BACK TO BASICS...

Economics of CNC Gear Hobbing

Dr. G. Sulzer
Liebherr Machine Tools
Kempton, West Germany

In our March/April, 1986 issue, Dr. F. Sulzer discussed some of the technical and production advantages of CNC gear shaping. Now we bring you the sequal to that article, which discusses some of the economic factors to be taken into consideration when converting to NC or CNC gear cutting.

Conventional Hobbing Machine versus CNC Hobbing Machine

NC and CNC metal cutting machines are among the most popular machine tools in the business today. There is also a strong trend toward using flexible machining centers and flexible manufacturing systems. The same trend is apparent in gear cutting. Currently the trend toward CNC tools has increased, and sophisticated controls and peripheral equipment for gear cutting machines are now available; however, the investment in a CNC gear machine has to be justified on the basis of economic facts as well as technical advantages.

The reason for the rapid introduction of numerical control in gear cutting is the trend toward ever decreasing batch sizes and the increasing variety of current components. (Fig. 1) Machine changeovers are more frequent and productive utilization of the machine is too low.

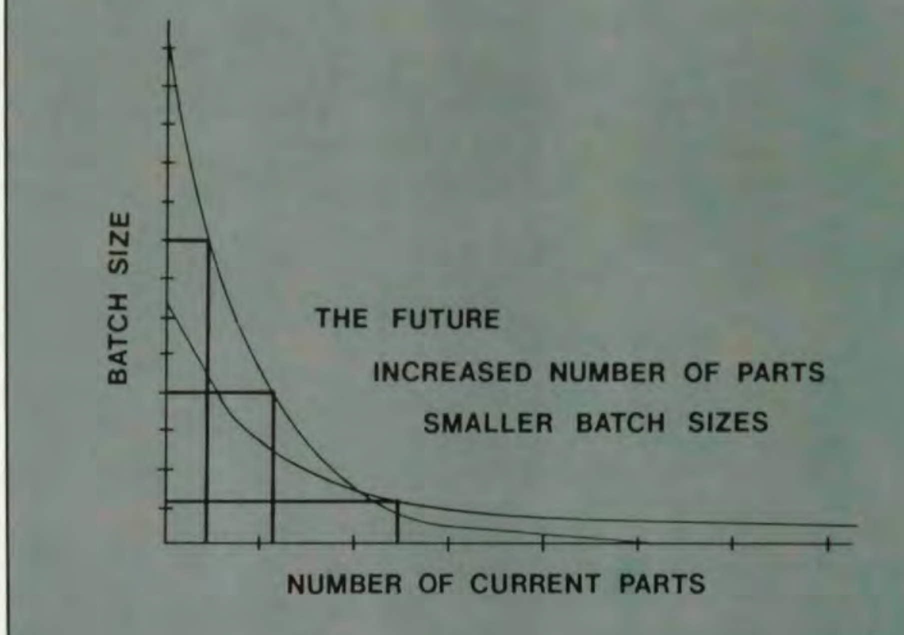


Fig. 1

On the other hand, the investment for a full CNC hobbing machine is considerably higher. Balancing these two factors, it becomes obvious that CNC hobbing is more economical than conventional hobbing, especially if many of the added features of a CNC machine are used. These extra features, such as, 2-cut cycles, copying, feed control, etc. are expensive in conventional machines.

The remaining question is how much sophisticated periphery, such as automatic fixture change, automatic part gauging, can be afforded.

Due to their complex kinematics and the high accuracy requirements, hobbing machines represent a special branch of machine tools. Hence for a long time, suitable NC controls for these machines were not available and machine tool manufacturers were forced to make developments of their own. This is especially true for the precise synchronization of hob and workpiece rotation. (Fig. 2) This problem is now solved, and today the whole range of hobbing machines covering one inch to 40 feet in gear diameter is available in full CNC versions. With the high cost of gears above 40 inches in diameter, machines are equipped with special features in case of power failure and emergency shut-down of the machines.

Cycle Times (Fig. 3)

In reducing the production time for any gear, it is necessary to cut down both idle and cutting times. With NC technology, cutting times can be reduced by 10-20%. This saving is achieved through the use of special feed control, without overloading the hob. During

AUTHOR:

DR. G. SULZER *is Manager of Research & Development at LIEBHERR in West Germany. He earned his doctorate at the University of Aachen in Aachen, Germany where he has worked in the role of Manager of Research Development for twelve years. He has been instrumental in the development of the Liebherr CNC machines.*

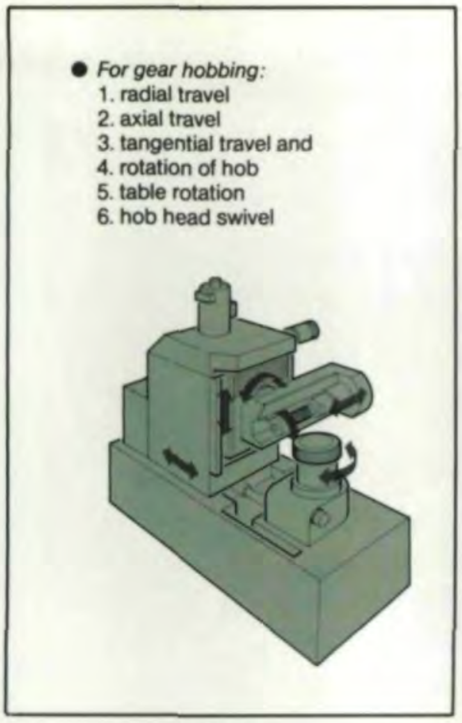


Fig. 2

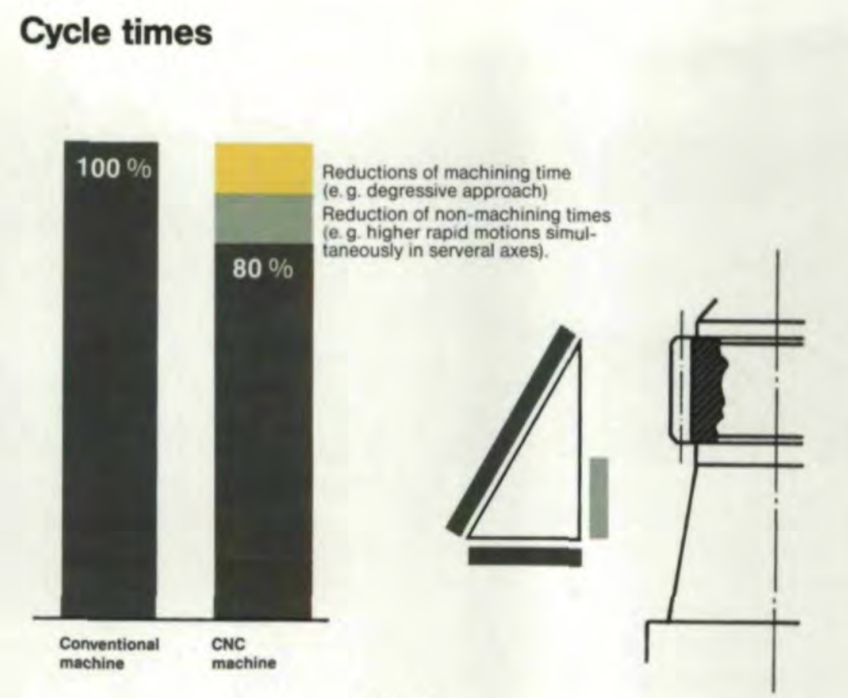


Fig. 3

radial or axial approach, the hob is only partially used, chip thickness is small, and the cutting path is short because of the small angles of action. With the use of degressive control for both speed and feed, time savings can be achieved.

Feed commences approximately 1.5 times normal, and the hob speed is approximately 1.3 times normal. When using a two-cut cycle, feed and speed can be increased during the exit of the tool on the first cut (progressive control). Multistart, tin-coated hobs can be fully used on modern CNC machines. These machines provide for the necessary hob and table speeds and power requirements.

CNC hobbing machines offer higher gear qualities with the same cutting conditions when compared with conventional machines. This applies especially to the lead, because on NC machines there is no longer a gear train which may distort under load. Thus, with quality requirements remaining the same, CNC hobbing machines allow higher feeds.

The second important factor influencing the cycle time is idle time. With NC control, the hobbing machine has shorter travels. The switching points are positioned more accurately and repeat more consistantly. Additional safety travels as used on manual machines are obsolete. All necessary travels are calculated by the control; thus, allowances are kept to a minimum. On top of this, the traverse rates of an NC machine are three to four times faster than those of a conventional machine, and several movements can be carried out simultaneously.

Additional savings can be made through the combination of several operations in one clamping of the workpiece. (Fig. 4) Two different gears on one component can be cut in one operation. The tools required may be hobs and/or milling cutters.

Loading and clamping the part only once represents a time saving and an increase in quality of the gears being machined. An additional effect can be obtained through the precise timing of one set of gear teeth to another.

An interesting example of this process is that of a planetary pinion used for controlling the flap actuation of aircraft. (Fig. 5) In this case, there are three gears

Fig. 4

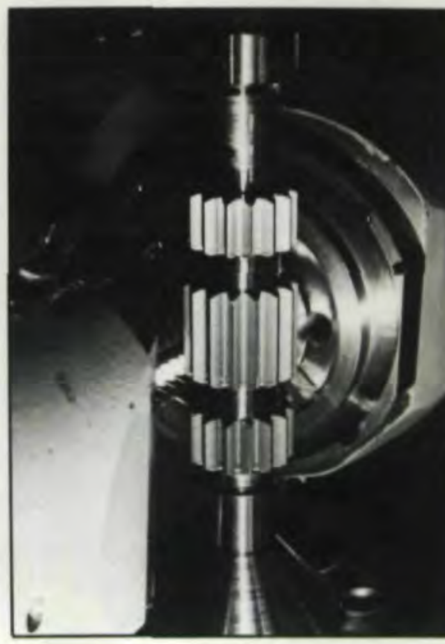


Fig. 5

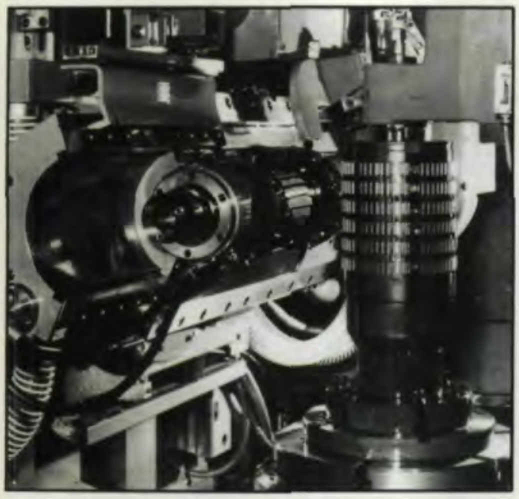


Fig. 6

on one pinion, each set of teeth timed to the others within close tolerances. In addition, these three gears have different crown and taper corrections in order to mesh correctly when under a load. The pinions are machined in one operation using one or two hobs, depending upon the design, and the time taken is less than four minutes.

A second application is a synchro gear for a truck reduction gear box.(Fig. 6) A gear is produced with a three-start hob, and, subsequently, nine slots are milled, these being positioned to the hob gear with unequal angles from slot to slot. These slots are machined with a milling cutter using indexible carbide inserts. In a similar application, a second milling cutter is removing particular teeth of the gear. With a stack of six gears, the total time taken for one gear is less than 1.5 minutes. Position of accuracy of teeth to slots is as close as 0.01 mm.

Another economical application for CNC hobbing machines is the skive hobbing of hardened gears. (Fig. 7) The closed-loop control for the work table rotation ensures high pitch and lead accuracy despite the remarkably high tangential forces in this process. NC technology enables fast automatic positioning of the pre-hobbed gear.

A worm with the same lead as the hob is mounted on the hob arbor. The worm can be moved axially against a spring in order to avoid collision between the worm and the gear.

By means of a separate NC subprogram, the gear first meshes with the worm. Through the use of synchronized shifting, the tangential slide is moved until the skive hob is in a position to cut. After clamping the gear, the machine

Fig. 7

center distance is compensated to allow for the necessary stock removal. This device is particularly suitable for small batches of gears with differing numbers of teeth, but with the same pitch. The advantages are that the worm has only to be adjusted once to the hob and can be applied to different gears. The whole process of positioning is automatically performed in no longer than 10 seconds.

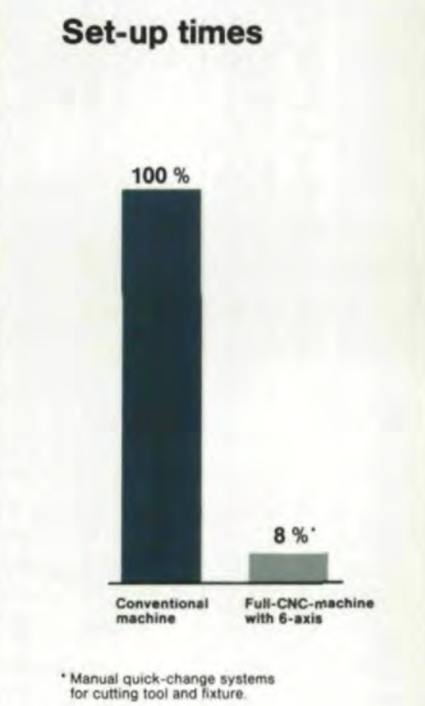


Fig. 8

Setup times (Fig. 8)

A conventional gear hobbing machine usually requires a time of 90 minutes for a full changeover including fixtures, tripdogs, hob swivel, etc.

With a three-axis NC machine this time can be reduced by approximately 20 minutes, as the setting of tripdogs and selecting the cycle and speeds and feeds are part of the NC program.

A drastic reduction is achieved when a quick change system is applied to both hob and fixture. (Fig. 9) The remaining axes of the machine are controlled by numerical control. For example, hob change can be reduced from 15 minutes to one minute, fixture change from 20 minutes (runout check and clamping) to less than five minutes.

Part of the set up can be carried out while the machine is working. This applies to the preparation of the next fix-

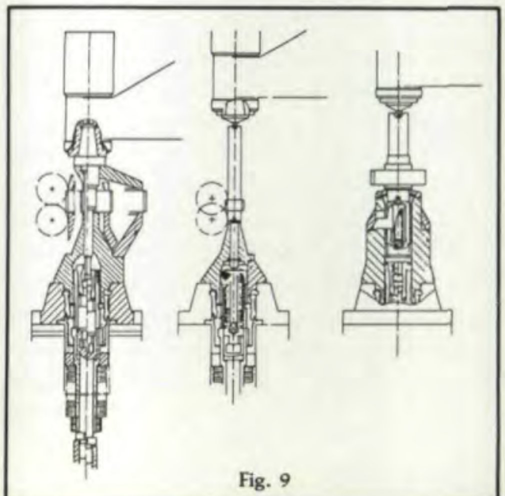


Fig. 9

ture, to the mounting of the next hob on a second arbor and to checking it for runout. (Fig. 10) Even machine offsets can be determined by measuring the hob prior to mounting it on the machine.

Gauging of the hob can be carried out either on an NC-tool setting machine or with a special measuring fixture which will check the hob effective diameter. With this fixture, runout and taper can also be checked. Checking the first part of a batch may become obsolete.

Further savings during set up time are achieved through the use of parallel programming; i.e., the machine can be programmed for the next part while it is in operation.

The question of whether or not fixture change and hob change should be automatic depends on the utilization of the machine. If the batches are small so that set up occurs at least once per shift, and the machine is being used over three shifts per day, an automatic change of both the fixture and hob can be justified economically. In other cases where batch sizes are larger, automatic hob change alone may be the economic solution. Manual change of the fixture takes a little longer, but as the changeover frequency is lower, this factor is really insignificant.

Uptime (Fig. 11)

Short cycle times and changeover

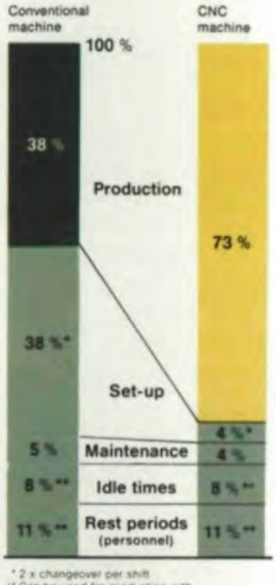
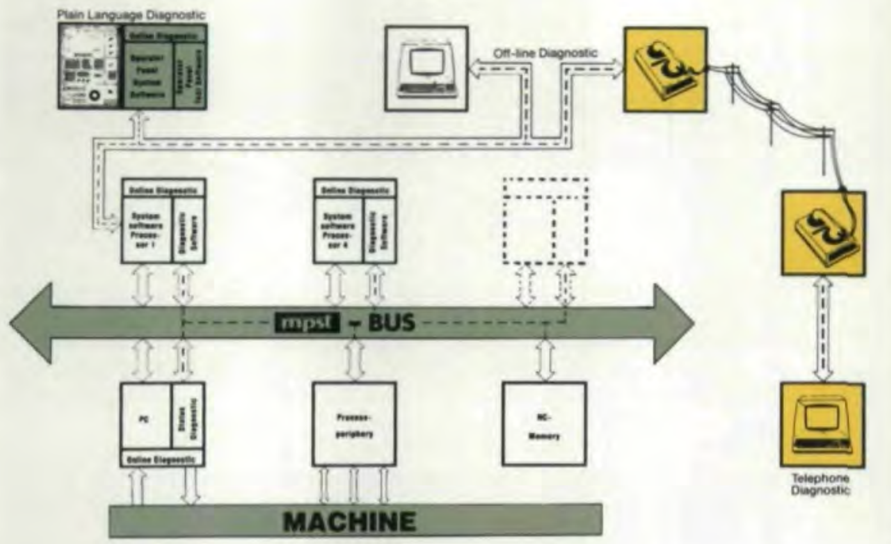


Fig. 11

Fig. 10

Fig. 12



times are only effective if the machine is available for production; i.e., downtimes are at a minimum.

Minimum downtimes are maintained through a highly reliable machine and control system and the use of an operator-friendly diagnostic system, which assists in the maintenance of the machine. A modern CNC hobbing machine is equipped with a sophisticated diagnostic system, (Fig. 12) allowing approximately 80% of all maintenance to be carried out in-house.

Through the use of a modem and a normal telephone system, remote diagnosis of faults by a machine tool manufacturer can be of great assistance in trouble shooting.

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 correction 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

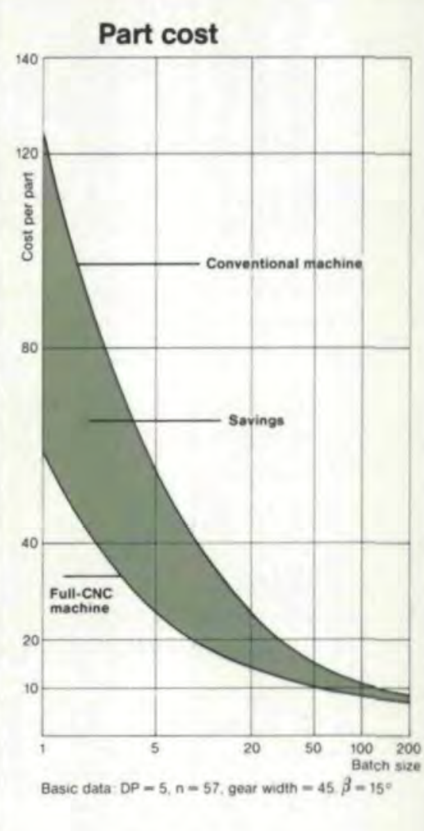


Fig. 13

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.

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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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