



Gear Blanking

Robert Endoy
Mandelli Inc., Farmington Hills, MI

Scope

The term "blanking" refers to the initial metal cutting operations in the process planning sequence which produce the contour of a part starting from rough material.

The scope of blanking is:

- To remove the excess material
- To machine the part to print specifications, except for those surfaces with subsequent finishing operations.
- To leave adequate machining stock for finishing operations
- To prepare good quality surfaces for location and clamping of the part throughout the process.

Process Selection. Processes and machines for blanking of driveline parts are selected based on part configuration and production volume.

Part Configuration. Gears, countershafts, and cluster gears can be described as being rotational parts. As such, the contour of the part can be generated by a single point tool travelling longitudinally along the axis of the part, while the part rotates around its axis.

Depending on the diameter-to-length ratio, rotational parts can be further classified as disk type and shaft type parts (Fig. 1).

The sequence of operations and machinery required to produce blanks is characteristic for each basic configuration.

Disk-type parts, such as gears, are turned on open-ended lathes or chuckers, which locate and clamp the part on internal or external diameters in concentric chucks.

Shafts, on the other hand, are located between centers. The first operation consists in machining the end faces of the shaft to a specific length and drilling opposite and in-line center holes.

Production Volume. The type of machine used for a specific blanking operation and the degree of automation is determined by the required output in pieces per hour of the operation.

Low-volume production is processed on manually operated, universal machinery with standard low-cost tooling. This type of job shop equipment typically handles a wide variety of parts in lot sizes of one to several hundred.

A medium-volume production line is set up to handle a family of 10 to 20 parts in quantities of several thousand per year. Monthly requirements are produced in batches of 500 to a few thousand, with line change-over between production runs.

This is the sector of the manufacturing industry where CNC machines are employed to their fullest potential. The versatility and change-over flexibility of CNC equipment make it ideally suited for short intermittent production runs. The universal tooling packages used on CNC lathes and chuckers, combined with short change-over time, result in efficient batch production at low inventory level.

The inherent accuracy of CNC machines offers the added advantage of roughing and finishing in the same setup, reducing the number of machining operations in the process plan.

Characteristically for a high-volume production line, machining operations must be completed in very short cycle times. For instance, to make one million pieces per year in a three-shift

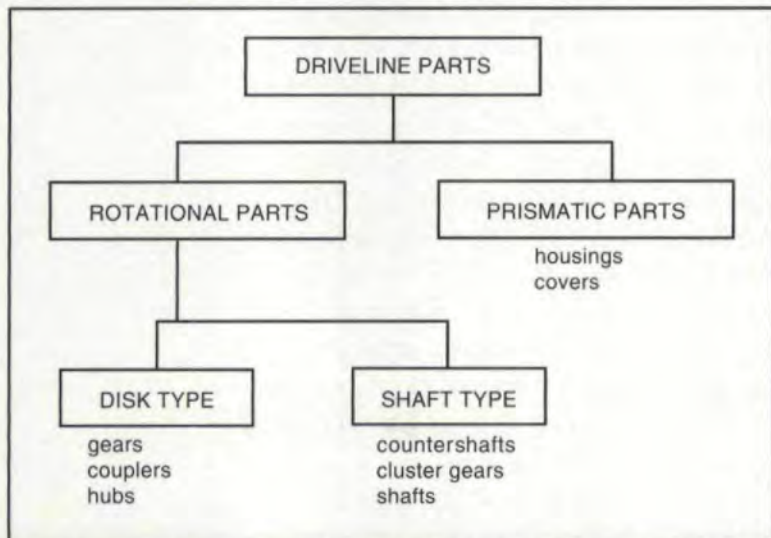


Fig. 1 - Basic classification of parts according to their configuration.

operating pattern at 80% efficiency, machine cycle time plus part handling must be less than 15 seconds per part.

To meet line speed demands, roughing and finishing operations are processed on separate machines. Multi-spindle machines with special dedicated tooling are used to cut more than one part per cycle. Automatic loading and unloading of parts is used extensively to reduce idle time to the minimum.

Rough Material. Barstock, forgings, extrusions, or precision forgings are used to make driveline gears and shafts. The most suitable raw material form is selected, based on a financial evaluation which includes all manufacturing costs, raw material, vendor tooling, in-house machining cost, and investment in facilities and tooling.

Barstock is the simplest and cheapest form of raw material frequently used for small-lot sizes. More complex fabricated forms like forgings and extrusions become economically attractive with increasing production volumes.

Barstock

Hot rolled barstock is extensively used in job shop work. The advantages of barstock are:

- Low purchase cost. Rolled barstock from the mill is the least costly material available.
- Short lead time. Barstock is offered in standard sizes which are available from stock.
- No vendor tooling cost. Barstock is selected from existing standard sizes and requires no special operations by the vendor.
- Many sources. Changing from one supplier to another does not create problems. Purchasing is not locked in with only one supplier.

The disadvantages of barstock are:

- High material waste. Parts with large variation in diameter have a high percentage of wasted material.
- Long machining time. Removing excess material requires many turning passes on lathes.
- More machining operations. Barstock needs to be cut to individual lengths before it can be processed.
- Special handling for transport and storage.
- Material strength may be affected due to the interrupted fiber flow in the part.

In general, there is no cost advantage in using barstock instead of fabricated raw material. It is the appropriate solution for low-volume produc-

Table 1 - Process, Machines, and Equipment Characteristics in Low-, Medium-, and High Volume Manufacturing Operations

Process Characteristics	Low Volume	Medium Volume	High Volume
<u>Machines and Equipment</u>			
Universal Machines	yes	yes	no
CNC Machines	yes	yes	no
Multi-spindle Machines	no	no	yes
Special Machines	no	no	yes
Manually Operated	yes	no	no
Automatic Cycle	no	yes	yes
<u>Material Handling</u>			
Manual Part Handling	yes	yes	no
Automated Part Handling	no	no	yes
Flexible Automation - Robots	no	yes	yes
<u>Tooling</u>			
Universal Tooling	yes	yes	no
Special Tooling	no	no	yes
<u>Operating Conditions</u>			
Change Over	yes	yes	no
Number of Different Parts	>100	10-20	1
Labor Content	High	Low	Low
Floor Layout	Stand alone	Line	Line
Retooling Cost for New Parts	Low	Low	High
Production Lot Sizes	1-500	500-2,000	Continuous
Annual Production Volumes	1-500	500-20,000	>100,000

tion because it avoids investment in vendor tooling and is readily available. The low material cost is, however, more than offset by the cost of additional machining and the high proportion of wasted material.

When the variation in section is small, barstock can be used economically for high-volume production. Examples are screw machine parts, shifter rails, spool valves, pins, etc.

Forgings

Forgings are used for medium- and high-volume production. The fabricated form is made as close as possible to the finish contour of the part to reduce machining time and to keep the

Robert Endoy

is Systems Division Manager at Mandelli, Inc., a producer of flexible manufacturing systems and cells. Educated in Holland, he is the author of *Gear Hobbing, Shaping and Shaving* published by SME and a contributor to *Gear Technology*.

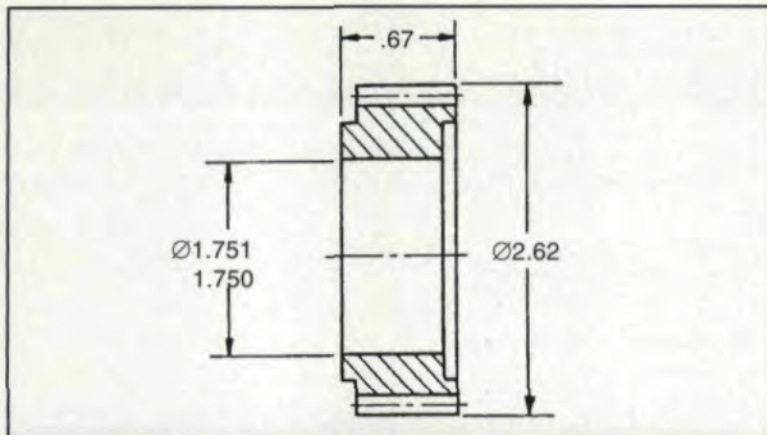


Fig. 2 - Planet gear made from barstock.

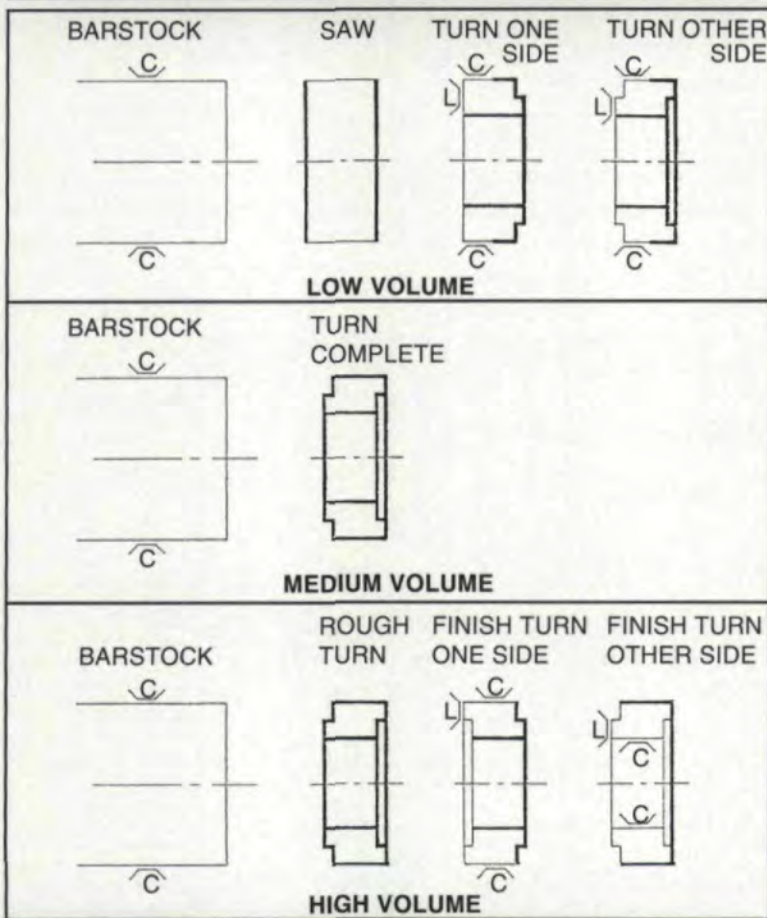


Fig. 3 - Process planning sequence for turning of gear blanks.

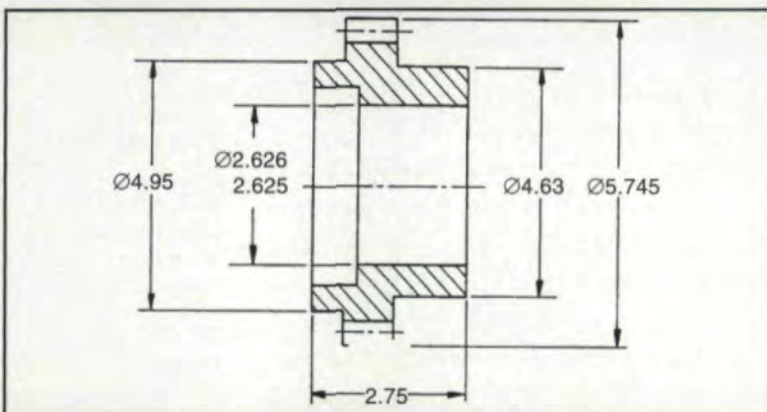


Fig. 4 - Transmission gear blank made from barstock for low-volume and from forging for medium- and high-volume.

amount of wasted material low. Forging tolerances are held within ± 0.030 " (0.8 mm) and machining stock allowance is in the range of 0.080 to 0.120 per side. The surface finish of forged surfaces is around 500 micro-inches.

The advantages of forgings are:

- Short machining times. The raw material is shaped close to the final contour of the part and excess material can usually be removed in a single turning pass.

- Less machining. Nonfunctional surfaces do not require machining. Forging tolerances and surface conditions permit usage of parts with surfaces in forged condition.

- Higher material strength due to the oriented fibers and the compact material structure.

- Easy to handle and transport.

The disadvantages of forgings are:

- Forgings have parting lines, draft angles of 3 to 6°, and flash trim marks which affect tooling performance.

- Higher material cost in dollars per unit of weight.

- Forgings require vendor tooling and lead time.

Forgings are economically feasible even at relatively low volumes of 500 to 1,000 pieces per year. Vendor tooling cost for drop forgings and upset forgings commonly used for gears and shafts can be written off over a few thousand pieces.

Precision hot forgings or flashless forgings for automotive parts are produced on transfer forging presses. Precision forgings have minimum draft angles of $1/2$ to 1° and no parting lines. Machining stock allowance is only 0.040" (1.0 mm) and length and diameter dimensions are held within ± 0.012 " (0.3 mm) tolerance.

Extrusions

Cold extrusion is the most sophisticated form of rough material which finds economic application in high-volume production of automotive parts.

The advantages of extruded parts are:

- Close tolerance control. Extrusion tolerances can be held within 0.005" (0.13 mm) on the diameter and 0.060" (1.5 mm) overall length.

- Excellent surface finish. Cold extrusion produces surfaces with finishes ranging between 32 and 125 microinches (0.8 and 3 mm).

- Improved mechanical properties. The work hardening effect of cold forming in-

increases the tensile strength and yield strength.

- Minimum wasted material because of the close tolerances which can be held with extrusion techniques.

- Machining savings. Extruded surfaces may be used in the final product because they provide extremely smooth finish and close tolerance control.

The disadvantages of extrusions are:

- High piece cost
- Very high vendor tooling cost. Investment in equipment and tooling is virtually never justified by low- and medium-volume production requirements.

Examples of Blanking Operations

The following three examples of blanking operations illustrate the principles explained in this section.

Example 1. A small planet gear which, because of the small outside diameter and the uniformity in section, is made most economically from barstock (Fig. 2).

When a small quantity of parts is required, as for prototype work, the barstock is sawed into individual pieces, and the part is turned completely in two setups on a lathe (Fig. 3).

Short intermittent runs of 500 to 2,000 pieces are produced most effectively on a single spindle CNC barchucker that performs the complete rough and finish turning operation in one setup.

A mass production manufacturer will utilize a multi-spindle barchucker to perform the rough turning operation, followed by two separate setups to finish-turn both sides of the gear.

Example 2. Transmission gear blank made from barstock for low-volume and from forging for medium- and high-volume (Fig. 4).

The low-volume process consists of cutting the barstock to length and roughing and finishing in two setups on a lathe (Fig. 5).

Medium-volume processing starts with a forging which is rough- and finish-turned in two setups on a single-spindle CNC chucker.

To meet the required output per machine, the high-volume process splits the turning operations in separate roughing and finishing setups on multispindle machines.

Example 3. Fig. 6 illustrates a transmission countershaft with a gear on one end of the shaft.

The low-volume process starts with barstock which is cut to length and prepared for turning by facing both ends and drilling center holes

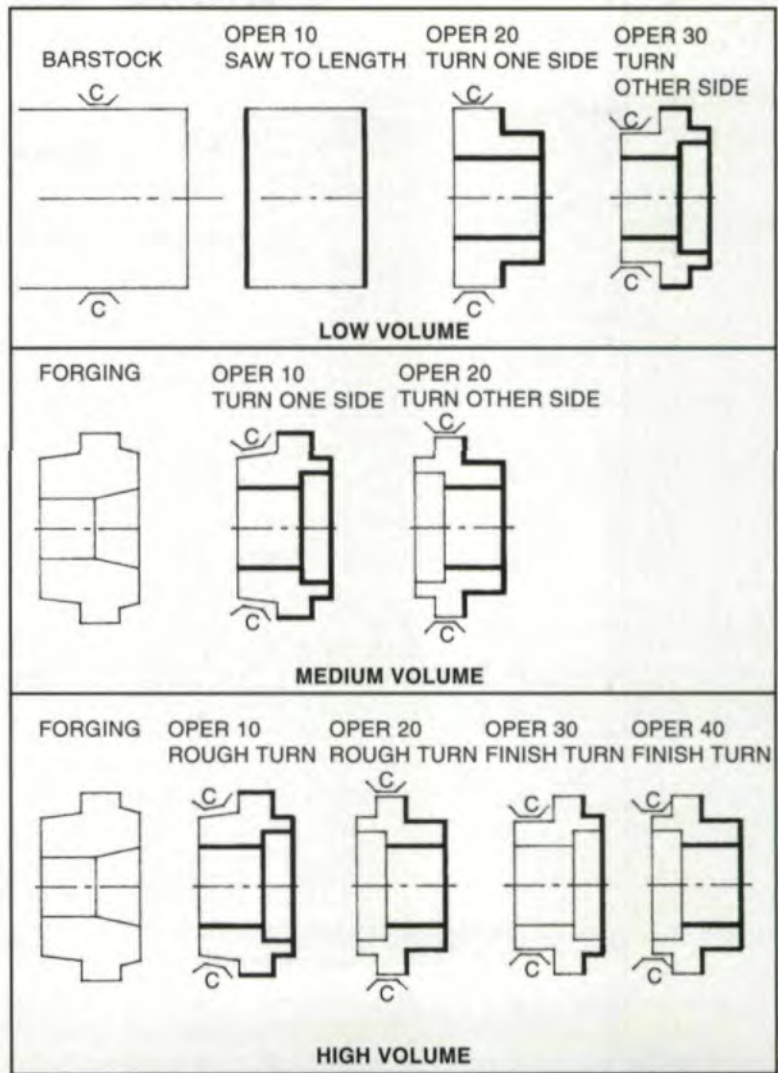


Fig. 5 - Process planning sequence for turning of gear blanks.

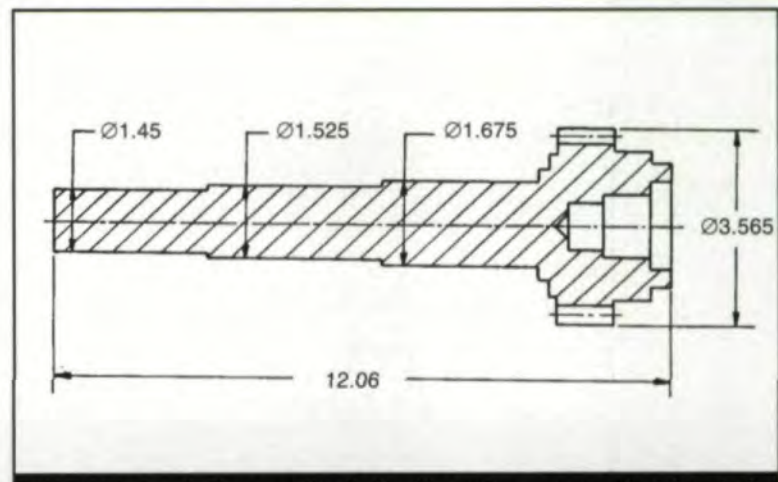


Fig. 6 - Transmission countershaft with a gear on one end of the shaft.

(Fig. 7). Two turning operations are planned to finish-turn the external contour of the part. This is followed by an internal turning operation on a chucker where the part is clamped and located on the outside diameter near the gear. This example illustrates the inefficient material utilization of barstock, as almost half the material is wasted in chip removal.

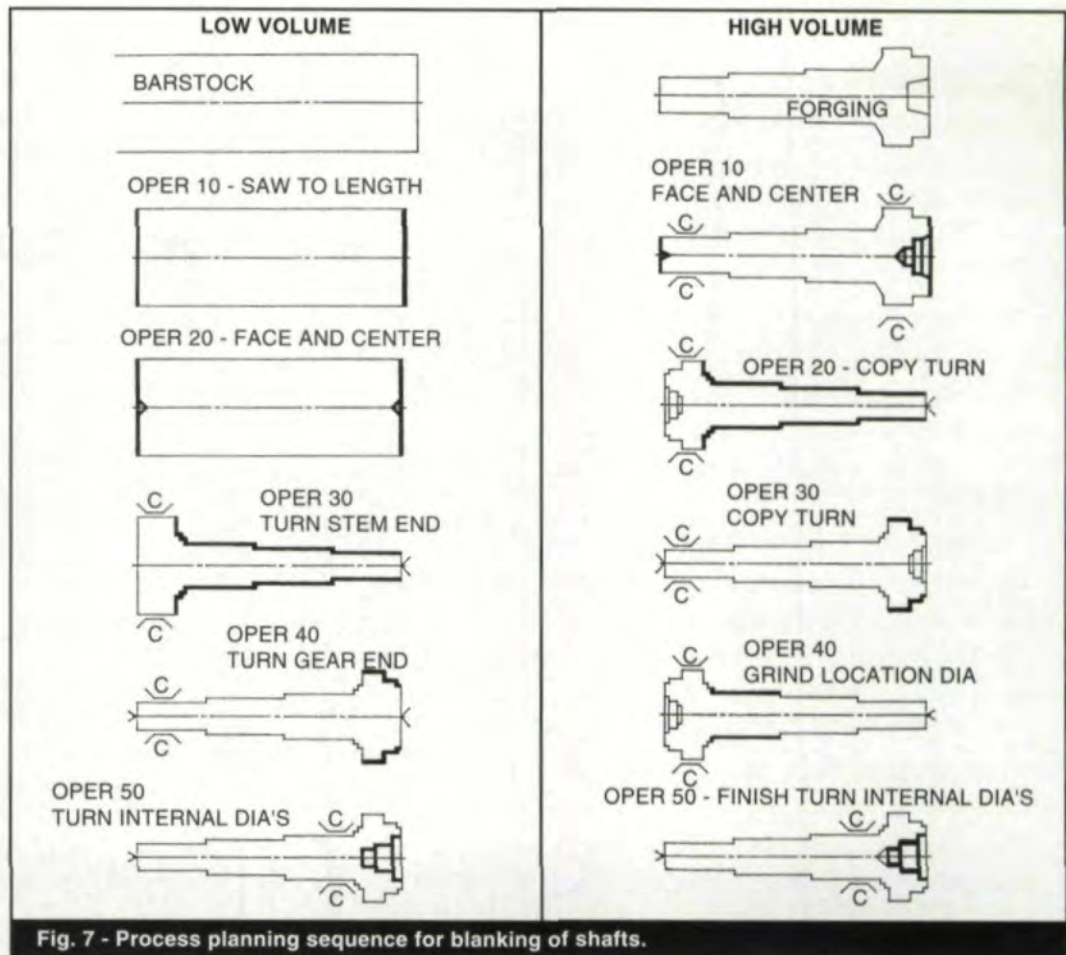


Fig. 7 - Process planning sequence for blanking of shafts.

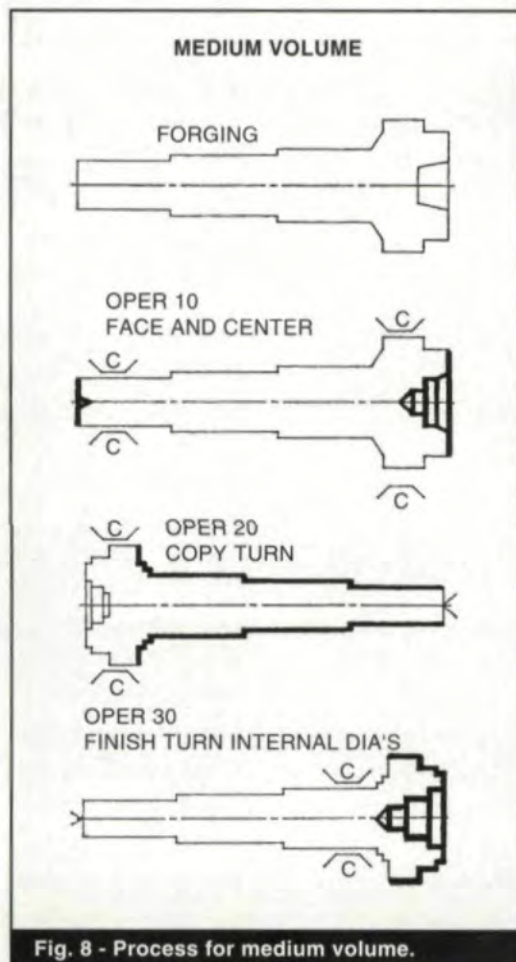


Fig. 8 - Process for medium volume.

The high-volume process starts with a forging which is faced and centered on both sides, while the internal diameters are roughed in the same setup. Two copy turning operations turn the external contour. The outside diameter near the gear is ground in operation 40 to control the runout of the diameter used as locator in operation 50 (Fig. 7) and in the gear cutting operation, which is not shown here.

A medium-volume process with fewer operations is possible by combining operations 30 and 50 in one setup. The external and internal diameters are rough- and finish-turned on a CNC chucker in operation 30. Grinding of the location diameter is not required, provided good runout tolerance can be maintained in operation 20. If operation 20 also is performed on a CNC lathe, the location diameter can be machined to close tolerances in one additional finishing pass (Fig. 8). ■

Excerpted from Gear Hobbing, Shaping & Shaving by Robert Endoy. ©1990, Society of Manufacturing Engineers, Dearborn, MI. Reprinted with permission. For information on this publication, call 800-733-4SME.