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D03555

Distr.
LIMITED

ID/WG.113/3
23 June 1972

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

Regional Seminar on Machine Tools
for Countries in Latin America

Buenos Aires, Argentina
16 to 25 October 1972

Sao Paulo, Brasil
26 to 27 October 1972

GUIDING POLICIES AND PLANS FOR THE DEVELOPMENT OF MACHINE TOOLS 1/

by

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id.72-4060

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche.

The development of machine tools is influenced by a wide variety of factors, mainly under the following three heads:

(1) The requirements of the users of machine tools and simultaneously their ability to make economic use of modern machine tools.

(2) The technical, financial and personnel capacities of the industry producing machine tools.

(3) The capacity of the supply industry for manufacturers and users of machine tools.

The demand for machine tools among users is decisively influenced by the following factors:

(a) The aims of the national economy,
(b) Technological development,
(c) The situation in the labour market.

One requires different machine tools to expand and operate an existing highly developed processing industry in a country and to equip a manufacturing industry that is only in process of establishment. While all these economic factors have to be considered separately for each country, technological development proceeds in a fairly uniform manner throughout the world. Its application in the individual countries is of course closely connected with the situation in the labour market. In countries with a large shortage of manpower, and thus of operating personnel for machine tools, a considerable degree of automation is necessary and economic in order to manufacture a product with as small as possible an expenditure of man-hours. In countries whose labour reserves are still sufficient, certain particular functions related to machine tools can be more advantageously carried out by hand. Under certain circumstances this makes it possible to give the unemployed work and an opportunity to earn money. However, this basic principle should not blind us to the fact that economic manufacture can no longer be carried on with the methods of yesterday. Modern cutting materials, for example carbide tipped tools and ceramics, operate at cutting speeds and advance speeds that are possible only with an automated working process. Human reactions are too slow to control such processes. In addition, manpower is becoming more and more valuable throughout the world, so that generally speaking there is only a difference in degree in the demand for automation.

Figure 1 shows by the example of the manufacture of disc brakes for cars that by the use of new cutting materials, for example, disposable carbide tips and ceramic tips, cutting speeds were increased by almost 90 per cent in the eight years between 1963 and 1971 and that it was possible to reduce machining time by almost 60 per cent. The use of modern cutting materials requires correspondingly powerful machine tools. We have already supplied automatic multi-spindle lathes equipped with 55 kW drive motors. Normal drives are of 30 to 40 kW. Such power requires adequately dimensioned gear trains with hardened and ground gear wheels and hard-wearing, well lubricated carriage guides, because considerably shorter cycle times and correspondingly more frequent carriage movements result from higher loads and higher carriage speeds.

However, high-quality machines operate economically only if idle time is short. One reason for idle time is changing over tools that have become blunt. In this area, the development of machine tools and the development of the technology of metal removal by the cutting tool must also correspond to the organization of change-over of tools in the factory. High cutting speeds and high advance speeds lead to relatively short tool life. By well organized change-over of tools, however, a high utilization factor is achieved with the machine. Figure 2 shows the tooling plan for machining a wheel hub in 17 seconds. Only disposable carbide tips are used. The tools are changed according to a tooling plan as shown in figure 3. After 200 work-pieces have been machined, certain tools are exchanged in the individual working positions. Additional devices, for example, tool change counters and signal lamps (figure 4) ensure that the correct tool is exchanged at the correct time, even with unskilled personnel.

Another cause of uneconomic idle time of machines is re-setting of tools and pre-setting. In this case, tool pre-setting devices are of assistance. While the machine tool is still working on the current series, the replacement tool with a sharp edge is set to the exact dimension by means of a pre-setting device (figure 5) and then placed in readiness on the machine. Normally, there are three sets of tools and toolholders (figure 6):

One working in the machine

One in readiness

One, with a sharp edge being pre-set.

So much for pre-setting. By computation of the economic factor, particularly in the use of numerical control machine tools, it has been noted that valuable machine hours can be saved by pre-setting the tools in order to prepare for change-over. Such pre-setting devices are universally applicable and equipped with various measurement systems according to the desired precision (figure 7). The most simple version works with two mechanical measurement systems similar to slide gauges which are set on z and x co-ordinates and form the reference point for the cutting edge of the tool.

The commonest type is a tool setting device in which a profile projector with twenty-times magnification sets the tools to the desired dimension in the z and x directions with help of precision measurement systems with 5 micron scales. Thereafter, the tool is so fitted in the change-over toolholder that its cutting edge is exactly underneath the hairline cross of the profile projector.

By such pre-setting of the tools on inexpensive appliances outside the machine tool, the re-setting time of the machine is reduced to 15 - 30 minutes. The economic advantage of such appliances is shown in figure 9. Here the vertical axis represents the total production costs per work-piece, while the horizontal axis represents the number of work-pieces per batch. Assuming that the total number of work-pieces is greater than 1,000, the production costs per piece depend only in the different expenditure in re-setting the machine. The curve a) shows the costs if the individual tools are re-set on the machine itself. The curve b1) beneath it shows re-setting using a pre-setting device. The curve b2) is even lower and shows the production costs using a pre-setting device to serve three machines.

It will be noted that when using such a pre-setting device for three automatic lathes, between 20 and 45 per cent reduction in manufacturing costs is achieved, according to the size of the batch.

A further development trend for the better utilization of high-quality, powerful automatic machine tools is automatic handling of the work-pieces. There are three reasons for such automatic feed systems:

(1) The work-pieces are too heavy to be lifted on to the machine and clamped in the machine manually.

(2) Though the parts are suitable for manual handling by reason of their weight, the cycle time of the machine (time of operation) is so short that work-pieces cannot be inserted and removed quickly enough by hand, and unproductive idle time must be avoided.

(3) Environmental influences, for example unacceptable nuisance to the operator by means of coolant, chips, etc.

The various possibilities of handling the work-piece in automatic lathes are shown in the following illustrations:

The first illustration (figure 10) shows a semi-automatic loading aid in which the operator pushes the 13 kg work-piece on to a loading arbor and swings this into position in front of the chuck of the automatic lathe. The work-piece is pushed into the chuck with hydraulic assistance and is also clamped by hydraulic means. The finished piece is then removed in the reverse order. With a machining time of approximately one minute such a device is very economic when there is sufficient manpower available.

The next illustration (figure 11) shows the fully automatic handling of relatively large work-pieces with two multi-spindle automatic lathes for the machining of automobile clutch housings. By means of lifting conveyor devices, the work-pieces are brought to the necessary height and then roll down to the machines on inclined planes by their own weight.

The next illustration (figure 12) shows the arrangement of two multi-spindle automatic lathes in the process of machining small gear-train parts. This installation in a Swedish works was completely automated because of the shortage of manpower. The work-pieces are tipped into a hopper unsorted. From this hopper they are automatically conveyed in the correct position to the feed channel of first machine. After automatic machining of the first side, the parts are automatically conveyed further on, turned through 180°, and finished on the second machine.

If the required production runs are not large enough for full utilisation of the capacity of a multi-spindle automatic lathe, single-spindle automatic lathes can be used. Figure 13 shows a PIFAT single-spindle lathe, again with automatic feed and removal appliances, for incorporation into an automatic production line. The machine is fitted with two cross-slides which are arranged for contour turning by means of hydraulic copying devices. The two contour followers can be seen on the left and on the right. The machine, in a Swedish automobile factory, is set for machining of seven different bevel gears. The bevel gears are machined on two settings. The total machining time is 1.5 minutes, including loading. The machine operates at a maximum cutting speed of 260 m/min at advance speeds of up to 0.4 mm/revolution and chip depth of 4 mm.

Naturally, it is possible to use such automatic work-piece handling devices with practically all machine tools.

1. <u>Summary (technological development)</u>

Modern cutting materials give such high cutting speeds and advance speeds that automatic control of the machine tool is necessary. The machine tool must be correspondingly powerful, free of chatter, i.e. vibration proof, and hard-wearing. Highly developed machine tools should have as little idle time as possible.

Therefore devices for rapid change of tools are necessary - both when tools are blunt and when re-setting in the machine tool - and the user must have appropriate appliances and organisation.

All these requirements and special characteristics of the users of the machine tools have a decisive influence on the development of machine tools by the machine tool industry. It is the task of machine tool manufacturers to develop the machine tools most suitable in view of the manufacturing problems raised by the customers. For that they need adequate capacity, qualified development engineers and manufacturing facilities for the economic production of the machine tools in the required quality.

Apart from these development trends dependent on the development of tools, an important problem lies in the fact that the manufacturers of machine tools cannot be guided in their development by the present wishes and requirements of their customers alone but must already take future requirements into account also. Such future requirements can be either of a quantitative or a qualitative nature. For example, if a steep increase in numbers of work-pieces is expected in certain sectors of industry, the main emphasis in development will be laid on highly automated and productive manufacturing equipment (quantitative future requirement). With regard to the quality of the machine tools to be developed, the manufacturer of machine tools must bear in mind the fact that quality requirements with regard to work-pieces machined by metal cutting methods are constantly rising (figure 14). In the case of grinding and turning, the permissible tolerance has become one ISO quality grade smaller every ten years.

In considering future development, particular attention should be devoted to signs of breaks in trend. One good example is the increasing change-over from machining bar stock to the machining of pre-formed work-pieces in automatic lathes.

The next illustrations (figures 15, 16 and 17) show the effect of one particular technological development on the development of lathes. Originally, the bolt was machined on a bar stock automatic lathe, using high speed steel tools in accordance with the sequence of operations in figure 15. Machining time was 40 seconds per work-piece. Figure 16 illustrates the machining of the same work-piece two years later on the same type of machine. Now, however, the basis is not bar stock but forgings. This pre-forming of the work-piece and the use of carbide tipped tools bring a considerable reduction in machining time. The work-piece is finish turned on both sides in a total of 27 seconds. The consequences for the manufacture of machine tools lie in the fact that the pre-formed work-pieces are automatically fed to the machine and introduced into the rotating collet. In addition, the work-piece is automatically removed from the rotating collet at position 3, automatically turned through 180° and again fed into the collet for machining of the second side (Figure 17). Further technological development with the customer led to a further pre-treatment of the work-piece. Now, the blanks are no longer forged but are fed into the machine as cold impact pressings. This further reduces the amount of machining necessary. Three spindle positions are adequate for machining, so that an eight-spindle automatic lathe can now be used for machining, on which two work-pieces are simultaneously machined. In this case also, the work-pieces are automatically fed to the machine. The machining time for one work-piece is 3.6 seconds.

In the machining of such blanks, which have been very accurately pre-formed, there are often only very slight chip depths left for turning, so that wire-like chips are formed. Owing to the surface hardening occurring in the cold impact pressing process, these chips are very tough. Tangles of such chips are formed, which hinder automatic machining. In the case illustrated in the figure, [illegible] by chips occurs in the boring operation in positions [illegible] and 6. By the combination of the toolholder with special axial bearings in these positions, additional axially oscillating motion is imparted to the boring tools, by which the long chips are broken up into short brittle fragments.

From these few examples it can already be seen that the manufacturer of machine tools must maintain close contact with the users of machine tools on the one hand and with the research bodies on the other hand. In particular contacts with research bodies will become more and more important in the future. The rapidity of development makes world-wide observation necessary. Such comprehensive information can be provided only by means of co-operation, either through technical associations - in Germany through the Association of German Machine Tool Manufacturers in co-operation with the professors of the technical colleges - or by co-operation between several firms. Co-operation with scientific research institutes also promotes contact with the engineers trained there, whose work in the machine tool factories ensures that the findings of science are translated into practice.

2. Summary (future developments)

The great progress in foundry technology and forming technique have made superfluous a number of processes that were previously carried out by means of metal cutting machining. On the other hand, requirements regarding the finish machining of such pre-formed work-pieces on metal cutting machine tools have increased sharply. New types of materials require new machining processes and correspondingly new machine tools, for example milling machines for machining large work-pieces of solid titanium blanks in aeronautical and space travel technology, the spark machining and electro-chemical processing of highly wear-resistant materials in the construction of internal combustion engines, the chemical industry and the construction of dies, as a consequence of the increasing degree of forming and/or pre-forming.

Great attention must also be devoted to the continual process of substitution of plastics for metals, in order to recognize in time emerging requirements with regard to suitable machine tools (figure 18).

Very far-reaching changes in machine tools have been caused by the developments of control techniques in recent years. Modern construction elements that have proved their value in other applications, for example aeronautical and space travel technology, radio and computer technology, are now available for the control of machine tools, so that automation problems, and measurement and control assignments with regard to machine tools which were considered insoluble as recently as ten years ago can be carried out reliably and economically. In this case, the research institutes are very useful liaison elements between the manufacturers of machine tools and the supply industry, in that they investigate the applicability to machine tool construction of such new techniques from other branches of industry, which leads to appropriate adaptation in the accessories industry.

Without an efficient accessories industry, modern machine tools cannot be constructed.

Modern machine tool drives operate either with very powerful quick-change clutch transmissions - electro-magnetic disc clutches have given excellent service - or, where greater power is required, with regulated direct-current motors, which have recently become increasingly popular.

In view of the many and various problems arising with regard to bearings, a large number of different types of roller bearings are required, such as are offered by efficient special manufacturers for all applications.

Materials of impeccable quality, both cast iron, which is still the most frequently used material for machine tools, and also steel, for example for guideways, gearwheels or parts subject to very high wear, must always be supplied to the machine tool manufacturer in uniform quality.

The electronic elements mentioned already must be appropriate as regards reliability, robustness and also price, in view of the special conditions of machine tool construction.

Modern measurement systems are needed by machine tool manufacturers both for incorporation into numerically controlled machines and also for inspection of their own products.

3. Summary (accessories industry)

The development of modern machine tools must therefore also be co-ordinated with the capacity of the accessories industry. Here also, it should be examined in each particular case whether every national economy must have the full range of such accessories plants in its own country, or whether more economic solutions are possible by menas of co-operation across national frontiers.

<u>Conclusions</u>

Modern machine tools are a synthesis between the realistic requirements of the production experts in the workshops of users of machine tools and the forward-looking thinking of research bodies, using all possibilities of development in other sectors of industry.

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