IN THE WORKSHOP

by "Duplex"

*39—Gear-cutting in the Lathe

THE method of making gear-cutters here described is that devised by Mr. J. Rodway, an eminent engineer who has, very kindly, not only given us full particulars of the processes involved, but has also granted permission for their publication.

While we have closely followed the original method, we have at the same time added some suggestions to make the work easier for those whose workshop equipment is limited. Furthermore, we have designed and made a simple type of honing jig to enable the cutters to be accurately sharpened where a cutter-grinding machine is not available.

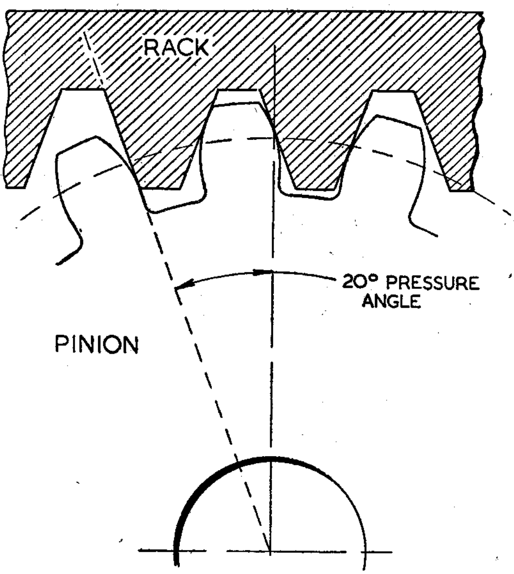

Fig. 1. Illustrating the pressure angle

As has already been pointed out, in ordinary workshop practice, gears are cut to only an approximate standard of accuracy as judged by the theoretical requirements; that is to say, a single cutter is used to machine wheels of several tooth numbers, over a small range, whereas to obtain the theoretically correct tooth form, a single cutter should be employed for each tooth number.

The system of gear-cutter production here described also departs from theoretical accuracy in both this and in other minor particulars; nevertheless, in practice, good results have been obtained, and the cutters made have produced gear wheels of good finish and having a highly satisfactory performance.

The cutters described are suitable for machining gear wheels of any diametral pitch and with any number of teeth, from 17 to a rack; the pressure angle specified is 20 deg.

A description of diametral pitch in relation to the number of teeth on the wheel has already been given, but a new term—pressure angle—has been introduced at this stage. Those who are interested in the geometrical considerations concerning the form of the involute tooth should consult a standard reference book on the subject, but to put it briefly, the pressure angle is the measure of the obliquity of the contact surfaces of the teeth of two gear wheels set in mesh, and it represents the direction in which pressure falls on the teeth when a load is applied.

The pressure angle is shown diagrammatically in Fig. 1, and for the sake of clarity and to avoid possible confusion from more elaborate geometrical construction, a rack geared to a pinion

*Continued from page 683, "M.E.," June 2, 1949.

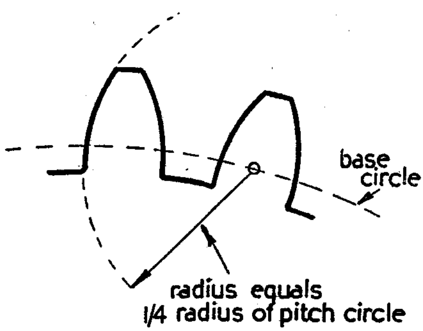

Fig. 2. Single-curve tooth form

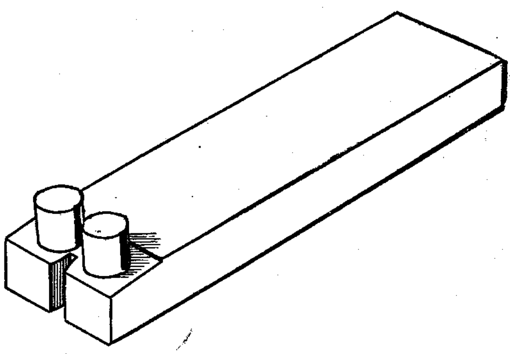

Fig. 3. The form-tool used for shaping the cutter teeth

is used for the purpose of illustration; for a rack here represents a gear wheel of infinitely large diameter.

The practical importance of the pressure angle is that, with the form of tooth used and with a standard angle of 14½ deg., 32 is the lowest number of teeth that can be used, without

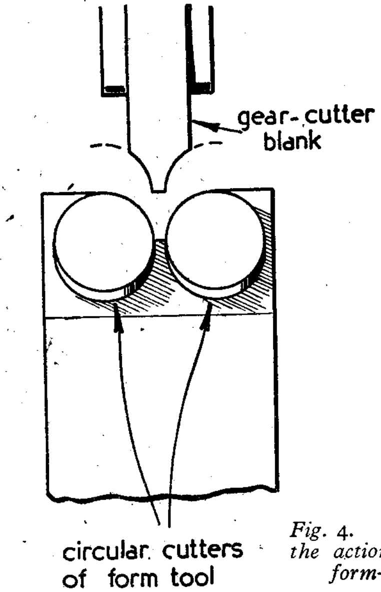

Fig. 4. Showing the action of the form-tool

undercutting the tooth flank, if interference between the teeth is to be avoided when the wheels are running together.

If, however, the pressure angle is increased to 20 deg., then a 17-tooth wheel, machined without undercutting of the teeth, will run in gear with a wheel of any other size. This 20 deg. pressure angle, in conjunction with a shortened form of tooth, is now largely used in automobile engineering, as it produces a stronger type of tooth.

in question is equal to a quarter of the radius of the pitch circle. In the present instance, the corresponding arcs on the teeth of the gear cutter are machined by means of a tool consisting of two circular cutters, of the appropriate radius, mounted at the correct distance apart in a suitable form of holder. The tool itself is depicted in Fig. 3, and its mode of action is illustrated diagrammatically in Fig. 4, where it will be apparent that the two circular cutters will form on the gear-cutter two similar segments of circles, representing the flanks of the gear teeth which it is required to cut.

In order to machine the teeth of the gear-cutter to the correct shape, it is necessary, in addition, to determine by calculation both the distance apart of the two circular cutters and also the distance to which this form tool must be fed into the work.

For reference purposes, these dimensions are set out in Table A, which shows that six cutters are required for machining the whole range of gear wheels of any one diametral pitch.

TABLE A.—Pressure angle 20 deg.

Cutter	Gears cut	Pin Diam. D. in.	Pin centres C. in.	Feed-in. E. in.	Cutter width F. in.	Back-lash in.
A	135 to rack	51.30	49.60	3.89	4.00	0.050
B	55 to 134	32.15	31.60	3.64	4.00	0.060
C	35 to 54	15.07	15.52	3.19	4.00	0.070
D	26 to 34	10.26	11.03	2.88	4.00	0.080
E	21 to 25	8.55	9.40	2.75	4.00	0.090
F	17 to 20	7.80	8.70	2.65	4.00	0.100

All the above dimensions relate to cutters of 1 Diametral Pitch; for other pitches, divide the values given by the corresponding diametral pitch.

The feed-in (E), determines the depth and thickness of the cutter teeth, and is measured

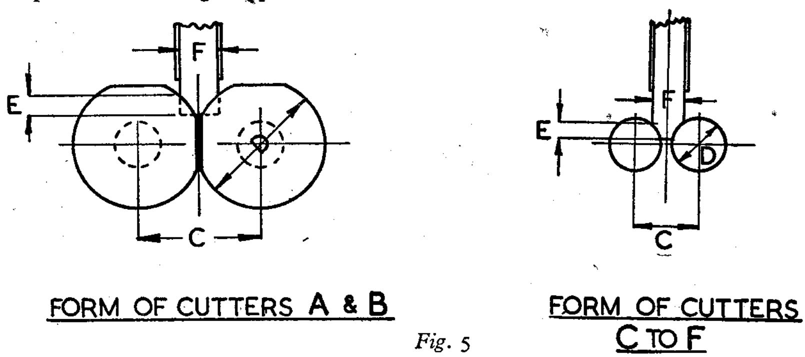

Fig. 5

Leaving out the geometrical construction of the tooth, it may suffice to say that, in the tooth form used in the cutters described, the flanks of the teeth are represented by a segment of a single circle as illustrated in Fig. 2; this is in accordance with the system described by Messrs. Brown & Sharpe, and the radius of the circle

from the point where the pins of the form-tool make contact with the cutter blank.

The dimension (F), represents the breadth of the cutter blank, and serves as a datum dimension when engaging the form-tool.

The backlash is the extra depth given to the teeth when using the gear-cutter to machine gear wheels; this allowance takes into account the approximations involved where arcs of circles are used for the tooth face profiles.

All these terms will be further explained, and their practical application considered, when directions are given for making the form tools and gear-cutters, as well as when describing the actual gear cutting operation.

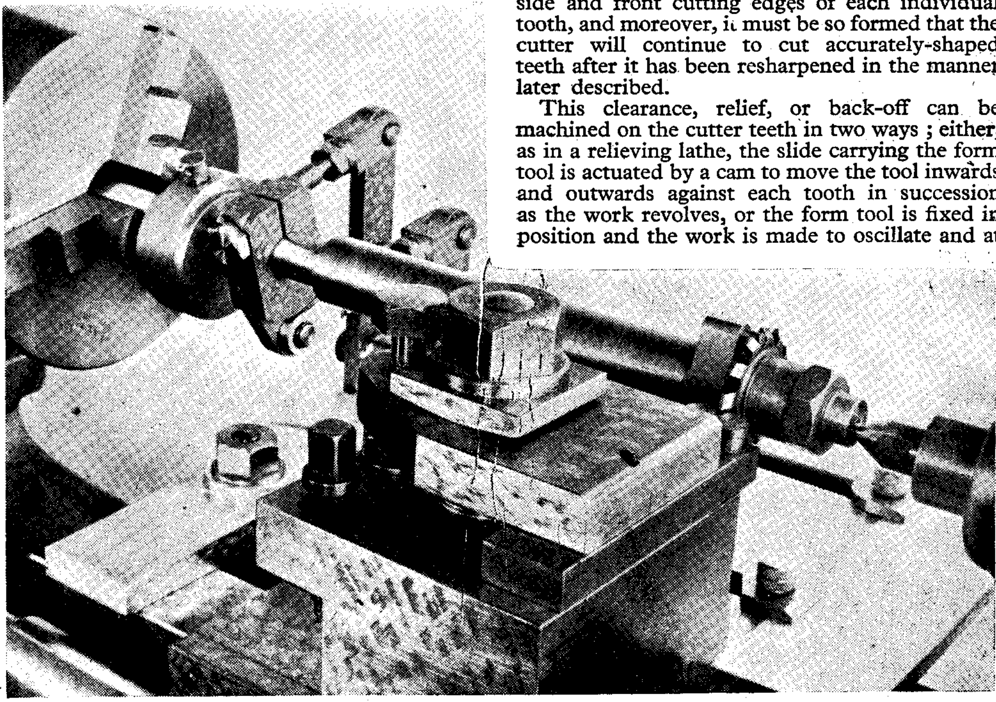

Fig. 6. The attachment set up for machining the cutter blank

Where gear wheels having less than 17 teeth are required, the pressure angle must be correspondingly increased to enable the gears to run together without interference between their teeth.

The new values applicable to these wheels are given in Table B.

TABLE B.—Pressure angle 30 deg.

Cutter	Gear Teeth	D. in.	C. in.	E. in.	F. in.	Back-lash in.
A	135 to rack	67.5	59.5	3.20	4.0	0.05
B	55 to 134	27.5	25.0	2.85	4.0	0.06
C	35 to 54	17.5	16.3	2.67	4.0	0.07
D	26 to 34	13.0	12.4	2.54	4.0	0.08
E	21 to 25	10.5	10.25	2.41	4.0	0.09
F	17 to 20	8.5	8.5	2.31	4.0	0.10
G	14 to 16	7.0	7.2	2.18	4.0	0.10
H	12 & 13	6.0	6.36	2.06	4.0	0.10
J	10 & 11	5.0	5.6	1.98	4.0	0.10

Relieving the Cutter Teeth

If, as in an ordinary turning operation, the teeth of the gear-cutter were machined to shape with the form tool described, the gear-cutter would then be unsuitable for machining the teeth of a gear wheel, as it would have no clearance behind the cutting edges such as is given to all lathe tools.

Now, this clearance must be given to both the side and front cutting edges of each individual tooth, and moreover, it must be so formed that the cutter will continue to cut accurately-shaped teeth after it has been resharpened in the manner later described.

This clearance, relief, or back-off can be machined on the cutter teeth in two ways; either, as in a relieving lathe, the slide carrying the form tool is actuated by a cam to move the tool inwards and outwards against each tooth in succession as the work revolves, or the form tool is fixed in position and the work is made to oscillate and at the same time to move towards and then away from the form tool.

In the system adopted the latter method is used, that is to say the form tool is fixed in the lathe toolpost and the cutter blank is mounted eccentrically on an arbor carried between the lathe centres; when, therefore, this arbor is turned to and fro, the blank will move alternately towards and away from the tool.

In the present instance, as illustrated in Fig. 6, an eccentric is fitted to the lathe mandrel, and a link attached to the strap of the eccentric is used to rock the work backwards and forwards while turning it for a small part of a revolution.

The effect of these movements is that the work is turned for a sufficient distance to machine a single tooth, and the inward and outward motion serves to cut the requisite amount of back-off. In this way each tooth, located by a register pin, is in turn correctly machined.

To amplify, and, perhaps clarify this description, reference should be made to the illustrations in order that the purpose and working of the several parts of the mechanism may be more readily understood. Fig. 6 shows how the cutter relieving gear is mounted in the lathe; Fig. 7 illustrates the construction of the rocking mechanism; and Fig. 8 depicts the form of rocking arbor on which the cutter blank is mounted.

The general arrangement drawings are given in Fig. 9, and the attached numbers are applicable throughout the series of working drawings of the several parts of the mechanism.

A cross-reference, should therefore, enable any particular part to be identified and its dimensions determined.

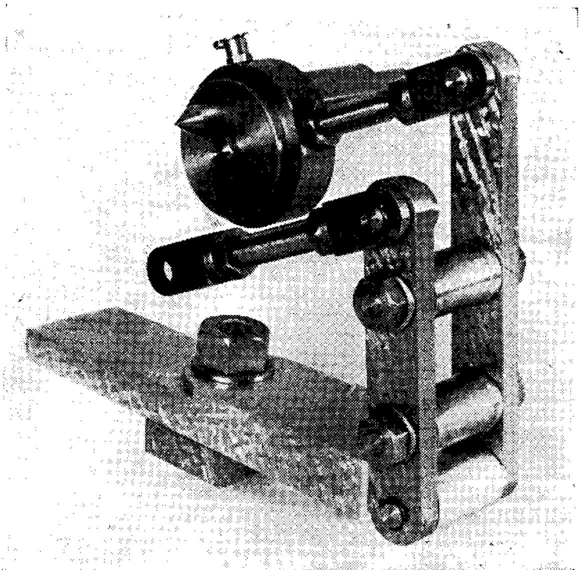

Fig. 7. Details of the rocking mechanism

The eccentric (1) is secured by its shaft in the lathe mandrel chuck or collet, and the eccentric strap is connected to a rocking lever (6) which is pivoted to the anchor block (9) bolted to the lathe bed. Attached to the rocking lever (6) is an arm (7) which is connected by a link (12) to the arm (4) secured to the cutter arbor (2).

The cutter blank is mounted on an eccentric seating formed at the end of the arbor, but the remaining portion of the arbor runs truly on the tailstock centre and on the coned centre, fitted centrally in the shaft of the eccentric.

It follows, therefore, that, when the lathe mandrel revolves, the eccentric causes the lever (6), and with it the lever (7), to rock to and fro, thus making the arm (4) rock the arbor backwards and forwards for a small part of a revolution.

The lengths of the levers concerned and the travel of the eccentric are so arranged that the cutter blank is turned for a distance sufficient for machining each individual tooth.

In addition, the eccentric mounting of the cutter blank on the arbor causes the cutter, as it is turned, to advance towards the form tool. It will be apparent that the combination of these two movements results in the machining of the heel of each cutter tooth to a lesser diameter than the cutting face, that is to say the tooth is relieved or backed-off and is thus enabled to cut freely when at work.

The Eccentric. Part 1. Fig. 10.

The body of this component is machined from a length of $1\frac{1}{2}$-in. diameter round, mild-steel bar. The bar is secured in the chuck to allow both ends to be faced true. Next, the work is clamped in a V-block resting on the surface plate and the cross centre-lines are scribed with the surface gauge at both ends; in addition, the subsidiary cross centre-line is scribed exactly $\frac{3}{8}$ in. below the horizontal centre-line to denote the throw of the eccentric. The centres indicated by the intersections of all these lines are then carefully centre-punched, and afterwards drilled with a small centre drill; the purpose of the latter operation is to afford centres for the wobbler, or centre-finder, which will enable the work to be set to run truly or with the specified amount of eccentricity.

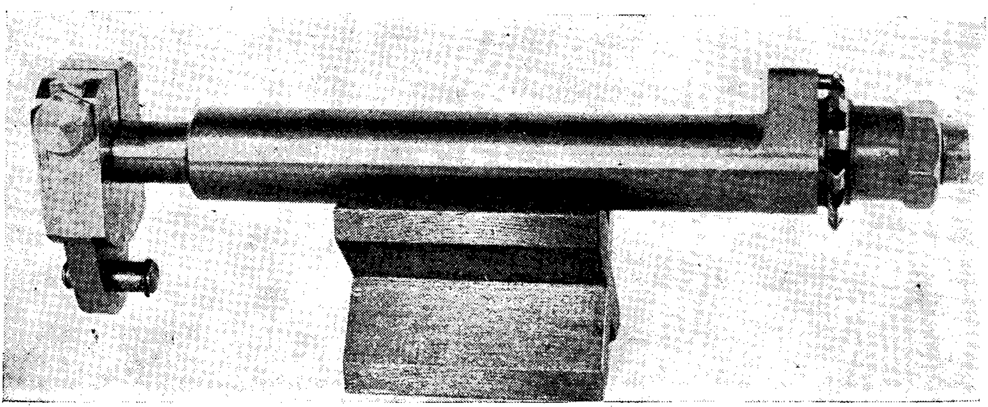

Fig. 8, The arbor fitted with its rocking arm. The cutter blank is shown in place

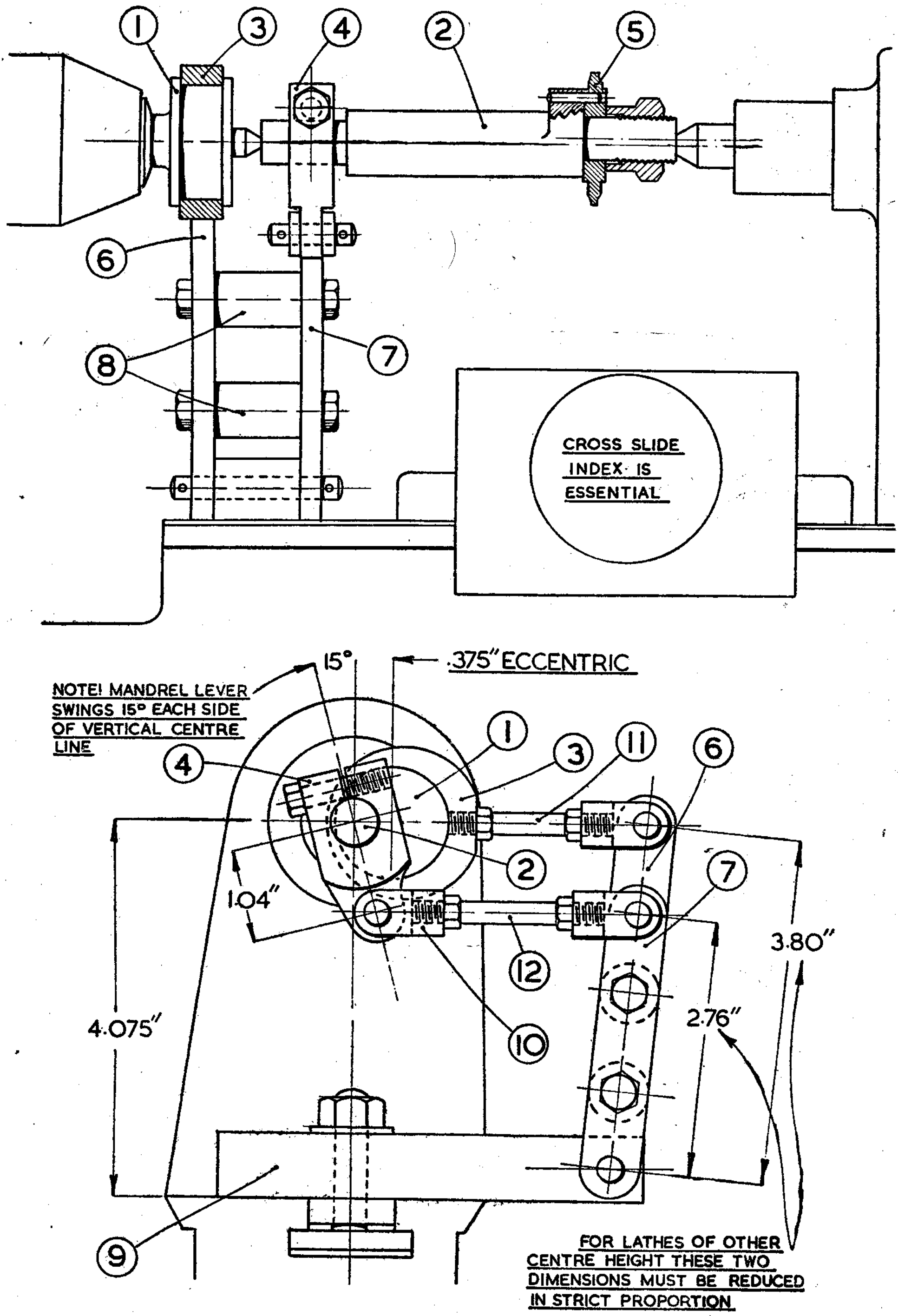

Fig. 9. General arrangement drawings of the attachment

Grip the bar in the four-jaw chuck, and with the aid of the wobbler set the true centre to run truly; reduce the overall diameter to 1 15/32 in. and turn the 1¼-in. diameter portion to receive the eccentric strap; drill the centre with a No. 24 drill and tap the hole No. 2 B.A. as indicated in the drawing.

The wobbler is then again used to set the work in the chuck so that the centre scribed ⅜ in. away runs truly; this allows the seating for the will depend mainly on the width of the lathe cross-slide, for the base to which the rocking gear is anchored is bolted to the lathe bed, and the cutter blank, when mounted on the arbor, should be in a convenient position for being machined with a tool secured to the lathe saddle.

The ends of the material are faced flat, and the work is then mounted in a V-block resting on the surface plate to enable the cross centre-lines to be scribed at both ends.

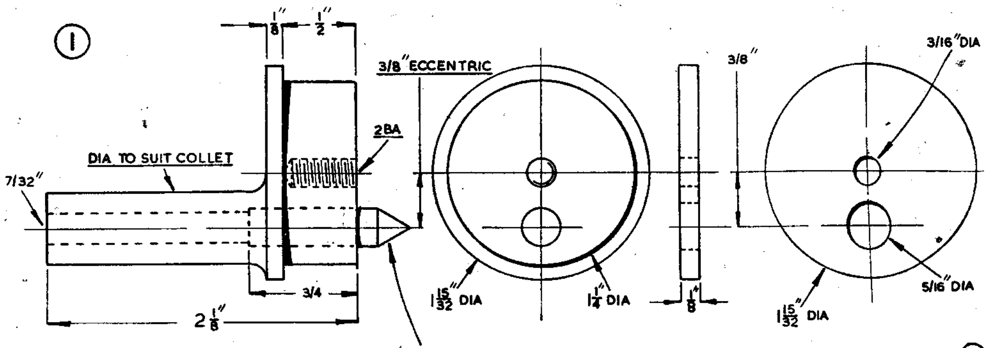

Fig. 10

coned centre to be drilled and bored in the correct position.

The coned centre can be fitted into a well-fitting parallel bore, or a taper seating as in the lathe mandrel can be used; alternatively, the centre can be provided with an abutment shoulder and screwed into place.

The work, when reversed, is gripped in the chuck by the 1¼-in. diameter portion to enable the shank to be centred with the wobbler so that it can then be reduced in diameter to ⅝ in. or so, or turned to fit a mandrel collet should the lathe be so equipped.

Where a pressed-in coned centre is used, it is advisable at this stage to drill a 7/32 in. diameter axial hole to meet the centre housing; this will enable the coned centre to be driven out when required.

The keep plate of the eccentric sheave can be turned and parted off from the 1½-in. diameter material used to make the eccentric body; the central bolting hole is drilled in the lathe at the time of the turning operation, and the clearing size hole for the passage of the coned centre is marked-out with the jenny callipers on the cross centre-line, and then drilled in the drilling machine.

The coned centre is made of silver-steel, and the coned portion is turned to an included angle of 60 deg. by setting over the lathe top slide. As this is a working centre, it should be hardened and tempered in order to resist wear.

The Cutter Arbor. Part 2. Fig. 11

A piece of 1⅛-in. diameter round mild steel is used for making this part, but alloy steel, such as that found in motor car axle shafts, can be employed for this purpose if better wearing qualities are required. The length of the arbor

The two centres shown at B—B in the diagram in Fig. 12 are then marked-out with the jenny callipers ⅜ in. from the periphery; this is to allow sufficient material for forming the web to carry the cutter driving-pin.

The two centres A—A are scribed on the cross centre-line at a distance of 0.09 in. from B—B.

Those who experience difficulty in attaining accuracy in marking-out operations will find this subject dealt with in *Marking-out Practice for Mechanics* published by Percival Marshall & Co.

As will be apparent, the arbor when mounted on the centres A—A will cause the cutter blank to run truly so that it can then be machined to the correct width; but when the centres B—B are used, the blank will turn eccentrically as is required for the operation of relieving the teeth.

When the four centres have been carefully centre-punched, their position should be checked with a hand lens before they are centre-drilled. As the paired centres are rather close together, it is advisable to employ a centre drill with a ⅛-in. diameter shank and a 3/64 in. drilling point.

It will be observed that the end view of the arbor given in Fig. 11 shows that the cutter driving peg is located at an angle of 15 deg. from the cross centre-line common to the two centres.

This angle is set out by attaching a 60-T wheel to the tail of the mandrel, but as 15 deg. equals 2½ teeth on this wheel, a 2 to 1 reduction gear is fitted to enable 5 wheel teeth to be used for the indexing operation. A 20-T wheel, gearing with the 60-T wheel, is, therefore, keyed to a 40-T wheel mounted on the same stud; five tooth spaces on the latter wheel will then give the required 15 deg. of rotation.

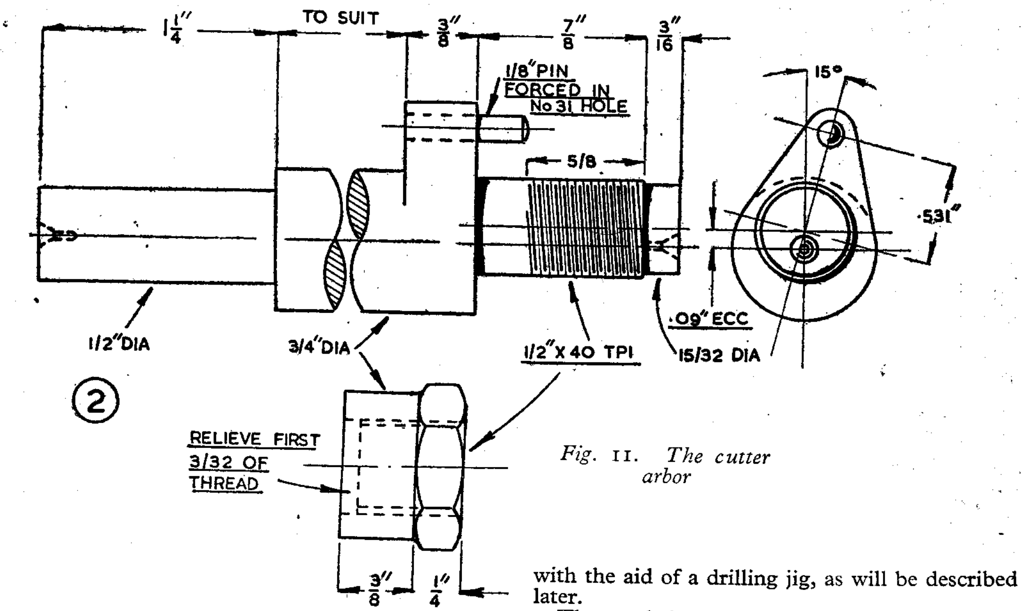

Fig. 11. *The cutter arbor*

The next step is, with the aid of the surface gauge, to set the cross centre-line on the end of the arbor to lie parallel with the surface of the lathe bed, and the quadrant detent is then adjusted to engage a tooth space on the 40-T wheel.

Mark the fifth tooth space from this point, as it will be required later when marking-out the position of the cutter driving-pin.

With the arbor still mounted on the centres A—A, turn the parallel portion on which the cutter blank fits to exactly 0.500 in. in diameter, with the aid of a drilling jig, as will be described later.

The work is now reversed between the lathe centres for turning the remaining portion of the arbor on the centres B—B.

The end portion of the arbor is reduced to ½-in. diameter for fitting the rocking arm (4), but the remainder is turned to ¾-in. diameter in order to afford rigidity.

For the sake of appearance, the web on the shaft lying at the junction of the turned portions is reduced by filing to the shape represented in the drawing, but this also serves to allow the arbor to fit into the cutter honing jig which will be described later.

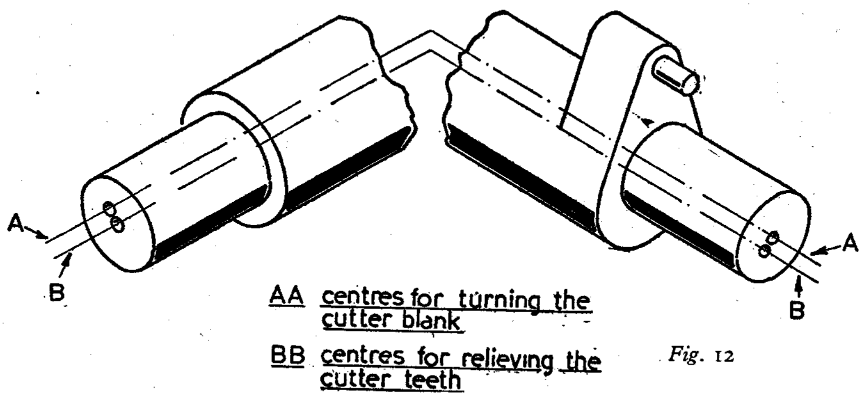

Fig. 12

and then screw-cut it 40 t.p.i. for a distance of ⅝ in. to receive the clamping-nut.

Next, engage the detent with the tooth space previously marked on the 40-T wheel, and with a V-tool, set on its side at centre height, scribe the centre-line for the driving peg on the face of the web ; the hole to receive this peg is drilled

The clamping-cut can conveniently be turned from a length of ⅜-in. Whitworth nut-size hexagon bar, and following the turning and boring operations, the thread can be cut with a tap supported by the lathe tailstock while the work is still gripped in the mandrel chuck.

(*To be continued*)