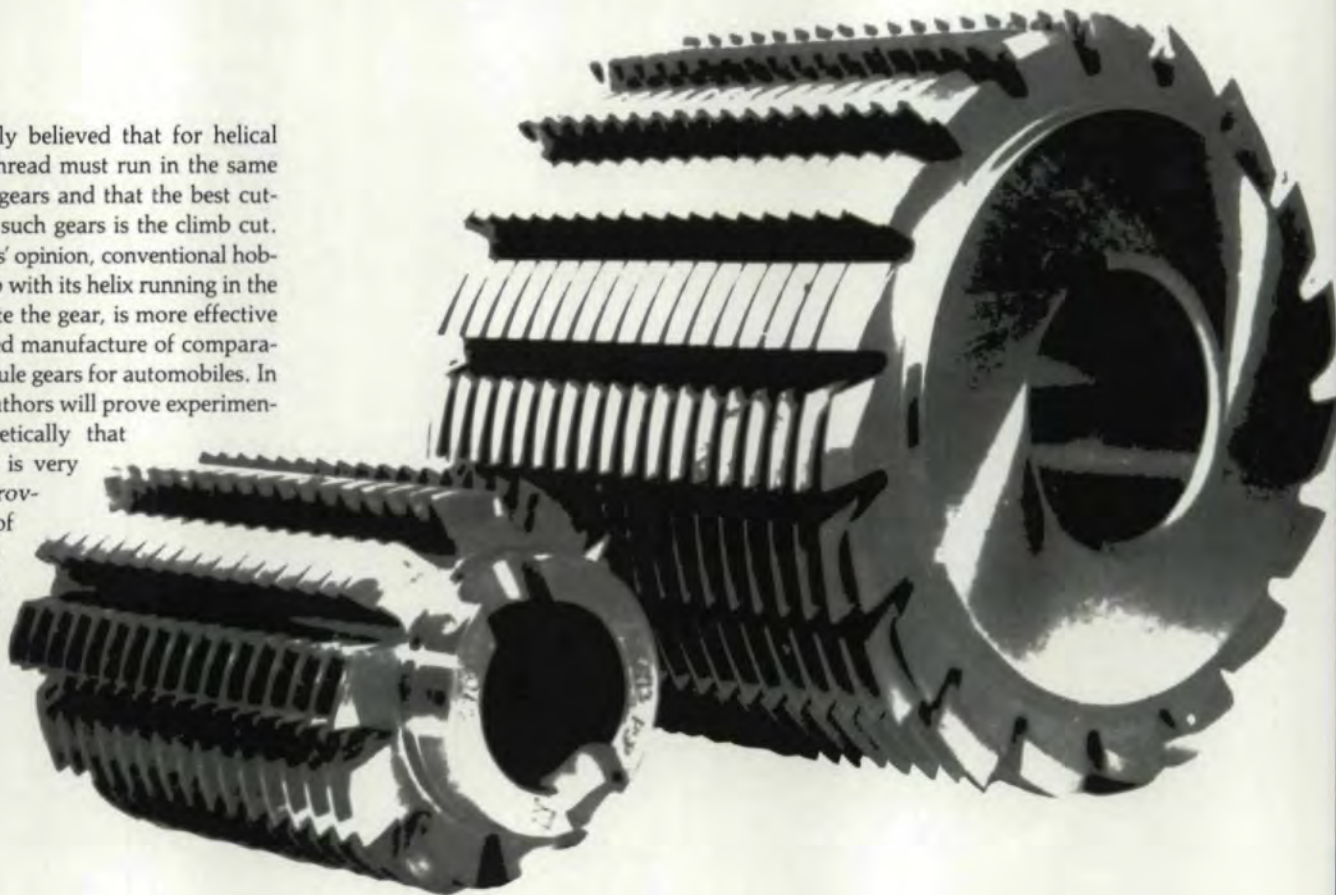


# The Effect of Reverse Hobbing at a High Speed

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## Abstract

It is commonly believed that for helical gears, the hob thread must run in the same direction as the gears and that the best cutting method for such gears is the climb cut. But in the authors' opinion, conventional hobbing, using a hob with its helix running in the direction opposite the gear, is more effective for the high-speed manufacture of comparatively small module gears for automobiles. In this article the authors will prove experimentally and theoretically that reverse hobbing is very effective for improving both the life of hobs and cutting precision when performing high-speed, high-efficiency hobbing.



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In 1966 he was awarded the Japan Society of Mechanical Engineering Paper Prize for research on hobbing and again in 1979 for research on the development of gear honing machines with screw-shaped hones.

## Introduction

Today it is common practice when climb hobbing to keep the direction of the hob thread the same as that of the helical gear. The same generalization holds true for the mass production of gears for automobiles. It is the authors' opinion, however, that conventional hobbing with a reverse-handed hob is more effective for the high-speed manufacture of comparatively small module gears for automobiles. The authors have proven both experimentally and theoretically that reverse-handed conventional hobbing, using a multi-thread hob with a smaller diameter is very effective for lengthening the life of the hob and for increasing cutting efficiency at high speeds.

## Cutting Function of Hob Teeth

Fig. 1(a) shows the same-handed climb hobbing commonly used for cutting helical gears. Fig. 1(b) shows reverse-handed hobbing using a hob set opposite to a helical gear. Cutting edges on the generating center are identified as Nos. 0, 1, 2, etc. in the direction of roughing.

Fig. 2 shows the profile of cutting chips theoretically calculated<sup>(1)</sup> and the function of each top cutting edge when the direction of the feed and the thread are varied. Black areas are chips numbered by every two cutting edges. Note that when reverse-handed, conventional hobbing is used, the entrance angle of every cutting edge is larger, and the thickness of the chips is reduced by half. (See

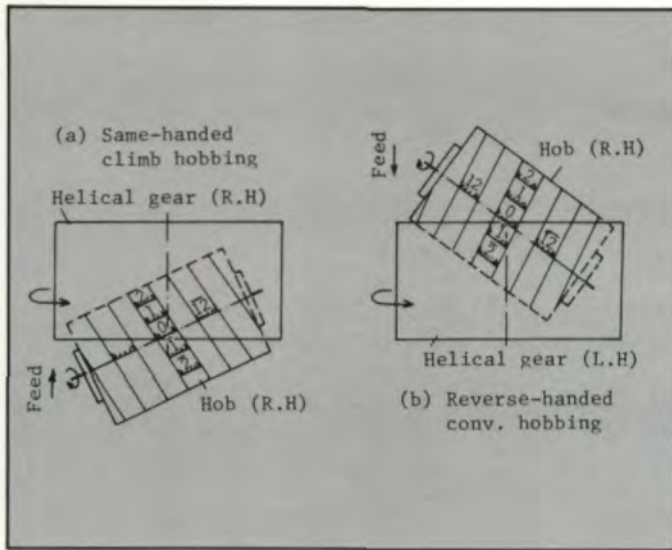


Fig. 1 - Hobbing method of helical gear

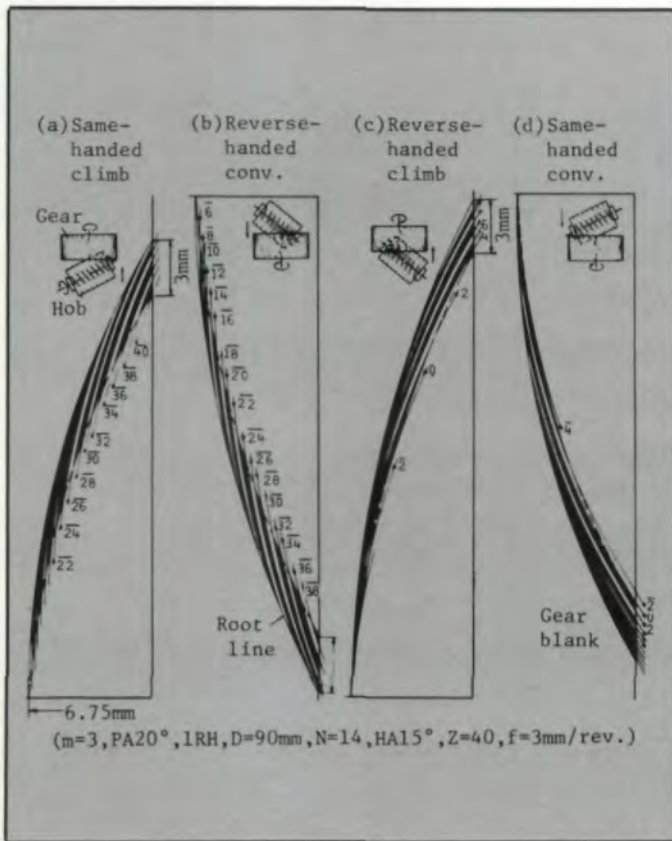


Fig. 2 - Function of each top cutting edge

Fig. 3.) Moreover, a conventionally hobbled chip is long and thick. When the entrance angle is smaller, wear is increased, and the cutting edge is easily chipped because the cutting edge barely cuts in and tends to slip. When a chip is thick and short, the deepest crater wear is distant from the cutting edge. Then the edge is hardly broken because the temperature rises more slowly<sup>(2)</sup> and,

naturally, extraordinary wear at the corner of the cutting edge is very limited.<sup>(3)</sup> In other words, the life of the hob is greatly extended.

#### Damage to a Cutting Tooth

Fig. 4 shows the maximum relief wear after hobbing gears of SCM 415 case-carburizing steel for automobiles, using a cutting speed of 120m/min. and a feed

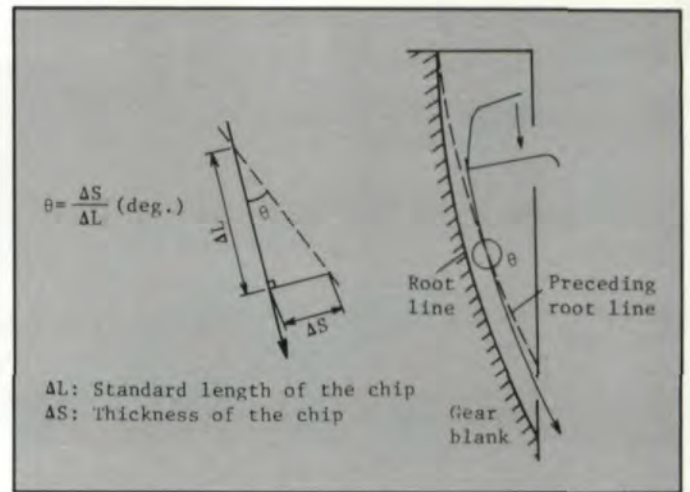


Fig. 3 - Entrance Angle  $\theta$  of the cutting edge

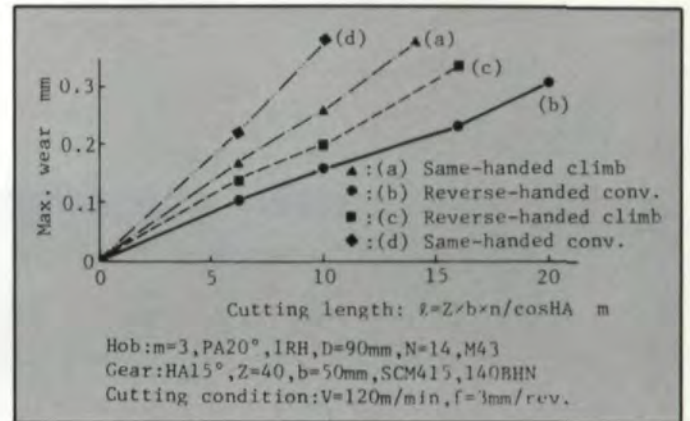


Fig. 4 - The progress of the maximum relief wear (in case of a single-thread non-coated hob)

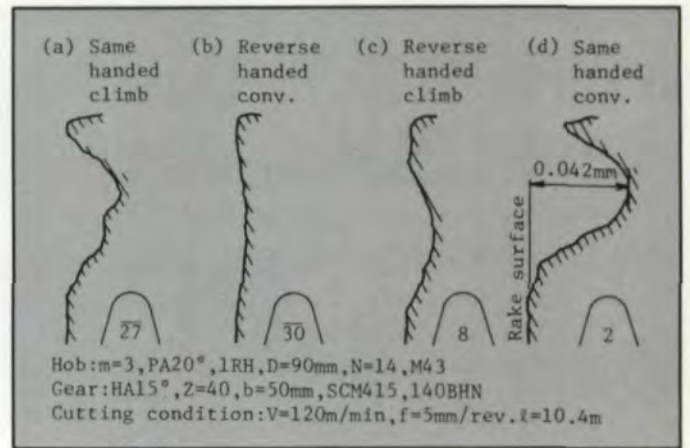


Fig. 5 - Comparison of the crater wear

of 3 mm/rev. without a hob shift. As shown in the table, the life of a hob is the longest when reverse-handed conventional hobbing has been used.

Fig. 5 shows the crater wear after five gears (cutting length  $l=10m$ ) were cut. The amount of crater wear is least in the case of reverse-handed conventional hobbing because the temperature of a cutting edge rises more slowly when this

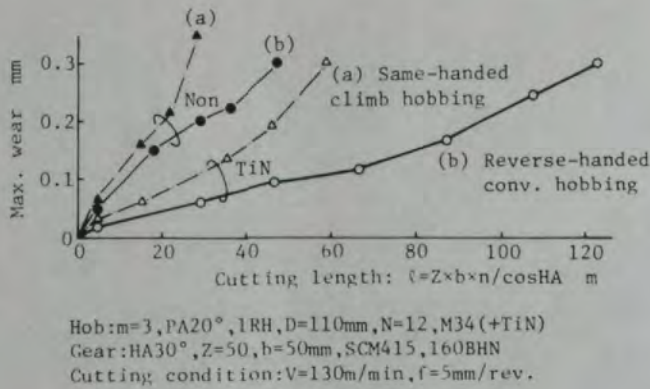


Fig. 6—The progress of the maximum relief wear (in the case of a single-thread TiN-coated hob)

method is used and extraordinary wear does not occur. From these figures, it can be seen that reverse-handed conventional hobbing is the most suitable method for use at high speeds.

Fig. 6 shows a comparison of the maximum relief wear after same-handed climb hobbing and after reverse-handed conventional hobbing at a cutting speed of 130m/min. and a feed of 5mm/rev., using a TiN-coated hob. (PVD method.) The life of a TiN-coated hob is greatly lengthened by the use of the reverse-handed conventional method because crater wear is so much less.

Fig. 7 shows the damage to each hob after gears with a cutting length,  $l=12m$

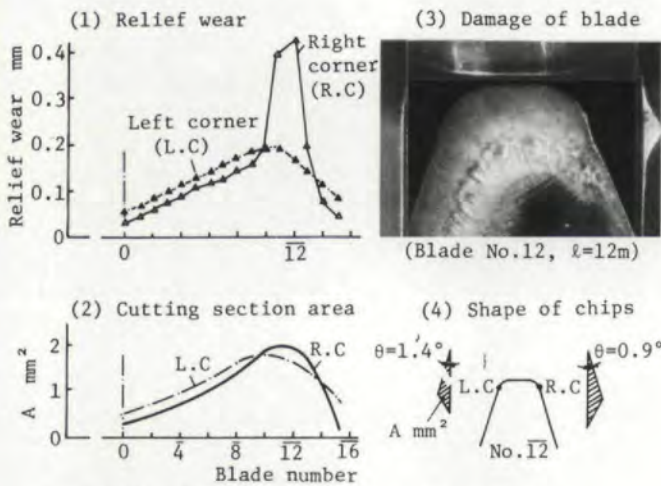


Fig. 7-(a) The same-handed climb hobbing

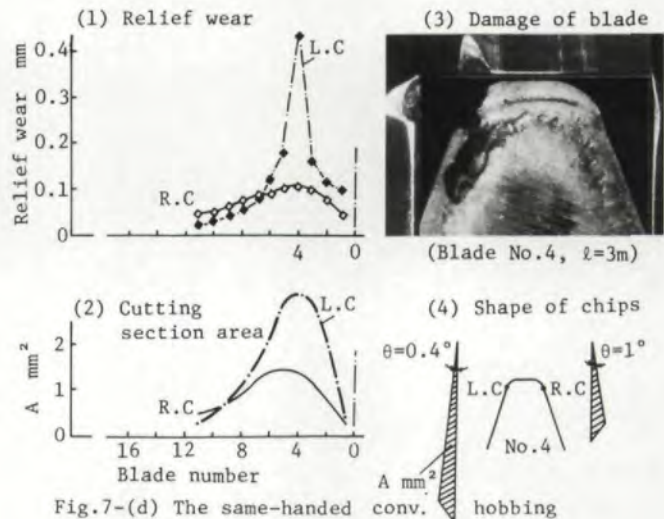


Fig. 7-(d) The same-handed conv. hobbing

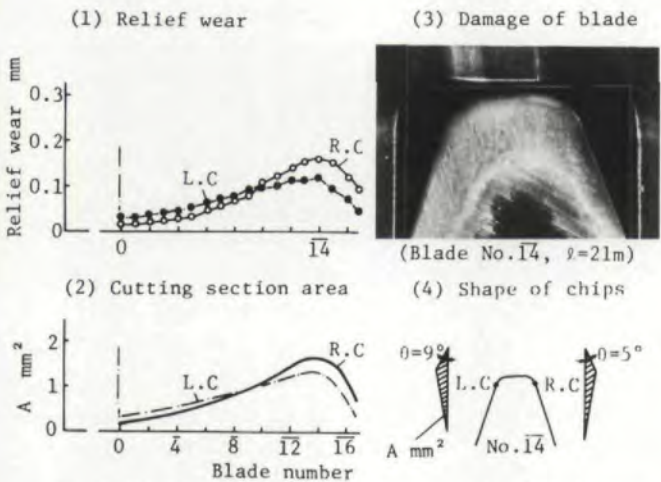


Fig. 7-(b) The reverse-handed conventional hobbing

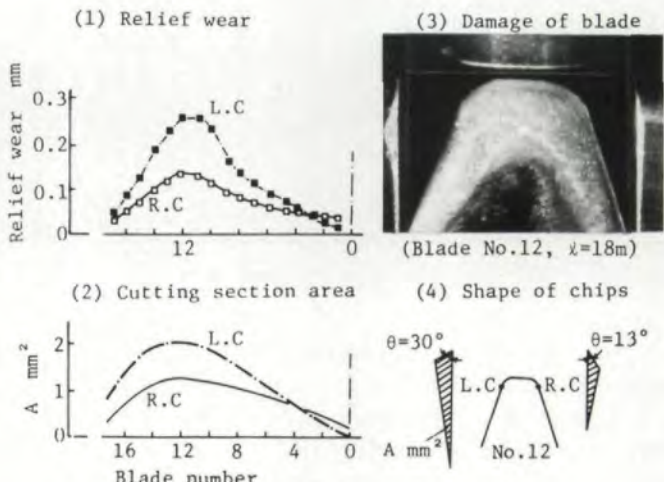


Fig. 7-(c) The reverse-handed climb hobbing

Hob:  $m=3, PA20^\circ, 3RH, D=110mm, N=12, M34, \text{Non-coated}$  Gear:  $HA30^\circ, Z=57, b=60mm, SCM415 (\text{AISI } 4118), 140BHN$   
 Cutting condition:  $V=130m/min, f=5mm/rev.,$  Hobbing machine: KS-14 Cutting oil: Daphne cut HS-4M

Fig. 7—The relief wear and shape of chips in various hobbing methods (in the case of a triple-thread hob)

had been cut at a speed of 130m/min. and a feed of 5mm/rev. using a triple-thread hob. Fig. 7(a) shows the damage to a hob after the same-handed climb hobbing method was used. The graph and photo at the top of the figure show the maximum relief wear on each right and left corner. The figures below show the cutting load<sup>(4)</sup> theoretically calculated at the right and left corners, and the shape of the chips that come out from the right and left corners.<sup>(5)</sup>

Fig. 7(b) shows the amount of relief wear after reverse-handed conventional hobbing. The entrance angle of the cutting chips at the right and left corners (See Fig. 4.) is larger in comparison to Fig. 7(a). As cutting speed increases, the amount of wear decreases. The cutting load to each blade also decreases as the number of cutting blades increases.

Fig. 7(c) shows the results of reverse-handed climb hobbing, and Fig. 7(d) shows the results of same-handed conventional hobbing. As the figures show, there is a great difference between the cutting load of the right and left corners, and the amount of damage is greater than Fig. 7(b).

Fig. 8 shows the comparison of the maximum relief wear after hobbing at a high speed and feed with a triple-threaded hob. The amount of damage is influenced by the cutting method, and it is more evident when triple-threaded hobs are used.

From these figures, it can be seen that the reverse-handed conventional hobbing method with a multi-threaded hob at a high speed and feed is indispensable for improving cutting efficiency.

### Answer to Higher Efficiency

*Influence of a large feed.* When using a multi-threaded hob, it is important to perform at high speed and with a large feed to increase cutting efficiency. Fig. 9 shows 2-, 3-, 4-, and 5-thread hobs for this experiment. All hob dimensions are the same.

Fig. 10 shows the maximum relief wear after same-handed conventional hobbing and reverse-handed conventional hobbing at various amount of feed with a double-threaded hob. In the case of same-handed climb hobbing, the hob life can be lengthened when the amount of feed is less. In the case of reverse-handed conventional hobbing, the hob life can

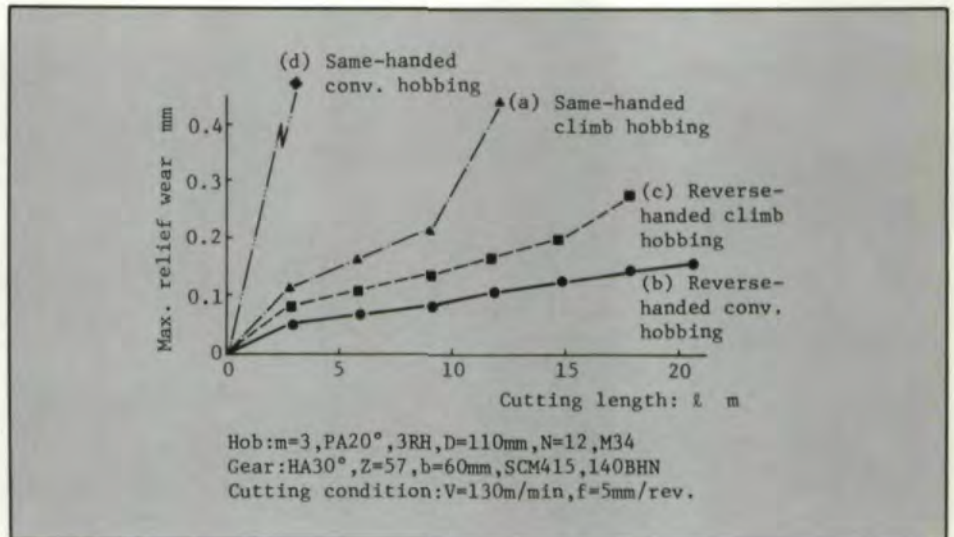


Fig. 8—The progress of the maximum relief wear (in case of a triple-thread non-coated hob)



Fig. 9—Multi-thread hobs with small diameter

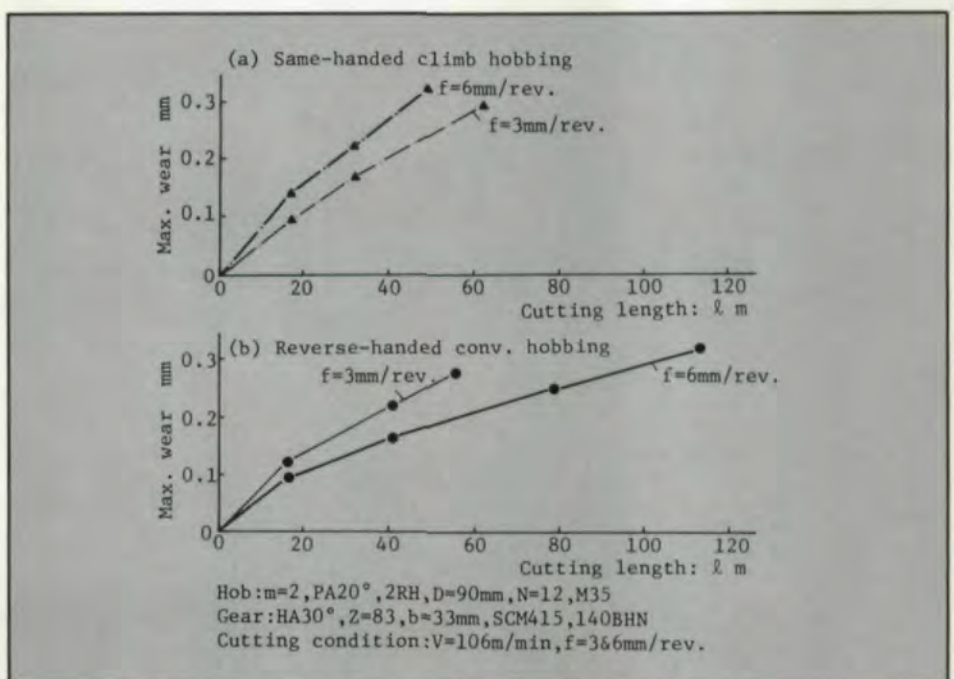


Fig. 10—Influence of hob feed (in the case of a 2-thread hob)

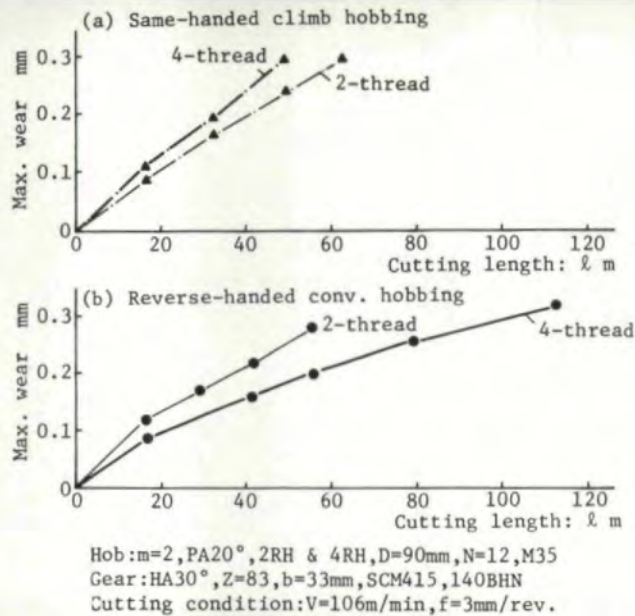


Fig. 11 - Influence of hob thread

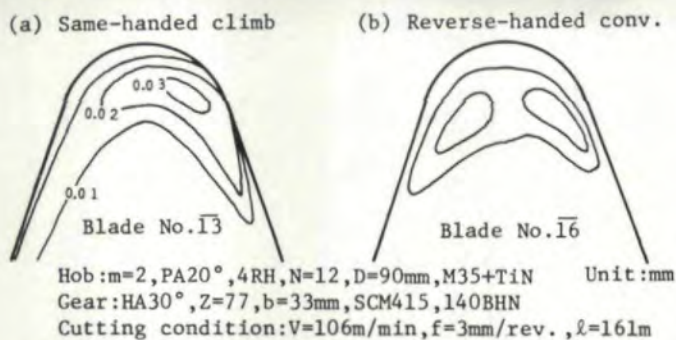


Fig. 12 - Comparison of the crater wear

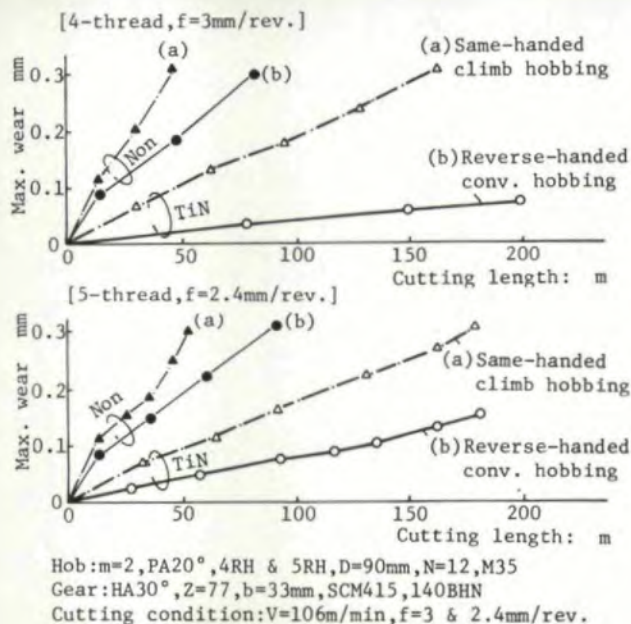


Fig. 13 - The progress of the maximum relief wear (in the case of a multiple-thread TiN-coated hob)

be lengthened when the amount of feed is greater. Therefore, reverse-handed conventional hobbing is suitable for increasing hobbing efficiency.

*A multi-threaded hob.* Fig. 11 compares the maximum relief wear after same-handed climb hobbing and reverse-handed conventional hobbing under the same cutting conditions when the number of threads varies. Fig. 12 shows the crater wear (contour line) of a four-thread hob.

Under the same cutting conditions, the hob life is shortened in same-handed climb hobbing as the number of hob threads increases. The life of the hob is dramatically increased when reverse-handed conventional hobbing is used and the number of hob threads increased.

Fig. 13 shows the effect of the reverse-handed conventional hobbing with 4-thread and 5-thread hobs that are TiN-coated. The life of a multi-threaded and TiN-coated hob is greatly increased and the amount of wear greatly decreased when reverse-handed conventional hobbing is used.

*Smaller diameter hobs.* Fig. 14 shows the life of a larger diameter/multi-threaded hob and a smaller diameter/multi-threaded/TiN-coated hob used for cutting differential drive ring gears in automobiles. If we suppose that a hob is resharpened when the maximum relief wear is 0.3mm, the cutting length becomes about 500m (175 pcs.) without hob shifting. Many gears can be produced before resharpening because a hob can be shifted.

### Hobbing of Helical & Profile Shifted Gears

Recently mass-produced gears have been profile-shifted. In the case of high speed hobbing of profile shifted gears, addendum modification has greatly influenced hob wear in same-handed climb hobbing. Fig. 15 shows the progress of hob wear after profile-shifted gears with various addendum modifications were cut at high speed. The tooth profiles for both reverse-and same-handed conventional cutting are shown. In the case of reverse-handed conventional hobbing, addendum modification has little influence on hob wear; therefore, the reverse-handed conventional hobbing method is suitable for profile-shifted gears.

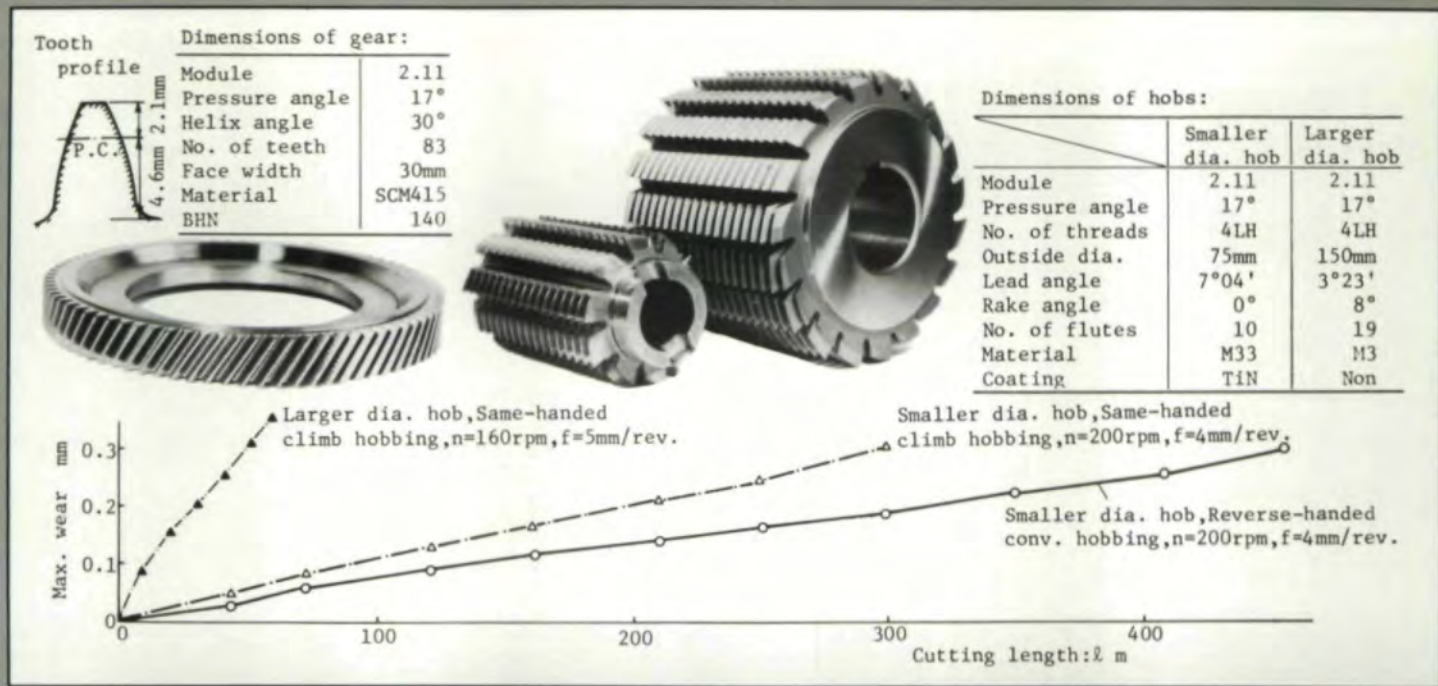


Fig. 14—The life of hobs for differential drive ring gears

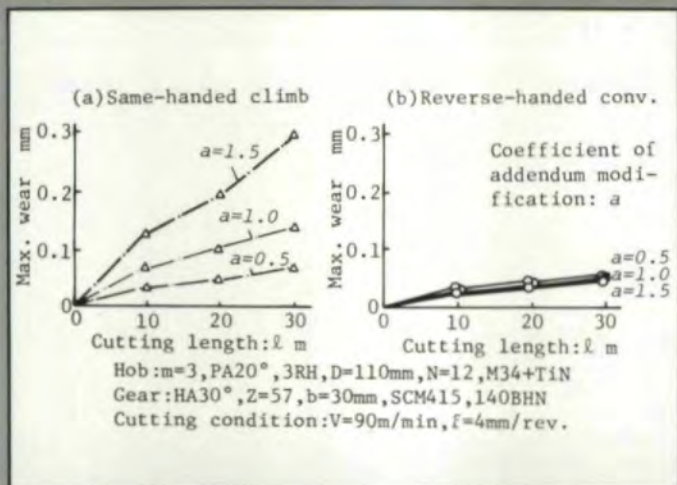


Fig. 15—The maximum wear of the profile-shifted gears

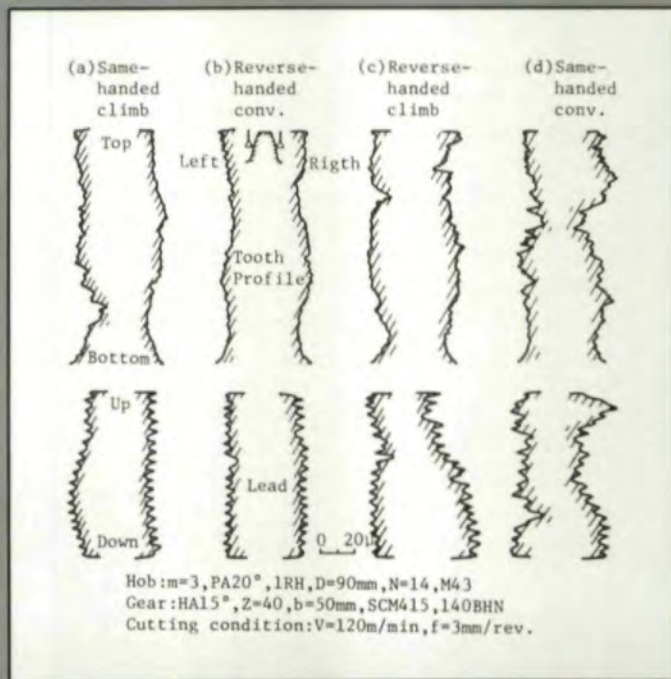


Fig. 16—Cutting precision of helical gears (in the case of single-thread hob)

### Cutting Precision

Fig. 16 shows the tooth profile errors and lead errors of helical gears cut by a single-thread hob. The cutting conditions are the same as in Fig. 4. The cutting precision of the reverse-handed, conventionally hobbled gears is better than that of the same-handed, climb hobbled ones.

Fig. 17 shows the lead error of helical gears with 5 and 10 degree helix angles, when both same-handed climb hobbing and reverse-handed conventional hobbing have been used. (In both cases, the gears are made of case-carburized steel SCM 415/HB160 for automobiles.)

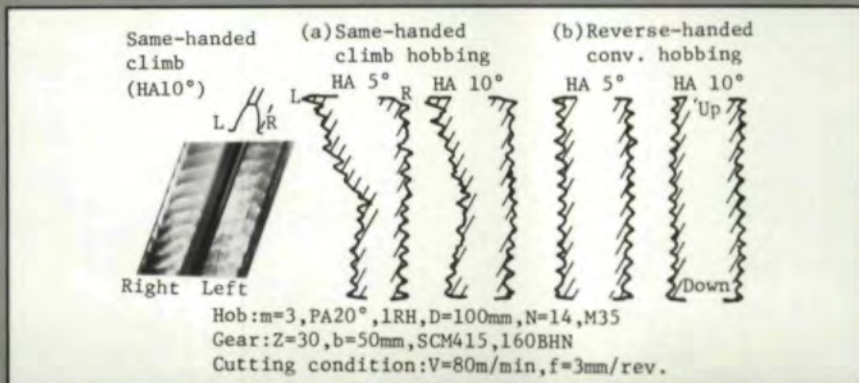


Fig. 17—The lead error of helical gear. 5° & 10°

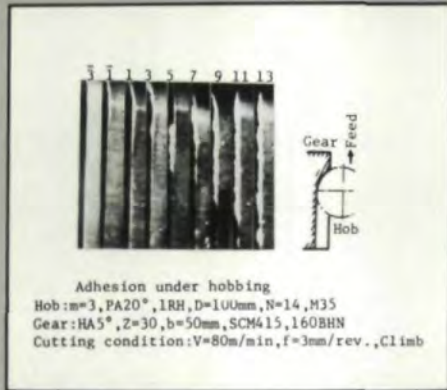


Fig. 18—The adhesion of each cutting edge

Fig. 18 shows the adhesion of each cutting edge in the gear with a helix angle of 5 degrees. This adhesion on each cutting edge makes the lead error and the tooth profile error worse in the case of the same-handed climb hobbled gear. On the other hand, little adhesion comes out in the case of the reverse-handed, conventionally hobbled gear or one with a large helix angle.

Fig. 19 shows the lead error of a helical gear cut by a 30 degree reverse-handed conventional hob with multi-threads and small diameter and TiN coating. When the number of hob threads and the gear helix angle increases, the hob setting angle becomes larger, and the component of the cutting force occurs in the direction of the table rotation of the hobbing machine. (See Fig. 20.) While the top of the hob blade is working, the cutting force is strong enough to accelerate the table, and while it is not working, the cutting force is not strong enough.

Naturally, lead error comes out at the end of hobbing. Therefore, it is necessary to eliminate the torsion, backlash and relative displacement of transmission system from a hob to a table and to eliminate the backlash of master worm gears.

Fig. 19—Lead error after reverse-handed conventional hobbing with multi-thread hob

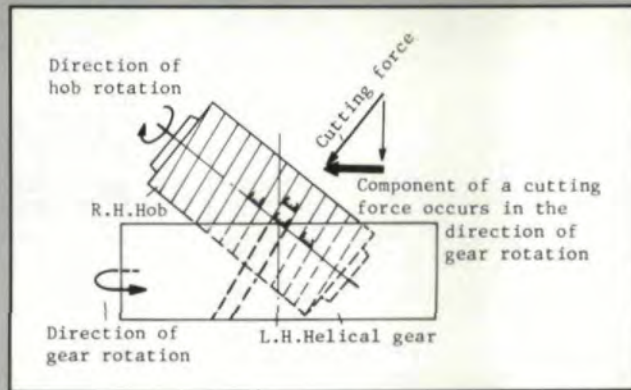
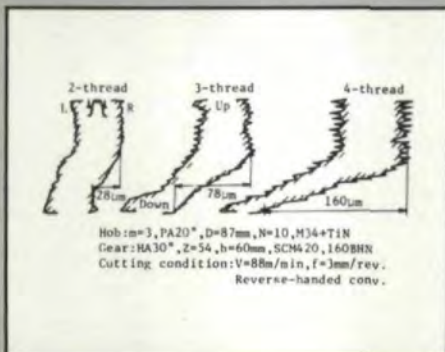


Fig. 20—Component of a cutting force and the direction of gear rotation

Fig. 21—Influence of hob feed after the reverse-handed conventional hobbing with triple-thread hob

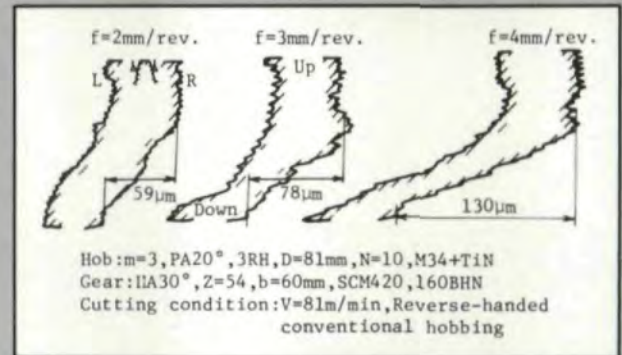


Fig. 22—Influence of hobbing machine

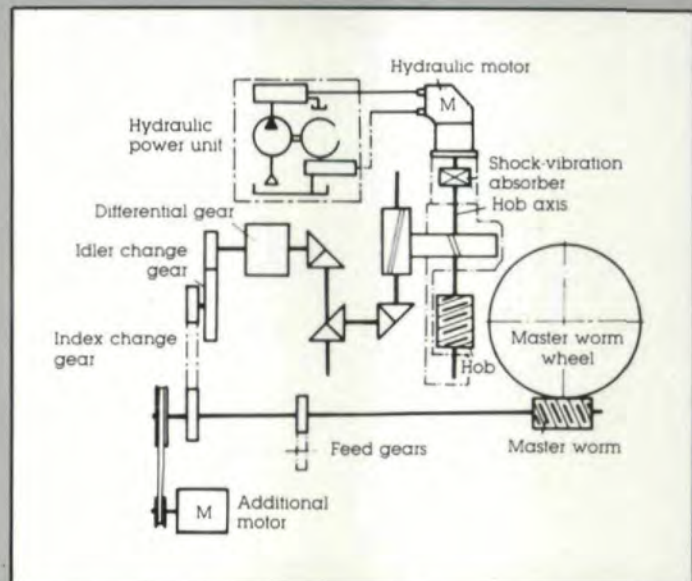
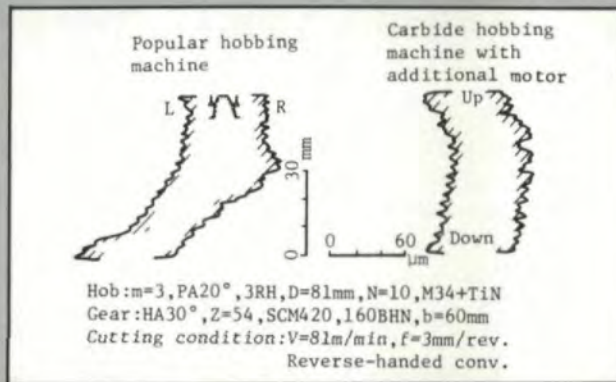


Fig. 23—Carbide hobbing machine with additional motor

Fig. 21 shows the lead error of gears reverse-handed and conventionally hobbled with a triple-threaded hob using an ordinary hobbing machine. The lead error becomes larger as the cutting force of the hob increases.

Fig. 22 shows the comparison of lead errors occurring when a gear is reverse-handed and conventionally hobbled on a ordinary hobbing machine with those taking place when a gear is hobbled with additional rotation to the master worm axis to eliminate the torsion, backlash and relative displacement of a table driving system on a direct-drive hobbing machine, as shown in Fig. 23.<sup>(6)</sup> Figs. 24 and 25 show the improvements of lead error on an ordinary hobbing machine.

As a countermeasure, it is important to prepare the direct drive hobbing machine with high rigidity when helical gears with a large helix angle are reverse-handed and conventionally hobbled at high speeds and feeds, using a multi-thread hob.

#### Conclusion

The authors have proven both experimentally and theoretically that the reverse-handed conventional hobbing is more effective than same-handed climb hobbing when cutting comparatively small module mass-production gears at high speed and efficiency. But it is also important to reduce the torsion, backlash, and relative displacement of the driving system for generating motion, such as master worm gears, on a direct-drive hobbing machine. It is further recommended that reverse-handed hob-

(continued on page 46)

Fig. 24—Improvement of lead error on an ordinary hobbing machine

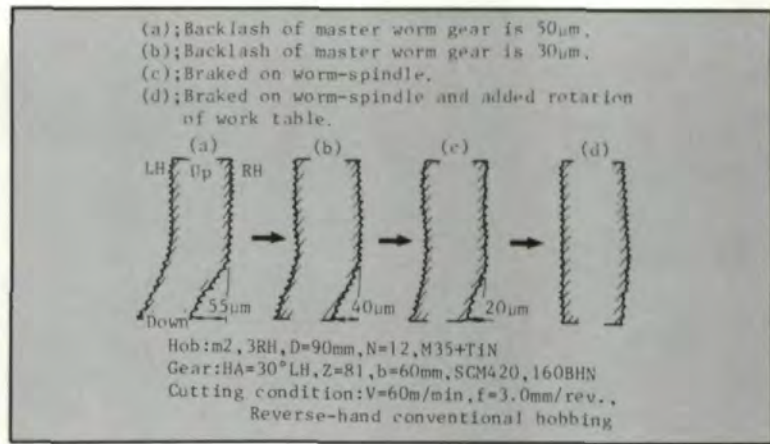
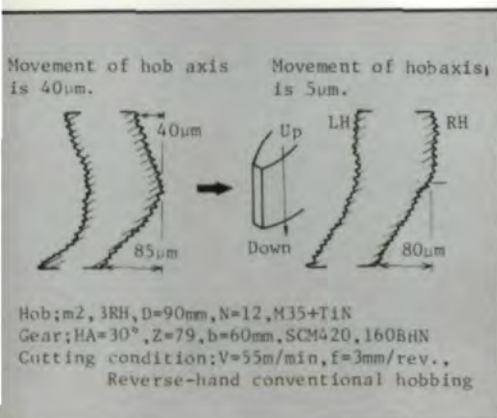


Fig. 25—Improvement of lead error on an ordinary hobbing machine

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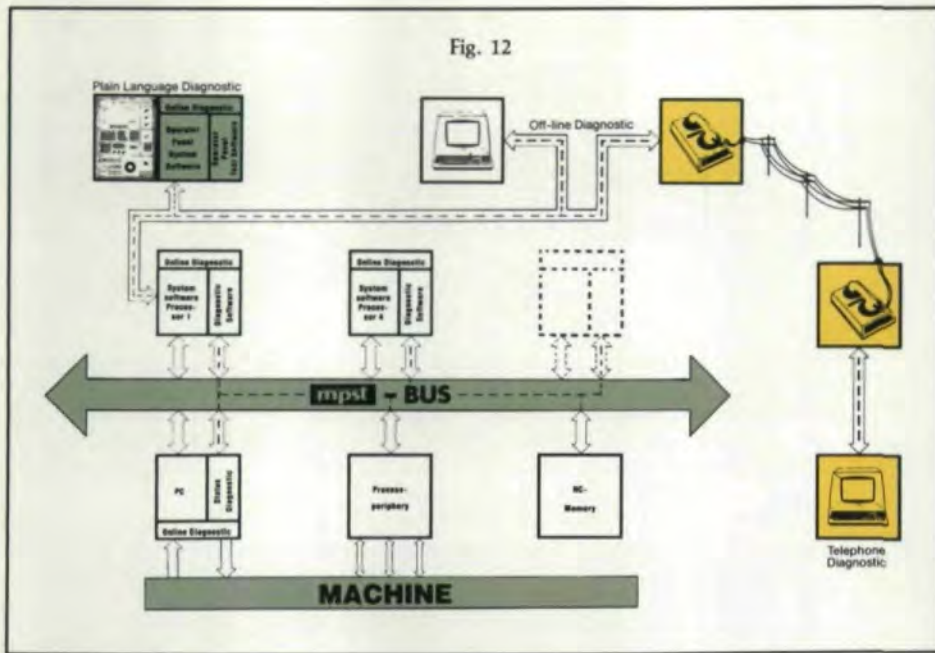
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#### Cost per piece (Fig. 13)

CNC techniques allow economical small batch production. A reduction in both cycle and set-up times makes CNC economically superior to the conventional machine, despite the higher investment involved.

Obviously, savings are larger with small batches, but with medium sized batches advantages are still shown.

In the above calculations, savings are achieved by means of the shorter throughput of a batch, because of combined operations and better tool utilization due to the ability to use partially used tools on subsequent batches. Another saving can be achieved through the ability to program any required cor-

rection to allow for subsequent shaving or heat treatment without added time, making shaving less expensive. In addition, with CNC machines, batch sizes and, thus, capital costs can be reduced.

The consequences of these considerations give the base for a model gear

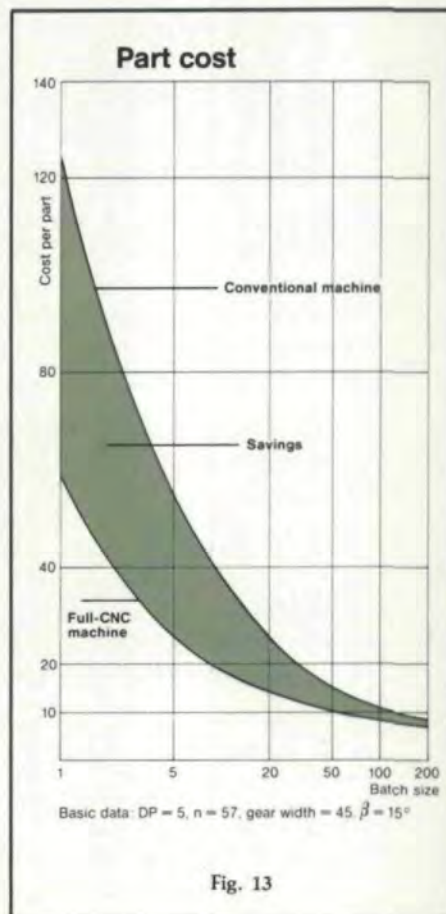


Fig. 13

cutting center. It shows what can be realized today: a six axis full CNC hobbing machine serviced by a six axis CNC gantry automatic loader and a system designed for batch sizes of 1-200 in an unmanned three-shift operation. Economic justification has to be carried out individually, but in this example, calculations show that with 60 different parts and four machine changeovers per shift, this system can be justified.

**Acknowledgement:** This paper was presented at the SME "Gear Processing & Manufacturing Clinic," Nov. 1985.

#### THE EFFECT OF REVERSE HOBBING . . .

(continued from page 15)

bing with multi-threaded (4-, 5-threads), small diameter and TiN coated hobs be used for the low cost production of helical gears. Thus high speed steel hobs will be able to stand against severe cutting conditions such as cutting speeds of 100m/m and hob feed rates of 4-6 mm/rev.

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