, the speed necessary to produce true smooth work at the point being too fast for the full diameter. This may be remedied on centres for small work, as, say, three inches and less in diameter, by cutting away the back part of the cone, leaving but a short part to be turned up to true the centre.

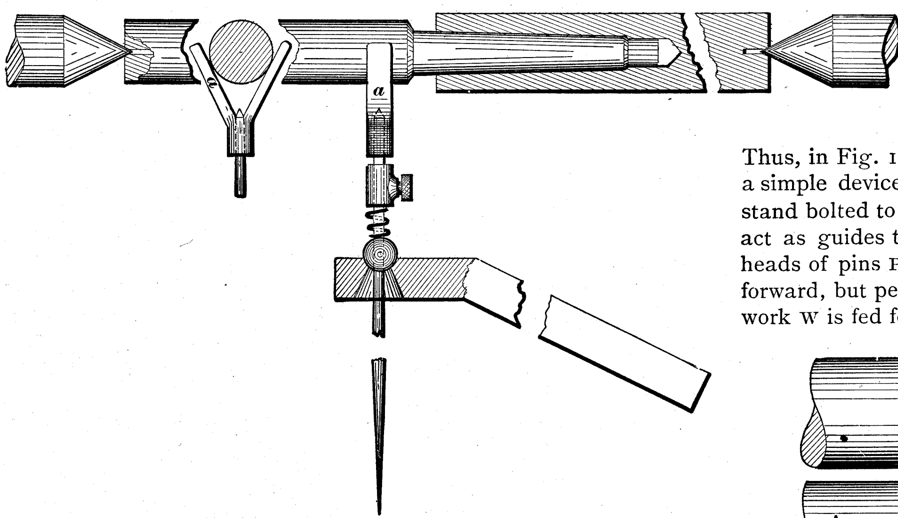


Fig. 1162.

To permit the cutting off or squaring tool to pass close up to the centre, and thus prevent leaving a burr or projection on the work end, the centre may be thus relieved at the back and have a small parallel relief, as in Fig. 1164 at A, the coned point being left as large as possible, but still small enough to pass within the countersink.

In centres for large and heavy work it is not unusual to provide some kind of an oil way to afford means of lubrication, and an excellent method of accomplishing this object is to drill a hole A, Fig. 1163, to the axis of the centre and let it pass thence to the point as denoted by the dotted line; there may also be a small groove at B in the figure to distribute the oil along the centre, but grooves of this kind make the returning of the centre more difficult and are apt to cause the work centres to enlarge more from wear, especially in turning tapers with the tailstock set over the lathe centre, these being out of line with the work centre.

To enable a broad tool such as a chaser to meet work of smaller diameter than the lathe centre, the latter is cut away on one side as in Fig. 1164. It is obvious also that the flat place being turned uppermost, will facilitate the use of the file on work of smaller diameter than the lathe centre, and that placed in the position shown in the cut, it will permit a squaring tool to pass clear down to the centre and avoid leaving the projecting burr which is left when the tool cannot pass clear down the face to the edge of the countersink of the work centre.

The method to be employed for centring work depends upon its diameter, and upon whether its ends are square or not. When the pieces are cut from a rod or bar in a cutting-off machine, the ends are square, and they may be utilized to set the work by in centring it. Thus, in Fig. 1165 is a top, and in Fig. 1166 is an end view of a simple device, or lathe attachment for centre drilling. S is a stand bolted to the lathe shears and carrying two pins P, which act as guides to the cup chuck or work guide G; between the heads of pins P and the hubs of G are spiral springs, forcing it forward, but permitting it to advance over the drill chuck; the work W is fed forward to the drill. At the dead centre end the

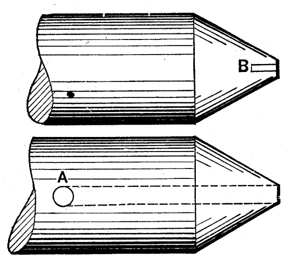


Fig. 1163.

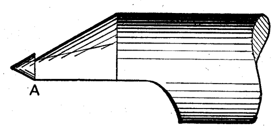


Fig. 1164.

work is supported by a female cone centre D in the tail spindle T. The work rests in mouths of G and D, and as the pieces are cut from the rod they are sufficiently straight, and being cut off in a cutting-off machine the ends are presumably square; hence the coned chucks will hold them sufficiently true with the ends, and the alignment of the centre drilled holes will not be impaired by any subsequent straightening processes; for it is to be observed, that if work is centre-drilled and straightened afterwards, the straightening throws the centre holes out of line one with the other, and the work will be more liable to gradually run out of true as its centres wear.

Thus, in Fig. 1167, let W represent a bent piece of work centre-drilled, and the axis of the holes will be in line as denoted by the

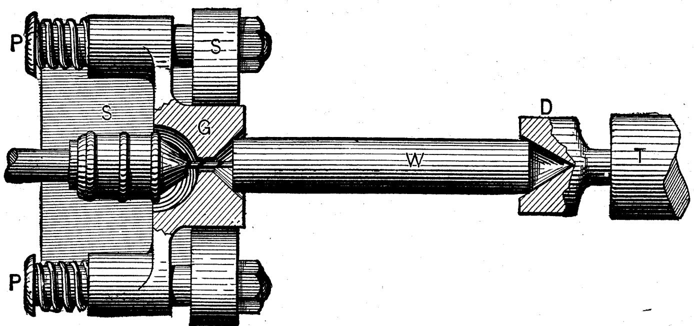


Fig. 1165.

dotted line, but after the piece is straightened the holes will lie in the planes denoted by the dotted line in Fig. 1168, and there will be a tendency for the work centres to move over towards the sides C D as the wear proceeds.

In Fig. 1169 is shown a centre-drilling machine, which consists of a live spindle carrying the centre-drilling tool, and capable of

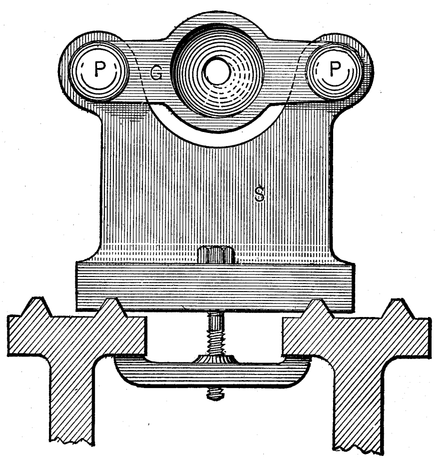


Fig. 1166.

end motion for the drill feed. The work is held in a universal chuck, and if long is supported by a stay as shown in the figure. The axis of the work being in line with that of the chuck, the work requires no setting.

In this case the centre hole will be drilled true with that part of

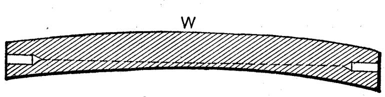


Fig. 1167.

the work that is held in the chuck, and the alignment of the centre hole will depend upon the length of the rod being supported with its axis in line with the live spindle. If the work is not straightened after drilling, the results produced are sufficiently correct for the requirements; but it follows from what has been said, that work

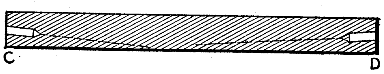


Fig. 1168.

which requires to be straightened and tried for straightness in the lathe should be centred temporarily and not centre-drilled until after the straightening has been done.

In Fig. 1170 is shown a combined centre-drill and countersink not unfrequently used in centring machines. The objection to it is, that the cutting edges of the drill get dull quicker than those of the countersink, and in regrinding them the drill gets shorter. Of course the drill may be made longer than necessary so as to admit of successive grindings, but this entails drilling the centre holes deeper than necessary, until such time as the drill has worn to its proper length. To overcome this difficulty the countersink

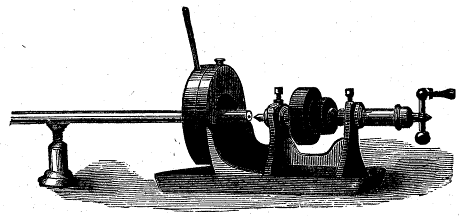


Fig. 1169.

may be pierced to receive a drill as in Fig. 1171, the drill being secured by a set-screw S.

Among the devices for centring work by hand, or of pricking the centre preparatory for centre-drilling, are the following:—

In Fig. 1172 is a centre-marking square. A B C D represents the back and E the blade of the square. Suppose then that the dotted circle F represents the end of a piece of work, and we apply the square as shown in the cut and mark a line on the end of the

Fig. 1170.

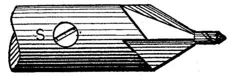


Fig. 1171.

work, and then moving the square a quarter turn around the work, draw another line, the point of contact of these two lines (as at G in the cut) will be the centre of the work, or if the work is of large diameter as denoted by the circle H H, by a similar process we obtain the centre E. In this case, however, the ends A B of the square back must be of equal lengths, so that the end faces at A B will form a right angle to the edge of the blade, and this enables

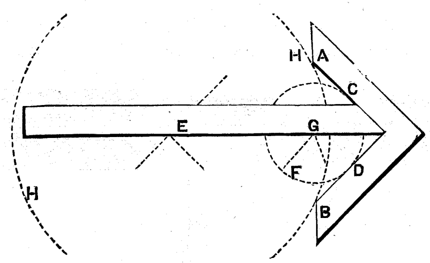


Fig. 1172.

the use of the square for ordinary purposes as well as for marking centres.

The point *a* of the centre punch shown in Fig. 1173 is then placed at the intersection of the two lines thus marked, and a hammer blow produces the required indentation. The centre punch must be held upright or it will move laterally while entering the metal. The part *b* of the centre punch is tapered so as to obstruct the vision as little as possible, while it is made hexagon or octagon at the upper end to afford a better grip. By increas-

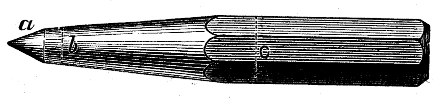


Fig. 1173.

ing the diameter at C, the tool is stiffened and is much less liable to fly out of the fingers when the hammer blow does not fall quite fair.

In Fig. 1174 is shown a device for guiding the centre punch true with the axis of the work, so as to avoid the necessity of finding the same by lines for the centres. It consists of a guide piece B and a parallel cylindrical centre punch A, C representing a piece of work. B is pierced above with a parallel hole fitting and guiding the centre punch, and has a conical hole at the lower end to rest on the work, so that if the device be held upright and pressed down upon the end of the work, and the top of the centre punch is struck with the hammer, the indentation made will be central to the points of contact of the end of the work with the

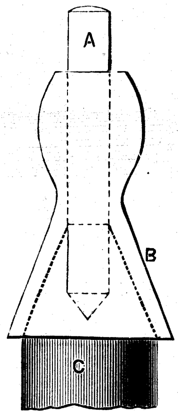


Fig. 1174.

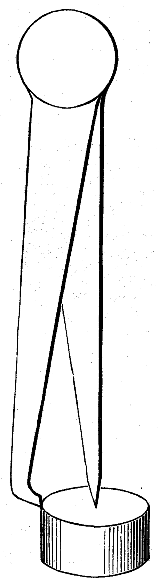


Fig. 1175.

coned hole of B. If then the end of the work has no projecting burrs the centring will be centred true.

In the absence of these devices, lines denoting the location for the conical recess or centre may be made, when either of the following methods may be pursued.

In Fig. 1175 is shown what is known as a pair of hermaphrodite calipers, which consists of two legs pivoted at the upper end; the

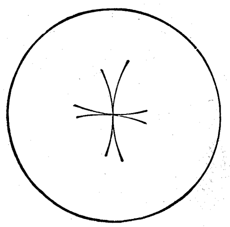


Fig. 1176.

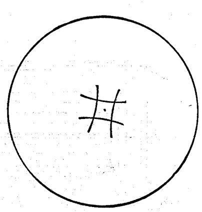


Fig. 1177.

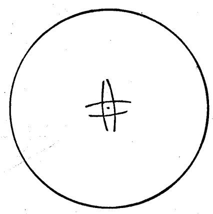


Fig. 1178.

bent leg is placed against the perimeter of the work, as shown, and held steadily, while with the point a line is marked on the work. This operation is performed from four equidistant (or thereabouts) points on the work, which will appear as shown in Fig. 1176, providing the radius to which the point was set be equal to the radius of the work. The point at which the lines meet is in this case the location for the centre. If, however, the radius to

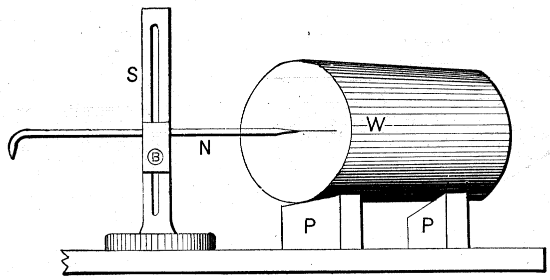


Fig. 1179.

whicn the points are set is less than the radius of the work, the lines will appear as in Fig. 1177, in which case the location is in the centre of the inscribed square, as denoted by the dot; or if the radius be set too great the lines will appear as in Fig. 1178, and the location for the centre will again be as denoted by the dot.

Another and very old method of marking these lines is to place the work on a pair of parallel pieces and draw the lines across it, as shown in Fig. 1179, in which W represents the work, P, P the parallel pieces of equal thickness, S a stand (termed a scribing block) carrying a needle N, which is held by a thumb screw and bolt at B. The point of the needle is adjusted for the centre of the work, a line is drawn, the work is then rotated, another line drawn, and so on, until the four lines are drawn as in Fig. 1180, when the

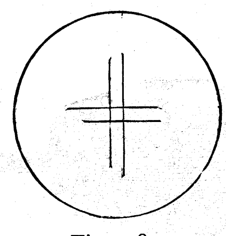


Fig. 1180.

work may be turned end for end if light, or if heavy the scribing block may be moved to the other end of the work.

The centre locations are here made true with the part of the work that rests on the parallel pieces, and this is in some cases an essential element in the centring.

Thus, in Fig. 1181, it is required to centre a piece true with the journals A B, and it is obvious that those journals may be rested on parallel pieces P, P, and the centres marked by the scribing block on the faces E, F in the manner before described.

If there is a spot in the length of a long piece of work where

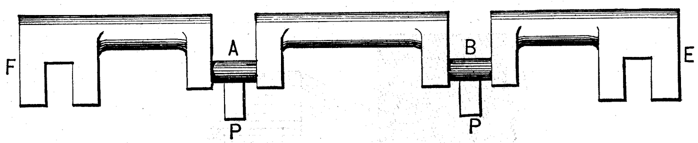


Fig. 1181.

the metal is scant and out of round, so that it is necessary to centre the work true by that part, the surface gauge and parallel pieces may be used with advantage, but for ordinary centring it is a slow process. When a piece of work is not cylindrical, and it is doubtful if it will clean up, the centring requires care, for it must not always be assumed, that if two diametrically opposite points meet the turning tool at an equal depth of cut, the piece is centred so as to true up to the largest possible diameter.

This is pointed out in Fig. 1182, which is extracted from an

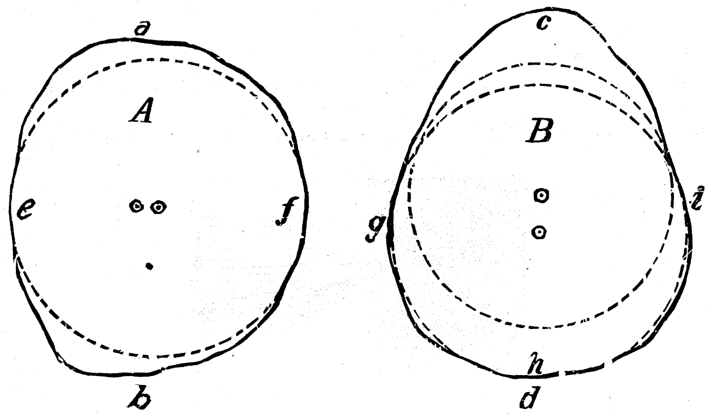


Fig. 1182.

article by Professor Sweet. "In a piece of the irregular form A, the points *a* and *b* might be even and still be no indication of the best location for the centre, and in the piece B it is evident that if *c* and *d* were even, nothing like the largest cylinder could be got from it. In the case of shape A, the two points *e* and *f* should be equidistant from the centre, and in the case of shape B, the three points *g*, *h*, *i* should be equidistant from the centre."

The depth of the centre drill holes should be such as to leave them in the work after it is cut off to its proper length, and will, therefore, be deeper as the amount to be cut off is greater.

The diameter of the centre drill is larger as the size of the work increases, and may be stated as about $\frac{3}{64}$ for work of about $\frac{1}{2}$ inch, increasing up to $\frac{1}{8}$ inch for work of about an inch, and up to three inches in diameter; for work of a foot or over the centre drill may be $\frac{3}{16}$ inch in diameter.

The centre drilling and countersinking may, when the work is cut to length, be performed at one operation, but when it requires to be cut to length in the lathe, that should be done before the countersinking. A very simple chuck for centre drilling is shown

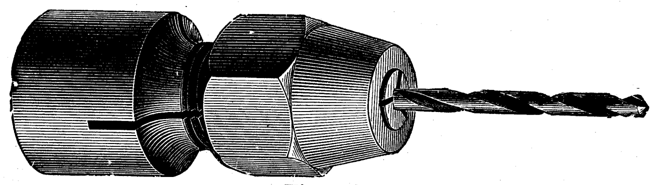


Fig. 1183.

in Fig. 1183, with a twist drill (which is an excellent tool for centre-drilling). If the work is held in the hand and fed to the drill by the lathe dead centre, the weight of the work will cause the hole to be out of straight with the work axis, unless the grip is occasionally relaxed, and the work made to rotate a half or a quarter turn as the drilling proceeds.

After the work is centre-drilled and cut off to length, it must be finally countersunk, so as to provide ample bearing area for the lathe centres.

The countersinking should be true to the centre hole; and it is sometimes made to exactly fit the lathe centres, and in other

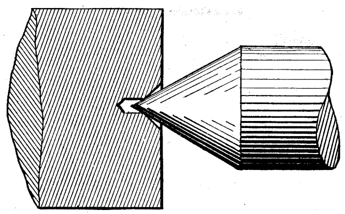


Fig. 1184.

cases it is made more acute than the lathe centre, so that the oil may pass up the countersink, while it is bedding itself to the lathe centres.

If the countersinking is done before the end of the work is squared, it will not be true with the centre-drilled hole.

In order that the countersinking may wear true with the centre-drilled hole, it may be made of a more obtuse angle (as, say, one degree) than the lathe centre, as in Fig. 1184, so that the hole may form a guide to cause the lathe centre to wear the countersinking true to the hole, and thus correct any error that may exist.

If the countersink is made more acute than the lathe centre, as

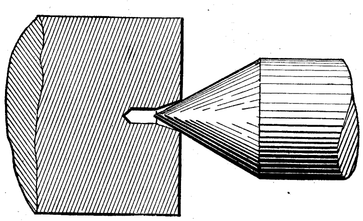


Fig. 1185.

shown in Fig. 1185, the wear of its mouth will act as a guide, causing the centre to be true with the countersinking; and when the bearing area extends to the centre-drilled hole, there will be introduced, if that hole does not run true, an element tending to cause the work to run out of true again, because the countersinking will have more bearing area on one side than on the other.

It is to be observed, however, that if the difference between the countersink angle and that of the lathe centre be not more than about one degree, the work centre will bed itself fully to the lathe centre very rapidly, and usually before the first cut is carried over the work, unless the work centres have been made to have unduly large countersinks.

Fig. 1186 represents a half-round countersink, in which the cutting edge is produced by cutting away the coned point slightly below the dotted axial line. This secures two advantages: first, it gives the cutting edge clearance without requiring the grinding or filing such clearance; and, secondly, the cone being the same angle as the lathe centres, filing away more than half of it causes it to give the lathe centre at first a bearing at the small end of the

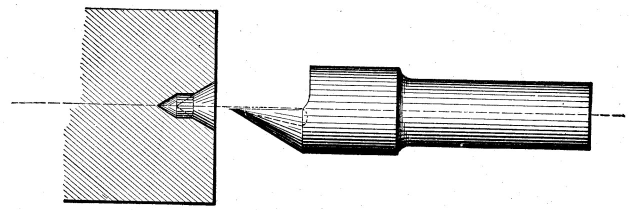


Fig. 1186.

countersink, as in Fig. 1184, and this secures the advantage mentioned with reference to that figure. It is obvious that such a reamer, however, does not produce strictly a cone countersink, as is shown in Fig. 1187, where the cutting away of the cone is carried to excess simply to explain the principle, and the cone becomes an hyperbolic curve.

The small amount, however, that it is necessary to carry the face below the line of centres, practically serves to make the cone somewhat less acute, and is not therefore undesirable.

Another method of forming the half-round countersink is shown

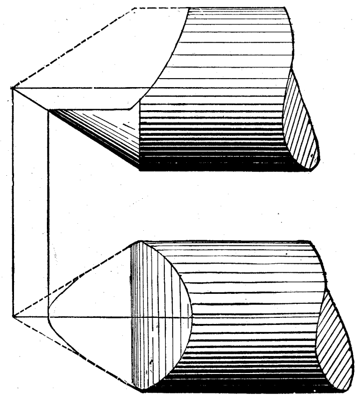


Fig. 1187.

in Fig. 1188, in which the cone is of the same angle as the lathe centres; the back A is ground away to avoid its contact with the work and give clearance, while clearance to the cutting edge is obtained by filing or grinding a flat surface B at the necessary angle to the upper face of the cone. In this case it is assumed that the centre-drilling and countersinking are true one with the other. Yet another form of countersink is shown in Fig. 1189, consisting of a cone having three or four teeth. It may be pro-

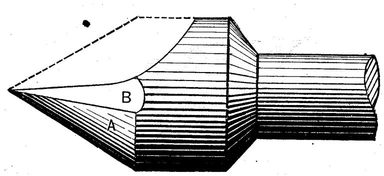


Fig. 1188.

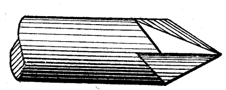


Fig. 1189.

vided with a tit, which will serve as a guide to keep the countersink true with the hole, and this tit may be made a trifle larger in diameter than the hole, and given teeth like a reamer, so as to ream the hole out while the countersinking is proceeding.

Unless one side of a half-round reamer is filed away so as to give the cutting edge alone contact with the bore of the hole, an improper strain is produced both upon the work and the countersink.

In Fig. 1190, for example, is shown, enlarged for clearness of illustration, a hole, and a half-round countersink in section, and it is evident that if the countersink is set central to the hole, it will have contact at A and at B, and A cannot enter the metal to cut without springing towards C.

But when the lathe has made rather more than one-half a revolution, the forcible contact at B will be relieved, and either the work or the countersink will move back towards D. This may be remedied by setting the countersink to one side, as in Fig. 1191,

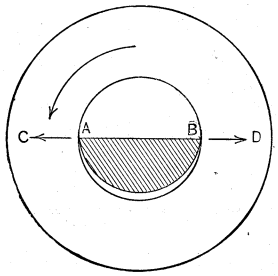


Fig. 1190.

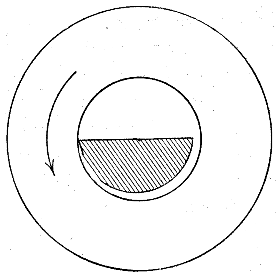


Fig. 1191.

or by cutting it away on one side, as in Fig. 1192, when the half-round reamer will, if the work be rigidly held while being countersunk, act as a cutting tool. But it is more troublesome to hold the work rigidly while countersinking it than it is to simply hold it in the hands, and for these reasons the square centre is an excellent tool to produce true countersinking.

Fig. 1193 represents a square centre, the conical end being provided with four flat sides, two of which appear at A B, or it may have three flat sides which will give it keener cutting edges, and

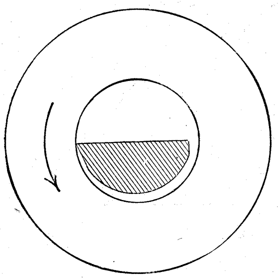


Fig. 1192.

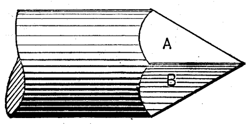


Fig. 1193.

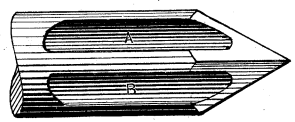


Fig. 1194.

will serve equally well to keep it true with the drilled hole. But it is questionable whether it is not an advantage not to have the cutting edges so keen as is given by the three flat faces, because the less keen the cutting edges are, the more true the countersinking will be with the hole, the extra pressure required to feed the square centre tending to cause it to remain true with the hole notwithstanding any unequal density of the metal on different sides of the hole. An objection to the square centre is that it involves more labor in the grinding to resharpen it, and is not so

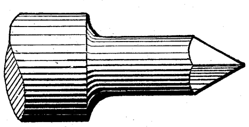


Fig. 1195.

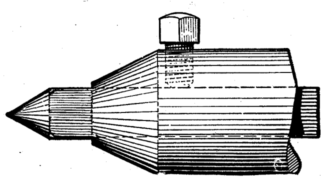


Fig. 1196.

easy to grind true, but for fine work this is more than compensated for in the better quality of its work.

This labor, however, may be lessened in two ways: first, the faces may be fluted, as in Fig. 1194, at A and at B, or its diameter may be turned down, as in Fig. 1195. In using the square centre it is placed in the position of the live centre and revolved at high speed, all the cutting edges operating simultaneously; the work is fed up by the dead centre and held in the hand.

To prevent the weight of the work from causing the countersinking being out of true with the hole, the work should be occasionally allowed (by relaxing the grip upon it) to make part of a revolution, as explained with reference to centre-drilling without a work guide. Another and simple form of square centre for countersinking is shown in Fig. 1196. It consists of a piece of square steel set into a stock or holder.

Work that is to be hardened and whose centres are, therefore, liable to warp in the hardening, may be countersunk as in Fig.

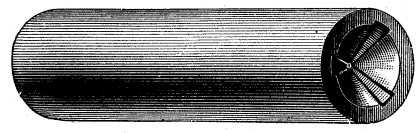


Fig. 1197.

1197, there being three indentations in the countersink as shown. This insures that there shall be three points of contact, and the work will run steadily and true. Furthermore, the indentations form passages for the oil, facilitating the lubrication and preventing wear both to the work and to the lathe centres.

These indentations are produced after the countersinking by the punch, shown in Fig. 1198. Except when tapers are turned by

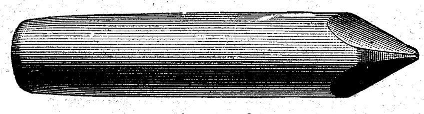


Fig. 1198.

setting the lathe centres out of line with the lathe shears (as in setting the tailstock over), all the wear falls on the dead centre end of the work, as there is no motion of the work centre on the live centre, hence the work centres will not have worn to a full bearing until the work has been reversed end for end in the lathe.

If it be attempted to countersink a piece of work whose end face is not square, the countersinking will not be true with the

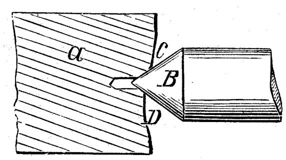


Fig. 1199

centre hole, and furthermore the causes producing this want of truth will continue to operate to throw the work out of true while it is being turned. Thus, in Fig. 1199, *a* represents a piece of work and B the dead centre; if the side C is higher than side D of the work end, the increased bearing area at C will cause the most wear to occur at D, and the countersink in the work will move over towards D, and it follows that the face of a rough piece of

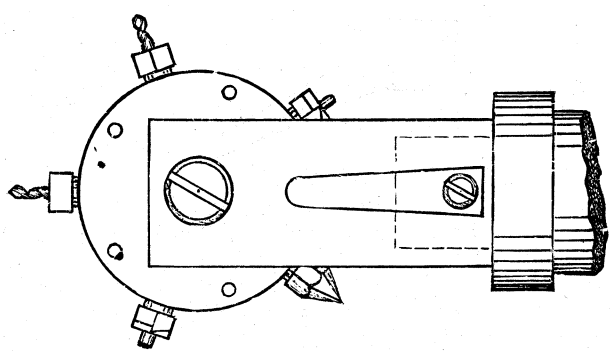


Fig. 1200.

work should be faced before being countersunk. Professor Sweet designed the centre-drilling device shown in Fig. 1200, which consists of a stock fitting the holes for the lathe centres, and carrying what may be called a turret head, in which are the centre drills, facing tools, and countersinks. The turret has 6 holes corresponding to the number of tools it carries, and each tool is held in position by a pin, upon a spring, which projects into the necessary hole, the construction being obvious. The facing tool is placed next to the drill and is followed by a countersink, in whatever direction the turret is rotated to bring the next tool into operation. The work should, on account of the power necessary for the facing, be driven in a chuck.

A similar tool, which may, however, be used for other work besides centring and countersinking, is shown in Fig. 1201. It consists of a stem fitting into the hole of the tail spindle, and carrying a base having a pin D, on which fits a cap having holes *b*, and set-screws C for fastening drills, countersinks, or cutting tools. The cap is pierced with six taper holes, and a pin projects

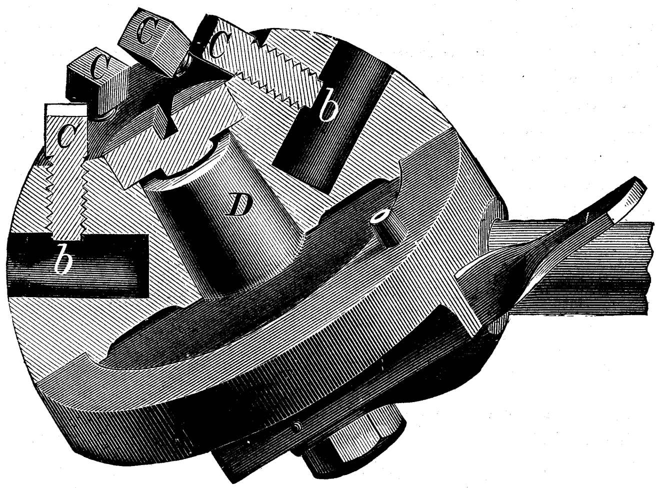


Fig. 1201.

through the base into these holes to lock the cap in position, this pin being operated by the spring lever shown.

Work that has already been turned, but has had its centres cut off, may be recentred as follows. One end may be held and driven by a chuck, while the other end is held in a steady rest such as was shown in Fig. 802, and the centre may then be formed in the free end by a half-round reamer, such as shown in Fig. 1190, placed in the position of the dead centre, or the square centre may be used in place of the dead centre, being so placed that one of its faces stands vertically, and therefore that two of its edges will operate to cut. The location for the work centre should be centre punched as accurately as possible, and the work is then placed in the lathe with a driver on it, as for turning it up; a crotch, such as shown in Fig. 1202, is then fastened in the lathe tool post, and fed up by the cross-feed screw until it causes the work to run true,

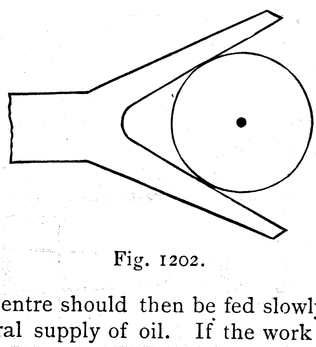


Fig. 1202.

and the square centre should then be fed slowly up and into the work, with a liberal supply of oil. If the work runs out of true, the crotch should be fed in again, but care must be taken not to feed it too far. So long as the square centre is altering the position of the centre in the work, it will be found that the feed-wheel of the tailstock will feed by jumps and starts; and after the feeding feels to proceed evenly, the crotch may be withdrawn and the work tried for being true. The crotch, as well as the square centre, should be oiled to prevent its damaging the work surface. It is obvious that in order to prevent the lathe dead centre point from seating at the point or bottom of the work centre, the square centre should be two or three degrees more acute in angle than the lathe dead centre. If the work is tried for truth while running on the square centre, the latter is apt to enlarge the work centre, while the work will not run steadily, hence it is better (and necessary where truth is a requisite) to try the work with the dead centre in place of the square one.

In thus using a square centre to true work, great care should be taken not to cut the work centres too large, and this may be avoided by making the temporary centre-punch centres small, and feeding the crotch rapidly up to the work, until the latter runs true, while the square centre is fed up only sufficiently to just hold the work steady.

To test the truth of a piece of rough work, it may, if sufficiently light, be placed between the lathe centres with a light contact, and rotated by drawing the hand across it, a piece of chalk being held in the right hand sufficiently near to just touch the work, and if the chalk mark extends all round the work, the latter is as true as can be tested by so crude a test, and a more correct test may be made by a tool held in the tool rest. If the test made at various positions in the length of the work shows the work to be

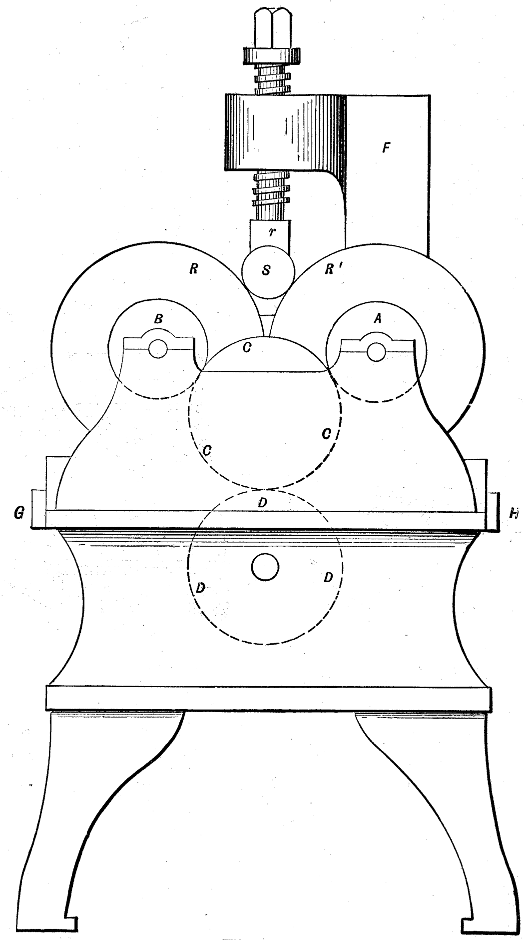


Fig. 1203.

bent enough to require straightening, such straightening may be done by a straightening lever.

In shops where large quantities of shafting are produced, there are special straightening tools or devices: thus, Figs. 1203 and 1204 represent two views of a straightening machine. The shaft to be straightened is rotated by the friction caused by its own weight as it lies between rollers, which saves the trouble of placing the shaft upon centres. Furthermore, the belt that is the prime mover of the gears driving these rollers is driven from the line shaft itself without the aid of any belt pulley. The tension of this driving belt is so adjusted that it will just drive the heaviest shaft the machine will straighten; but if the operator grasps the shaft in his hand, the driving mechanism will stop and the belt will slip, the shaft remaining stationary until the operator sets it in motion again with his hand, when the belt ceases to slip and the mechanism again acts to drive the shaft.

Fig. 1203 represents the mechanism for driving the shaft S, to be straightened, which lies upon and between two rollers, R, R'. Upon the shafts of these rollers are the gear-wheels A and B, which are in gear with wheel C, the latter being driven by gear-wheel D. Motion to D is derived from a pair of gears, the pinion of which is driven by the belt from the line shaft. H is a head carrying all these gears (and the rollers) except D. There are two of these heads, one at each end of the machine, the two wheels D being connected by a rod running between the shears, but the motion is communicated at one end only of this rod, the shaft is driven out so as to cause N, P to meet the shaft before I is operated. This is necessary to accommodate the different diameters of shaft S. The operator simply marks the rotating shaft with chalk in the usual manner to show where it is out of true, and then straightens wherever it is found necessary.

Fig. 1205 represents a similar device for straightening rods or shafts while they are in the lathe. A is a frame or box which is fitted to rest on the Vs of the lathe shears, the straightening frame resting on the box. Instead, however, of simply adjusting

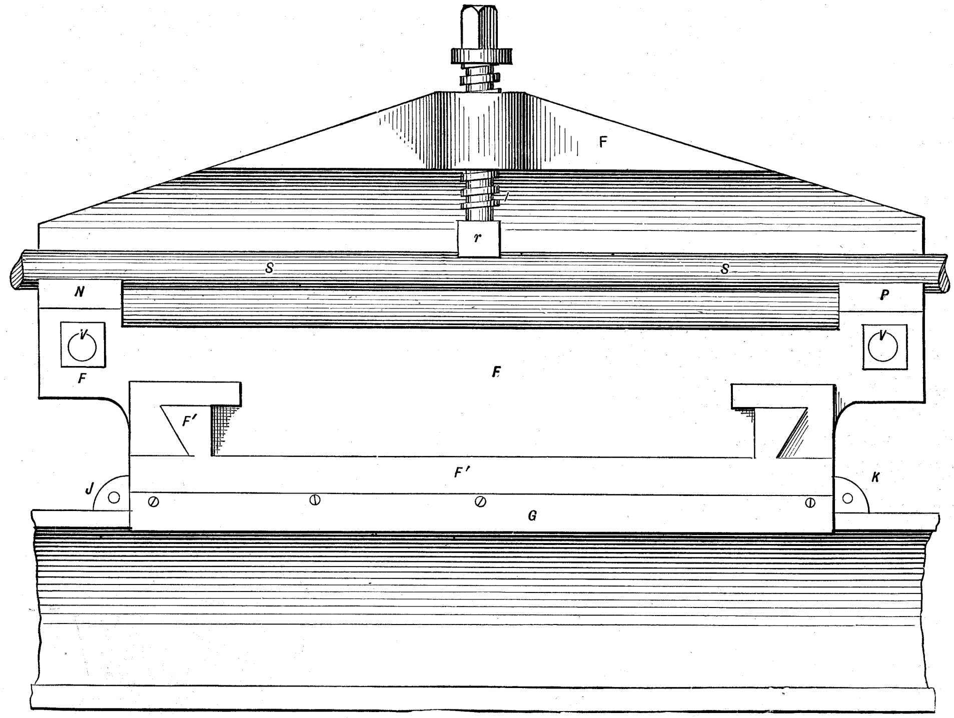


Fig. 1204.

between four rollers, of which two, R R', are shown in the engraving.

In Fig. 1204 the straightening device is shown. A frame consisting of two parts, F, F', is gibbed to the edge of the shears at G and H. The upper part of this frame carries a square-threaded screw I, and is capable of sliding across the shears upon the part F'. It rests upon the shears through the medium of four small rollers (which are encased), two of which are at J, K, and two are similarly situated at the back of the frame F'. The motion of F across the machine is provided so that the upper part F may

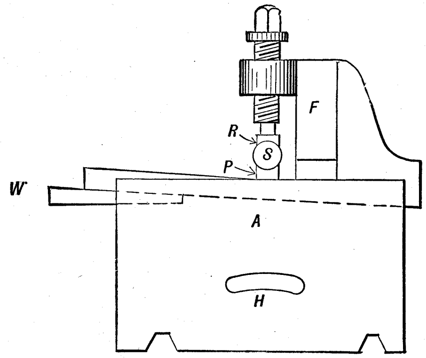


Fig. 1205.

be pushed back out of the way, to permit the shaft being easily put on and taken off the friction rollers R R'. The motion along the shears is provided to enable the straightening device to be moved to the required spot along the shaft S'. The shaft S is laid on two pieces N, P, and a similar piece r is placed above to receive the pressure of the screw I, which is operated by a hand lever to perform the straightening. The pieces N, P rest upon two square taper blocks V, which are provided with circular knobs at their outer ends to enable them to be held and pushed in or pulled

the height of the pieces P to suit different diameters of the shaft, the whole frame is adjusted by means of the wedge W, which is inserted between the frame F and the upper surface of the box A. At H is a hole to admit the operator's hand to move A along the lathe shears.

A method of straightening wire or small rods that are too rigid to be straightened by hand, and on which it is inadvisable to use hammer blows, is shown in Fig. 1206. It consists of a head revolved in a suitable machine, and having a hole passing endways through it. In the middle is a slot and through the body pass the pins A, being so located that their perimeters just press the rod or wire when it is straight, and in line with the axis of the bore through

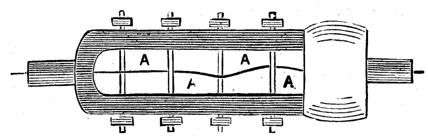


Fig. 1206.

the head, each successive pin A touching an opposite side of the wire or rod. It is obvious that these pins in revolving force out any crooks or bent places in the wire or rod, and that as the work may be pulled somewhat rapidly through the head or frame, the operation is a rapid one.

When pieces of lathe work are to be made from rod or bar iron, they should be cut off to the proper length in a cutting-off machine, such as described in special forms of the lathe, and for the reasons set forth in describing that machine.

An excellent tool, however, for cutting up rods of not more than $\frac{1}{2}$ inch in diameter, is Elliott's cutting-off tool shown in Fig. 1207. It consists of a jaw carrying steadying pieces for the rod to be cut up, these pieces being adjusted to fit the rod by the screw and nut shown. On the same jaw is pivoted a tool-holder, carrying a cutting-off tool, which is fed to its cut by the upper handle being pressed towards the lower one.

An adjustable stop or gauge is attached, by means of a small rod, to the swinging arm which carries the cutting tool, and can be removed when its use is not desirable.

The operation of this tool is as follows:—The rod to be cut up is held in the lathe chuck, projecting beyond any desired distance, and arranged to revolve at the same speed as for turning. The tool is placed upon the rod, and the movable jaw of the rest adjusted to a bearing. If several pieces are to be cut to a length, the gauge is adjusted, the tool moved along the rod till the gauge-stop comes in contact with the end, the handles pressed together, which moves the cutting tool up to the work in such a way that it will come exactly to the centre, thus cutting the piece entirely off, no adjustment of the tool ever being necessary to provide for its cutting to the centre, except keeping the cutting edge (which is not in this respect changed by grinding) at a distance specified in the directions from the part in which it is clamped. As the tool is moved up to cut, by the same operation the gauge is moved back out of contact with the end. When the pressure on the handles is removed, a spring returns the cutting tool to its original position, and also brings the gauge in position for determining the length of the next piece to be cut. The operation is repeated by simply moving the tool along the rod, the cutting up being done with great rapidity and accuracy. It will be noticed that all the appliances for cutting, gauging, &c., being a part of the tool itself, if the rod runs out of truth—in other words, wabbles—it will have no effect on the cutting, the rod to be cut forming the gauge for all the operations required; also that comparatively no time is lost in adjustment between the several pieces to be cut from a rod.

The cutting tool is a piece of steel of the proper thickness, cleared on the sides by concave grinding. It is held in place by a clamp and two small screws, and requires grinding on the end only.

When the work is centred, it should, for reasons already explained, have its end faces trued up.

In doing this, however, it is desirable in some cases to cut off the work to its exact finished length. This possesses the advantage, that when the work is finished, the work centres will be left intact, and the work may be put into the lathe at any time, and it will run true to the original centres. But this is not always the best plan; suppose, for example, that there are a number of collars or flanges on the work, then it is better to leave a little extra length to the work when truing up the ends, so that if any of the collars are scant of metal, or if it be desirable to turn off more on one side of a collar than on another, as may be necessary to turn out a faulty place in the material, the end measurements on the work may be conformed to accommodate this requirement, and not confined to an exact measurement from the end of the work.

Again, in the case of work having a taper part to be fitted, it is very difficult to obtain the exact proper fit and entrance of taper to an exact distance, hence it is best to leave the work a little too long, with its collars too thick, and to then fit the taper properly and adjust all other end measurements to suit the taper after it is fitted.

Before any one part of a piece of work turned between the lathe centres is finished to diameter, all the parts to be turned should be roughed out, and for the following reasons, which apply with additional force to work chucked instead of being turned between the lathe centres.

It is found, that all iron work changes its form if the surface metal be removed from it. Thus, though the lathe centres be true, and a piece of work be turned for half its length in the lathe, after it has been turned end for end in the lathe to turn the other half of its length, the part already turned will run out of true after the second half is turned up. This occurs from the tension and unequal internal strains which exist in the metal from its being forged or rolled at a constantly diminishing temperature, and from the fact that the surface of the metal receives the greatest amount of compression during the forging.

In castings it is caused by the unequal and internal strains set up by the unequal cooling of the casting in the mould, because of one part being thicker than another.

When the whole of the work surfaces have been cut down to nearly the finished size, this alteration will have taken place, and the finishing may be proceeded with, leaving the work as true as possible. In chucked work, or the most of it rather, it is impracticable (from being too troublesome) to rough out all over before finishing; hence at each chucking all the work to be done at that chucking is finished.

The roughing cuts on a piece of work should always be taken with as coarse a feed as possible, because the object is to remove the mass of the metal to be cut away rather than to produce a finish, and this may be most quickly done by a deep cut and coarse feed. Theoretically also the finishing should be done with a coarse feed, since the coarser the feed, the less the length of time the cutting edge is in action. But the length of cutting edge in action, with a given tool and under a given depth of cut, increases as that edge is made longer to carry the coarse feed, and the long cutting edge produces a strain that tends to spring or bend the work, and that causes the tool to dip into seams or soft spots, or into spongy or other places, where the cutting strain is reduced, and also to spring away from hard spots or seams, where the cutting strain is increased. The most desirable rate of feed, therefore, is that which is as coarse as can be used without springing either the work or the tool, and this will depend upon the rigidity of the work of the lathe, and of the cutting tool. Short or slight work may be turned very true by a light cut fine feed and quick cutting speed, but the speed must obviously be slower in proportion as the length of the work increases, because the finishing cut should be taken without taking the tool out to resharpen it, since it is very difficult to set the tool to the exact proper depth a second time.

Since the cutting edge will, at any given rate of cutting speed, retain its keenness better for a given surface of work in proportion as the time it is under duty is diminished, it follows, therefore, that the coarser the feed the better (so long as both the work and the tool are sufficiently rigid to withstand the rate of feed without springing).

Under conditions of rigidity that are sufficiently favorable a tool, such as in Fig. 948, may be used on wrought or cast iron, at

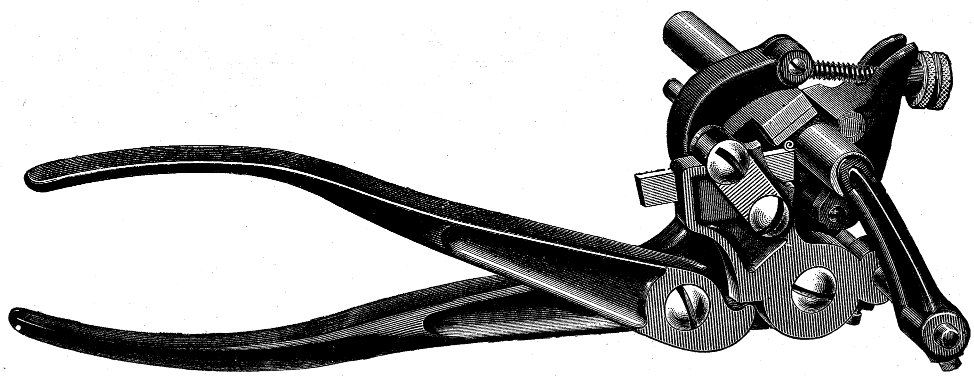


Fig. 1207.

a feed of $\frac{1}{2}$ or even $\frac{3}{8}$ inch of traverse per lathe revolution, producing true and smooth work, providing that the tool be given a very slight degree of clearance, that its cutting edge is ground quite straight, that it is set parallel to the line of feed, or what is the same thing, to the work axis, and that the length of cutting edge is greater than the amount of tool traverse per lathe revolution, as is shown in the figure, the amount of tool traverse per lathe revolution obviously being from A to B. It may also be observed that the leading corner of the tool may with advantage be very slightly rounded as shown, so that there shall be no pointed corner to dull rapidly.

In proportion as the work is light and the pressure of the cut may spring it, the feed must be lessened, so that on very slender work a feed of 100 lathe revolutions per inch of tool travel may be used. On cast-iron work the feeds may be coarser than for wrought-iron, the other conditions being equal, because cast iron cuts easier and therefore springs the work less for a given depth of cut. But since cast iron is apt to break out, exposing the pores of the metal, and thus leaving small holes plainly visible on the work surface, the finishing cut should be of very small depth, indeed a mere scrape; and if the surface is to be polished, a fine feed and a quick speed will leave a cleaner cut surface, and one that will require the least polishing operations to produce a clean and spotless surface. Brass work also is best finished with a fine feed and a quick speed.

It is obvious that the top face of the tool should be given more rake for wrought iron than for cast iron or steel, and that in the case of the very fine feeds, the form of tool shown in figure is the best for finishing these metals.

In turning a number of pieces requiring to be of the same diameter, it is to be borne in mind that a great part of the time is consumed in accurately setting the tool for the finishing cut, and that if one piece is finished at a time, this operation will require to be done separately for each piece.

It is more expeditious, therefore, to rough all the pieces out, leaving enough metal for a fine finishing cut to be taken, and then finish these pieces without moving the tool; which may be done, after the tool is once set, by letting the tool stand still at the end of the first finishing cut, and taking the work out of the lathe. The carriage is then traversed back to the dead centre, and another piece of work is put in, and it is obvious that as the cross-feed screw is not operated after the tool is once set, the work will all be turned to the same diameter without any further measuring than that necessary for the first piece.

If the tool is traversed back to the dead centre before the lathe is stopped or before the work is removed from the lathe, one of two results is liable to follow. If the lathe is left running, the tool will probably cut a spiral groove on the work, during its back traverse; or if the lathe be stopped, the tool point will mark a line along the work, and the contact of the tool point with the work will dull the cutting edge of the tool. The reason of this is as follows: When the slide rest and carriage are traversing in one direction, the resistance between the tool and the cut causes all the play in the carriage and rest, and all the spring or deflection of those parts, to be in an opposite direction. Now if the play and spring were precisely equal for both directions, the tool should cut to an equal diameter with the carriage traversed in either direction, but the carriage in feeding is fed by the feed nut or friction feed device, while when being traversed back the traversing handle is used; thus the power is applied to the carriage in the two cases at two different points, hence the spring of the parts, whether from lost motion, or play from wear, or from deflection, is variable. Again, even with the tool fed both to its cut and on the back traverse with the hand feed handle, the play is, from the altered direction of resistance of the cut, reversed in direction, and the depth of cut is therefore altered.

Thus, in Fig. 1208, let S S represent the cross slide on the carriage and R R the cross slide of the tool rest shown in section, and suppose the tool to be traversing towards the live centre, then to whatever amount there may be play or spring between the slide and the slide way, the slide will from the pressure of the cut twist over, bearing against the slide way at A and B, and being clear of it at G and H. On reversing the direction of traverse of the rest, so as to feed the tool towards the dead centre, the exactly opposite condition will set in, that is, the pressure of the cut will force the slides in the opposite direction, or in other words, the contact will be as in Fig. 1029, at C, D, and the play at E, F. During the change of location of bearing between the slides and the way, there will have been a certain amount of tool motion altering the distance of the tool point from the line of centres, and therefore the diameter to which it will cut. The angle at which the body of the tool stands will influence the effect: thus, if when traversing towards the live centre the tool stands at an angle pointing towards the live centre, it would recede and cause the tool to clear the cut, if removed on the back traverse without being moved to or from the line of centres. Conversely, if the body of the tool was at an angle, so that it pointed towards the dead centre, and a cut was taken towards the live centre, and the tool was traversed back without being moved in or out, it would take another cut while being moved back.

The conditions, however, are so uncertain, that it is always advisable to be on the safe side, and either wind the tool out from its cut before winding the rest and carriage back (thus destroying its set for diameter), or else to stop the lathe and remove the work before traversing the carriage back as already directed. If the latter plan is followed the trouble of setting the tool is avoided and much time is saved, while greater accuracy of work diameter is obtained. It is obvious that this plan may be adopted for roughing cuts in cases where two cuts only are to be taken, so as to leave finishing cuts of equal depths; or if three cuts are to be taken, it may advantageously be followed for the second and last cuts, the depth of the first cut being of less importance in this case.

The following rules apply to all tools and metals:

When the pressure between the tool and the work is sufficient, from the proportions of the work, to cause the work to spring or bend, the length of acting cutting edge on the tool should be reduced.

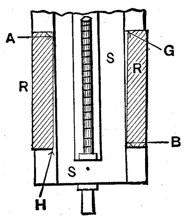


Fig. 1208.

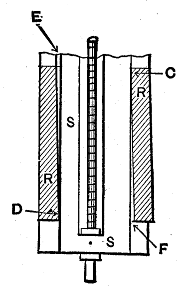


Fig. 1209.

As the diameter and rigidity of the work increases, the length of tool cutting edge may increase. The cutting edge of the tool should be kept as close as the work will conveniently admit to the slide rest tool post, $\frac{1}{4}$ *inch even* of this distance being *important.*

The slide rest tool should always be resharpened to take the finishing cut, with which, for wrought iron or steel, soapy water with soda in it should be used, the soda serving to prevent the dripping water from rusting the parts of the lathe.

Cast iron will cut with an exquisite polish if finished at a *very slow* rate of cutting speed, and turned with a spring tool, such as was shown in Fig. 974, and water is used. But being a slow process it is not usual to finish it in this manner, though for round corners, curves, &c., this method is highly advantageous.

For cast iron the tool should be as keen as the hardness of the metal of the work will permit. If an insufficiently keen tool, or too deep a cut, or too coarse a feed be taken, the metal will break out instead of cutting clean, and numerous fine holes will be perceived over the whole surface, impairing that dead flatness which is necessary to an even and fine polish.

To remove these specks or holes in cylindrical work, the file may be used, but for radial faces hand-scrapers, such as shown in Fig. 1295, are used, the work rotating in either case at high speed. Such scrapers are oilstoned and held with the handle end above the horizontal level.

The *rest* should be so conformed to suit the shape of the work, that the scraper will be supported close to the work, which will prevent chattering, and a piece of leather should (as a further preventive of chattering) be placed beneath the scraper. A very good method of using a scraper is to adjust it to the work, and holding it still on the rest, traverse the slide rest to move the scraper to its cut.

After the scraping, three methods of polishing radial faces are commonly employed; the first is to use emery paper only, and the second is by the use first of grain, emery, and oil, and the subsequent use of emery paper or cloth, and the third is by the use of emery wheels and crocus cloth.

If the work is finished by emery paper only, and it requires much application of the same to efface the scraper marks, the evil will be induced that the emery cuts out the metal most where it is most porous, so that the finished surface is composed of minute hills and hollows, and the polish, though bright and free from marks, will not have that dead flat smooth appearance necessary to a really fine polish and finish; indeed, the finish is in this case to some extent sacrificed to obtain the polish.

It is for this reason that stoning the work (as hereafter described) is resorted to, and that grain emery and lead is employed, which is done as follows:—

For a flat radial face, a flat piece of lead, say $\frac{3}{8}$ inch thick, and of a size to suit the work, may be pivoted to the end of a piece of wood of convenient length and used with grain emery and oil, the work rotating quickly. To afford a fulcrum for the piece of wood, a lever or rest of some kind, as either a hand rest or a piece fastened in the tool post, is used.

The rest should be placed a short distance from the work surface and the lever held partly vertical until the lead meets the work surface, when depressing the lever end will force the lead against the work. The lever end must be quickly moved laterally, so that the lead will approach and then recede from the work centre; this is necessary for two reasons. First, to prevent the emery from cutting rings in the work surface, and secondly, to prevent the formation of grooves behind any hollow spots or specks the work may contain. The reason of the formation of these grooves is that the emery lodges in them and works out from the contact of the lead, so that if on working out they move always in the same line they cut grooves.

When a lathe is provided with belt motion to run both ways, it is an excellent plan to apply the lead with the lathe running forward and then with it running backward.

When by this means the scraper marks are removed, the next object is to let the marks left by the lead be as fine and smooth as possible, for which purpose flour emery should be used; but towards the last no emery, but oil only, should be applied, the lead being kept in constant lateral motion, first quickly and then slowly, so that the marks on the work cross and recross it at different angles.

For round or hollow corners the lead need not be pivoted to the stick, but should be spherical at the end, the marks being made to cross by partly rotating the lever first in one direction and then in the other.

Sometimes the end of the lever is used without the addition of lead, but this does not produce so flat a surface, as it cuts out hollows in the pores of the metal.

For polishing to be done entirely in the lathe, emery paper and crocus may follow the lead, being used dry and kept also in constant lateral motion. Each successive grade of emery paper must entirely remove all marks existing on the work at the time of its (the paper's) first application, and, furthermore, each successive grade should be continued until it is well worn, because of two pieces of emery paper of the same grade that most worn will cut the smoothest and polish the best. For the final polishing a piece of the finest emery paper should be prepared in the manner hereafter described for polishing plain cylindrical surfaces.

The radial faces of wrought iron must be finished as smoothly and true as possible, because being harder than cast iron the emery acts less rapidly upon it. For radial faces on brass the surfaces should be finished as smooth as possible with the slide rest tool, which should be round nosed, with the round flattened somewhat where the tool cuts, and the tool should not, under any condition, have any rake on its top face, while the feed should be fine as, say, 32 revolutions per inch of tool travel. Under skillful manipulation scraping may then be dispensed with, although it may be used to a slight extent without impairing the truth.

Very small radial surfaces of brass may best be finished by the scraper and polished with emery paper, while large ones may be finished with dry emery paper.

Round corners on brass work should be finished with a spring tool, such as shown in Fig. 974, but having negative top rake; but if the corners are of small radius a well oilstoned hand-scraper is best.

To enable the smooth and true turning of all radial faces of large diameter, the lathe head should, when it is possible, be steadied for end motion by placing a rod between the lathe centres, but if the radial face is solid at the centre so that such a rod cannot be put in, the end motion adjusting device of the lathe should be adjusted. The slides of the lathe should also be set up to have good firm contact, and the tool should be brought up to the work by putting the feed motion in gear and operating it by hand at the cone pulley, or gear-wheel on the feed spindle. If the lathe has no compound rest, the cut should be put on by this means, but otherwise the tool may be brought near the work by the feed motion and the cut put on by the compound rest, the object in both cases being to take up all lost motion and hold the rest firmly or steadily on the lathe shears, so that it shall not move back as the cut proceeds.

Work of cast iron or brass and of small dimensions and irregular or curved outline should be finished with scraping tools, such as shown in Figs. 1303 and 1310, polished with emery cloth or paper. But whenever scrapers are made with curves to suit the form of the work, such tool curves should be so formed (for all metals) as not to cut along the whole length of cutting edge at once, unless the curve be of very small length as, say, $\frac{1}{4}$ inch. This is necessary, because if the cutting edge operates on too great a length it will jar or chatter.

For convex surfaces the curve on the scraper should be of greater radius than that of the work, while in the case of concave curves the tool should have a less radius. In both cases the tool will require a lateral movement to cause it to operate over the full width of work curve.

If the work curves are sufficiently large, and the same is sufficiently rigid that a slide rest tool may be used, the length of cutting edge may be increased, so that under very favorable conditions of rigidity the tool edge may cut along its whole length without inducing either jarring or chattering, but the best results will always be obtained when with a broad cutting edge the tool is of the spring tool form shown in Fig. 974.

Work of wrought iron or steel of small dimensions and of irregular form, must also be finished by hand tools, such as the graver shown in Figs. 1285 and 1286, and the finishing tool shown in Figs. 1289 and 1292, the shape of the tool varying to suit the shape of the work.

Round corners or sweeps cannot on any kind of work be finished by a file, because the latter is apt to pin and cut scratches in the work.

For the final tool finishing of lathe work of plain cylindrical outline, no tool equals the flat file if it be used under proper conditions, which are, that the work be turned true and smooth with slide rest tools, the marks left by these tools being exceedingly shallow and smooth.

A dead smooth file that has been used enough to wear down the projecting teeth (which would cut scratches) should then be used, the work rotating at as fast a speed as the file teeth will stand without undue wear. The file strokes should be made under a light pressure, which will prevent the cuttings from clogging its teeth, and the cuttings should be cleaned from the file after every few strokes. Under these conditions work of moderate diameter may be turned to the greatest degree of smoothness and truth attainable with steel cutting tools, providing that the work makes several revolutions during each file stroke, and it therefore follows that the file strokes may be more rapid as the diameter of the work decreases, and should be more slow as that diameter increases. Allowing the greatest speed of the filed surface permissible, without too rapid destruction of the file teeth, to be 200 feet per minute, and the slowest speed of file stroke that will prevent the file teeth from being ground away or from becoming pinned (when used on wrought iron) to be one stroke in two seconds, the greatest diameter of work that can be finished by filing under the condition that the work must make more than one rotation per file stroke, is about 25 inches in diameter, running about 30 revolutions per minute. The same diameter and speed may be also taken for cast iron, but brass may be filed under increased speed, rendering it practicable to file it up to a diameter of about 36 inches under the above conditions of work rotation and file stroke speed.

Supposing, however, that from hardness of the metal or from its increased diameter the work cannot make a rotation per file stroke unless that stroke be more slowly performed, then the cuttings gather in the teeth of the file, become locked and form projections, termed pins, above the file teeth, and these projections cut scratches in the work, and this it is that renders it impracticable to hold the file still while the work rotates. But suppose the file be applied to work of such a diameter that, with a stroke in two seconds and the work surface rotating at 200 feet per minute, each stroke acts on a fraction of the circumference only, then there can be no assurance that the filed surface will be cylindrical, because there is no means of applying the file equally over the whole surface. But it is to be noted, nevertheless, that the file acts with greater effect in proportion as the area filed is decreased, and that as the tool marks are filed out the area of surface operated upon is increased. Suppose, then, that starting from any point on the work circumference a file stroke be taken, and that it extends around one-third of the circumference, that the second file stroke extends around one-third also, but that there is an unfiled space of, say, two inches between the area of surface filed by these two strokes, and that at the third file stroke the file starts on the surface filed at the first stroke, passes over the two inches previously unfiled and terminates on the surface filed by the second stroke; then the conditions will be as follows:—

Part of the surface filed at the first stroke will have been filed twice, part of the surface filed at the second stroke will also have been filed twice, while the two inches will have been filed once only. But this latter part will have had much more taken off it during the third stroke than did the rest of the surface filed at that stroke, because it operated on the ridges or tool marks where, being unfiled, their area in contact with the file teeth was at a minimum. This condition will prevail until the tool marks are effaced, and tends to preserve the truth of the work up to that point, hence the necessity of leaving very fine tool marks becomes obvious.

Apart from these considerations, however, there is the fact that filing work in the lathe is a very slow operation, and therefore inapplicable to large work; and furthermore, on large work the surface is not needed to be so smooth as in small work; for example, tool feed marks $\frac{1}{1000}$ inch deep would upon work of $\frac{1}{2}$ inch diameter leave a surface appearing very uneven, and the wearing away of those ridges or marks would destroy the fit of the piece; but in a piece, say, six feet in diameter, tool marks of that depth would not appear to much disadvantage, and their wearing away would have but little effect upon the fit of the piece.

Finishing with the file, therefore, is usually applied to work of about 24 inches in diameter, and less, larger work being finished with the cutting tool or by emery grinding, where a greater degree of finish is required.

Small work—as, say, of six inches, or less, in diameter—may be finished with the file so cylindrically true, that no error can be discovered by measurement with measuring tools of the calipering class, though the marks of contact if made apparent by gently forcing the work through a closely fitting ring-gauge may not appear to entirely cover the surface.

To produce filed work thus true, all that is necessary is to set the cutting edge of the finishing tool at the horizontal centre of the work, properly adjust the live spindle of the lathe for fit to its bearings, adjust the slides of the slide rest so that there is no lost motion, and follow the rules already given with reference to the shape of the tool cutting edge, employing a cutting speed not so fast as to dull the tool before it has finished its cut, using a fine feed except in the case of cast iron, as already explained.

The requirement that the tool shall not become dull before it has finished its cut, brings us to the fact that the length of work that can be thus accurately turned is limited, as the diameter of the work increases.

Indeed, the length of the work in proportion to its diameter is a very important element. Thus, it would be very difficult indeed to turn up a spindle of an inch in diameter and, say, 14 feet long, and finish it cylindrically true, parallel, and smooth, because

1st. The slightness of the work would cause it to spring or deflect from the pressure or strain due to the cut. This may to some extent be remedied by steadying the work in a follower rest, but the bore of such follower itself wears as the cut proceeds, though the amount may be so small as to be almost inappreciable.

2nd. The work being better supported (by the lathe centres) at the two ends than in the middle of its length, the duty placed on the follower rest will increase as the middle of the work length is approached, hence the spring or deflection of the follower rest will be a disturbing element.

3rd. The tool gets duller as the cut proceeds, causing more strain from the cut, and, therefore, placing more strain on the follower rest; and,

4th. It would be necessary, on account of the length of the cut, to resharpen the tool before the cut was carried from end to end of the spindle, and it would be almost impracticable to set the reground tool to cut to the exact diameter.

The second, third, and fourth of the above reasons operate together in causing increased work spring as the tool approaches the middle of the work length; thus the deflection of the follower rest, the increased weakness of the work, and the comparative dullness of the tool would all operate to cause the work to gradually increase in diameter as the cut proceeded towards the work centre (of length).

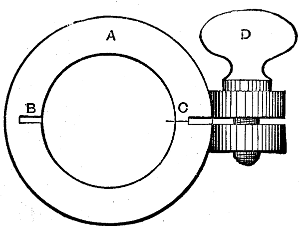
Suppose, for example, a cut to have been carried from the dead centre, say, five feet along the work; at the end of this five feet the tool will be at its dullest, the shaft at its weakest, and supported the least from the dead centre and follower rest.

Suppose, then, that the reground tool be placed in the rest again and set to just meet the turned surface without cutting it, then when it meets the cut to carry it farther along the work the cut will produce (on account of the tool being sharper) less strain on the work, which will therefore spring or deflect less. Precisely what effect this may have upon the diameter to which the tool will turn the work will depend upon various conditions: thus, if the top face of the tool be sufficiently keen to cause the strain due to bending the shaving cut or chip to pull the work forward, the tool would turn to a smaller diameter. If the depth of the cut be sufficient to cause the work to endeavor to lift, and the tool edge be above the centre of the work, it would be cut to smaller diameter. If the tool cutting edge were below the centre, or if its top face be at an angle tending to force the work away from the tool point, the diameter of the work would be increased.

From these considerations it is obvious that the finishing cut should be started at the centre of the work length, and carried towards the lathe centres, because in this case the tool will be sharpest, and therefore will produce less tensional strain on the work at the point where the latter is the weakest, while the resisting strength of the work would increase as the cut proceeded, and the tool became dull from use. Furthermore, if it were necessary to regrind the tool, it would be reset nearer to the lathe centres, where the work would be more rigidly held; hence the tool could be more accurately set to the diameter of the finishing cut.

By following this plan, however, it becomes necessary to have the shaft as near true and parallel as possible before taking the finishing cut, for the following reasons:—

Let the diameter of the spindle before the finishing cut be $1\frac{1}{32}$ inches, leaving $\frac{1}{32}$ inch to be taken off at the finishing cut, then the ring in the follower rest must be at starting that cut $1\frac{1}{32}$ inch bore, and if the rest is to follow the cut the bush must be changed (so soon as it meets the finishing cut) to one of an inch bore. But if the spindle be turned as true and parallel as possible before the finishing cut the rest may lead the tool, in which case the bush need not be changed. There are differences of opinion as to the desirability of either changing the bush or letting the tool follow the rest, but there can be no dispute that (from the considerations already given) a spindle turned as true and parallel as may be with the tool started from the dead centre and carried forward can be improved by carrying yet another cut from the middle towards the dead centre. In any event, however, work liable to spring or too long to be finished at one cut without



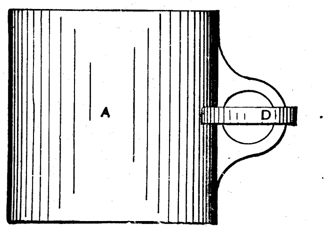


Fig. 1210.

removing the tool to grind it, can be more accurately finished by grinding in a lathe, such as was shown in Figs. 676 or 679, than by steel-cutting tools, and for the following reasons :—

If it be attempted with steel tools to take a very fine cut, as, say, one of sufficient depth to reduce a diameter, say $\frac{1}{500}$ inch, the tool is apt to turn an uneven surface. There appears, indeed, to be a necessity to have the cut produce sufficient strain to bring the bearing surfaces of the rest into close contact and to place a slight strain on the tool, because under very light cuts, such as named above, the tool will generally momentarily leave the cut or take a reduced cut, and subsequently an increased one.

It may be accepted that from these causes a finishing cut taken with a steel tool should not be less than that sufficient to reduce the diameter of the work $\frac{1}{64}$ inch. Now an emery-wheel will take a cut whose fineness is simply limited by the wear of the wheel in the length of the cut. Some experiments made by Messrs. J. Morton Poole and Sons, of Wilmington, Delaware, upon this subject led to the conclusion that with corundum wheels of the best quality the cut could be made so fine that a 12-inch wheel used upon a piece of work (a calender roll) 16 inches in diameter and 6 feet long, would require about forty thousand traverses to reduce the diameter of the work an inch, leading to the conclusion that the wear of the wheel diameter was less than one eighty-thousandth part of an inch per traverse.

Now the strain placed upon the work of an emery-wheel taking a cut of, say, $\frac{1}{1000}$ inch, is infinitely less than that caused by a cutting tool taking a cut of $\frac{1}{120}$ inch in diameter; hence the accuracy of grinding consists as much in the small amount of strain and, therefore, of deflection it places upon the work, as upon the endurance of the wheel itself.

Since both in finishing and in polishing a piece of work the object is to obtain as true and smooth a surface as possible, the processes are to a certain extent similar, but there is this difference between the two : where polishing alone is to be done, the truth of the work or refined truth in its cylindrical form or parallelism may be made subservient to the convenience of polish. Thus, in the case of the stem of the connecting rod that has been turned and filed and finished as true as possible, the polishing processes may be continued with emery-cloth, &c., producing the finest of polish without impairing the quality of the work, whereas the degree of error in straightness or parallelism induced by the polishing may impair the degree of truth desirable for a piston rod.

The degree of finish or polish for any piece of work is, therefore, governed to some extent by the nature of its use. Thus a piston rod may be finished and polished to the maximum degree consistent with maintaining its parallelism and truth, while a connecting rod stem may be polished to any required attainable degree.

In finishing for truth, as in the case of journal bearings, the work, being turned as true and smooth as possible, may be filed with the finest of cut files, and polished with a fine grade of emery-cloth or paper; the amount of metal removed by filing and polishing being so small as not to impair to any practically important degree the truth of the work : a journal so finished will be as true as it is possible to make it without the use of a grinding lathe.

Instead of using emery-paper, grain emery and oil may be used, but the work will not be so true, because in this case much more metal will be removed from the work in the finishing or polishing process.

When it is required to polish and to keep the work as true and parallel as possible, these ends may be simultaneously obtained by means of clamps, such as shown in Fig. 1210, which represents a form of grinding and polishing clamp used by the Pratt and Whitney Company for grinding their standard cylindrical gauges. A cast-iron cylindrical body A is split partly through at B and entirely through at C, being closed by the screw D to take up the wear. The split B not only weakens the body A and enables its easy closure, but it affords ingress to the grinding material. It may be noted that cast iron is the best metal that can be used for this purpose, not only on account of the dead smooth surface it will take, but also because its porosity enables it to carry the oil better than a closer grained metal. For work of larger diameter, as, say, 2 or 3 inches, the form of lap shown in Fig. 1211 is used for external grinding, there being a hinge B C instead of a split, and handles are added to permit the holding and moving of the lap. The bore of this clamp is sometimes recessed and filled with lead. It is then reamed out to fit the work and used with emery and oil, the lathe running at about 300 feet per minute.

For grinding and polishing the bores of pieces, many different forms of expanding grinding mandrels have been devised, in most of which the mandrel has been given a slight degree of curvature in its length ; or in other words, the diameter is slightly increased as the middle of the mandrel length is approached from either end. But with this curvature of outline, as small as it may be, it rather

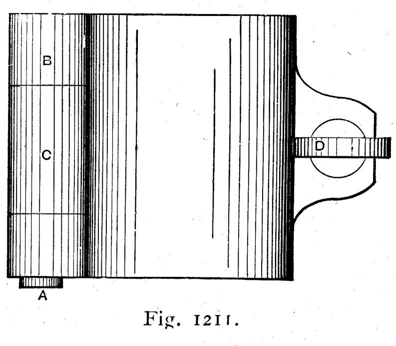


Fig. 1211.

increases the difficulty of grinding a bore parallel instead of diminishing it. When expanding mandrels are caused to expand by a wedge acting upon split sections of the mandrel, they rarely expand evenly and do not maintain a true cylindrical form.

Fig. 1212 represents a superior form of expanding mandrel for this purpose. The length A is taper and contains a flute C. The lead is cast on and turned upon the mandrel, the metal in the flute C driving the lead. The diameter of the lap is increased by driving the taper mandrel through it, and the lead is therefore maintained cylindrically true.

While these appliances are supplied with the flour emery and oil, their action is to grind rather than to polish, but as they are used without the addition of emery, the action becomes more a polishing one.

Fig. 1213 represents at A A a wooden clamp for rough polishing with emery and oil. It consists of two arms hinged by leather at B and having circular recesses, as C, D, to receive the work. At J J is represented a similar grinding and polishing clamp for more accurate work. G and H are screws passing through the top arm and threaded into the lower, while E, F are threaded into the lower arm, and abut at their ends against the face of the upper arm. It is obvious that by means of these screws the clamp may be set to size, adjusted to give the required degree of pressure, and held firmly together. Lead bushes may be inserted in the bores as grinding laps. As this clamp is used by hand,

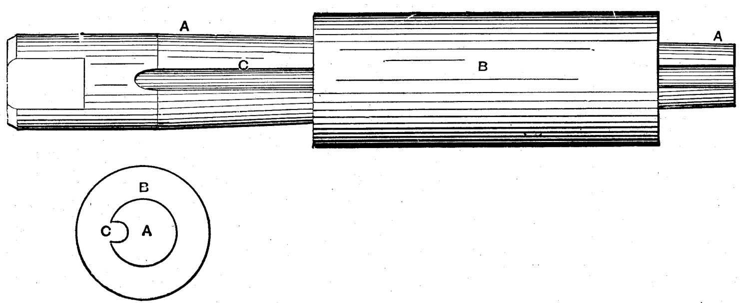


Fig. 1212.

it must be moved along the work at an exactly even speed of traverse, or else it will operate on the work for a longer period of time at some parts than at others; hence the greatest care is necessary in its use.

The best method of polishing cylindrical work to be operated on entirely in the lathe, the primary object being the polish, is by means of emery paper, and as follows :—

In all polishing the lathe should run at a fast speed; hence special high speeded lathes, termed speed lathes, are provided for polishing purposes only.

The emery paper or cloth should be of a fine grade, which is all that is necessary if the work has been properly filed, if cylindrical, and scraped if radial or of curved outline.

In determining whether emery paper or cloth should be used, the following is pertinent :—

The same grade of emery cuts more freely on cloth than on paper, because the surface of the cloth is more uneven; hence the emery grains project in places, causing them to cut more freely until worn down. If, then, the surface is narrow, so that there is no opportunity to move the emery cloth endways on the work, emery paper should be used. It should be wrapped closely (with not more than one, or at least two folds) around a *smooth* file, and not a coarse one, whose teeth would press the emery to the work at the points of its coarse teeth only. The file should be given short, rapid, light strokes.

For work of curved outline emery cloth should be used, because it will bend without cracking, and the cloth should be moved quickly backwards and forwards across, and not round, the curve; and when the work is long enough to permit it, the emery paper or cloth should be moved rapidly backwards and forwards along the work so that its marks cross and recross at an obtuse angle.

Now, suppose the grade of emery paper first used to be flour emery, and the final polish is to be of the highest order, then 0000 French emery paper will be required to finish, and it is to be observed that nothing will polish a metal so exquisitely as an impalpable powder of the metal itself: hence, while performing the earlier stages of polishing, it is well to prepare the final finishing piece, so as to give it a glaze of metal from the work surface.

When, therefore, all the file marks are removed by the use of the flour emery cloth, the surface of the work should be slightly oiled and then wiped, so as not to appear oily and yet not quite dry, with a piece of rag or waste, then the piece of 0000 emery paper, or, what is equally as good, a piece of crocus cloth, to be used for the final finishing should be applied to the work, and the slightly oily surface will cause the cuttings to clog and fill the crocus cloth. The cloth should be frequently changed in position so as to bring all parts of its surface in contact with the work and wear down all projections on the cloth as well as filling it with fine cuttings from the work. Then a finer grade, as, say, No. 0 French emery paper, must be used, moving it rapidly endwise of the work, as before, and using it until all the marks left by the flour emery have been removed.

One, or at most two drops of lard oil should then be put on the work, and spread over as far as it will extend with the palm of the hand, when the finishing crocus may again be applied and reversed as before in every direction; 00 emery paper may then be used until all the marks of the 0 are removed, and with the work left quite dry the crocus for final finishing may again be applied; 000 emery paper may then be used to efface all the marks left by the 00. This 000 emery paper should be used until it is very much worn, the final finish being laid with the glazed crocus.

If this crocus has been properly prepared, its whole surface will be covered with a film of fine particles of metal, so that if the metal be brass the crocus surface will appear like gold leaf. If cast iron, the crocus surface will appear as though polished with plumbago or blacklead, while in any case the crocus surface will be polished and quite dry. The crocus should be pressed lightly to the work, so that its polishing marks will not be visible to the naked eye.

If emery paper be applied to work finished to exact diameter it should be borne in mind that the process reduces to some extent the size of the work, and that the amount under proper conditions though small is yet of importance, where preciseness of diameter is a requisite.

In the practice, however, of some of the best machine shops of the United States, the lathe alone is not relied upon to produce the best of polish. Thus, in the engine works of Charles H. Brown, of Fitchburg, Massachusetts, whose engines are unsurpassed for finish and polish, and which the majority of mechanics would suppose were finely silver plated, the following is the process adopted for polishing connecting rods.

The rod is carefully tool-finished with a fine feed. The tool marks are then erased with a fine smooth file, and these file marks by a dead-smooth file, the work rotating at a quick speed, little metal being left, so as to file as little as possible. Next comes *fine* emery cloth to smooth down and remove the file marks. The lathe is then stopped and the rod stoned lengthwise with Hindostan stone and benzine, removing all streaks. The Scotch stone used with water follows, until the surface is without scratches or marks, as near perfect as possible. The next process is, for the

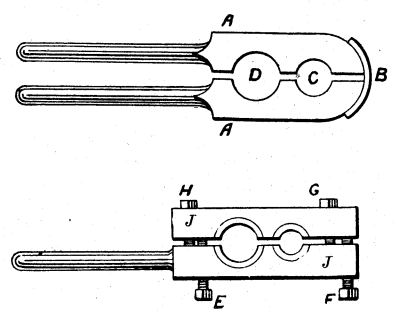


Fig. 1213.

finest work, the burnisher used by hand. But if not quite so exquisite a polish is required, the rod is finished by the use of three grades of emery cloth, the last being very fine.

Sometimes, however, the streaks made by polishing with emery paper used before the application of the stones are too difficult to remove by them. In this case, for a very fine finish, the lathe is stopped and draw-filing with the finest of files is performed, removing all streaks; and the stones then follow the draw-filing. All stoning is done by hand with the work at rest, as is also all burnishing.

After the burnisher comes fine imported crocus cloth, well worn, which makes the surface more even and dead than that left by the burnisher. The crocus is used with the lathe at its quickest speed, and is moved as slowly and as evenly as possible, the slower and more even the crocus movement along the rod, the more even the finish. If the rod has filleted corners, such corners are in all cases draw-filed before the stoning.

The method of polishing a cylinder cover at the Brown Engine Works is as follows.

The finishing cut is taken with a feed of 32 lathe-revolutions per inch of tool traverse, and at as quick a cutting speed as the hardness of the iron will permit. This is necessary in order to have the tool-edge cut the metal without breaking it out as a coarse one would do. With the fine feed and quick speed the

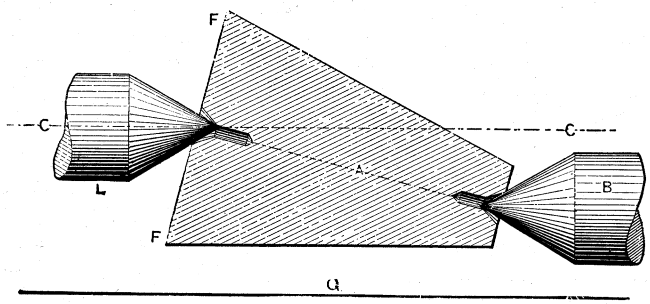


Fig. 1214.

pores of the iron do not show; with a coarse feed the pores show very plainly and are exposed for quite a depth.

After the lathe-tool comes a well oil-stoned hand-scraper, with a piece of leather between it and the tool rest to prevent the scraper from chattering. The scraper not only smoothes the surface, but it cuts without opening the pores. It is used at a quick speed, as quick indeed as it will stand, which varies with the hardness of the metal, but is always greater than is possible with a slide-rest tool.

After the scraper the cover is removed from the lathe, and all flat surfaces are filed as level as possible with a second-cut file, and then stoned with soft Hindostan stone, used with benzine or turpentine, so as to wash away the cuttings and prevent them from clogging the stone or forming scratches. In using all stones the direction of motion is frequently reversed so as to level the surface. Next comes stoning with Scotch stone (Water of Ayr), used with water; in this part of the operation great care must be taken, otherwise the cuttings will induce scratches. When the Scotch stone marks have removed all those left by the Hindostan stone, and left the surface as smooth as possible, the cover is again put in the lathe and the grain is laid and finished with very fine emery cloth and oil. The emery cloth is pressed lightly to the work and allowed to become well worn so as to obtain a fine lustre without leaving any streaks.

It will be noticed here that the use of the emery stick and oil is entirely dispensed with; but for a less fine polish it may be used,

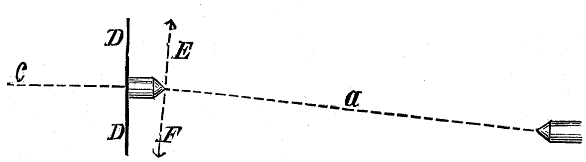


Fig. 1215.

providing it be kept in quick motion radially on the work. The objection to its use is that if there be any speck on the work it is apt to cut a streak or groove following the spot like a comet's tail.

TURNING TAPERS.—There are five methods of turning outside tapers; 1st, by setting over the tailstock of the lathe; 2nd, by the use of a former or taper turning attachment such as was shown in Fig. 508; 3rd, by the use of a compound slide rest; 4th, by means of a lathe in which the head and tailstock are upon a bed that can be set at an angle to the lathe shears on which the lathe carriage slides; and 5th, by causing the cross-feed screw to operate simultaneously with the feed traverse.

Referring to the first method, it is objectionable, inasmuch as that the work axis is thrown at an angle to the axis of the lathe centres, which causes the work centres to wear rapidly, and this often induces them to move their positions and throw the work out of true. Furthermore, the tailstock has to be moved back in line with the live spindle axis for turning parallel again, and this is a troublesome matter, especially when the work is long.

Fig. 1214 shows the manner in which the lathe centres and the work centres have contact, L being the live and B the dead centre; hence C C is the axis of the live spindle which is parallel to the lathe shear slides, which are represented by G; obviously A is the work axis. The wear is greatest at the dead centre end of the work, but there is some wear at the live centre end, because there is at that end also a certain amount of motion of the work centre upon the live centre. Thus, in Fig. 1215, let *c* represent the live centre axis, *a* the work axis, D the lathe face plate, and E F the plane of the driver or dog upon the work, and it is obvious that the tail of the driver will when at one part of the lathe revolution stand at E, while when diametrically opposite it will stand at F; hence, during each work revolution the driver moves, first towards and then away from the face plate D, and care must be taken in adjusting the

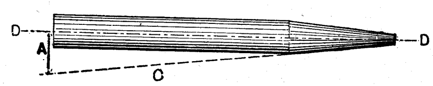


Fig. 1216.

position of the driver to see that it has liberty to move in this direction, for if obstructed in its motion it will spring or bend the work.

To determine how much the tailstock of a lathe must be set over to turn a given taper, the construction shown in Fig. 1216 may be employed. Draw the outline of the work and mark its axis D, draw line C parallel to one side of the taper end, and the distance A between this line and the work axis is the amount the tailstock requires to be set over. This construction is proved in Fig. 1217, in which the piece of work is shown set over, C representing the line of the lathe ways, with which the side F of the taper must be parallel. D is the line of the live spindle, and E that of the work, and the distance B will be found the same as distance A in Fig. 1216.

It may be remarked, however, that in setting the tailstock over it is the point of the dead centre when set adjusted to the work length that must be measured, and not the tailblock itself.

Other methods of setting tailstocks for taper turning are as follows: If a new piece is to be made from an old one, or a

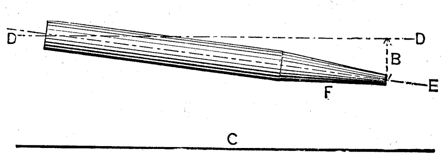


Fig. 1217.

duplicate of a piece of work is to be turned, the one already turned, or the old piece as the case may be, may be put in the lathe and we may put a tool in the tool post and set the tailstock over until the tool traversed along the work (the latter remaining stationary) will touch the taper surface from end to end.

If, however, the taper is given as so much per foot, the distance to set the tailstock over can be readily calculated.

Thus, suppose a piece of work has a taper part, having a taper of an inch per foot, the work being three feet long, then there would be three inches of taper in the whole length of the piece and the tailstock requires to be set over one-half of the three inches, or $1\frac{1}{2}$ inches. It will not matter how long the taper part of the work is, nor in what part of the work it is, the rule will be found correct so long as the tailstock is set over one-half the amount obtained by multiplying the full length of the work per foot by the amount of taper per foot.

If we have no pattern we may turn at each end of the part that is to be taper a short parallel place, truing it up and leaving it larger to the same amount at each end than the finished size, and taking care that the parallel part at the small end will all turn out in the finishing. We then fasten a tool in the lathe tool post, place it so that it will clear the metal of the part requiring to be turned taper, and placing it at one extreme end of said part, we take a wedge, or a piece of metal sufficiently thick, and place it to just contact with the turned part of the work and the tool point (adjusting the tool with the cross-feed screw), we then wind the rest to the other end of the required taper part, and inserting same wedge or piece of iron, gauge the distance from the tool point to the work, it being obvious that when the tool point wound along is found to stand at an equal distance from each end of the turned part, the lathe is set to the requisite taper.

Figs. 1218 and 1219 illustrate this method of setting. A represents a piece of work requiring to be turned taper from B to C, and turned down to within $\frac{1}{32}$ inch of the required size at E and F. If then we place the tool point H first at one end and then at the other, and insert the piece I and adjust the lathe so that the piece of metal I will just fit between the tool point and the work

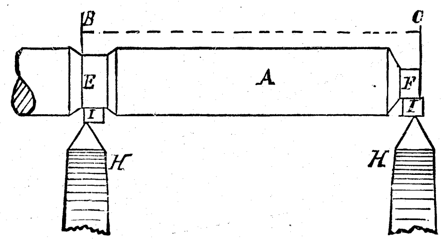


Fig. 1218.

at each extreme end of the required taper part, the lathe will be set to the requisite taper as near as practicable without trying the work to the taper hole. The parallel part at the small end of the work should be turned as true as possible, or the marks may not be obliterated in finishing the work.

Fig. 1220 (from *The American Machinist*) represents a gauge for setting the tailstock over for a taper. A groove is cut as at E and D, these diameters corresponding to the required taper; a holder A is then put in the tool point, and to this holder is pivoted the gauge B. The tailstock is set over until the point of B will just touch the bottom of the groove at each end of the work.

To try a taper into its place, we either make a chalked stripe along it from end to end, smoothing the chalked surface with the finger, or else apply red marking to it, and then while pressing it firmly into its place, revolve it backwards and forwards, holding it the while firmly to its seat in the hole; we move the longest outwardly projecting end up and down and sideways, carefully noting at which end of the taper there is the most movement. The amount of such movement will denote how far the taper is from fitting the hole, while the end having the least movement will

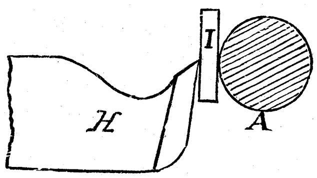


Fig. 1219.

require to have the most taken off it, because the fulcrum off which the movement takes place is the highest part, and hence requires the greatest amount of metal to be taken off.

Having fitted a taper as nearly as possible with the lathe tool, that is to say, so nearly that we cannot find any movement or unequal movement at the ends of the taper (for there is sure to be movement if the tapers do not agree, or if the surfaces do not touch at more than one part of their lengths), we must finish it with a fine smooth file as follows: After marking the inside of the hole with a very light coat of red marking, taking care that there is no dirt or grit in it, we press the taper into the hole firmly, forcing it to its seat while revolving it backwards and forwards.

By advancing it gradually on the forward stroke, the movement will be a reciprocating and yet a revolving one. The work must then be run in the lathe at a high speed, and a smooth file used to ease off the mark visible on the taper, applying the file the most to parts or marks having the darkest appearance, since the darker the marks the harder the bearing has been. Too much care in trying the taper to its hole cannot be taken, because it is apt to mark itself in the hole as though it were a correct fit when at the same time it is not; it is necessary therefore at each insertion to minutely examine the fit by the lateral and vertical movement of projecting part of the taper, as before directed.

A taper or cone should be fitted to great exactitude before it is attempted to grind it, the latter process being merely intended to make the surfaces even.

For wrought-iron, cast-iron, or steel work, oil and emery may be used as the grinding materials (for brass, burnt sand and water are the best). The oil and emery should be spread evenly with the finger over the surfaces of the hole and the taper; the latter should then be placed carefully in its place and pressed firmly to its seat while it is being revolved backwards and forwards, and slowly rotated forward by moving it farther during the forward than during the backward movement of the reciprocating motion.

After about every dozen strokes the taper should be carefully removed from the hole and the emery again spread evenly over the surfaces with the finger, and at and during about every fourth one of the back strokes of the reciprocating movement the taper should be slightly lifted from its bed in the hole, being pressed lightly home again on the return stroke, which procedure acts to spread the grinding material and to make the grinding smooth and even. The emery used should be about number 60 to 70 for large work, about 80 to 100 for small, and flour emery for very fine work.

Any attempt to grind work by revolving it steady in one direction will cause it to cut rings and destroy the surface.

Referring to the second method, all that is necessary in setting

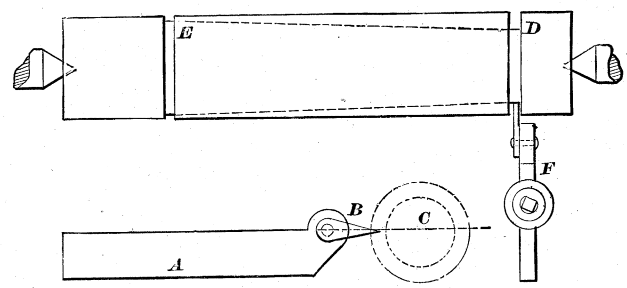


Fig. 1220.

a former or taper attachment bar is to set it out of line with the lathe shears to half the amount of taper that is to be turned, the bar being measured along a length equal to that of the work. Turning tapers with a bar or taper-turning attachment possesses the advantage that the tailstock not being set over, the work centres are not thrown out of line with the live centres, and the latter are not subject to the wear explained with reference to Fig. 1214. Furthermore, the tailstock being kept set to turn parallel, the operator may readily change from turning taper to turning parallel, and may, therefore, rough out all parts before finishing any of them, and thus keep the work more true, whereas in turning tapers by setting the tailstock over we are confronted by the following considerations:—

If we turn up and finish the plain part first, the removing of the skin and the wear of the centres during the operation of turning the taper part will cause the work to run out of true, and hence it will not, when finished, be true; or if, on the other hand, we turn up the taper part first, the same effects will be experienced in afterwards turning the plain part. We may, it is true, first rough out the plain part, then rough out the taper part, and finish first the one and then the other; to do this, however, we shall require to set the lathe twice for the taper and once for the parallel part.

It is found in practice that the work will be more true by turning the taper part the last, because the work will alter less upon the lathe centres when changed from parallel to taper turning than when changed from the latter to the former. In cases, however, in which the parts fitting the taper part require turning, it is better to finish the parallel part last, and to then turn up the work fastened upon the taper part while it is fast upon its place: thus, in the case of a piston rod and piston, were we to turn up the parallel part of the rod first and the taper last, and the centres altered during the last operation, when the piston head was placed upon the rod, and the latter was placed in the lathe, the plain part or stem would not run true, and we should require to true the centres to make the rod run true before turning up the piston head. If, however, we first rough out the plain part or stem of the rod, and then rough out and finish the taper part, we may then fasten the head to its place on the rod, and turn the two

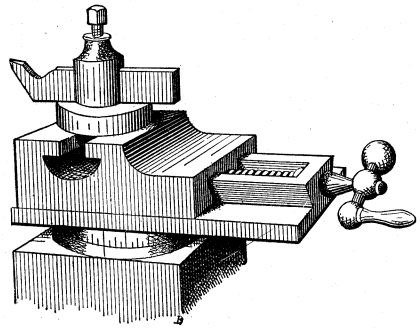


Fig. 1221.

together; that is to say, rough out the piston head and finish its taper hole; then rough out the parallel part of the rod, but finish its taper end. The rod may then be put together and finished at one operation; thus the head will be true with the rod whether the taper is true with the parallel part of the rod or not. With a taper-turning attachment the rod may be finished separately, which is a great advantage.

If, however, one part of the length of a taper turning attachment is much more used than another, it is apt to wear more, which impairs the use of the bar for longer work, as it affects its straightness and causes the slide to be loose in the part most used, and on account of the wear of the sliding block it is proper to wind the tool out from its cut on the back traverse, or otherwise the tool may cut deeper on the back than on the forward traverse, and thus leave a mark on the work surface.

Referring to the third method, a compound slide rest provides

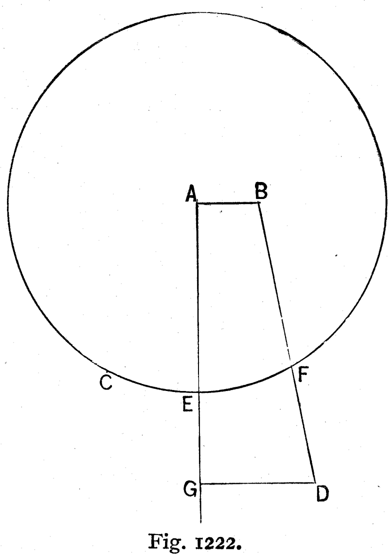


Fig. 1222.

an excellent method of turning tapers whose lengths are within the capacity of the upper slide of the compound rest, because that slide may be used to turn the taper, while the ordinary carriage feed may be used for the parallel parts of the work, and as the tailstock does not require to set over, the work centres are not subject to undue wear.

If the seat for the upper slide of the rest is circular, and the taper is given in degrees of angle, a mark may be made on the seat, and the base of the upper slide may be marked in degrees of a circle, as shown in Fig. 1221, which will facilitate the setting; or the following construction, which is extracted from *Mechanics*, may be employed. Measure the diameter of the slide rest seat, and scribe on a flat surface a circle of corresponding diameter. Mark its centre, as A in Fig. 1222, and mark the line A B. From the centre A mark the point B, whose radius is that of the small end of the hole to be bored. Mark the length of the taper to be turned on the line A G and draw the line G D distant from A B equal to the diameter of the large end of the hole to be bored. Draw the line B D. Then the distance E F is the amount the rest must be swiveled to turn the required taper.

It is obvious that the same method may also be used for setting the rest.

Referring to the fourth method, by having an upper bed or base plate for the head and tailstock, so that the line of lathe centres may be set at the required angle to the Vs or slides on which the

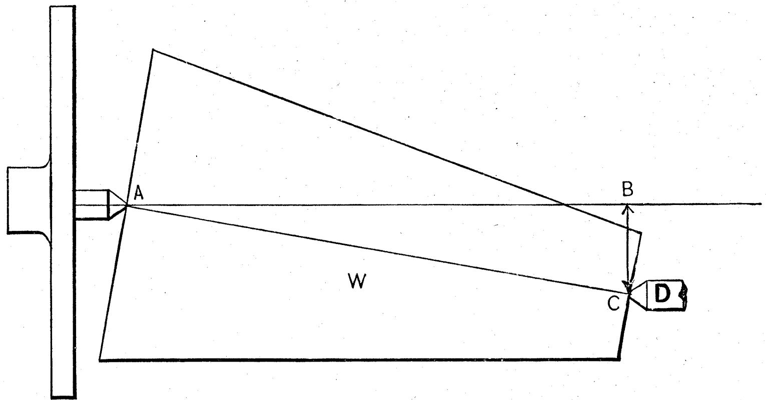


Fig. 1223.—Top View.

carriage traverses, it affords an excellent means of turning tapers, since it avoids the disadvantages mentioned with regard to other systems, while at the same time it enables the turning of tapers of the full length of the carriage traverse, but it is obvious that the head and tailstock are less rigidly supported than when they are bolted direct to the lathe shears.

In turning tapers it is essential that the tool point be set to the exact height of the work axis, or, in other words, level with the line of centres. If this is not the case the taper will have a curved outline along its length. Furthermore, it may be shown that if a straight taper be turned and the tool be afterwards either raised

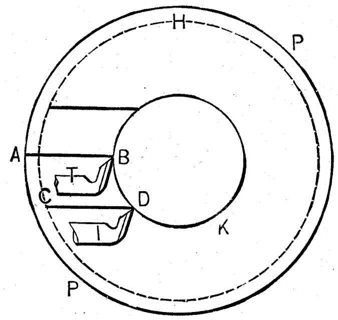
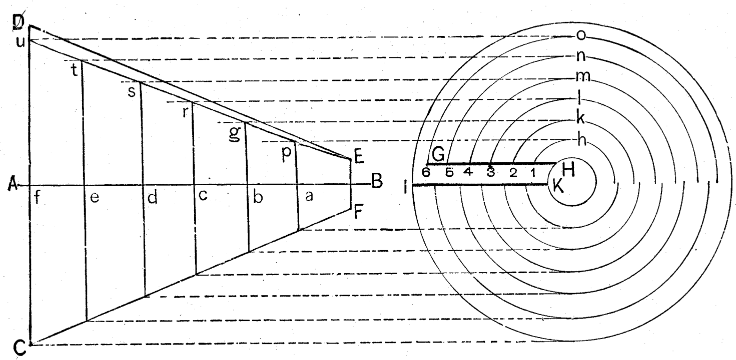


Fig. 1224.—End View.

or lowered, the amount of taper will be diminished as well as the length being turned to a curve.

Figs. 1223 and 1224 demonstrate that the amount of taper will be changed by any alteration in the height of the tool. In Fig. 1223, A B represents the line of centres of the spindle of a lathe, or, in other words, the axis of the work W, when the lathe is set to turn parallel; A C represents the axis of the work or cone when the lathe tailstock is set over to turn the taper or cone; hence the length of the line C B represents the amount the tailstock is set over. Referring now to Fig. 1224, the cone is supposed to stand level, as it will do in the end view, because the lathe centres remain at an equal height from the lathe bed or Vs, notwithstanding that the tailstock is set over. The tool therefore travels at the same height throughout its whole length of feed; hence, if it is set, as at T, level with the line of centres, its line of feed while travelling from end to end of the cone is shone by the line A B. The length of the line A B is equal to the length of the line B C Fig. 1223. Hence, the line A B, Fig. 1224, represents two things: first, the line of motion of the point of tool T as it feeds along the cone, and second its length represents the amount the work axis is out of parallel with the line of lathe centres. Now, suppose that the tool be lowered to the position shown at I; its line of motion as it feeds will be the line C D, which is equal in length to the line A B. It is obvious, therefore, that though the tool is set to the diameter of the small end, it will turn at the large end a diameter represented by the dotted circle H. The result is precisely the same if the taper is turned by a taper-turning attachment instead of setting the tailstock out of line.

The demonstration is more readily understood when made with



Side View. Fig. 1225. End View.

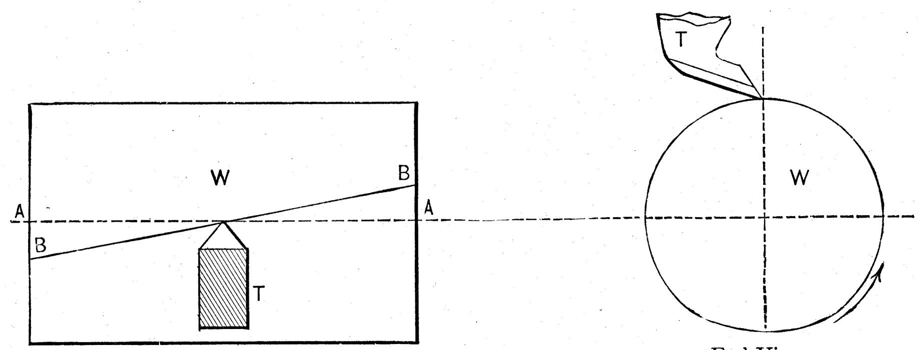
reference to such an attachment as the one just mentioned, because the line A B represents the line of tool feed along the work, and its length represents the amount the attachment causes the tool to recede from the work axis. Now as this amount depends upon the set-over of the attachment it will be governed by the degree of that set over, and is, therefore, with any given degree, the same whatever the length of the tool travel may be. All that is required, then, to find the result of placing the tool in any particular position, as at I in the end view, is to draw from the tool point a line parallel to A B and equal in length to it, as C D. The two ends of that line will represent in their distances from the work axis the radius the work will be turned to at each end with the tool in that position. Thus, at one end of the line C D is the circle K, representing the diameter the tool I would turn the cone at the small end, while at the other end the dotted circle H gives the diameter at the large end that the tool would turn to when at the end of its traverse. But if the tool be placed as at T, it will turn the same diameter K at the small end, and the diameter of the circle P at the large end.

We have here taken account of the diameters at the ends only of the work, without reference to the result given at any intermediate point along the cone surface, but this we may now proceed to do, in order to prove that a curved instead of a straight taper is produced if the tool be placed either above or below the line of lathe centres.

In Fig. 1225, D E F C represents the complete outline of a straight taper, whose diameter at the ends is represented in the end view by the outer and inner circles. Now, a line from A to B will represent the axis of the work, and also the line of tool point motion or traverse, if that point is set level with the axis. The line I K in the end view corresponds to the line A B in the side view, in so far that it represents the line of tool traverse when the tool point is set level with the line of centres. Now, suppose the tool point to be raised to stand level with the line G H, instead of at I K, and its line of feed traverse be along the line G H, whose length is equal to that of I K. If we divide the length of G H into six equal divisions, as marked from 1 to 6, and also divide the length of the work in the side view into six equal divisions (*a* to *f*), we shall have the length of line G H in the first division in the end view (that is, the length from H to G), representing the same amount or length of tool traverse as from the end B of the cone to the line A in the side view. Now, suppose the tool point has arrived at 1; the diameter of work it will turn when in that position is evidently given by the arc or half-circle *h*, which meets the point 1 on G H. To mark that diameter on the side view, we first draw a horizontal line, as *h p*, just touching the top of *h*; a perpendicular dropped from it cutting the line A B, gives the radius of work transferred from the end view to the side view. When the tool point has arrived at 2 on G H in the end view, its position will be shown in the side view at the line *b*, and the diameter of work it will turn is shown in the end view by the half-circle *k*. To transfer this diameter to the side view we draw the line *k g*, and where it cuts the line *b* in the side view is the radius of the work diameter when the tool has arrived at the point *b* in the side view. Continuing this process, we mark half-circles, as *l*, *m*, *n*, *o*, and the lines *l r*, *m s*, *n t*, *o u*, by means of which we find in the side view the work radius when the tool has arrived at *c*, *d*, *e*, and *f* respectively. All that remains to be done is to draw on the side view a line, as *u* E, that shall pass through the points. This line will represent the outline of the work turned by the tool when its height is that denoted by G H. Now, the line *u* E is shown to be a curve, hence it is proved that with the tool at the height G H a curved, and not a straight, taper will be turned.

It may now be proved that if the tool point is placed level with the line of centres, a straight taper will be turned. Thus its line of traverse will be denoted by A B in the side view and the line I K in the end view; hence we may divide I K into six equal divisions, and A B into six equal divisions (as *a*, *b*, *c*, &c.). From the points of division I K, we may draw half-circles as before, and from these half-circles horizontal lines, and where the lines meet the lines of division in the side view will be points in the outline of the work, as before. Through these points we draw a line, as before, and this line C F, being straight, it is proven that with the tool point level with the work axis, it will turn a straight taper.

It may now be shown that it is possible to turn a piece of work to a curve of equal curvature on each side of the middle of the work length. Suppose, for example, that the cutting tool stands on top of the work, as in the end view in Fig. 1226, and that while the tool is feeding along the work it also has a certain amount of motion in a direction at right angles to the work axis, so that its line of motion is denoted by the line B B in the top view. The outline of the work turned will be a curve, as is shown in Fig. 1227, in which the line of tool traverse is the line C D. Now the



Top View. Fig. 1226. End View.

amount of tool motion that occurs during this traverse in a direction at right angles to the work axis is represented by the line F E, because the upper end is opposite to the upper end of C D, while the lower end is opposite the lower end of C D. We may then divide one-half of the length of F E into the divisions marked from 1 to 6. Now, as we have taken half the length of F E, we must also take half the length of the work and divide it into six equal divisions marked from *a* to *f*. Now, suppose the tool point to stand in the line F S in the end view, its position in the top view

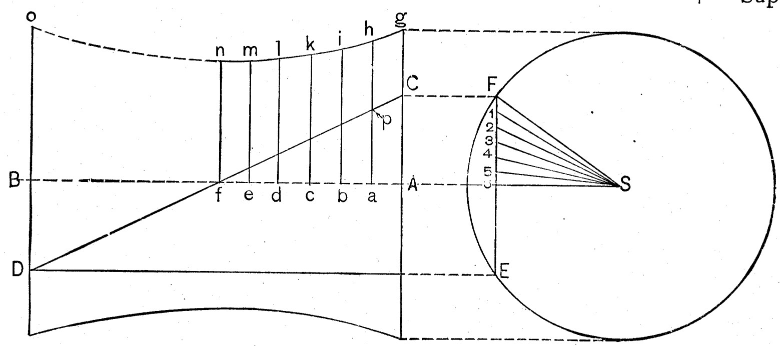


Fig. 1227.

will be at C. When it is at 1 on the end view it will have arrived at *p* in the top view. The radius of work it will then turn is shown in the end view by the length of line running from 1 to the work centre. Take this length, and from *a* in the work axis set it off on the line *a h*, and make the length equal the height of 1 S. In like manner, when the tool point has arrived at 2, the radius it will cut the work is shown by the length of line *i*; hence from 2 on the work axis we may set off the length of 2 S, making 2 S and *b i* of equal length. Continuing this process, we make the length of *c k* equal that of 3 S, the length of *d l* equal 4 S, and so on. All that remains then is to draw a line, *o g*, that shall meet the tops of these lines. This line will show the curve to which that half of the work length will be turned to. The other half of the work length will obviously be turned to the same curvature.

It is obvious that the curvature of the work outline will be determined by the proportion existing between the length of the work and the amount of tool motion in a direction at right angles to the work axis, or, in other words, between the length of the work and that of the line F E. It is evident, also, that with a given amount of tool motion across the work, the curvature of outline turned will be less in proportion as the work length is greater. Now, suppose that the smaller and the larger diameter of the work, together with its length, are given, and it is required to find how much curvature the tool must have, we may find this and

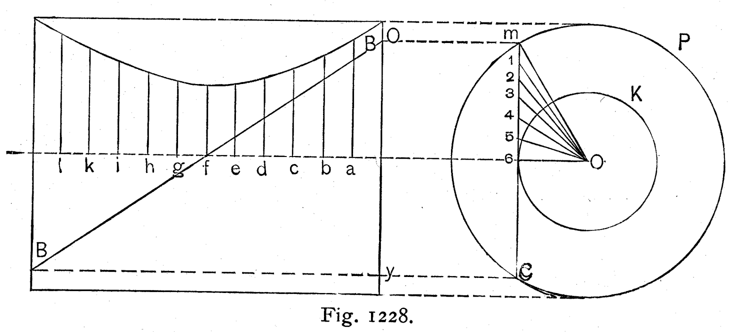


Fig. 1228.

work out the curve it will cut by the construction shown in Fig. 1228, in which the circle K is the smallest and the circle P the largest diameter. The line *m* C is drawn to just touch the perimeter of K, and this at once gives the amount of cross-motion for the tool. Hence, we may draw the line *m* B and C B, and from their extremities draw the line B B representing the path of traverse of the tool point. We may then obtain the full curve on one side of the work by dividing one-half the length of *m* C into six equal divisions and proceeding as before, except that we have here added the lines of division in the second half as from *f* to *l*. It will be observed that the centre of the curve is at the point where the tool point crosses the axis of the work; hence, by giving to the tool more traverse on one side than on the other of the work axis, the location of the smallest point of work diameter may be made to fall on one side of the middle of the work length.

In either turning or boring tapers that are to drive or force in or together, the amount to be allowed for the fit may be ascertained, so that the work may be made correct without driving each piece to its place to try its fit.

Suppose, for example, that the pieces are turned, and the holes are to be reamed, then the first hole reamed may be made to correct diameter by fit and trial, and a collar may be put on the reamer to permit it to enter the holes so far and no farther.

A taper gauge may then be made as in Fig. 1229, the line A representing the bore of the hole, and line B the diameter of the internal piece, the distance between the two being the amount found by trial to be necessary for the forcing or driving. The same gauge obviously serves for testing the taper of the holes reamed.

CHUCKED OR FACE PLATE WORK.—This class of work requires the most skillful manipulation, because the order in which the work may most advantageously proceed and the method of chucking are often matters for mature consideration.

In a piece of work driven between the lathe centres, the truth of any one part may be perceived at any time while operating upon the others, but in chucked work, such is not always the case, and truth in the work is then only to be obtained by holding it truly. Again, the work is apt to be sprung or deflected by the pressure of the devices holding it, and furthermore the removal of the skin or surface will in light work sometimes throw it out of true

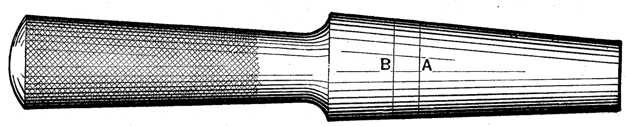


Fig. 1229.

as the work proceeds, the reason being already given, when referring to turning plain cylindrical work.

TO TURN A GLAND.—There are three methods of turning a gland: first, the hole and the face on the outside of the flange may be turned first, the subsequent turning being done on a mandrel; second, the hole only may be bored at the first chucking, all the remaining work being done on a mandrel; and, third, the hole, hub, and one radial face may be turned at one chucking, and the remaining face turned at a separate chucking.

If the first plan be adopted, any error in the truth of the mandrel will throw the hole out of true with the hub, which would be a serious defect, causing the gland to jamb against one side of the piston rod, and also of the gland bore. The same evil is liable to result from the second method; it is best, therefore, to chuck the gland by the hub in a universal chuck, and simply face the outer face of the flange, and also its edge. The gland may then be turned end for end, and the hole, the hub, the inside radial flange face, and the hub radial face, may then all be turned at one chucking; there is but one disadvantage in this method, which is that the gland must be unchucked to try its fit in the gland hole, but if standard gauges are used such trial will not be necessary, while if such is not the case and an error of measurement should occur, the gland may still be put on a mandrel and reduced if necessary.

In either method of chucking, the fit of the hole to the rod it is intended for cannot be tested without removing the gland from the chuck.

TO TURN A PLAIN CYLINDRICAL RING ALL OVER IN A UNIVERSAL CHUCK.—Three methods may be pursued in doing this simple job: first, the hole may be bored at one chucking, and the two radial faces and the circumference turned at a second chucking; second, the diameter may be turned, first on the hole and two radial faces turned at a second chucking; and third the hole and one radial face may be turned at one chucking, and the diameter and second radial face at a second chucking. The last method is best for the following reasons. The tool can pass clear over the surfaces at each chucking without danger of coming into contact with the chuck jaws, which would cause damage to both; second, at the last chucking, the chuck jaws being inside the ring, the latter may be tested for truth with a pointer fixed in the tool rest, and therefore set quite true.

It is obvious that at neither chucking should the ring be set so far within the chuck jaws that there will be danger of the tool touching them when turning the radial face.

In the case of a ring too thin to permit this, and of too large a bore to warrant making a mandrel for it, the ring may be held on the outside and bored, and both radial faces turned to within a short distance of the chuck jaws; at the second chucking, the chuck jaws being within the ring bore, the work may be set true with a pointer, as before, and finished.

If, however, a number of such rings were to be turned, it would pay to turn up another and thicker ring, and use it as a mandrel after the bore and one radial face of the ring had been turned.

To Turn an Eccentric Strap and Eccentric.—The eccentric strap should be turned first, because it can then be taken apart and its fit to the eccentric tried while the latter is in the lathe, which is not the case with the eccentric. The strap should first be held in a universal chuck bolted to the face plate, or held in dogs such as shown in Fig. 893 at C, and one face should be turned. It should then be turned round on the chuck to bore it, and face the other side.

If the shape of the strap will admit it, it is best chucked by plates and bolts holding the face first turned to the face plate,

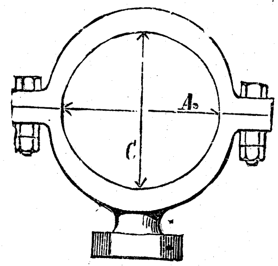


Fig. 1230.

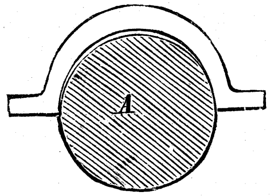


Fig. 1231.

because in this case there will be no pressure tending to spring the straps out of their natural shape; otherwise, however, it may be held in a universal or independent jaw chuck, or if too large for insertion in chucks of this kind (which are rarely made for large lathes) it may be held in dogs such as shown in Fig. 893 at C.

If after an eccentric strap is bored, and the bolts that hold its two halves together have been slackened, its diameter at A and at C, Fig. 1230, be measured, it will be found that A is less than C. The cause of this is partly explained under the head of tension of castings; but it is necessary to add that the diameters at A and at C in the figure are equal while the strap is in the lathe, or until the bolts holding the two halves of the strap together are released, yet so soon as this is done the diameter at A will reduce, the bore becoming an oval.*

Now, it is obvious that the eccentric must be turned to the diameter at C, or otherwise it will have lost motion in the strap. If, however, the eccentric be turned to the diameter of C, the strap cannot be tried on, as it will bind at the corners, as shown in Fig. 1231. To remedy this evil it is usual to put a piece of sheet tin or metal between the joint faces of the two halves of the eccentric straps before they are chucked to turn them, and to bore them too large to the amount of the thickness of sheet metal so employed. After the straps are bored these pieces of metal are removed, and the strap halves bolted together as in Fig. 1230, the diameter at C being that to which the eccentric must be turned.

If the sheet metal so inserted were thick enough, the strap bore will measure the same at A as at C, Fig. 1230. If it were too thick

* This occurs in all castings of similar form, as brasses, &c.

the diameter at A will be greatest, while if too thin the diameter at A will be the least. There is no rule whereby the necessary thickness for a given size of strap may be known, and the workman is usually governed by his experience on castings of similar metal, or from the same moulding shop.

He prefers, however, to be on the safe side by not putting in too great a thickness, because it is easier to scrape away the bore at the joint than it is to file away the joint faces. The following thicknesses for the respective diameters may be considered safe for castings that have not been reheated after casting.

Diameter of bore. Inches.	Thickness of metal to place between the strap valves. Inch.
6	$\frac{1}{64}$
12	$\frac{1}{32}$
18	$\frac{3}{64}$
24	$\frac{1}{8}$

In turning a new strap for an old eccentric, it will be necessary, when taking the diameter of the eccentric, to take a piece of tin of the same thickness as that placed between the eccentric lugs or jaws, and place it between the caliper leg and the eccentric, so that the diameter of the strap across C, Fig. 1230, may be made equal when the tin is removed to the diameter of the eccentric.

In turning up the eccentric, the plain face should be faced first, setting it true, or nearly so, with the circumference of the eccentric, as will be the case if the circumference is held in a universal chuck, but if the hub is so long that this cannot be done because the chuck jaws cannot reach the circumference, the hub itself may be held in an independent jaw chuck.

The face turned may then be turned round, so as to meet the face of the chuck against which it should bed fairly, so as to run true. At this chucking the hole bore, the hub, and the radial faces should be turned, all these surfaces being roughed out before any one surface is finished.

The eccentric must then be again reversed, so that the face of the hub meets, the face plate being held by bolts as shown for a crank in figure, when the work being set to the lines marked (so as to give it the correct amount of throw) may be turned to fit the bore of the strap, the strap being taken apart so as to try it on, which this method of chucking will readily permit.

Now, in an eccentric, the surfaces requiring to be most true one with the other are those of the bore and of the circumference where the strap fits, and since the latter was turned with the hub face to the chuck, and that hub face was turned at the same chucking as the hole was bored (and must, therefore, be true to the bore), the bore and circumference will be as true as it is practicable to get them, because upon the truth of the last chucking alone will the truth of the work depend.

Small eccentrics may be held for all their chuckings in jaw chucks, but not so truly as if chucked on a face plate, because of the difficulty of keeping the radial faces of such jaws true, which occurs by reason of the causes explained with reference to Figs. 848 and 849.

Eccentrics having so much throw upon them as to render it difficult to hold them for the last chucking by the method above given (by bolts through the bore), usually have openings through them on the throw side, and in this case parallel pieces may be placed behind the radial face (on the hub side of the eccentric), such parallel pieces being thick enough to keep the hub face clear of the chuck face, and bolts may be passed through the said opening to hold the eccentric. Another method would be as follows:—

The outside diameter of the eccentric may be gripped in a dog chuck, if the dogs of the chuck project out far enough to reach it (otherwise the dogs may grip the hub of the eccentric), while the hole is bored and the plain face of the eccentric turned. The eccentric must then be reversed in the lathe, and the hub and the radial face on that side must be turned. Then the plain face of the eccentric must be bolted to the face plate by plates placed across the spaces which are made to lighten the eccentric, and by a plate across the face of the hub. The eccentric, being set true to the lines, may then be turned on its outside diameter to fit the strap; to facilitate which fitting, thin parallel strips may be placed between the face plate and the plain face of the eccentric at this last chucking. It will be observed that, in either method of chucking, the outside diameter of the eccentric (that is to say, the part on which the strap fits) is turned with the face which was turned at the same chucking at which the hole was bored, clamped to the face plate. In cases where a number of eccentrics having the same size of bore and the same amount of throw are turned, there may be fitted to the face plate of the lathe a disk (such as shown in Fig. 888), of sufficient diameter to fit the hole of the eccentric, the said disk being fastened to the face plate at the required distance from the centre of the lathe to give the necessary amount of throw to the eccentric. The best method of fastening such a disk to the face plate is to provide it with a plain pin turned true with the disk, and let it fit a hole (bored in the face plate to receive it) sufficiently tightly to be just able to be taken in and out by the hand, the pin being provided with a screw at the end, so that it can be screwed tight by a nut to the face plate. The last chucking of the eccentric is then performed by placing the hole of the eccentric on the disk, which will insure the correctness of the throw without the aid of any lines on the eccentric which may be set as true as the diameter of the casting will permit, and then turned to fit the strap.

TO TURN A CYLINDER COVER.—A cylinder cover affords an example of chucking in which the work done at one chucking requires to be very true with that done at a subsequent chucking, thus the gland hole which is on one side requires to be quite true with the diameter that fits into the cylinder bore, this diameter being on the opposite side.

If the polished or gland side of the cover be turned first, the hole for the packing ring and that for the gland may be bored with the assurance that one will be true with the other, while the polished outside face may be turned at the same chucking.

But when the cover is turned round in the lathe to turn the straight face, though the hole may be set true as far as can be ascertained in its short length, yet that length is too short to be an accurate guide, and the hole for the packing ring may appear true, while that for the gland, being longer, will have any error in the setting, multiplied by reason of its greater length. It is better, therefore, to turn the plain face first, gripping the cover by the gland flange so that the plain radial face, the step that fits the cylinder bore, and the outer edge of the cover flange may be turned at one chucking; then when the cover is turned round in the chuck, the flat face may be set true by resting against the radial surface of the chuck jaws, and the concentric truth may be set by the outer edge of the flange, which, being of the extreme diameter of the cover, will most readily show any want of truth in the setting. If in this case a universal chuck be used, and the work does not run quite true, it may be corrected by slacking the necessary dog or jaw on one side, and tightening up again from the screw of the necessary jaw on the other.

This occurs because from the wear, &c., there is always some small amount of play or lost motion in the jaw screws, and in the mechanism operating them, and by the above means this is taken advantage of to true the work.

If from any cause the work cannot be held for the first chucking by means of the gland hole flange, it must be held by the circumferential edge of the cover, letting the jaws envelop as small a distance over that edge as possible, the protruding part of it may then be turned up as close to the chuck jaws as possible, and this turned part may still be used to set the cover concentrically true at the second chucking.

In a very small cover the gland hole may have a mandrel fitted to it and be turned therefrom on both radial faces, or on one face only, the other being turned at the chucking at which the holes were bored.

In a cover too large to be held in a jaw chuck, the cover may be held in chucking dogs such as shown at C in Fig. 893, the edge protruding as much as possible from the dog screws, and being turned half way across at one chucking, and finished at the second chucking. To set the radial face at the second chucking, the surface gauge, applied as shown in Fig. 894, may be employed. If the bore of the packing ring or piston rod hole is large enough to permit it, that hole and the gland hole may be bored at the same chucking as that at which the plain face and step that fits in the cylinder bore is turned, thus ensuring truth in all the essential parts of the cover.

But in this case these operations should be performed at the last of the two chuckings, so as to eliminate any error that might arise from the casting altering its shape by reason of the removal of the metal on the radial face of the gland hole side of the cover.

TO TURN A PULLEY.—A pulley affords an excellent example of lathe work, because it may be operated upon by several different methods: thus, for boring it may be held, if small, in a dog chuck, with the jaws inside the rim; in a dog chuck with the jaws outside the rim; in a dog chuck by the hub itself (if the hub is long enough). A larger pulley may be chucked for boring by the rim held in a jaw chuck; by the rim held by bolts and plates, or by the rim held by dogs, such as shown in Fig. 893, or by the arms rested on pieces placed between them and the chuck, and then bolts and plates applied to those arms.

The rim may be turned by placing the pulley on a mandrel and driving that mandrel by a dog or carrier; by placing it on a mandrel and driving it by a Clements driver such as shown in Fig. 753, and having two diametrically opposite driving pins, placed to bear against diametrically opposite arms; by holding the arms to the chuck as before described, and performing the boring and facing at one chucking; or by holding the rim on its inside by the chuck jaws, so as to turn and bore the pulley at one chucking, which can be done when the inside of the rim is parallel, or not sufficiently coned to cause it to slip off the jaws, or when the jaws will reach to the centre of the rim width.

The advantages and disadvantages of these various methods are as follows:—

From the weakness of the pulley rim it is apt to distort when held with sufficient chuck-jaw pressure to enable the turning of the rim face and edge. But this would not affect the truth of the hole; hence the rim may be gripped in a chuck to bore the hole and face the hub. If so held it should be held true to the inside face of the rim, so that the bore will be true to the same, and then in turning the outside diameter it will be made as true as possible with the rim, which will preserve the balance of the pulley as much as possible. For these reasons the inside of the rim should be the part set to run true, whatever method of chucking be employed; hence, if the circumstances will permit of holding the hub to bore it, an independent jaw chuck should be employed (that is, of course, a chuck capable of independent jaw movement).

If the pulley be chucked by the arms, it is well-nigh impossible to avoid springing those arms from the pressure of the bolts, &c., holding them, and as a result the pulley face, though turned true, will not be true of itself, nor true with the hole, when the arms are released from such pressure.

If the pulley is of such a large size that its rim must be held by bolts and plates while the boring is progressing, such bolts, &c., must be placed on the outside of the rim, so as not to be in the way when setting the pulley true to the inside of the rim.

A small pulley may be turned on a mandrel driven by a dog, which is the truest method of turning, because the rim is in this case strained by the pressure of the cut only. But a dog will not drive a cut at such a leverage as exists at the rim of a pulley above about 18 inches in diameter; furthermore, in a large wheel there would not be sufficient friction between a mandrel and the pulley bore to drive the roughing cut on the pulley face.

It is necessary, therefore, to drive the pulley from the arms, while holding it on a mandrel, but if it be driven by one arm the whole strain due to driving will fall on that one arm, and on one side of the pulley only, and this will have a tendency to cause the rim at and near its junction with that arm to spring or deflect from its natural position, and, therefore, to be not quite true; all that can be done, therefore, is to drive by two arms with a Clements driver, so as to equalize the pressure on them.

An excellent method of chucking a pulley, and one that with care avoids the disadvantages mentioned in the foregoing methods, is shown in Figs. 1232 and 1233. It consists of a clamping dog, Fig. 1234, that fastens to the lathe face plate, and secures the pulley by its arms, while supporting the rim and preventing it from chattering, if it is weak or slight.

This dog is bolted to the face plate by the two studs A and B.

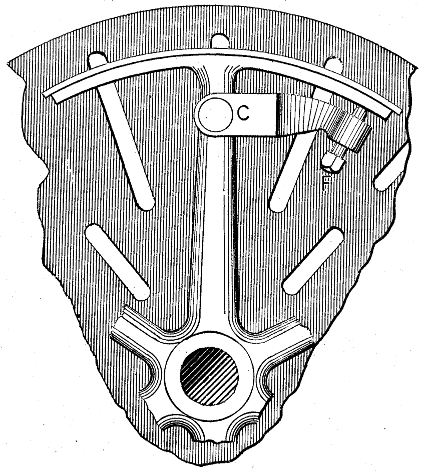


Fig. 1232.

At C is a set screw for clamping the pulley arms against the screw D, and at F is a screw that steadies the pulley rim between the arms.

CUTTING SCREWS IN THE LATHE WITH SLIDE REST TOOLS.—In order to cut a thread in the lathe with a slide rest tool,

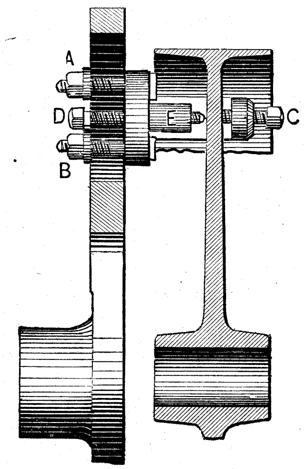


Fig. 1233.

it is necessary that the gear-wheels which transmit motion from the cone spindle to the feed screw shall be of the proportions necessary to give to the lathe carriage and slide rest sufficient lateral movement or traverse for lathe revolution to cut a thread of the desired pitch.

Suppose now that the feed screw makes a revolution in the

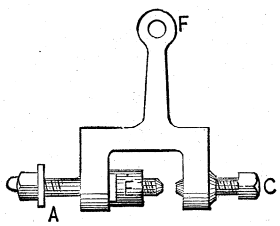


Fig. 1234.

same time that the cone spindle does, and it is evident that the thread cut by the slide rest tool will be of the same pitch as is the pitch of the lathe feed screw. If the feed screw gear-wheels of the lathe are what is called single geared (which means that no one stud in the change gearing carries more than one gear-wheel), it does not matter what are the sizes or how many teeth there are in the wheels used to convey or transmit motion from the cone spindle to the feed screw, for so long as the number of teeth on the cone spindle gear and that on the feed screw are equal, the feed screw will make one revolution in the same time as the cone spindle makes a revolution, and the cutting tool will travel a lateral distance equal to the pitch of the lead screw.

Suppose, for example, that Fig. 1235 represents the screw cutting gear or change wheels of a lathe, wheel D being the driver, I an intermediate wheel for transmitting motion from the driver D to the lead-screw wheel S. Suppose, also, that D has 32, I 80, and S 32 teeth, and we have a simple or single-geared lathe. In this

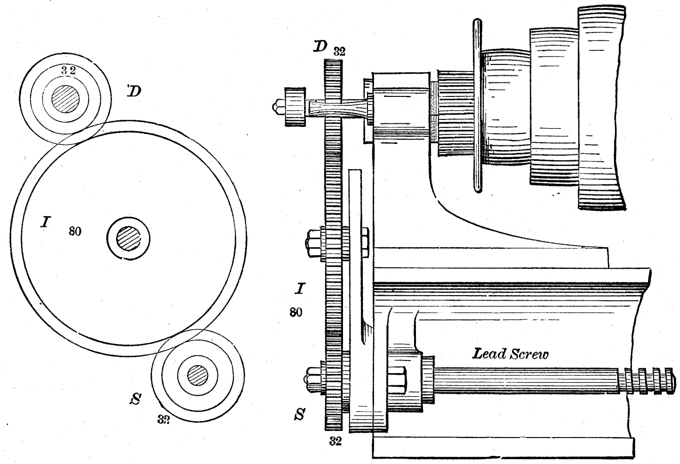


Fig. 1235.

case it may first be proved that we need not concern ourselves with the number of teeth in the intermediate I, because its number of teeth is of no consequence. For example, the 32 teeth in D will in a revolution move 32 of the teeth in I past the line of centres, and it is obvious that I will move the 32 teeth in S past the line of centres, causing it to make one revolution the same as D. If any other size of wheel be used for an intermediate, the effect will be precisely the same, the revolutions of D and of S remaining equal. Under these conditions the lathe would cut a thread whose pitch would be the same as that of the thread on the lead screw.

Now let us turn to Fig. 1236, representing an arrangement of gearing common in American practice, and we have within the lathe-head three gears, A, B, and C, which cannot be changed.

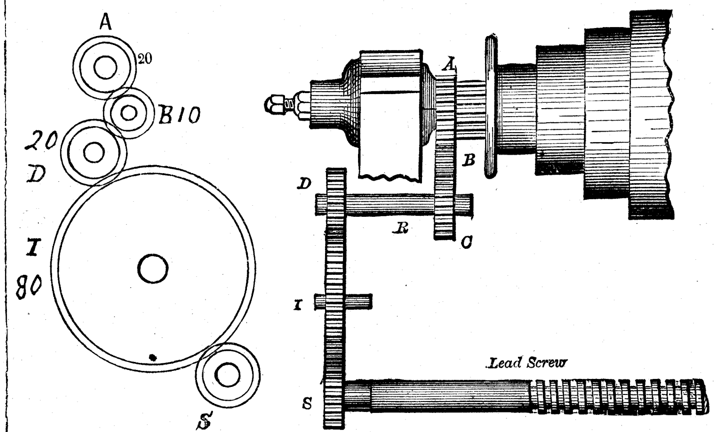


Fig. 1236.

Of these, B and C are simply intermediate wheels, the respective diameters of which have no effect upon the revolutions of the lead screw, except that they convey the motion to D. To demonstrate this, suppose the wheels to have the number of teeth marked respectively against them in the end view of the figure, C and D having each 20 teeth, and the one revolution of the live spindle wheel A will cause the lead-screw wheel to make one revolution, because A and S contain the same number of teeth. This may be made plain as follows: The 20 teeth in A will in one revolution cause B to make two revolutions, because B has but half as many teeth as A. The two revolutions of B will cause C to make but one revolution, because C has twice as many teeth as B has. Now, C and D are fast on the same shaft R; hence they revolve together, the one revolution of C simply being conveyed by the shaft R to D, and it is clear that the one revolution of A has been conveyed without change to D, and that, therefore, D may be considered to have simply taken the place of A, unaffected by the wheels B, C. Wheel I is again an intermediate, so that, whatever its diameter or number of teeth, one revolution of D will cause one revolution of S. Thus in this arrangement the lead screw will again revolve at the same speed as the live spindle, and the thread cut will be of the same pitch as the pitch of the lead screw. Practically, then, all the wheels between A and S, as thus arranged, act as simple intermediates, the same as though it were a single-geared lathe, which occurs because C and D have the same number of teeth, and we have, therefore, made no use of the shaft R to compound the gearing.

The term "compounded" as applied to the change gears of a lathe, means that there exists in it a shaft or some equivalent means by which the velocity of the wheels may be changed. Such a shaft is shown at R in Fig. 1236, and it affords a means of compounding by placing on its outer end, as at D, a wheel that has a different number of teeth to that in wheel C. In Fig. 1237 this change is made, wheel D having 40 teeth instead of the 20 it had before. As in the former case, however, it will make one revolution to one of C or one of A, but having 40 teeth it will move 40 of the teeth in I past the line of centres, and this will cause the lead screw wheel S to make two revolutions, because it has 20 teeth only. Thus, the compounding of C and D on shaft R has caused S to make two revolutions to one of A, or, what is the same thing, one revolution of A will in this case cause S to make two revolutions, and the thread cut would be twice as coarse as the lead-screw thread. In the case of a lathe geared as in either Fig. 1235 or 1236, all the wheels that we require to consider in calculating the change wheels are D and S. Now, the shaft R is called the "mandrel," the "stud," or the "spindle," all three terms being used, and the wheel D is the wheel on the stud, mandrel, or spindle, while in every case S is that on the lead screw, and the revolutions of this wheel D and those of the lead screw will be in the same proportion as exists between their numbers of teeth. In considering their revolutions it is to be borne in mind that when D has more teeth than S the speed of the lead screw is increased, and the lathe will cut a thread coarser than that of its lead screw, or when D has less teeth than S the speed of the lead screw is diminished, and the pitch of thread cut will be finer than that of the lead screw.

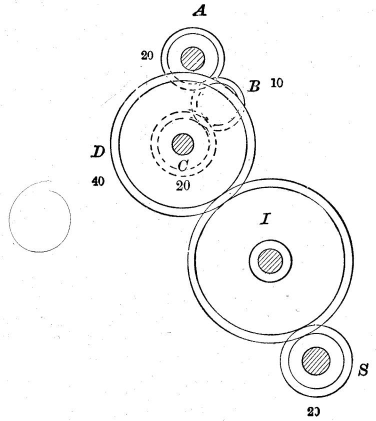


Fig. 1237.

Another method of compounding is shown in Fig. 1238, the compounded pair C D being on a stud carried in the swing frame F. Now, suppose A has 32, C 64, D 32, and S 64 teeth, the revolution being in the same proportion as the numbers of teeth, C will make one-half a revolution to one revolution of A, and D, being fast to the same stud as C, will also make one-half revolution to one revolution of A. This one-half revolution of D will cause S to make one-quarter of a revolution; hence the thread cut will be four times as fine as the pitch of the thread on the lead screw, because while the lathe makes one turn the lead screw makes one-quarter of a turn. In this arrangement we are enabled to change wheel C as well as wheel D (which could not be done in the arrangement shown in Fig. 1236), and for this reason more changes can be made with the same number of wheels. When the wheel C makes either more or less revolutions than the driver A, it must be taken into account in calculating the change wheels. As arranged in Fig. 1236, it makes the same number as A, which is a very common arrangement, but in Fig. 1238 it is shown to have twice as many teeth as A; hence it makes half as many revolutions. In the latter case we have two pairs of wheels, in

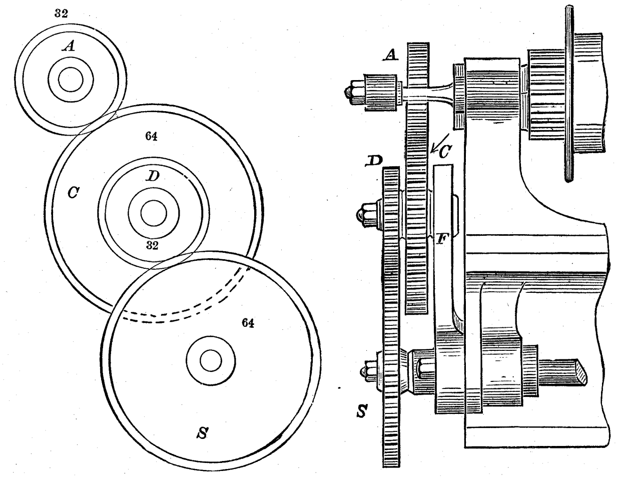


Fig. 1238.

each of which the driven wheel is twice the size of the driver; hence the revolutions are reduced four times.

Suppose it is required to cut a thread of eight to an inch on a lathe such as shown in Fig. 1235, the lead screw pitch being four per inch, and for such simple trains of gearing we have a very simple rule, as follows:—

Rule.—Put down the pitch of the lead screw as the numerator, and the pitch of thread you want to cut as the denominator of a vulgar fraction, and multiply both by the pitch of the lead screw, thus:

$$\frac{\text{Pitch of lead screw } 4}{\text{Pitch to be cut } 8} \times \frac{4}{4}\ (\text{Pitch of lead screw}) = \frac{16}{32} = \frac{\text{the number of teeth for the wheel on the spindle.}}{\text{the number of teeth for the wheel on the lead screw.}}$$

There are three things to be noted in this rule; and the first is, that when the pitch of the lead screw and the pitch of thread you want to cut is put down as a fraction, the numerator at once represents the wheel to go on the stud, and the denominator represents the wheel to go on the lead screw, and no figuring would require to be done providing there were gear-wheels having as few teeth as there are threads per inch in the lead screw, and that there was a gear-wheel having as many teeth as the threads per inch required to be cut. For example, suppose the lathe in Fig. 1236 to have a lead screw of 20 per inch, and that the change wheels are required to cut a pitch 40, then we have $\frac{20}{40}$, the 20 to go on at D in Fig. 1236 and the 40 to go on the lead screw. But since lead screws are not made of such fine pitch, but vary from two threads to about six per inch, we simply multiply the fraction by any number we choose that will give us numbers corresponding to the teeth in the change wheels. Suppose, for example, the pitch of lead screw is 2, and we wish to cut 6, then we have $\frac{2}{6}$, and as the smallest change wheel has, say, 12 teeth we multiply the fraction by 6, thus: $\frac{2}{6} \times \frac{6}{6} = \frac{12}{36}$. If we have not a 12 and a 36 wheel, we may multiply the fraction by any other number, as, say, 8; thus: $\frac{2}{6} \times \frac{8}{8} = \frac{16}{48}$, giving us a 16 wheel for D, Fig. 1236, and a 48 wheel for the lead screw.

The second notable feature in this rule is that it applies just the same whether the pitch to be cut is coarser or finer than the lead screw; thus: Suppose the pitch of the lead screw is 4, and we want to cut 2. We put these figures down as before $\frac{4}{2}$, and proceed to multiply, say, by 8; thus: $\frac{4}{2} \times \frac{8}{8} = \frac{32}{16}$, giving a 32 and a 16 as the necessary wheels.

The third feature is, that no matter whether the pitch to be cut is coarser or finer than the lead screw, the wheels go on the lathe just as they stand in the fraction; the top figure goes on top in the lathe, as, for example, on the driving stud, and the bottom figures of the fraction are for the teeth in the wheel that goes on the bottom of the lathe or on the lead screw. No rule can possibly be simpler than this. Suppose now that the pitch of the lead screw is 4 per inch and we want to cut $1\frac{1}{2}$ per inch. As the required pitch is expressed in half inches, we express the pitch of the lead in half inches, and employ the rule precisely as before. Thus, in four there are eight halves; hence, we put down 8 as the numerator, and in $1\frac{1}{2}$ there are three halves, so we put down 3 and get the fraction $\frac{8}{3}$. This will multiply by any number, as, say, 6; thus: $\frac{8 \times 6}{3 \times 6} = \frac{48}{18}$, giving us 48 teeth for the wheel D in Fig. 1236, and 18 for the lead screw wheel S.

In a lathe geared as in Fig. 1235 the top wheel D could not be readily changed, and it would be more convenient to change the lead screw wheel S only. Suppose, then, that the lead screw pitch is 2 per inch, and we want to cut 8. Putting down the fraction as before, we have $\frac{2}{8}$, and to get the wheel S for the lead screw we may multiply the number of teeth in D by 8 and divide it by 2; thus: $32 \times 8 = 256$, and $256 \div 2 = 128$; hence all we have to do is to put on the lead screw a wheel having 128 teeth. But suppose the pitch to be cut is $4\frac{1}{4}$, the pitch of the lead screw being 2. Then we put both numbers into quarters, thus: In 2 there are 8 quarters, and in $4\frac{1}{4}$ there are 17 quarters; hence the fraction is $\frac{8}{17}$. If now we multiply both terms of this $\frac{8}{17}$ by 4 we get $\frac{32}{68}$, and all we have to do is to put on the lead screw a wheel having 68 teeth.

When we have to deal with a lathe compounded as in Fig. 1238, in which the combination can be altered in two places—that is, between A and C and between D and S—the wheel A remaining fixed, and the pitch of the lead screw is 2 per inch, and it is required to cut 8 per inch—this gives us the fraction $\frac{2}{8}$, which is at once the proportion that must exist between the revolutions of the wheel A and the wheel S. But in this case the fraction gives us the number of revolutions that wheel S must make while the wheel A is making two revolutions, and it is more convenient to obtain the number that S requires to make while A is making one revolution, which we may do by simply dividing the pitch required to be cut by the pitch of the lead screw, as follows: Pitch of thread required, 8; pitch of lead screw, 2; $8 \div 2 = 4$ = the revolutions S must make while A makes one. We have then to reduce the revolutions four times, which we may do by putting on at C a wheel with twice as many teeth in it as there are in A, and as A has 32, therefore C must have 64 teeth. When we come to the second pair of wheels, D and S, we may put any wheel we like in place of D, providing we put on S a wheel having twice as many.

But suppose we require to cut a fractional pitch, as, say, $4\frac{1}{8}$ per inch, the pitch of lead screw being 2, all we have to do is to put the pitch of the lead screw into eighths, and also put the number of teeth in A into eighths; thus: In two there are 16 eighths, and in the pitch required there are 33 eighths; hence for the pitch of the lead screw we use the 16, and for the thread required we use the 33, and proceed as before; thus:

Pitch of thread required.		Pitch of lead screw.				
33	$\div$	16	=	$2\frac{1}{16}$	=	the revolution which A must make while wheel B makes one revolution.

The simplest method of doing this would be to put on at C a wheel having $2\frac{1}{16}$ times as many teeth as there are in A. Suppose then that A has 32 teeth, and one sixteenth of 32 = 2, because $32 \div 16 = 2$. Then twice 32 is 64, and if we add the 2 to this we get 66; hence, if we give wheel C 66 teeth, we have reduced the motion the $2\frac{1}{16}$ times, and we may put on D and S wheels having an equal number of teeth. Or we may put on a wheel at C having the same number as A has, and then put on any two wheels at D and C, so long as that at S has $2\frac{1}{16}$ times as many teeth as that at D.

Again, suppose that the pitch of a lead screw is 4 threads per inch, and that it be required to find what wheels to use to cut a thread of $\frac{11}{16}$ inch pitch, that is to say, a thread that measures $\frac{11}{16}$ inch from one thread to the other, and not a pitch of $\frac{11}{16}$ threads per inch: First we must bring the pitch of the lead screw and the pitch to be cut to the same terms, and as the pitch to be cut is expressed in sixteenths we must bring the lead screw pitch to sixteenths also. Thus, in an inch of the length of the lead screw there are 16 sixteenths, and in this inch there are 4 threads; hence each thread is $\frac{4}{16}$ pitch, because $16 \div 4 = 4$. Our pitch of lead screw expressed in sixteenths is, therefore, 4, and as the pitch to be cut is $\frac{11}{16}$ it is expressed in sixteenths by 11; hence we have the fraction $\frac{4}{11}$, which is the proportion that must exist between the wheels, or in other words, while the lathe spindle (or what is the same thing, the work) makes 4 revolutions the lead screw must make 11.

Suppose the lathe to be single geared, and not compounded, and we multiply this fraction and get—

$$\frac{4 \times 4}{11 \times 4} = \frac{16}{44} \begin{array}{l} = \text{wheel to go on lead screw.} \\ = \text{,, ,, stud or mandrel.} \end{array}$$

$$\text{Or, } \frac{4 \times 5}{11 \times 5} = \frac{20}{55} \begin{array}{l} = \text{wheel to go on lead screw.} \\ = \text{,, ,, stud or mandrel.} \end{array}$$

$$\text{Or, } \frac{4 \times 6}{11 \times 6} = \frac{24}{66} \begin{array}{l} = \text{wheel to go on lead screw.} \\ = \text{,, ,, stud or mandrel.} \end{array}$$

But suppose the lathe to be compounded as in Fig. 1235, and we may arrange the wheels in several ways, and in order to make the problem more practical, we may suppose the lathe to have wheels with the following numbers of teeth, 18, 24, 36, 36, 48, 60, 66, 72, 84, 90, 96, 102, 108, and 132.

Here we have two wheels having each 36 teeth; hence we may place one of them on the lathe spindle and one on the lead screw,

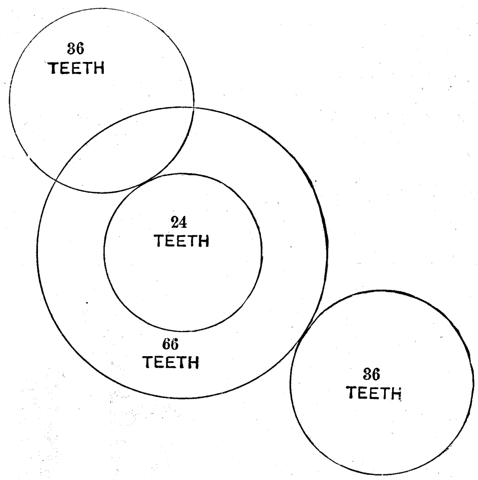


Fig. 1239.

as in Fig. 1239; and putting down the pitch of the lead screw, expressed in sixteenths as before, and beneath it the thread to cut also in sixteenths, we have:

$$\frac{4 \times 6}{11 \times 6} = \frac{24}{66} \begin{array}{l} = \text{wheel to be driven by lathe spindle,} \\ = \text{,, to drive lead screw wheel;} \end{array}$$

the arrangement of the wheels being shown in Fig. 1239.

We may prove the correctness of this arrangement as follows: The 36 teeth on the lathe spindle will in a revolution cause the 24 wheel to make $1\frac{1}{2}$ revolutions, because there are one and a half times as many teeth in the one wheel as there are in the other; thus: $36 \div 24 = 1\frac{1}{2}$. Now, while the 24 wheel makes $1\frac{1}{2}$, the 66 will also make $1\frac{1}{2}$, because they are both on the same sleeve and revolve together. In revolving $1\frac{1}{2}$ times the 66 will cause the 36 on the lead screw to make $2\frac{3}{4}$ turns, because $66 \div 36 = 2\frac{3}{4}$ (or expressed in decimals 2·75), and it thus appears that while the lathe spindle makes one turn, the lead screw will make $2\frac{3}{4}$ turns.

Now, the proportion between 1 and $2\frac{3}{4}$ is the same as that existing between the pitch of the lead screw and the pitch of the thread we want to cut, both being expressed in sixteenths; thus:

$$\begin{array}{l} \text{Pitch of lead screw in sixteenths} \\ \text{,, to be cut in sixteenths} \end{array} \frac{4}{11}, \text{ and } 11 \div 4 = 2\tfrac{3}{4};$$

that is to say, 11 is $2\frac{3}{4}$ times 4.

Suppose it is required, however, to find what thread a set of gears already on the lathe will cut, and we have the following rule:

Rule.—Take either of the driven wheels and divide its number of teeth by the number of teeth in the wheel that drives it, then multiply by the number of teeth in the other driving wheel, and divide by the teeth in the last driven wheel. Then multiply by the pitch of the lead screw.

Example.—In Fig. 1240 are a set of change wheels, the first pair of which has a driving wheel having 36 teeth, and a driven

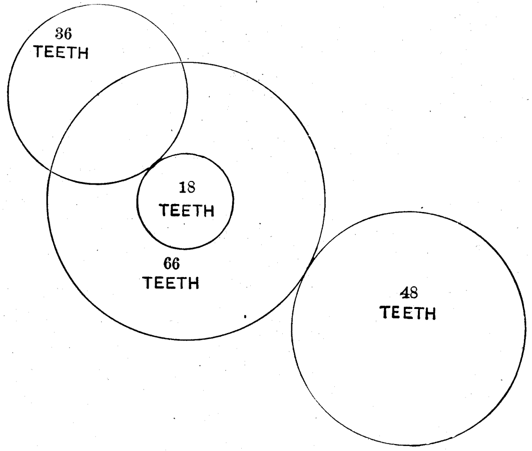


Fig. 1240.

wheel having 18 teeth. The second pair has a driving wheel of 66 teeth, and a driven wheel of 48.

Let us begin with the first pair and we have $36 \div 18 = 2$, and this multiplied by 66 is 132. Then $132 \div 48 = 2{\cdot}75$, and 2·75 multiplied by 4 is 11, which is the pitch of thread that will be cut. Now, whether this 11 will be eleven threads per inch, or as in our previous examples a pitch of $\frac{11}{16}$ inch from one thread to another or to the next one, depends upon what the pitch of the lead screw was measured in.

If it is a pitch of 4 threads per inch, the wheels will cut a thread

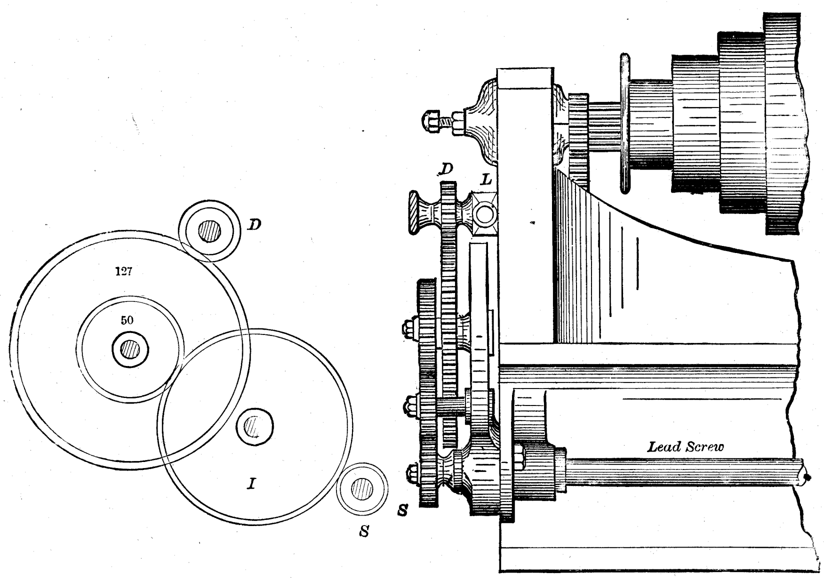


Fig. 1241.

of 11 per inch, while if it were a thread of $\frac{4}{16}$ pitch, the thread cut will be $\frac{11}{16}$ pitch.

Let us now work out the same gears beginning from the lead screw pair, and we have as follows:

Number of teeth in driver is 66, which divided by the number in the driven, 48, gives 1·375. This multiplied by the number of teeth in the driver of the other pair = 36 gives 49·5, which divided by the number of teeth in the driven wheel of the first pair gives 2·75, which multiplied by the pitch of the lead screw 4 gives 11 as before.

Taking now the second example as in Fig. 1240, and beginning from the first pair of gears, we have, according to the rule, $36 \div 48 \times 66 \div 18 \times 4 = 11$ = pitch the gears will cut; or proceeding from the second pair of gears, we have by the rule, $66 \div 18 \times 36 \div 48 \times 4 = 11$ = the pitch the gears will cut. It is not often, however, that it is required to determine what threads the wheels already on a lathe will cut, the problem usually being to find the wheels to cut some required pitch. But it may be pointed out that when the problem is to find the result produced by a given set of wheels, it is simpler to begin the calculation from the wheel already on the lathe spindle, rather than beginning with that on the lead screw, because in that case we begin at the first wheel and calculate the successive ones in the same order in which we find them on the lathe, instead of having to take the last pair in their reverse order, as has been done in the examples, when we began at the wheel on the lead screw, which we have termed the second pair.

The wheels necessary to cut a left-hand thread are obviously the same as those for a right-hand one having an equal pitch; all

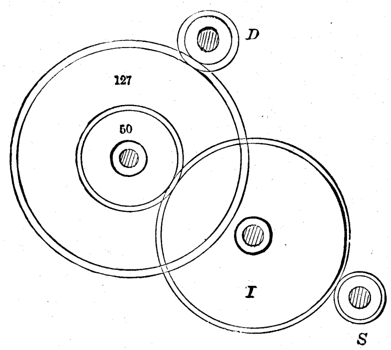


Fig. 1242.

the alteration that is necessary is to employ an additional intermediate wheel, as at J in Fig. 1241, which will reverse the direction of motion of the lead screw. For a lathe such as shown in Fig. 1235, this intermediate wheel may be interposed between wheels D and I or between I and S. In Fig. 1236, it may be placed between D and I or between I and S, and in Fig. 1238 it may be placed between A and C or between D and S.

Here it may be well to add instructions as to how to arrange the change wheels to cut threads in terms of the French centimètre. Thus, an inch equals $\frac{254}{100}$ of a centimètre, or, in other words, 1 inch bears the same proportion to a centimètre as 254 does to 100, and we may take the fraction $\frac{254}{100}$ and reduce it by any number that will divide both terms of the fraction without leaving a remainder; thus, $\frac{254}{100} \div 2 = \frac{127}{50}$. If, then, we take a pair of wheels having respectively 127 and 50 teeth, they will form a compound pair that if placed as in Fig. 1242 will enable the cutting of threads in terms of the centimètre instead of in terms of the inch.

Thus, for example, to cut 6 threads to the centimètre, we use the same change wheels on the stud and on the lead screw that would be used to cut 6 threads to the inch, and so on throughout all other pitches.

CUTTING DOUBLE OR OTHER MULTIPLE THREADS IN THE LATHE.—In cutting a double thread the change wheels are obviously arranged for the pitch of the thread, and one thread, as A in Fig. 251 is cut first, and the other, B, afterwards. In order to insure that B shall be exactly midway between A, the following method is pursued. Suppose the pitch of the lead screw is 4 threads per inch, and that we require to cut a double thread, whose actual pitch is 8 per inch, and apparent pitch 16 per inch, then the lead screw requires to make half a turn to one turn of the lathe spindle; or what is the same thing, the lathe spindle must make two turns to one of the lead screw, hence the gears will be two to one, and in a single-geared lathe we may put on a 36 and a 72, as in Fig. 1243, in which the intermediate wheels are omitted, as they do not affect the case. With these wheels we cut a thread of 8 per inch and then, leaving the lead screw nut still engaged with the lead screw and the tool still in position to cut the thread already formed, we make on the change wheels a mark as at S T, and after taking off the driving gear we make a mark at space *u*, which is 18 teeth distant from S, or half-way around the wheel. We then pull the lathe around half a turn and put the driving gear on again with the space *u* engaged with the tooth T, and the lathe will cut the second thread exactly intermediate to the first one. If it were three threads that we require to cut, we should after the driving gear was taken off give the lathe one-third a revolution, and put it back again, engaging the twelfth space from S with tooth T, because one-third of 36 is 12.

It is obviously necessary, in cutting multiple threads in this way, to so select the change wheels that the driving gear contains a number of teeth that is divisible without leaving a remainder by the thread to be cut: thus, for a double thread the teeth must be divisible by two, hence a 24, 30, 34, 36, or any even number of

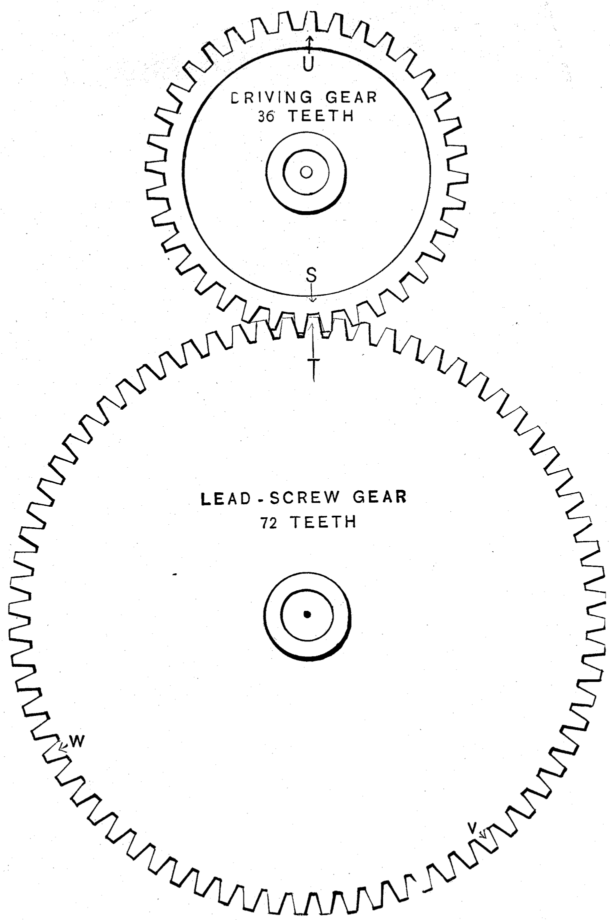


Fig. 1243.

teeth will do. For a triple thread the number of teeth in the driving gear must be divisible by 3, and so on.

But suppose the driving gear is fast upon the lathe spindle and cannot be taken off, and we may then change the position of the lead screw gear to accomplish the same object as moving the lathe spindle. Thus for a double thread we would require to remove the driving gear as before, and then pull round the lead screw so that the eighteenth tooth from T would engage with space S, which is obviously the same thing as moving the driving gear round 18 teeth.

In short work of small diameter the tool will retain its sharpness so long, that one tool will rough out and finish a number of pieces without requiring regrinding, and in this case the finishing cuts can be set by noting the position of the feed screw handle when the first piece is finished to size and the tool is touching the work, so that it may be brought to the same position in taking finishing cuts on the succeeding pieces; but the calipers should nevertheless be used, being applied to the threads as in Figs. 1244 and 1245, which is the best method when there is a standard to set the calipers by.

After a threading tool has carried its cut along the required length of the work, the carriage must be traversed back, so that the second cut may be started. In short work the overhead cross belt that runs the lathe backwards is sufficiently convenient and rapid for this purpose, but in long screws much time would be lost in waiting while the carriage runs back. In the Ames lathe there is a device that enables the carriage to be traversed back by hand, and the feed nut to be engaged without danger of

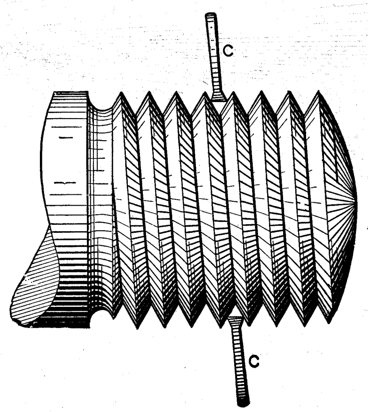


Fig. 1244.

cutting a double thread, or of the tool coursing to one side of the proper thread groove, which is a great convenience.

The construction of this device is shown in Fig. 574. In lathes not having a device for this purpose, the workman makes a chalk mark on the tail of the work driver, and another on the top of the lead screw gear, and by always moving the carriage back to the same point on the lathe bed, and engaging the lead screw nut when these two chalk marks are at the top of their paths of revolution, the tool will fall into its correct position and there will be no danger of cutting a double thread.

In cutting **V** threads of very coarse pitch it will save time, if the thread is a round top and bottom one, to use a single-pointed

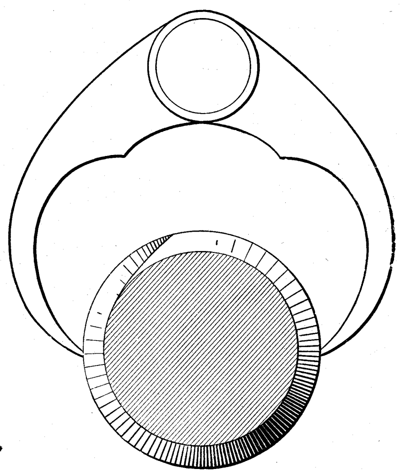


Fig. 1245.

slide rest tool, and cut up the thread to nearly the finished depth, leaving just sufficient metal for the chaser to finish the thread.

In using the single-pointed tool *on* the roughing cuts of very coarse pitches, it is an advantage to move the tool laterally a trifle, so that it will cut on one side or edge only. This prevents excessive tool spring, and avoids tool breakage.

This lateral movement should be sufficient to let the follower side or edge of the tool just escape the side of the thread, and all the cut be taken by the leading side or edge of the tool.

This is necessary because the tool will not cut so steadily on the follower as on the leading cutting edge, for the reason that the pressure of the cut assists to keep the feed screw nut against the sides of the feed screw thread, taking up the lost motion between them, whereas the pressure of a cut taken on the follower side of the thread tends to force the thread of the feed nut away from the sides of the feed screw thread and into the space between

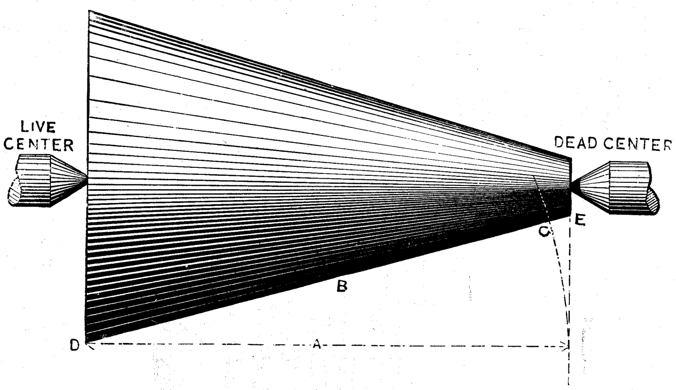


Fig. 1246.

the nut thread afforded by the lost motion, and as a result the slide rest will move forward when the tool edges meet exceptionally hard places or spots in the metal of the work, while in any event the tool will not operate so steadily and smoothly.

If the screw is a long one, the cutting should be done with a liberal supply of oil or water to keep it cool, otherwise the contraction of the metal in cooling will leave the thread finer than it was when cut. This is of special importance where accuracy of pitch is requisite.

In cutting a taper thread in a lathe, it is preferable that the taper be given by setting over the lathe tailstock, rather than by operating the cross slider from a taper-turning attachment, because the latter causes the thread to be cut of improper pitch. Thus, in Fig. 1246 is a piece of work between the lathe centres, and it will be readily seen that supposing the lathe to be geared to cut, say, 10 threads per inch, and the length A of the work to be 2 inches long, when the tool has traversed the distance A it will have cut 20 threads, and it will have passed along the whole length of the side B of the work and have cut 20 threads upon it, but since the length of line B is greater than that of A, the pitch of the thread cut will be coarser than that due to the change wheels.

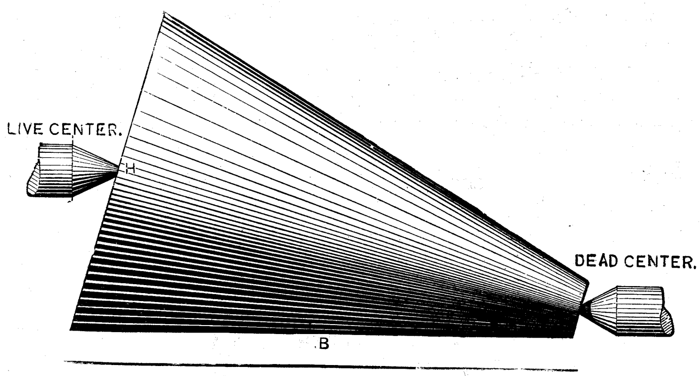


Fig. 1247.

The amount of the error is shown by the arc C, which is struck from D as a centre; hence from C to E is the total amount of error of thread pitch.

But if the lathe tailstock sets over as in Fig. 1247, then the pitch of the thread will be cut correct, because the length of B will equal the length of tool traverse; hence at each work revolution the tool would advance one-twentieth of the length of the surface on which the thread is cut, which is correct for the conditions.

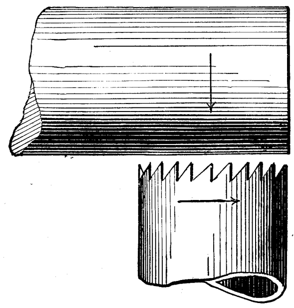


Fig. 1248.

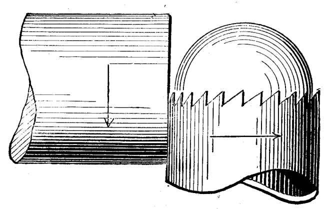


Fig. 1249.

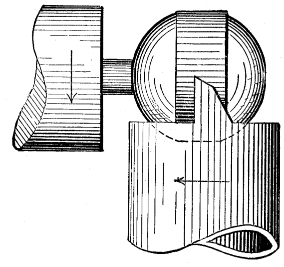


Fig. 1250.

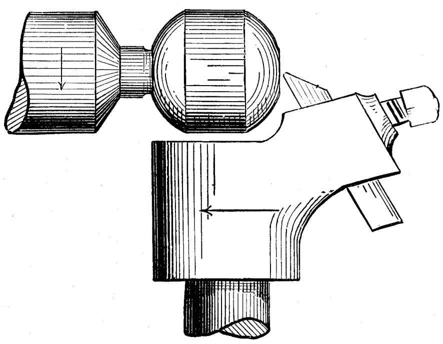


Fig. 1251.

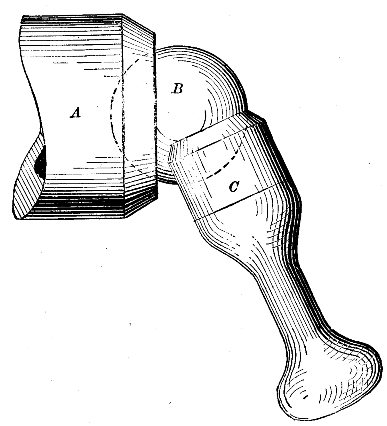


Fig. 1252.

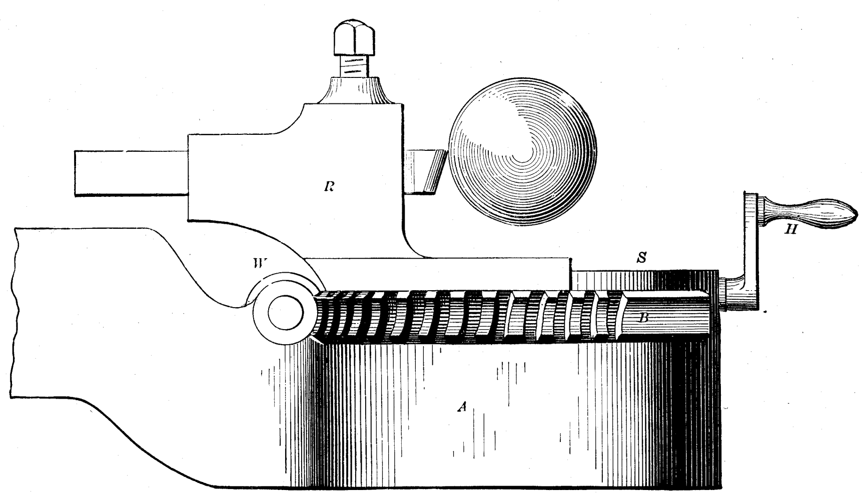


Fig. 1253.

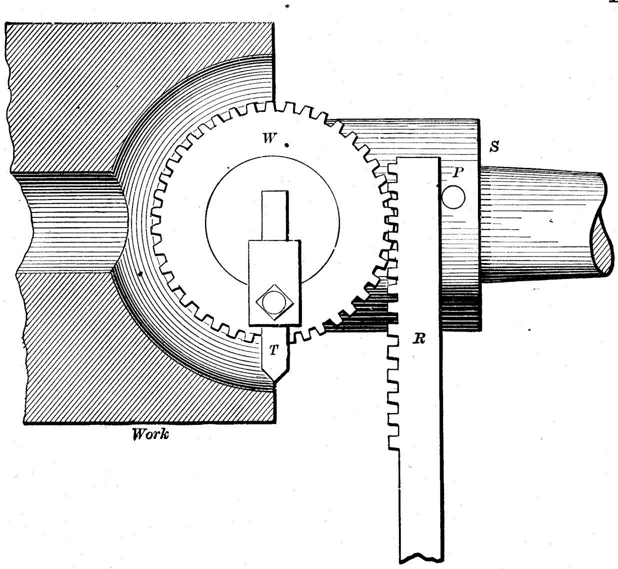


Fig. 1254.

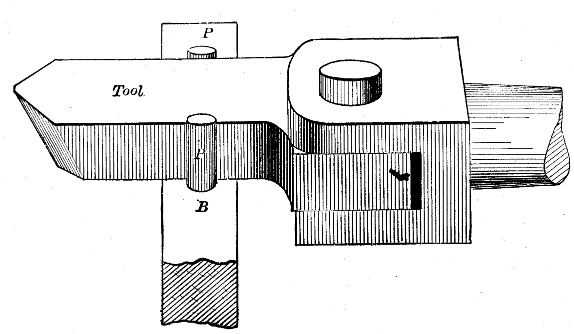


Fig. 1255.