Gear Generating Using Rack Cutters

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Universal machines capable of cutting both spur and helical gears were developed in 1910, followed later by machines capable of cutting double helical gears with continuous teeth. Following the initial success, the machines were further developed both in England and France under the name *Sunderland*, and later in Switzerland under the name *Maag*.

This article explains the fundamental advantages which have made rack-shaped cutting machines successful, particularly in the production of large gears.

Basic Principles

A basic rack is essentially the starting point of the geometry of all conjugate gear forms, and from this basic rack, a series of gears may be graphically developed. If the rack has straight-sided teeth, the gears developed from it will have involute form — now the most common form of gear tooth. The development of an involute gear is illustrated in Fig. 1.

Such a straight sided basic rack may be used to develop both gears with standard proportions and also, within limits, gears with larger or smaller diameters than standard. Advantage is frequently taken of this fact to achieve stronger teeth by increasing the outside diameter, *ie* lengthening the addendum of the teeth. As can be seen in the example illustrated in Fig. 2, although both pairs of gears mesh correctly together, the 12-tooth pinion shown to the right of the diagram exhibits a much stronger tooth form as a result of 'addendum modification'. If the generating process is used to produce gears developed from the basic rack, the foregoing principles are fully exploited and the same cutter may be used to cut all numbers of teeth.

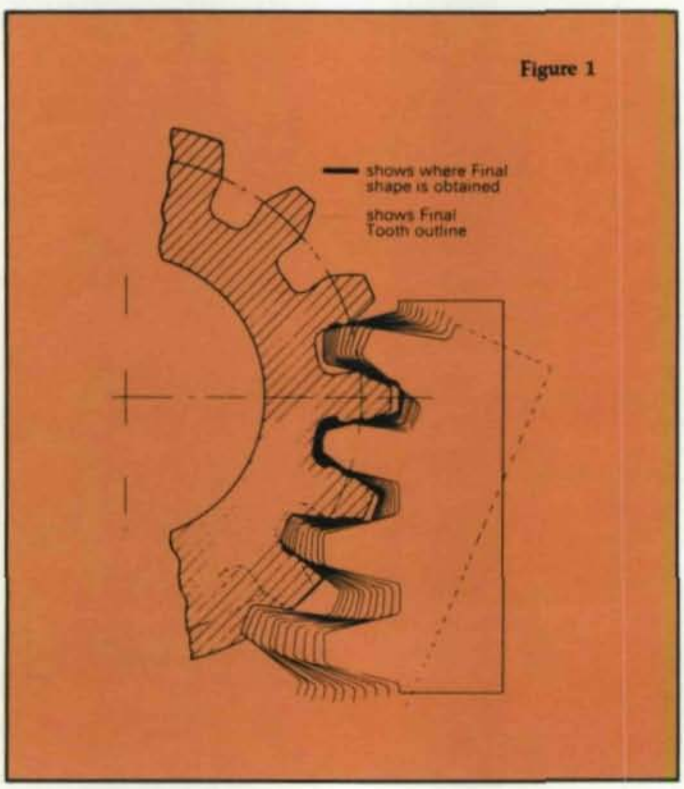

Figure 1

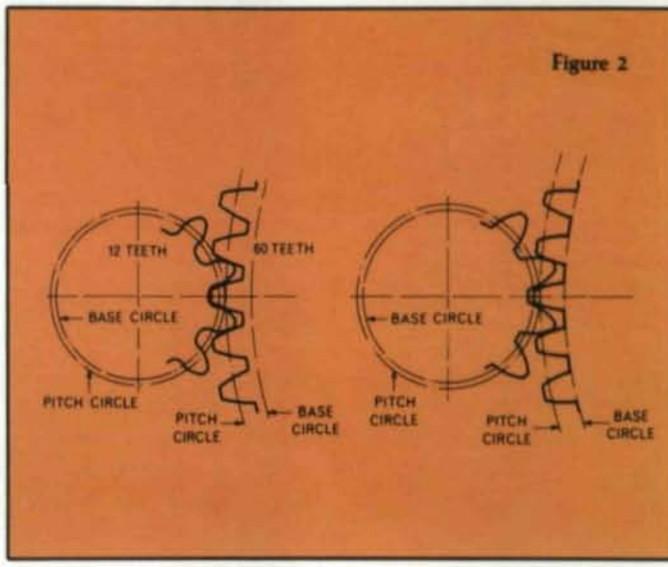

Figure 2

To generate accurate conjugate gears it is necessary to use cutters which have the same characteristics as the basic rack. A rack-shaped cutter is thus the logical first choice; therefore, the gears are produced virtually by the basic rack itself, simply and directly, without the use of any intermediary.

Practical Advantages

Important as the theoretical justification is, the main considerations for the use of rack-shaped cutters are practical ones. There is a considerable advantage with regard to cost due to the relative ease of achieving accuracy in manufacture. Some hobs are five times as expensive, and some pinion-type cutters twice as expensive. Additionally, rack-shaped cutters, with modified or special tooth profiles, may be manufactured with little difficulty. Maintenance costs also are much lower than for other types of cutter, as sharpening is not difficult, and does not require expensive equipment as a conventional surface grinding machine may be used.

There is no alteration to the tooth form when rack-shaped cutters are re-ground. By using support plates mounted behind the cutter, cutters can by repeatedly sharpened until they are only 5 mm ($\frac{3}{16}$ in.) thick, giving almost complete utilization.

Due to the very rigid mounting of the rack-shaped cutter, high rates of metal removal are possible. Even the largest pitches may be generated, whereas the use of 'standard' pinion-type cutters is largely restricted to gears of limited pitch. Lastly, compact integral spur or helical gearing which cannot be made by using a hob, are easily manufactured using a rack-shaped cutter.

Automatic Indexing

During any gear generating process the movements of cutter and gear must be synchronised. The cutter moves tangentially to the gear, *ie* a rolling motion, and as it is mounted on a reciprocating slide it is continually planing the gear and generating teeth and spaces.

On first examination, it would appear that a cutter would always have to be equivalent in length to the gear circumference. Such a long cutter would not be practicable, however, except when cutting small pinions. Therefore, the cutters index automatically after the rolling motion has operated for a distance of one or more pitches; then the rolling motion commences once more. The cutting action of the rack-shaped cutter is similar to other machining operations, as both roughing and finishing cuts are required, the number of cuts depending on the specification of the material, the amount to be removed and the surface finish required.

Wide Range of Gear Cutting

Gear generating machines can be used for the economic production of a wide range of gears. When cutting helical gears, *there is infinite choice of helix angle, from zero up to the maximum* capacity of the machine. No special equipment need be used; the cutter slide is simply set to the correct helix angle, either right hand or left hand as required.

When cutting coarse pitch spur gears a double-acting cutter box is a most important aid to efficient production. The boxes are designed to achieve heavy metal removal on coarse pitches, *ie* over 12 Mod (2 DP). In the double-acting process two cutters are mounted back to back, one cutting the sides of the tooth on the forward stroke and the other the root of the tooth on the return stroke. Thus, there is virtually continuous cutting, and as cutting loads are more evenly distributed high metal removal rates are possible.

Special profiles and a wide range of other types of gears and components may be easily produced, including integral cluster gears, pinions with long shaft extension, chain wheels, ratchet wheels, fluted rolls and splined shafts.

For cutting double helical gears with either a narrow gap or with continuous teeth, special purpose cutter slides designed with two slides inclined at fixed helilx angles (usually 30°) have been developed (Fig. 3). Matched pairs of cutters with inclined teeth are utilized and arranged to cut each hand of helix alternately. As both helices are finished simultaneously, matching is easily achieved and rotational errors between the two halves are eliminated.

The facility to produce double helical gears without a gap enables gears of maximum strength and load-carrying capacity to be designed within a given width. Continuous teeth have proved to give greater resistance to shock loads, hence, both strength and smoothness of operation are achieved.

Purpose-Built Machines

On some machines, the gear is mounted with its axis horizontal so that it is cut as it will run (see Fig. 4). This layout allows both large wheels and small pinions to be cut on the same machine, without sacrificing the accuracy of the large gears; it permits double-acting cutting to be carried out and lends itself to the cutting of double helical gears. Swarf automatically falls away from the cutting area into the base, where it can easily be removed. As the axis of the work spindle is horizontal, it is easy to accomodate gears and pinions with long shaft extensions.

The course of the cutter across the whole face of the gear is determined accurately by the cutter slide guides; this accuracy of helix is maintained without adjustment over a long period. The involute form is more readily generated using a cutter with straight sides. Therefore, a given surface accuracy may be achieved, even when using high feed rates.

Rugged construction of the machines, with cutters of virtually 'built-in' design, permits high metal removal rates which may be further improved where it is possible to use a double-acting cutter box.

Fig. 3 — below

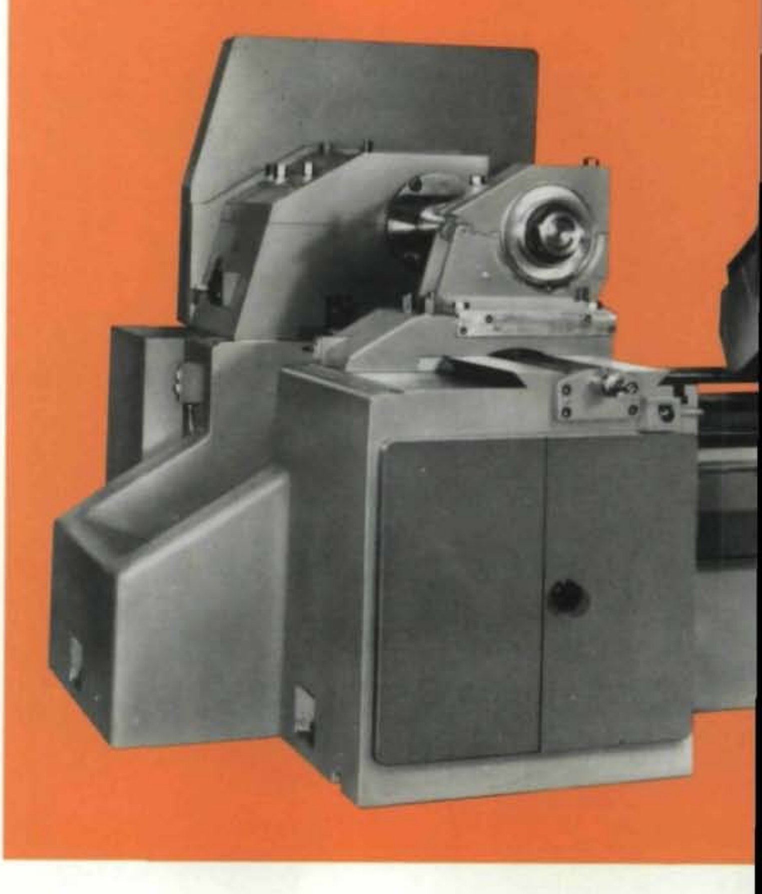

Fig. 4 — (Right) Illustrates a G250 cutting a large spur gear of 76" diameter 9" face width and 1 DP pitch, for a crane in a steelworks.

Recent Developments

Following the introduction of a new range of roughing cutters the cutting times on coarse pitch spur gears, *ie* over 16 Mod (1½ DP), have been reduced considerably. The principle of the new process is to reduce the cutting stresses normally set up during roughing, by using cutters of thin form and low pressure angle in conjunction with serial cutters of similar form. When the tooth has been fully 'roughed out', cutting is completed by the use of standard cutters.

Using normal methods of cutting, a spur gear of 25 Mod (1 DP), 3650 mm (12 ft.) *d* and 610 mm (2 ft.) face width, previously took seven cuts, *ie* a floor-to-floor time of 90 h. This has now been reduced to 64 h, a saving of 35 percent.

Current developments include new designs of both roughing and finishing cutters for continuous tooth double helical gears. These promise improvements in both production rate and surface finish.