Economics of CNC Gear Gashing Vs. Large D.P. Hobbing

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Gashing

Gear gashing is a gear machining process, very much like gear milling, utilizing the principle of cutting one or more tooth (or tooth space) at a time. The term "GASHING" today applies to the roughing, or roughing and finishing, of coarse diametral pitch gears and sprockets. Manufacturing these large coarse gears by conventional methods of rough and finish hobbing can lead to very long machining cycles and uneconomical machine utilization.

Gear gashing *is* gear milling, but the term "GASHING" is used to designate the application of using gear milling machines and tools designed with today's technology in mind and in effect (Fig. 1). Gear cutting tool development has taken a "back seat" to the advances in modern tooling technology. The advent of carbide and numerical controls has led to complete tooling systems for all other types of machine tools. The acceptance, use, and total dependence on carbide tools, has proven mandatory to meet the production demands of today. As a result of the "back seat" position, the gear cutting industry two years ago was far behind all other machine tools in all applications of machine design and tooling technology.

Gear Milling

Gear milling is still alive in both small and large shops. Most of them, however, are using 40 to 50 year-old underpowered mechanical machines with undersize tool arbors and high-speed cutters designed more than a generation ago. They are on our production floors nibbling away, creeping through material at a snail's pace and increasing manufacturing costs.

Today's millers are GASHERS, powerful milling machines with Numerically Controlled axes, oversize slide ways,

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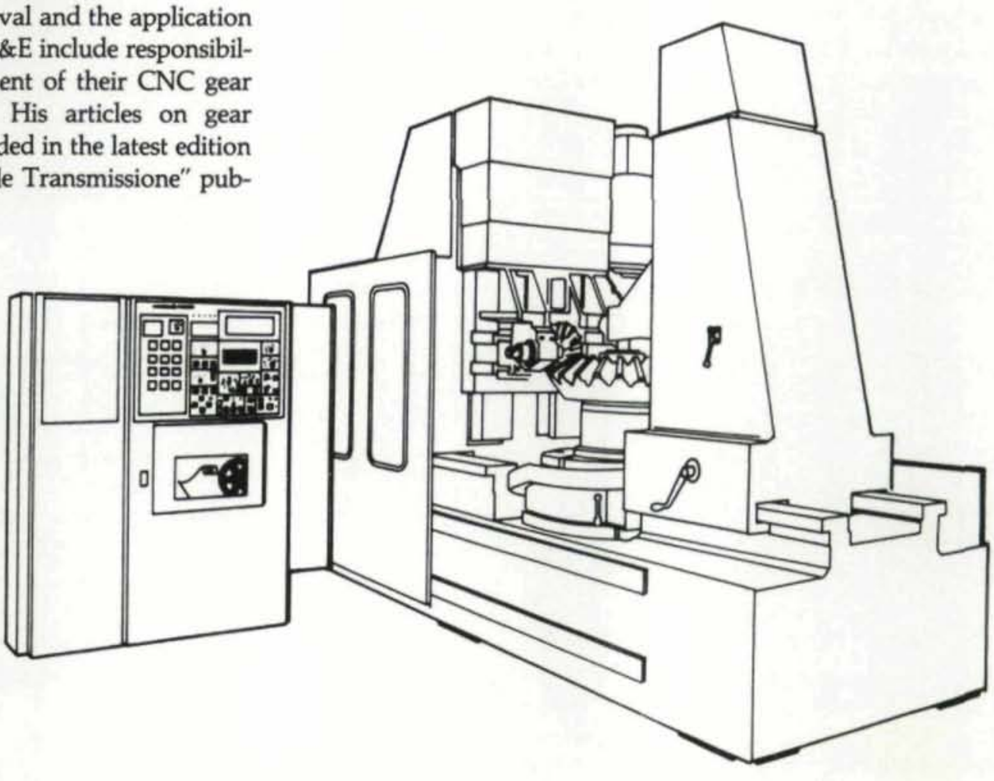

FIG. 1—The Gasher

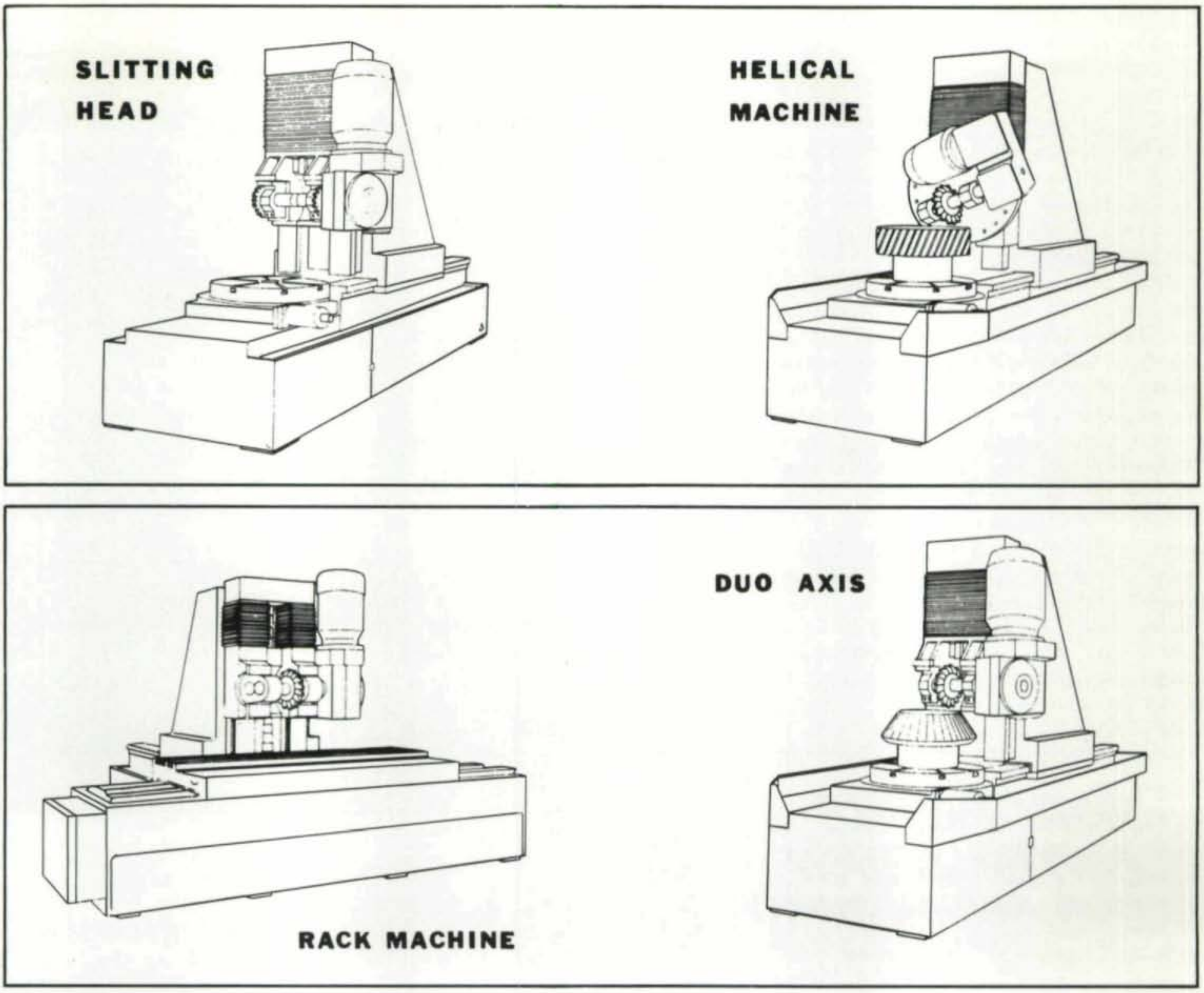

FIG. 2

50-100 HP D.C. spindle drives with carbide speed ranges, and super accurate indexing work tables.

Gashers are built in four different configurations:
See Fig. 2.

1. Spur gear and roller chain sprocket machines
2. Spur and helical machines
3. Spur and straight bevel machines
4. Rack cutting machines

All the machines, with the exception of the rack cutter, can be tooled to become slitter/gashers. The differences in the various types of gashers are accommodated in the control or control software.

Basic Economics

The economics of using the new GASHERS fall into the following areas: lower cutter cost per workpiece by use of inserted carbide cutters, ability to cut harder material more efficiently, time savings, increased production on other machines used to finish the workpiece, if necessary, and increased cutter life on the finishing equipment. Predictable cutting times permit more accurate work flow through the gear shop with proper machine utilization. One gasher, set up for roughing, can feed many hobbers and other types of gear finishing equipment.

Cutting Tools

Any material that can be milled by conventional methods can be "Gashed." The use of carbide and inserted carbide cutters permit cutting material in the upper recommended range of material removal charts. Harder materials, of course, pose no problem for the carbide cutters. The carbide cutters cut dry, without coolant, permitting cleaner cutting conditions, no oil contamination of workpiece, and cost reduction in handling clean chips. In some instances, it is advisable to direct a jet of compressed air on the inserts, during cutting, to dislodge any hair-like chips that may cling to the cutting edges. These chips are generally workhardened and can cause hairline cracks in the cutting edges, and ultimately the failure of the cutting edge.

In large diametral pitch gear cutting, the process of roughing with inserted carbide cutters has proven to be the most efficient of Gasher machine utilization.

Rough Gashing The Involute Form

In Fig. 3, we see the involute form of a gear tooth. The straight sided carbide inserts are superimposed to illustrate the "roughed out shape." The inserted carbide cutter, that roughs the "V" shape form, is shown in Fig. 4. Its mounting and use are also shown.

This cutter is efficiently used in the 300-375 SFM range. The normal feed range is between 12 and 22 inches per minute. The positioning of the carbide inserts is such that, even at the higher feed rates, the inserts have a unique chip thinning effect, and although the chips are large, they are thin. In using a carbide cutter of this type, the gear can be either finish hobbed, shaped, or milled to final involute form, and can be efficiently completed in one pass by the finishing machine. The accuracy of index of the gasher worktable permits a minimum of finishing stock to be allowed. The resultant effect on the finishing tools, reported by the users of this system, is the ability to obtain, as much as, twelve times longer tool life. Completion of the rough gashed blank can also be done on the gasher by using a form ground involute milling cutter. Again, the accuracy of the work table permits finishing to size and form without sacrifice of tooth to tooth spacing. Unfortunately, almost all the finish form involute milling cutters currently available are of H.S.S. Some brazed carbide cutters are around, but require grinding equipment that most shops do not have.

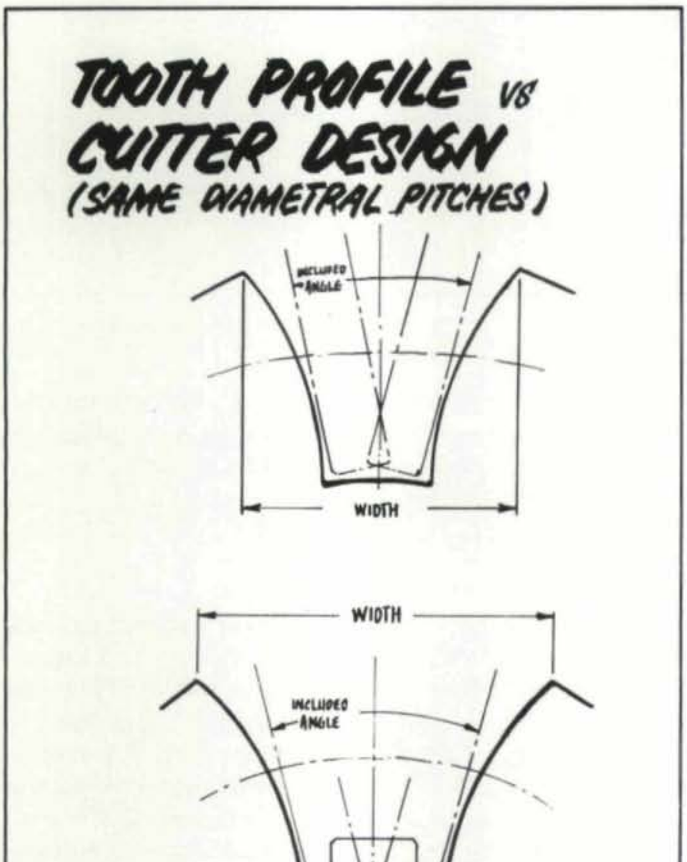

FIG. 3—(Courtesy: Ingersol Cutting Tool Co.)

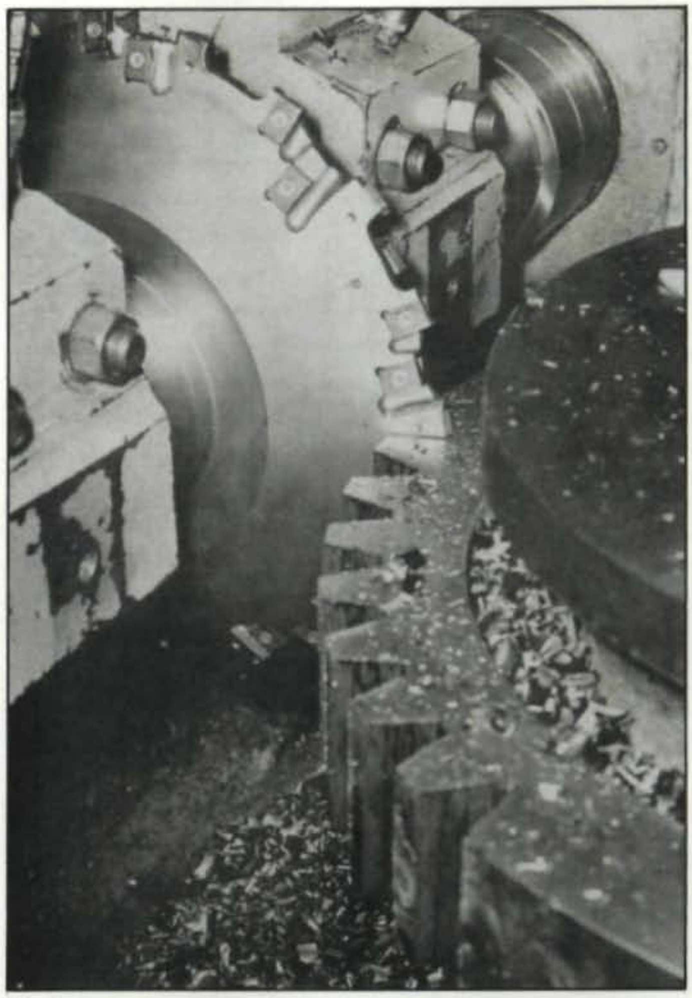
FIG. 4

Spur Gears

For example: in time savings only, for a mild steel gear 44 tooth, spur gear of 1 DP, and 5" face width; hobbed, two passes, 9" diameter hob, 100 SFM, .120 IPR roughing and .06 IPR finishing, the cutting time is a total of 229.8 minutes (3.83 hours) of which 153.2 minutes is the finish hobbing time.

If the gear is *rough gashed* at 400 SFM and 18 inches/minute feed, rate the over-all gear cutting time is reduced to 186.4 minutes — basically, a nominal savings of 40.4 minutes. Generally, we are not favored with mild steel as a gear material when cutting coarse pitch gears. Harder and tougher gear materials would, substantially, increase the rough hobbing time (Fig. 5). However, if we were to mill the gear by rough gashing at approximately 18 IPM feed rate; and then finish milled at a slightly reduced feed rate, say 10 inches per minute, we would now see an overall machining time of 86.6 minutes, a savings of 100 minutes per gear for rough gashing/finish hobbing.

Helical gears could be similarly processed, but at this time most roughed helical gears are finish hobbed or shaped rather

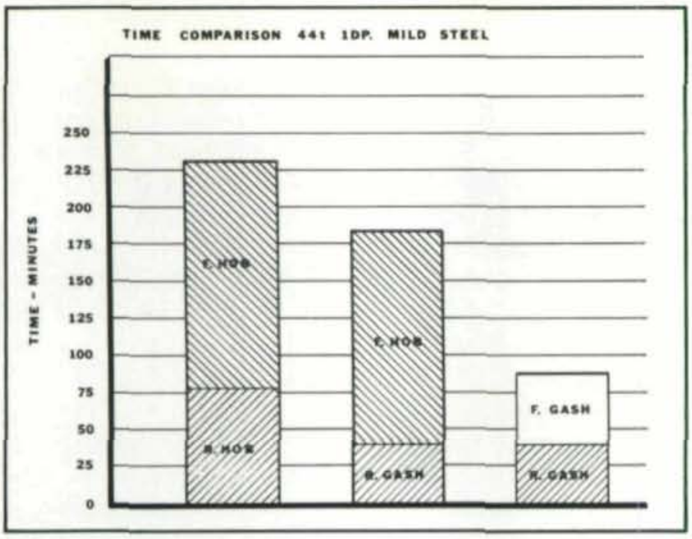

FIG. 5

than finish milled. Test data on helicals, at this time, is almost non-existent, because only a few gashers so equipped have been produced.

Bevel Gears

The gear gasher cutter shown in Fig. 4 is, also, used to rough gash straight bevel gears. The process used today is somewhat different from what most shops use, or have used, in the past. Older gear milling machines had indexing work tables that pivoted up, so the root angle could be generated by the vertical travel of the work slide. This created a very compromising situation where rigidity suffered and feeds and speeds disintegrated to nothingness. Today, through the use of controls capable of linear interpolation, the workpiece and table remain in the horizontal plane and the root angle is generated by the control.

The actual figures for previous methods of straight bevel roughing are not available, but data regarding rough gashing is available. For example: a 1 DP straight bevel gear, 25 teeth, material SAE 4340 forging, 340 BHN, gashed 1.8" depth of cut, 5.5 gear face, 14" diameter inserted carbide cutter at 90 RPM 14 IPM, took only 25 minutes cutting time. The machine set-up time was, also, greatly reduced from previous methods. Utilizing the gasher for roughing bevel gears leaves the finishing machine, the bevel generator, free to do what it was designed to do, produce the proper involute shape. The root angle/face angle effect of tapering the tooth encourages one more possibility in cutting straight bevels. The ability of the control to drive the cutting axis at variable feed rates permits the programmer to plunge into the workpiece at one feed, drive the root angle at the next feed (generally at 200-300% of plunge), and then exit the cut at a third rate (150-200% of second feed). The change in feed is accomplished by modern controllers without any hesitation in the motion of the cutter slide.

The programming ability of linear interpolation permits rapid moves that take the shortest path between two points. For lessening cutter shock when entering a workpiece, especially on bevel gears, we can program the plunge cut perpendicular to the root angle, thereby, reducing the tangent angle

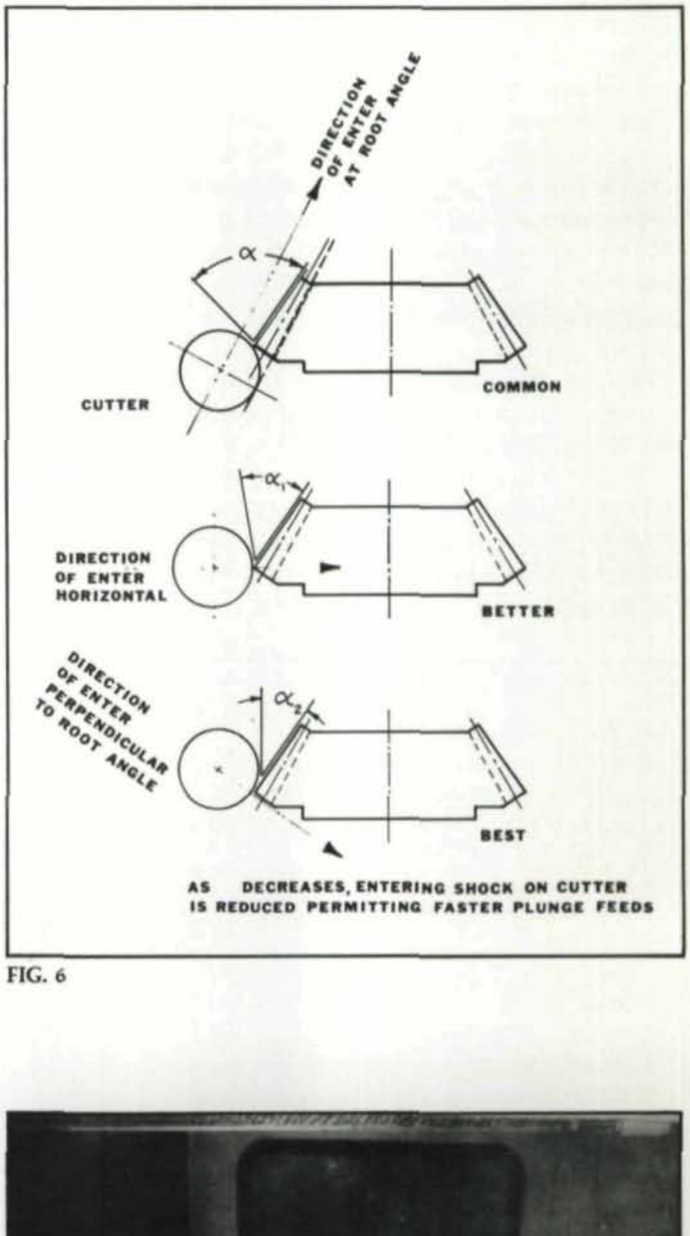

FIG. 6

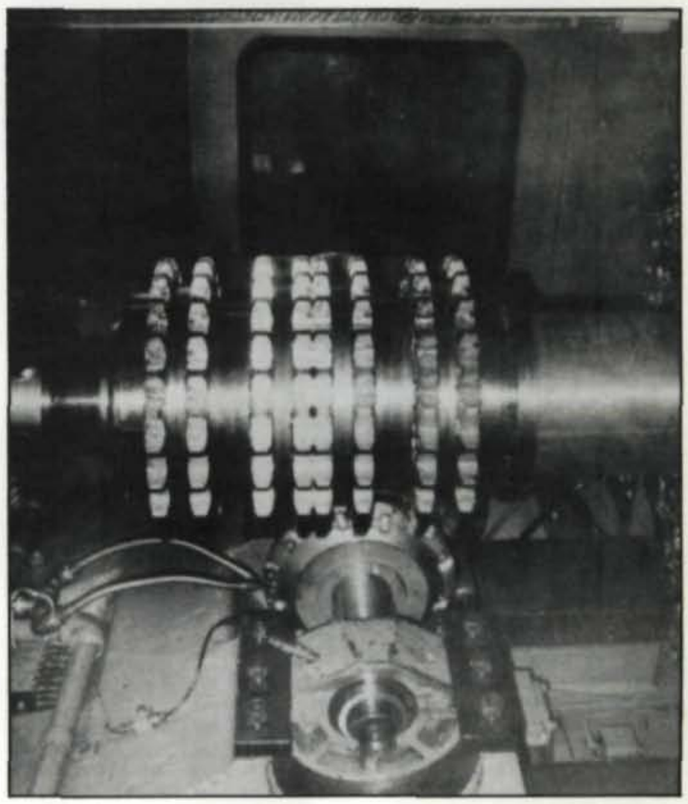

FIG. 7

between the workpiece and the top rake of the cutter teeth (Fig. 6). This gives longer cutter life by reducing the possibility of edge fractures or chipping of the cutter teeth.

Microprocessor equipped gashers and the linear interpolation of bevel gear angles generate very accurate angles. For example: the root angle tolerance on approximately an 8.5 inch face straight bevel would be about ± .002°.

The machine flexibility, created by the control and the non-pivoting work table, allows the methods people to switch readily from spur to bevel and back again without long set-up times.

We have seen excellent examples of using the machine to its maximum flexibility by gashing an integral bevel and spur gear in one program, one set up.

Sprockets

Almost everyone using gashers today produce sprockets. While not your ordinary bicycle type sprockets, the production of large sprockets, on older milling machines, because of the H.P. and tools available, has always been a slow process. In Fig. 7, we see the application of an inserted carbide sprocket milling cutter. The carbide inserts are placed and staggered to cut the full depth form as shown. During recent tests using a 75 HP gasher and a 1.5" circular pitch cutter with speeds of 375 surface feet per minute, full depth cuts were taken at 36 inches per minute. The finish was within acceptable limits of the end user. Thirty-six inches per minute is really fast, and the tests were performed without worry of excessive cutter wear. Interpolation of the results of the testing show that, dependent on the material and hardness, predicted rates of 22 to 24 inches per minute will give reasonable cutter economy.

The chips produced by this type of cutter differ greatly from the chips produced by the cutter in Fig. 4. These chips are short and almost flat. They have, however, substantial weight. Chips of this type are compact, easy to handle, and do not have the tendency to be carried over the top of the cutter and back into the cut.

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SPROCKET EXAMPLE #1* (H.S.S. HOB vs. INSERTED CARBIDE CUTTER)

PART - SPROCKET
CIRCULAR PITCH - 1.75"
STRANDS        - 4
TEETH          - 25
MATERIAL       - AISI 240 BHN
PARTS/STACK    - 2
TOTAL TRAVEL   - 22.0"

Using the Formula:
```

$$\text{TOOL COST PER CUT} = \left[\frac{\text{(COST OF CUTTER) + REGRIND COST}}{\text{NO OF USEFUL REGRINDS}}\right] \div \begin{matrix}\text{PTS PER}\\ \text{REGRIND}\end{matrix}$$

H.S.S. HOB

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PRICE          - $700.00
REGRIND LIFE   - 34
REGRIND COST   - $25.00
CUTS/GRIND     - 6
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$$\left[\frac{(700)}{34} + 25.00\right] \div 6 = \$7.60$$

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TOOL COST PER PART = $7.60

CARBIDE INSERTS

                  TYPE1*                                  TYPE 2**
PRICE         -  $440.00                                  $ 257.00
PRICE/INDEX - $ 88.00 (5 edges average with                  51.40
                        cross positioning)
CUTS/INDEX        18                                          18
TOOL COST/CUT   4.93 ($88.00 - 18)                        2.85 $51.40 - 18)

CUTTING TIME    - HOB/HOB                               GASH/GASH

ROUGHING  -       84 minutes @ .120 IPR                 35.5 @ 18 IPM
FINISHING -      126 minutes @ .080 IPR                 35.5 @ 18 IPM
                 210 minutes                            71.0 minutes

MACHINE TIME COST $45.00/hr
     HOB/HOB   = $157.00 + 7.60 + 7.60 = $172.20
     GASH/GASH = $ 53.00 + 4.93 + 4.93 = $ 62.86
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In using the new inserted carbide sprocket cutters, we find that up to 2" C.P. can be cut easily in one pass. In the example above, the cost for one pass gashing would then be based on 35.5 minutes @ $45.00/hour or $26.62 + $4.93 = $31.55 or approximately 1/5 the cost of two-pass hobbing.

**Data by Ingersoll Cutting Tool Company, Rockford, IL.*
***Data by Greenleaf Corporation, Seagertown, PA.*

Fixturing

No machine today is worth its weight if the application of the machine is not 100%. The efficiency of any machining system will suffer if the cutting tools, tool arbors, fixtures and set-ups are not commensurate with the machine potential.

The fixtures used on the old millers are not adequate today. Manual clamping of fixtures is not adequate today. Today's fixtures must be capable of transmitting the cutting force into the work table, without introducing vibrations or harmonics. Full ring type fixtures, with solid support directly at the root diameter of the cut, are essential. Plate top clamps, held by the integral work holding cylinder, become the vibration dampener. The mass of the fixture, also, is a good vibration dampener.

For most bevel and pinion cutting, the work support arm adds the rigidity we lose by the smaller diameter support under the gear. Simple systems of a basic fixture, with substantial locating bushings, adapter rings, and top plates, have been designed and proven to be more than adequate and readily adaptable to many types of gear set-up.

Options

The usual options on gasher machines include: coolant systems for H.S.S. cutter applications, various sized cutter arbors to accommodate the old and new cutters, workholding cylinders and assistance in programming and fixturing.

A high volume chip conveyor is a necessity as is a cutter removal frame, which permits an entire cutter arbor assembly to be preset off the machine, and installed as a single unit for fast and easy cutter changeover.

The following charts are examples of inserted carbide costs, and production records of both carbide and high speed steel cutting of an assortment of gears and sprockets.

Synopsis

The last few years have become all important to the gear industry. The advances in tooling for milling gears have been forced by the manufacturers of large D.P. gears and the manufacturers of the gear milling machines. They responded with a well-managed research and development program. The people involved were interested enough not to stop at the first, second, or even third generation design. Each generation of cutter design brought us larger, stronger, smoother cutting tools. The book on feed rates was thrown out the window.

The application of microprocessor based numerical controls to gear milling has given us the ease and speed of set-up, the elimination of shafts and gears in drive lines. Axis resolution and table index accuracy are enabling better quality gears to be milled than ever before. All of these features make better gears faster at a lower cost. The microprocessor is taught how to make the *good* gears. The machine is strong and rigid to cut the *big* gears, and the tools match the machines and the technology. Gear Milling has caught up.

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CARBIDE SPROCKET MILLING
PERISHABLE COST ESTIMATE*

Test No.	201	202	203	204	205	206	207
Material	Cast Steel	Steel Plate	Fab	Cast Steel	Cast Steel	Cast Steel	Cast Steel
Circular Pitch	1.25	1.75	1.75	1.25	1.50	1.75	2.50
No. of Teeth	88	50	18	29	42	26	50
No. of Strands	3	1	1	3	6	2	3
Inserts/Set	$325.00	$384.00	$384.00	$324.00	$384.00	$384.00	$480.00
Inserts/Edge	$ 81.00	$ 96.00	$ 81.00	$ 96.00	$ 96.00	$ 96.00	$120.00
Parts/Edge	11	43	121	34	9	43	10
Insert Cost/Part	$ 7.36	$ 2.23	$ .79	$ 2.38	$ 10.66	$ 2.23	$ 12.00
Insert Cost/Tooth	$ .083	$ .044	$ .043	$ .082	$ .25	$ .085	$ .24
Insert Cost/Inch	$ .041	$ .047	$ .046	$ .04	$ .049	$ .047	$ .059

**Data per Ingersol Cutting Tool Company*
Rockford, Illinois

(Continued on next page)

CARBIDE SPROCKET MILLING
PRODUCTION ESTIMATE*

Test No.	201	202	203	204	205	206	207
Material	Cast Steel	Steel Plate	Fab	Cast Steel "H"	Cast Steel "H"	Cast Steel "H"	Cast Steel "H"
Circular Pitch	1.25	1.75	1.75	1.25	1.50	1.75	2.50
No. of Teeth	88	50	18	29	42	26	50
No. of Strands	3	1	1	3	6	2	3
Part width O/A	3.5"	1.31"	4.87"	6.75"	12.0"	6.0"	7.5"
Parts/Stack	6	16	4	3	2	4	3
Total Travel	28.5"	28.5"	27.0"	26.75"	28.5"	28.5"	29.0"
Cutter Diameter	12"	12"	12"	12"	12"	12"	12"
Speed	350 SFM	350 SFM	350 SFM	300 SFM	300 SFM	300 SFM	300 SFM
Feed	18 IPM	18 IPM	18 IPM	15 IPM	15 IPM	15 IPM	15 IPM
Cut Direction	Climb	Climb	Climb	Climb	Climb	Climb	Climb
Total Linear	1061.28"	739.2"	66.52"				
Cut Time/Pass	1.58 min.	1.58 min.	1.5 min.	1.78 min.	1.9 min.	1.9 min.	1.93 min.
Idle/Pass	.12 min	.12 min.	.12 min.	.12 min.	.12 min.	.12 min.	.12 min.
Total Time/Pass	1.70 min.	1.70 min.	1.62 min.	1.90 min.	2.02 min.	2.02 min.	2.05 min.
Time/Stack	149.6 min.	85.0 min.	29.6 min.	55.1 min.	84.84 min.	52.52 min.	102.5 min.
Time/Piece	24.93 min.	5.31 min.	7.4 min.	18.4 min.	42.42 min.	13.13 min.	34.1 min.

**Data per Ingersol Cutting Tool Company
Rockford, Illinois*

TEST NO Unit Material	208 Gear SAE 1041	209 Sprocket CAST STEEL "H"	210 Sprocket Cast Steel "H"
Pitch	1 D.P.	2.0" C.P.	1.5" C.P.
No. of teeth	74	43	42
No. of strands	N/A	3	6
Part width O/A	5.0"	3.4"	3.7"
Parts/Stack	1	1	1
Total Travel	7.5"	7.7"	13.5"
Cutter Diameter	5.75"	9.0"	6.5"
Speed	72 SFM	80 SFM	68 SFM
Feed	10 IPM	5 IPM	8 IPM
Depth	.850	Full	Full
Cut Direction	Climb	Conv.	Conv.
Time/Stack	58 Min.	63 Min.	78 Min.
Time/Piece	58 Min.	63 Min.	78 Min.