# IN THE WORKSHOP

## by "Duplex"

### *41—Gear-cutting in the Lathe

THE next step is to make the form tools required for machining the flanks of the gear-cutter teeth to the correct profile.

An illustration of one of these tools was given in Fig. 3 on page 740 of the June 16th issue, and three examples are shown in the photograph in Fig. 25.

The dimensional data for the diameter of the cutting pins and the centre distances at which they are spaced have been set out in the Tables; and with this in mind it remains to describe the actual methods used to make the complete cutting tools.

Originally, the tool was designed with a solid shank in which the cutting pins were made a force fit. This mode of construction, however, rendered the resharpening of the pins a somewhat difficult matter where a special cutter grinder was not available. To overcome this difficulty, it was decided to make the pins readily removable, so that not only could they be sharpened in an ordinary grinder, but, in addition, the pins could be rotated when in place in order to set their rake angle correctly. The latter form of tool shank will be seen in the central tool in Fig. 25 as well as in the working drawings in Fig. 26; its method of construction, however, also applies in all essentials to the making of the simpler solid form of tool shank.

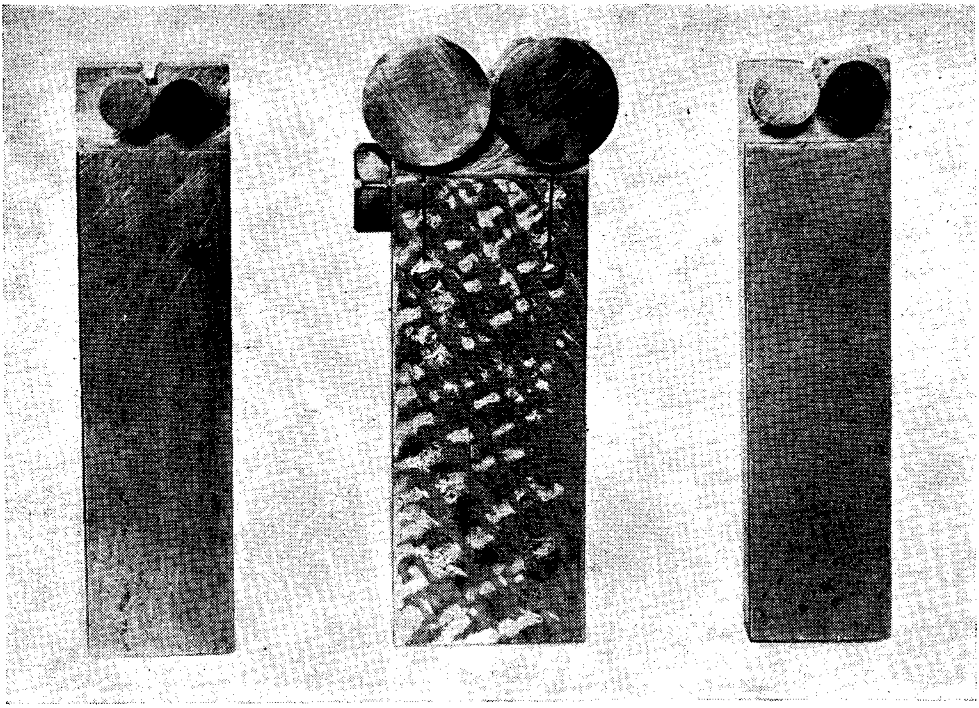

*Fig. 25. The form tools used for machining gear-cutters*

The dimensions of the material used for the shank will depend both on the size of the pins fitted and on the overall height available in the lathe tool-holder, but maximum dimensions are advisable to facilitate the machining, as well as the cutter grinding operations.

The first step is to machine, or file and scrape, the under surface of the material flat; the work is then mounted horizontally in the vice attached to the vertical milling slide, and the slide as a whole is set at an angle of 5 deg. across the lathe axis. This setting enables the angular flat, shown in Fig. 27A, to be machined at the end of the shank by means of either a circular milling-cutter or a fly-cutter.

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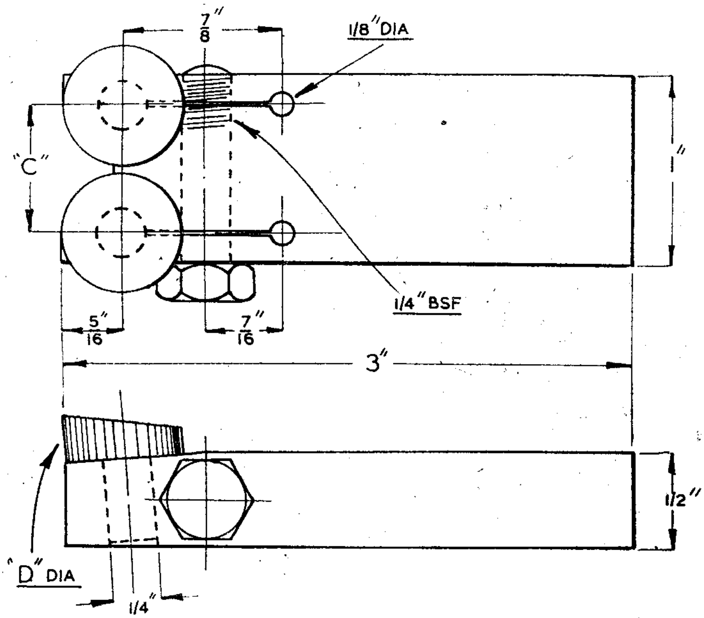
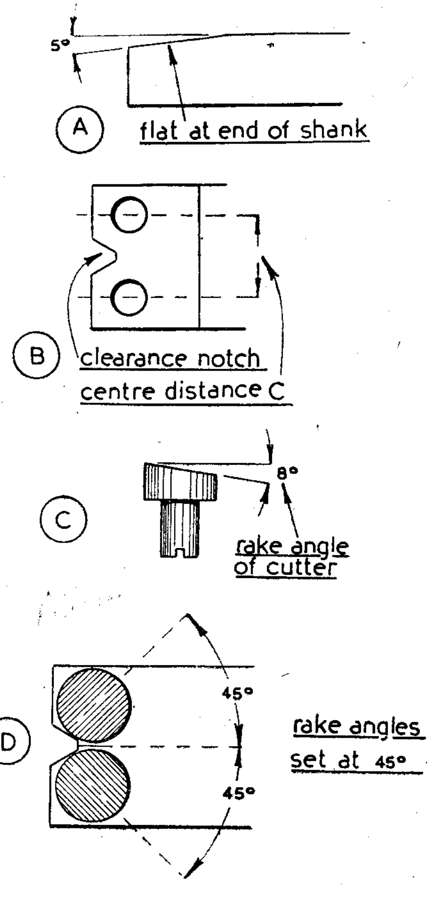
*Continued from page 801, Vol. 100, "M.E.," June 30, 1949.




*Left—Fig 26. Form tool fitted with a clamp-bolt*

*Below—Fig. 27. Details of the form tool*




Without removing the work from the lathe, the positions of the two holes to receive the cutter pins are marked-out approximately. A small Slocomb drill is gripped in the lathe chuck, and its point is brought against the marked-out centre of one of the holes by adjusting the setting of the cross-slide and the vertical-slide. The cross-slide and the vertical-slide are then locked, and the index of the vertical-slide is set to zero and locked in this position. In this way, the first hole is centre-drilled, drilled and finally reamed to size. The position of the second hole is determined by moving the vertical-slide, with the aid of its index, for a distance equal to the dimension given in the Table and indicated in Fig. 27B. After the slide has again been locked, the second hole is machined in a similar manner to the first. The work can now be removed from the lathe and the position of the cross clamping-bolt is marked-out and then drilled and threaded. The two saw slots shown in the drawing should next be marked-out and $\frac{1}{8}$ in. diameter holes drilled at their inner extremities right through the shank.

The slots may be cut by using a hacksaw blade of $\frac{1}{4}$ in. width threaded through the cutter hole and then secured in the hacksaw frame, but where the diameter of this hole is less than $\frac{1}{4}$ in., a narrow piercing saw blade must be employed for this purpose. To complete the work on the tool shank, a V-notch, as shown in Fig. 27B, is filed in its end to afford clearance for the cutter teeth when the tool is in operation.

The cutter pins, at one and the same setting in the chuck, have their shanks turned to a good fit in the tool shank, and their heads machined to the exact diameter given in the Table.

In order to facilitate rotating the cutter in the tool shank when setting the direction of its rake, a screwdriver slot is cut with a fine hacksaw at the end of the cutter shank.

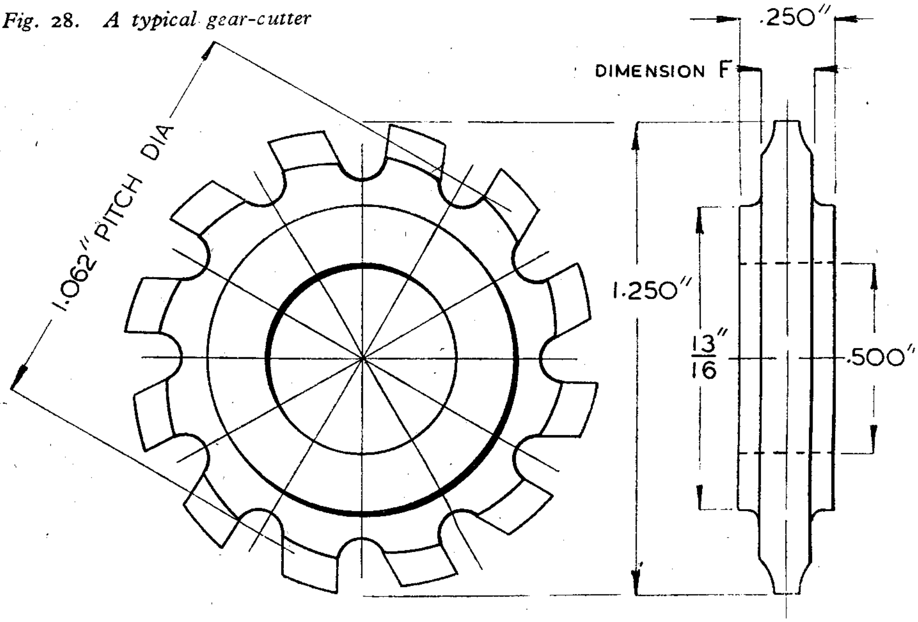
Either silver-steel or ordinary carbon tool-steel may be used for making the cutter pins, and after machining they are hardened and then tempered to a straw colour.

The final operation is to sharpen the tool by grinding the correct rake angle on the upper surface of the cutter pins, and then finishing the cutting edges with an oilstone slip.

Now, a rake angle of 5 deg. is required to offset the inclination given to the end of the the lathe axis; the rake angle can then be machined by taking a cut with a milling-cutter or a fly-cutter across the surface of both pins.

To ensure ready identification, it is advisable to mark the tool shank with its diametral pitch, pressure angle and tooth number. This can be done with hand punches, but if preferred, these particulars can be etched on the tool by the method to be described later for marking hardened gear-cutters.

*Fig. 28. A typical gear-cutter*




tool shank, but, as shown in Fig. 27C, this angle is increased to 8 deg. in order that when the cutter pins are finally rotated, as illustrated in Fig. 27D, a small amount of top rake remains in the direction of the tool's line of cut.

To grind this 8 deg. rake, the cutter pins are clamped one at a time in the tool shank, and when the angular rest of the grinding machine has been set to 8 deg the upper surface of the tool can be accurately ground without difficulty.

Should the tool shank have any tendency to rock on the grinding table, this may be overcome either by gripping the shank in a small vice or by clamping it to a suitable angle plate.

When the upper faces of the cutter have been ground in this way so as to leave them equal in height, the shanks are inserted in the tool and then turned with a screwdriver to align the rake angle at an angle of 45 deg. with the long axis of the tool shank, as illustrated in Fig. 27D. The cutters are finally secured in place by tightening the clamp-bolt and the tool is ready for use.

Where the cutter pins are of large diameter entailing the removal of much metal to form the rake angle, this operation will be facilitated if the tool shank, with the unhardened cutter pins secured in place, is mounted on the vertical slide set at an angle of 8 deg. across the line of

**Machining the Cutter Blank**

Now that the construction of the cutter machining attachment has been described, together with the making of the various tools and jigs required, the next step is to consider in detail the machining of the gear-cutter itself

The material used for making the cutters is round, tool steel bar, although for machining brass and aluminium gear wheels some workers find that case-hardened mild-steel cutters give satisfactory results if care is taken. However, as the labour expended in making cutters of these two materials does not differ materially, it is on the whole wisest, perhaps, to adhere to carbon steel for this purpose.

The form of a typical cutter is shown in Fig. 28, and it will be observed that the cutter has twelve teeth with an overall diameter of exactly $1\frac{1}{4}$ in. The pitch diameter indicated in the drawing refers to the holes drilled to form the bases of the teeth and not to the pitch circle of the teeth.

To provide an actual example, referred to throughout the machining operations that follow, the making of a gear wheel having 30 teeth of 40 diametral pitch and with a pressure angle of 20 deg. will be described. To obtain the data necessary for the machining operations, reference should be made to Table A given previously.

The operational drawings in Fig. 29, A to H,

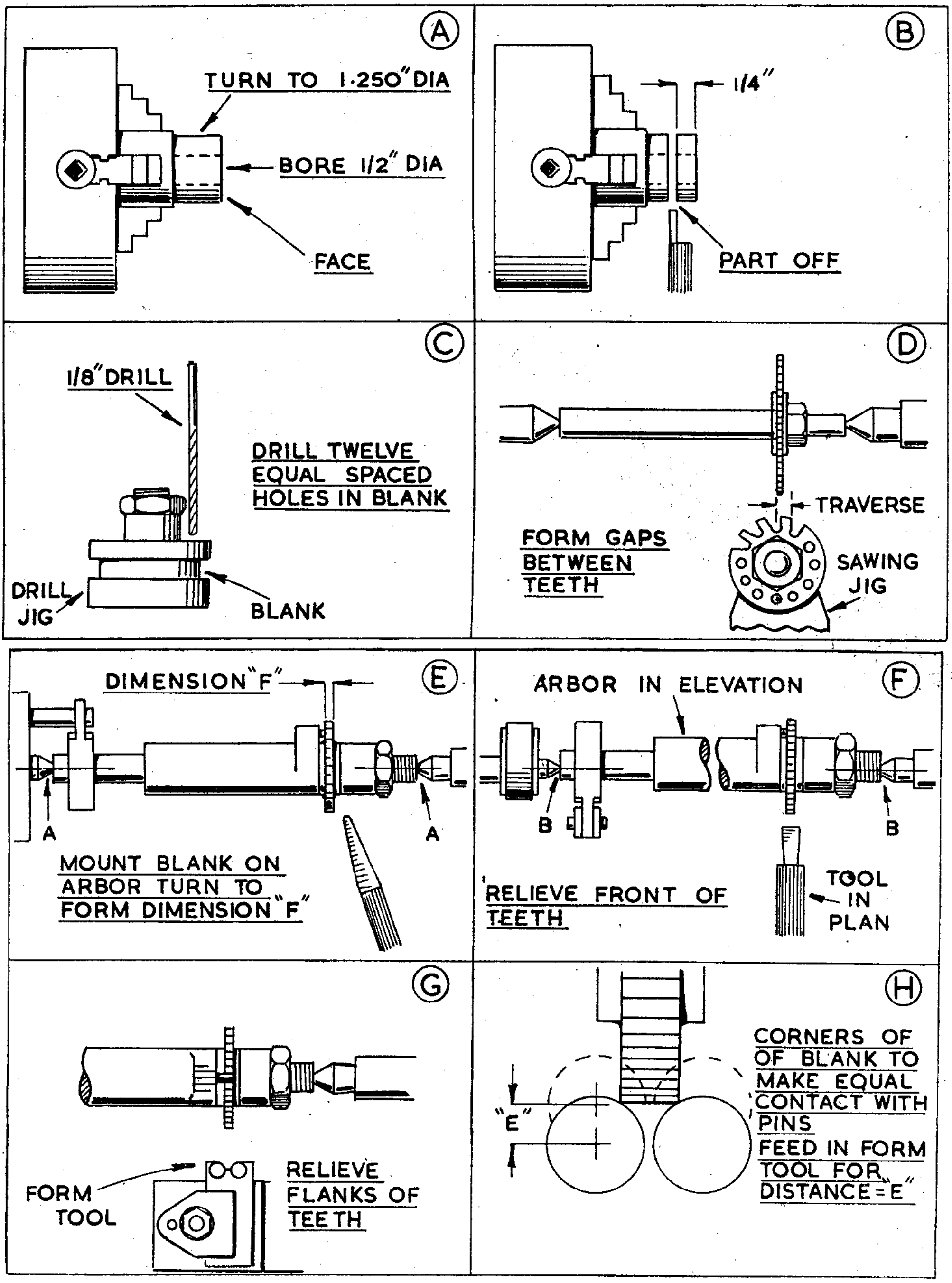



*Fig.* 29.

represent the machining sequence step by step.

The material is gripped in the lathe chuck (A), and its end is faced; the outside diameter is then finish-turned to exactly 1.250 in. The bore is next machined to ½ in. diameter to afford a close sliding fit on the eccentric end of the cutter arbor. The latter operation may be carried out either by boring to a fine finish, or by boring slightly under-size and then correcting with a reamer. If several cutters have to be made, time will be saved and uniformity will be ensured if an adjustable reamer of the type illustrated in Fig. 30 is employed, for when once this tool has been correctly set it may be used to finish all the bores accurately to size.

It should, perhaps, be pointed out that this form of reamer, being of American manufacture, is not always easily obtainable, but the more usual pattern with a much wider range of adjustment may be used instead.

order that the cutter teeth may be formed centrally; this allows the clamping faces of the cutter to be used as datum surfaces, when at a later stage the cutter is set centrally in relation to the gear-wheel blank.

Half the surplus metal is, therefore, removed from one side face, with the aid of a micrometer measurement, and, when the cutter has been reversed on the arbor, the remainder can be faced off with reference to the leadscrew index.

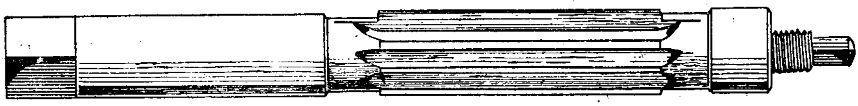


*Fig.* 30.

Next, as represented in B, part off the blank to $\frac{1}{4}$ in. width. The inner face of the blank can be turned to a good finish if the parting-tool, when it has reached to within about 3/32 in. of the bore, is withdrawn and then traversed a thousandth of an inch to the right in order to give a light facing cut; the parting-off operation is then completed. As an alternative, the blank can be mounted on a shouldered stub mandrel for facing the back surface.

The blank is now clamped in the drilling jig (C), and the twelve equally-spaced holes to locate the cutter teeth are drilled with an $\frac{1}{8}$ in. diameter drill. After taking the blank out of the jig, carefully remove the drilling burrs with the aid of a countersink or centre drill turned with the fingers, and as an additional precaution, rub the work on the surface plate to make sure that no high spots remain; should any bright spots show up, they can be levelled by using a small flat-ended scraper.

The cutter is now clamped in the sawing jig to enable the gaps between the teeth to be formed. This is carried out, as shown in D, with a slitting saw mounted on a mandrel between the lathe centres, while the jig itself is secured in the tool-post to lie parallel with the sides of the saw.

A fairly thick saw should be used for this purpose to prevent it being deflected from its true path. The work is aligned by means of the top slide to ensure that the saw cut meets the drilled hole almost at its extreme edge. The sawing operation is continued tooth by tooth until the blank has been slit all round in this manner; the top slide is then traversed, as indicated in the drawing, to bring the saw into line with the edge of the following drilled hole, thus enabling the machining of the tooth gaps to be completed and the teeth themselves to be formed with parallel sides. The saw-cut surfaces on the leading edges of the teeth should be carefully cleaned up with a fine file while the blank is gripped in the vice.

The thinned portion at the periphery of the blank, indicated in Fig. 28 and other drawings by the dimension F, is machined as shown in Fig. 29E. The cutter is secured against the shoulder of a true-running mandrel, or the cutter arbor itself can be used when mounted on its centres AA; the surplus metal is then removed with a round-nosed tool.

It is essential to remove an equal amount of metal from the two side faces of the blank in

The dimension F, will, of course, vary with the diametral pitch of the cutter; in the present instance, as the D.P. is 40, the figure 4.00, given in Table A, must be divided by 40, leaving a thickness of 0.100 in. This dimension must be observed exactly, as it is a datum figure, and on it will depend the accuracy of the tooth form of both the cutter and the gear teeth it eventually machines.

This completes the preliminary machining operations on the cutter blank, and it now remains to cut the teeth to their correct form and, at the same time, to afford them the necessary relief.

For this purpose, as depicted in F, and in the photograph in Fig. 6 (June 16th issue), the cutter blank is mounted on the arbor of the relieving attachment and with the cutting face of the tooth nearest the operator pointing downwards. The arbor is mounted on its centres BB so that the cutter moves eccentrically when the arbor is turned. A square-ended lathe tool is secured in the lathe tool-post with its cutting edge at centre height.

The rocking arm attached to the mandrel end of the arbor is then adjusted, in accordance with Figs. 9 and 31, so that, as the lathe is turned by hand, the eccentric gear moves the cutter blank with the appropriate motion for relieving the teeth.

To set the eccentric gear correctly, reference should be made to Fig. 31 as well as to Fig. 9; these illustrations show that the rocking motion should be adjusted so that the upper face of the relieving tool is clear of the face of the tooth at the start of the cutting stroke, and at the end of the stroke the heel of the tooth is again clear of the tool. (Fig. 31 has unavoidably had to be omitted from this instalment, but will be included in the next.)

It should be noted that once the arbor rocking arm has been correctly adjusted, it can remain permanently set in this position.

The lathe can now be started to run at from 60 to 100 r.p.m., and the tool is carefully fed in for a distance just sufficient to relieve the whole of the front face of the tooth.

The blank is then moved on the arbor to register the next tooth against the locking pin, and the machining is continued until all the teeth have been equally relieved with reference to the cross-slide index.

*(To be continued)*