BACK TO BASICS...

Gear Roll-Finishing

John P. Dugas
National Broach & Machine,
Mt. Clemens, MI

In this discussion of gear roll-finishing particular attention is called to the special tooth nomenclature resulting from the interaction between the rolling die teeth and the gear teeth. To eliminate confusion the side of a gear tooth that is in contact with the "approach" side of a rolling die tooth is also considered to be the approach side. The same holds true for the "trail" side. Thus, the side of the gear tooth that is in contact with the trail side of a rolling die is also considered to be the trail side.

Gear roll-finishing (Fig. 1) is much different from gear shaving in that a flow of material rather than a removal of material is involved. A study of gear tooth action is required to analyze the material flow in the rolling process. In Fig. 2 as a gear rolling die tooth engages the approach side of a workpiece tooth, sliding action occurs along the line of action in the arc of approach, in a direction from the top of the gear tooth toward the pitch point where instantaneous rolling action is achieved. As soon as the contact leaves the pitch point, sliding action occurs again, but in the opposite direction toward the pitch point in the arc of recession.

What is more interesting, however, is that the contact between the die and work gear teeth on the trail side produces exactly the opposite direction of sliding to that on the approach side. (See Fig. 3.) The result of these changing directions of sliding is that material is being compressed toward the pitch point on the approach side and extended away from the pitch point on the trail side. (See Fig. 4.)

This action causes a greater quantity of material to be displaced on the trail side than on the approach side by a ratio of about three to one. On the approach side, the tendency is to trap the material rather than permit it to flow toward the top and root of the teeth as on the trail side. Thus, unlike the situation in a metal removal process like gear shaving, the quantity of material flow during the rolling process, as well as the hardness of that material, have a significant effect on the accuracy of the produced form.

Fig. 1 (center) – Operating principle of double-die gear roll-finishing.

In successful roll-finishing, an undercut near the root section, such as is found conventional preshaved tooth forms, is desirable. Since most production gears are also provided with a tip chamfer, the material will tend to be pulled up into the chamfer on the trail side and down away from the chamfer on the approach side.

As a result, some adjustments in hobbed tooth tip chamfer depths and angles are required to balance out the opposed metal flow conditions on each tip side. These chamfer depths and angles have to be held to close tolerances.

If too much stock is left for gear roll-finishing, or if the gear material is too hard (above approximately 20Rc), several conditions may result. The sliding action on the approach side of the tooth may cause a "seaming" of material that builds up in the area of the pitch point. On the trail side, the flow of excess material may result in a burr on the tip of the gear tooth and a "slivering" of material into the root area. Fig. 5 shows the condition of a roll-finished gear tooth when too much stock is flowed or high hardness conditions are encountered.

In Fig. 6 photomicrographs show the conditions encountered when stock removal is excessive and material hardness is too high. A seam is evident in the approach side of the tooth at the left in

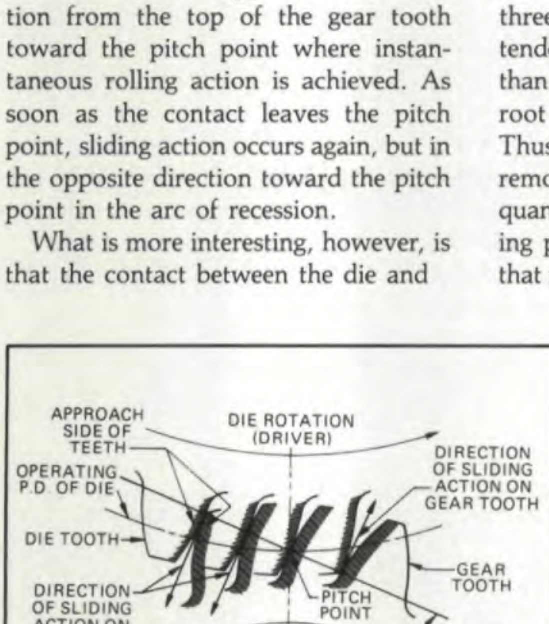
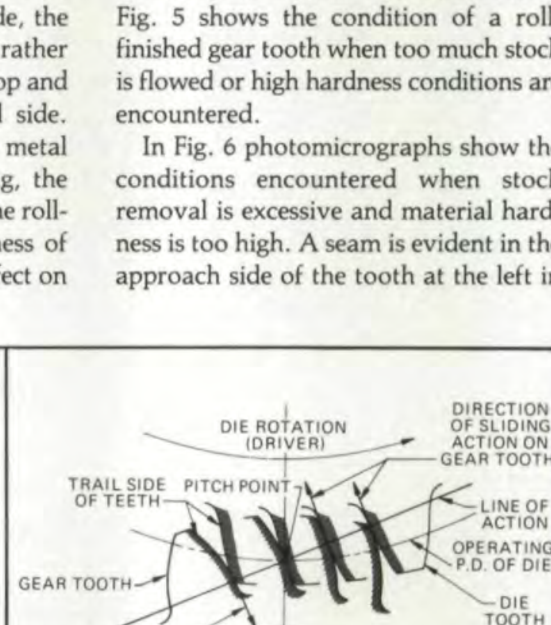


Fig. 2 (left) – Contact action between one tooth of a workpiece and the approach side of a rolling die tooth.

Fig. 3 (right) – Contact action between the tooth of a workpiece and the trail side of a rolling die tooth.



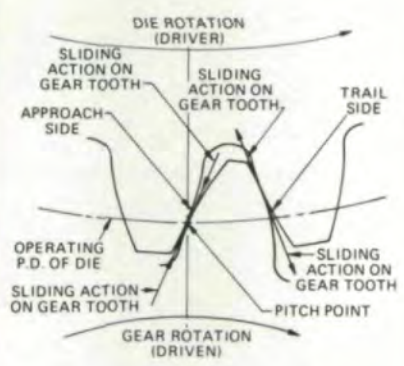


Fig. 4 (left) – Differing flow directions induced by each side of a die tooth with gear roll-finishing.

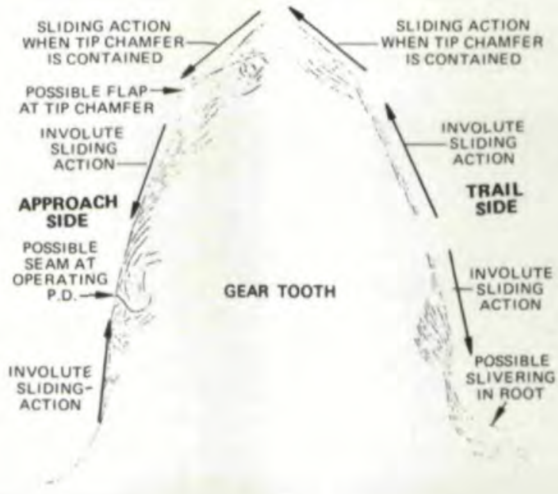


Fig. 5 (right) – Tooth flow pattern that results when too much stock is left for roll-finishing, or when material hardness is excessive.

the area of the operating pitch diamater. The trail side photomicrograph at the right in this figure shows slivering in the root portion with about 0.004-in. of lapped-over metal, and about 0.002-in. deep surface cold-working of the material.

In contrast, photomicrographs in Fig. 7 show the excellent tooth structure that can be achieved with roll-finishing if stock reduction is held to a minimum and material is not too hard. No evidence of cold-working or seaming is seen in the approach side at the left. In the trail side at the right in this figure, no evidence of slivering or cold-working is seen.

The amount of stock reduction with roll-forming should be held to about one half of that normally associated with shaving if seaming and slivering are to be avoided. The burr condition on the tip of the trail side of the tooth can be improved by close control of the angle and location of the protective tooth chamfer generated by the hob in the tooth generating operation.

Gear Rolling Dies

Since roll-finishing involves material

AUTHOR:

MR. JOHN P. DUGAS *is the Chief Gear Tool Engineer at National Broach & Machine Div., Lear Siegler, Inc., Mt. Clemens, Michigan. His Experience encompasses 20 years of design, analysis and development of gear finishing tools. He has attended Ohio State University and the University of Mass. He is an active member of several AGMA committees and annually participates in the SME Gear Manufacturing Symposium.*

flow rather than metal removal, it should be expected that the tooth form on the die would not be faithfully reproduced on the workpiece tooth because of minute material springback and material flow conditions.

Even with gear shaving it has been found necessary to modify the shaving cutter teeth profiles somewhat to produce a desired form on the work gear teeth. Experience to date has shown that a different type of tooth form modification is required for gear roll dies than for gear shaving cutters. As with gear shaving cutters, the correct amount of gear rolling die tooth form modification is determined from an extensive development program. Less rigid gear roll-finishing machines usually require greater and varying die form modifications.

Gear roll dies are made from a special fatique and impact resistant high speed steel to the tolerances shown in Table 1.

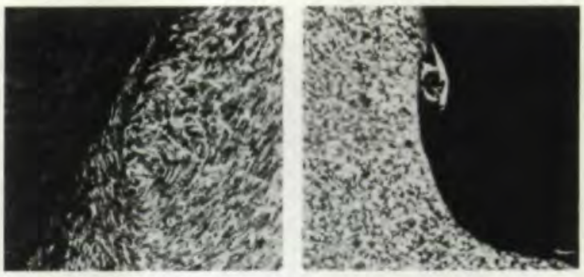


Fig. 6 – Photomicrographs of a gear tooth with high hardness. The approach side, left, has a seam in the area of the pitch diameter. The trail side, right, shows where excessive stock has caused cold-working and a sliver near the root.

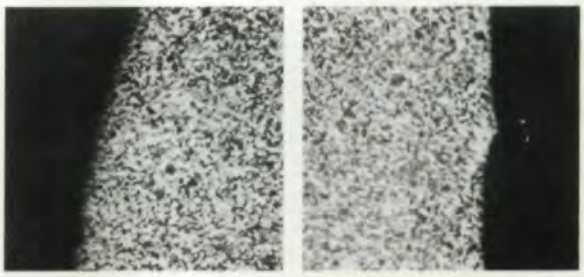


Fig. 7 – Photomicrographs of a properly roll-finished gear tooth. The approach side, left, has no seaming. The trail side, right, shows no slivering or cold-working.

Gear Rolling Machines

Several important design considerations have be met in a roll-finishing machine. These include rigidity, strength, high speed loading, die phasing, and independent adjustment for die axis and die positioning.

The force required to roll-finish a gear depends upon its width, diametral pitch, tooth shape, cycle time material, and hardness.

Double-Die Gear Rolling

The double-die machine shown in Fig. 8 is a vertical design with the dies mounted one above the other. Such a design provides maximum rigidity, requires minimum floor space and also gives max-accessibility for a hinged automatic work loader as well as die head positioning adjustments.

Table 2 and Fig. 9 illustrate the range of gearing for which gear rolling dies have been produced for finish-rolling production applications.

Single-Die Gear Rolling

A single-die gear rolling process is ideally adapted for low and medium production finishing operations where both roll-finishing and shaving operations or roll-finishing only are done economically.

A single gear rolling die is mounted in a heavy-duty gear head above the workpiece in Fig. 10. The die is driven by an electric motor to provide rotation of the workpiece that meshes with it. Normally, semi-automatic loading methods are utilized on single-die roll finishing machines whose work cycles are somewhat longer than those of the fully automatic, double-die machines.

The workpiece is mounted on an arbor between head and tailstock. In operation, the table supporting the head and tail-

Table 1 – Tolerances for Gear Roll-Finishing Dies

Die Specification	Tolerance-In.
Involute Profile (True Involute Form)— Active Length, tiv	
Through 0.177-in. Working Depth	0.00015
0.178 Through 0.395-in. Working Depth	0.00020
Lead—(Uniformity-tiv Per Inch of Face)	0.0003
Parallelism— (Opposite Sides of Same Tooth Alike Within)	0.0002
Helix Angle— (Deviation From True Angle—Per Inch of Face)	0.0005
Tooth Spacing— (Adjacent Teeth at Pitch Diameter)	0.00015
Circular Pitch—(Variation-tiv)	0.0002
Spacing Accumulation— (Over Three Consecutive Teeth)	0.00025
Runout—(tiv at Pitch Diameter)	0.0004
Face Runout—(tiv Below Teeth)	0.0002
Tooth Thickness	Minus 0.0010
Hole Diameter	Plus 0.0002
Note: Dies can be made in pairs alike within 0.0005-in. measured over pins, if necessary	

Fig. 8 – Operating components of a double-die gear roll-finishing machine.

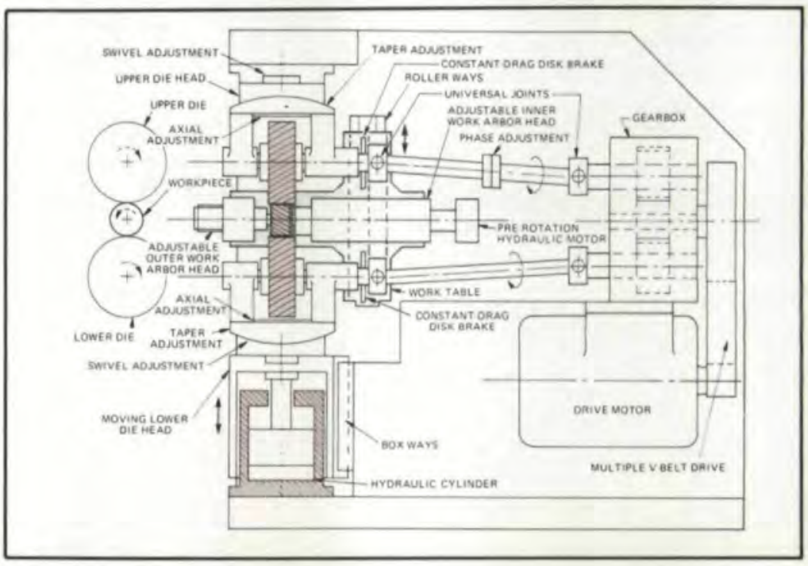


Table 2—Data on Roll-Finished Gears

No. Teeth	Pitch Diameter (in.)	Normal Diametral Pitch	Normal Pressure Angle	Helix Angle	Hand	Face Width (in.)	Material
26	4.6666	6.539	18° 28′	23° 25′	L	1.380	8620
25	3.3667	8.8709783	16° 30′	33° 10′	L	0.918	8620
14	1.0711	14	20°	21°	L	0.727	5140H
17	1.2143	15.1535	18° 35′ 09″	22° 30′	L	0.758	4024
28	2.0000	15.1535	18° 35′ 09″	22° 30′	R	3.04	4024
18	1.2542	15.5	17° 30′	22° 11′ 30″	R	1.935	4620
16	0.9621	18	18° 30′	22° 30′	R	0.728	5130, Fine Grain (5-8)
34	2.0445	18	18° 30′	22° 30′	L	0.860	5130, Fine Grain (5-8)
20	1.1580	18.5	18°	21°	R	0.874	4027H
19	1.0549	19.3	20°	21° 03′ 42″	R	0.705	4027H

Fig. 9—Gears that have been successfully roll-finished.

stock is fed upward by a unique, air-powered, heavy-duty radial feed system. The continuous upfeed of the table provides the large force necessary to roll-finish the gear teeth.

During the work cycle, the workpiece can be rotated in one direction for one part of the cycle, then reversed and rotated in the other direction for the balance of the cycle. This double-rotation sequence tends to balance the metal flow action on the approach and trail sides of the work gear teeth.

Tooth thickness size of the workpiece is controlled by adjusting the height of the table with a handwheel-controlled elevating screw.

Acknowledgement: *This article was presented at the SME Gear Processing Technology Clinic, Nov., 1986, Schaumburg, IL.*