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PROBLEMS OF ADOPTING NUMERICALLY CONTROLLED MACHINE TOOLS IN ENTERPRISES

ADVANTAGES OF INVESTIGATING THE POSSIBILITY 1/

by

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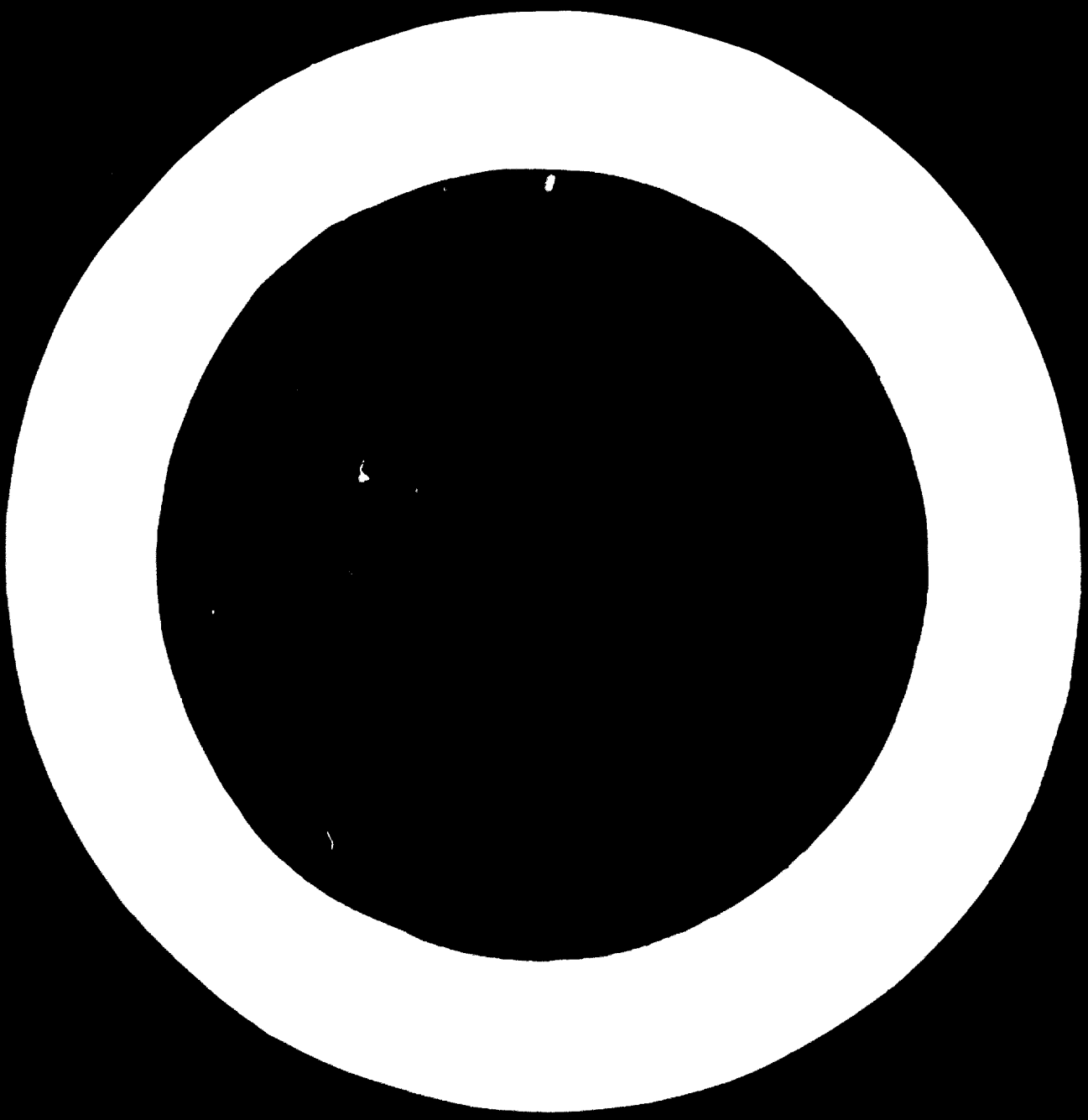

We consider that it is very important for the future of Argentine industry and for the country's economic development that a general and combined effort should be made to deal more consistently and thoroughly with the question of production techniques.

All sectors concerned should take part in this work, including industrialists, universities, state bodies, laboratories and research centres concerned with the subject. The aim would be to make our industry more efficient, to investigate the possibility of adapting new techniques of design and production and to develop original techniques.

The application of numerical control to machine tools is one of the major themes in the field of production techniques today, and one which Argentine industry needs to analyse, discuss and understand. It needs to do so not just at the technical level, as an advance in the field of automation, but at all levels of the enterprise, as a new idea, a new philosophy of production, the benefits of which are undeniable.

The following paper does not seek to explain what a numerically controlled machine tool is or how it operates, but to indicate briefly what is needed, apart from buying machinery, if the numerical control system is to be successful and what advantages may be derived both from adopting the system and also from simply considering the possibility of doing so.

Introduction

Numerically controlled machine tools are merely the result of combining the machine-tool machinery with automatic data processing, through the interface of the drive and control systems.

In the first industrial revolution, the aim was to reduce the physical effort required to carry out manufacturing processes and the progress made along those lines was enormous. The appearance a few years ago of computers, with their ability to store and process information, to take the place of human memory and to help human beings exercise their logical powers introduced a new element in the production process. In

addition, the improved development and greater reliability of electrical, hydraulic and pneumatic drive and control systems made it possible to combine the two. In this situation it was inevitable that the link should be made and that the process of integration should start.

Thus began what some people have called the second industrial revolution.

What does this extraordinary combination of production processes lead to? It leads to systems and machine tools which follow new trends in automation and which have a great impact on the design and manufacture of parts. A notable example is numerically controlled machine tools.

Numerically controlled machine tools

What is a numerically controlled machine tool? To take a simple definition, a machine is said to be numerically controlled when it operates automatically or semi-automatically in accordance with instructions given it in code, in the form of figures, letters or signs of various kinds [4].

It is not our intention to deal with the actual production of the machines and control systems, but to discuss numerical control as an idea, as a production philosophy. For our present purposes, therefore, we shall simply speak of the numerically controlled machine tool as a single system.

We refer the reader to the diagram in figure 1. All the information necessary to carry out the required operations is contained in a carrier, which is independent of the numerically controlled machine tool. It is generally a punched tape but can also be a magnetic tape.

This information carrier will be duly read and then de-coded by the numerical control director. Its interpretation will be translated into appropriate orders to the tool drive machinery. This is the direct or control chain. The main functions correspond to the tool movements. The information carrier will indicate the position to be reached by the moving part of the machine or the path to be followed. In the case of closed-loop numerical control, the movements will be effected on the basis of a comparison between the instruction given and the position of the moving part of the machinery. This parallel chain which also performs a control function is known as a feedback chain.

The problems of numerical control and the logical path leading to its adoption

Numerical control introduces into the productive system highly automated equipment with exceptional flexibility.

All the preparation work is done outside the machine itself, and changing over to new movements and operating conditions is merely a matter of changing the information carrier, i.e. the punched or magnetic tape.

The investment necessary to obtain a machine tool with these possibilities is very high (at least twice as much as the cost of a conventional machine with the same capacity), and particularly in our country is one of the factors most responsible for delaying the introduction of such machinery. However, the most important factor at the present time may be a failure to realize the advantages that such an advanced means of automation can have for production systems.

Inquiries made in various countries indicate that the problems of potential users of numerically controlled machines tools can be summarized as follows:

- Lack of information and advice;
- Lack of qualified personnel;
- Lack of know-how;
- Inadequate organization and planning;
- High level of investment and financial risk;
- Lack of confidence in numerical control technology in general.

Most Argentine industrial enterprises may very well have adopted numerical control within ten years, but for many of them it may be an immediate necessity if they are not to lose their capacity to compete and develop.

How are they to determine what is the right time and the right kind of investment? Only by studying, investigating and discussing numerical control at a high level and preparing the logical way for its successful introduction and utilization.

Today's numerically controlled machine tools are reliable. If they are to be profitable, the enterprise must possess or acquire the necessary knowledge and skills to ensure their efficient operation.

The responsibility and authority for ensuring correct use of numerical control should be exercised by one of the enterprise's managers, and not at a junior level. He should be the Numerical Control Co-ordinator and work in collaboration with all departments, because numerical control is a technique which concerns everyone in the factory.

The numerically controlled machine tool should not be regarded as just another piece of factory machinery. If it is so regarded, it will not prove profitable. The introduction of such machinery should be regarded as the adoption of a new system of production, requiring:

(a) Understanding at all levels of the enterprise;

(b) Identification of all units concerned;

(c) Appropriate training of the units and making of the necessary adjustments.

A study of the possibility of introducing numerical control is very instructive, because the adoption of this system entails a high degree of rationalization in various areas of the company's activities. Such rationalization is far from being normal in the manufacture of parts in small quantities. This is a task which in many cases can be undertaken immediately, yielding great advantages and preparing the way for the adoption of numerical control itself.

The manufacturing unit which starts working with numerical control makes itself an ideal organization for developing new ideas and evaluating equipment, controls and programmes, which can then be brought into general use throughout the enterprise as a whole.

Economic aspects

The most appropriate area for numerical control is small-series production. From 5 to 200 pieces, in repeated batches, is the most generally accepted quantity. The graph in figure 2 shows the economic range. No attempt is made to give figures, because much depends on the complexity and dimensions of the piece and the type of machine. New programmings simpler to process would in some cases lower the bottom limit.

We have already said that numerically controlled machine tools require a much higher investment than a set of traditional machine tools with the same output capacity.

When the very first machine is bought, the investment cost is generally increased by the need to acquire related equipment such as a tape puncher, tool pre-setter, control apparatus for maintenance, etc.

This higher cost makes it necessary to use numerically controlled machine tools more intensively, and generally speaking most enterprises which use them regard two full working shifts as a minimum.

The surveys made show a general trend towards more intensive use of all numerically controlled machines, in order to ensure a higher return. The machines may thus be worked for 24 hours a day, with 3 shifts, for more than 5 days a week. This increases the responsibility of the maintenance services, but stoppages and other troubles are proportionately less with continuous working. The experience of users in this respect should be borne very much in mind and if the machine tool cannot be kept adequately supplied with work by the enterprise itself, it should seek outside orders for processing by numerical control.

But in considering the economic aspects of adopting numerical control, it is not just the saving of manpower that should be taken into account, but also the lower expenditure on tools and appliances, the better quality and greater regularity of the parts, the shortening of delivery periods, the greater freedom in the design of parts, reduced need for quality control, the ease of adaptation, and consequently the facility with which changes can be made in design, less handling of the parts, etc. Thus the same criteria cannot be applied to numerically controlled machine tools as to conventional machine tools, because the possible economies affect a wider range of the company's activities. Furthermore, the economies are not immediate, but become evident in the long run.

Technical and organizational aspects

Apart from the unquestionable indirect advantages already mentioned, which are reflected in the economy of the enterprise as a whole, numerical control of machine tools also yields direct advantages with regard to machining times and the overall use of the machine.

Information from many enterprises producing in small batches indicates that with conventional machine tools the ratio between actual machining time and machine operation time is between about 15 and 30 per cent, whereas with numerical control, under good conditions, a ratio of 80 per cent can perfectly well be achieved.

This potentially high utilization rate, when production is not in series, is no doubt due to the high degree of automation, which makes the system extraordinarily flexible. There are two basic reasons for this situation:

1. All the work of preparing and programming the machine's activity (movement, operations, speeds, etc.) is done outside the machine itself;
2. Very little work is involved in adjusting the machine to the work in hand since it is more or less only a matter of changing the information carrier.

This latent production capacity can be used to the extent that the necessary arrangements are made to exploit it. To this end the operation will have to be properly prepared, aiming not just at optimization of the machining process, but also at rapid changeover from one part to another and from one operation to another.

The prerequisites are a reduction in operating time through better utilization of the machine tool-piece system and a drastic reduction in idle time, by means of a thorough reorganization of change-overs and the positioning of tools and pieces.

The preparation unit (methods) and the execution unit (workshop) will be most directly affected by the problem of numerical control and will have to adjust to the new ideas.

Figure 3 shows the close link between preparation and execution. A study of the figure can suggest many useful ideas.

But first let us recall what generally happens in both units when working in small series with traditional equipment. The instructions of the preparation unit are carried out by the operator, who participates directly in the manufacturing process, controlling the machines. This means that in dealing with small quantities of pieces, the specification of operations and conditions is done in a highly simplified and even rudimentary way. Many details, and sometimes modifications, are left to be dealt with by the operator, who therefore has to be highly skilled and intervenes in the course of the process, correcting any additional errors that may arise on the spot. In numerical control, the operator no longer executes the work, nor does he

directly control the machine, but works alongside it. His role is no longer an active one, as previously, but one of control. He checks that the operations are proceeding normally, exercises the required quality control over the piece and changes the pieces.

The numerically controlled machine tool cannot do anything which is not written into the information carrier or tape. Thus it is essential that at the preparation stage all details should be taken into account and all errors eliminated.

The preparation of detailed work begins already in the design offices, where the plans for the pieces to be produced under numerical control have to be duly dimensioned to fit into the new system. The influence of numerical control on design goes much further than this modification of dimensions, since it can give it a much greater freedom in the design of complex shapes. This is particularly important in the air and space industry.

The methods unit has to be properly equipped to meet the requirements of numerical control satisfactorily. The specification of operations, tools and operating conditions has to be made with all due precision. But this must not be done in a conservative way; the aim must be to establish the best sequence of operations and the most appropriate operating conditions. The large investment required for numerical control makes this essential. The aim is to optimize the machine tool-piece system.

This objective is not easy to achieve. Firstly, it means having personnel who have been properly trained in machining processes and theory and, secondly, it means organizing and having available adequate information on the possibilities of each element in the system.

The tool problem is one of the key elements in the intensive use of the machine. Generally speaking, numerically controlled machine tools tend to use normal tools, but it is essential that tools should be standardized within the enterprise and catalogued for use by the planner.

The possibility of reducing idle time also depends on the tool factor.

The great majority of numerically controlled machine tools, and particularly universal machines or machining assemblys, have the advantage that various operations can be carried out on the workpiece without dismounting it. This entails frequent changes of tools, which can be carried out manually or automatically. In either case,

the only possible solution is to use quick-change appliances, provided for by the designer of the machines, and to pre-set the tool outside the machine, which eliminates the problem of hold-ups for adjustment purposes.

It is therefore essential to have a team of workers capable of performing these tasks. That means that there must be a complete reorganization of the tool situation within the enterprise, covering the purchase, acceptance and maintenance of the tools.

The person preparing the machine for operation has to be sure that the quality, form, dimensions and grinding correspond exactly to the specifications given him.

This aspect must be considered by any industrialist, whether or not he is going to acquire numerical control. The next stage in the process is to make the specifications that have been worked out comprehensible to the user, that is, to draw up the programme in machine language, so that it can then be transferred to the information carrier, the punched tape.

The control instructions have to be given in a code language which the machine understands. The machne has a vocabulary and syntax of its own and the tapes have to be punched or printed in accordance with this machine language.

This task of translation is generally carried out by a specialist known as a programmer. Within a few years, a knowledge of computers will be sufficiently widespread to be part of a preparer's professional knowledge and he will then draw up his instructions directly.

Against this must be set the proliferation of programming languages lacking in uniformity or compatibility.

As far as tape punching is concerned, there is a higher degree of uniformity and there are virtually only two codes in use, EIA and ISO.

Programming can be manual or automatic. Which method is chosen will depend on the complexity of the pieces to be machined and the availability of a suitably equipped computer. Generally speaking, the use of automatic programming is tending to spread, thanks to the development of new languages suitable for simple tasks, and also - particularly in our country - to the greater amount of computer time available.

The number of programmer hours per day and per numerically controlled machine naturally varies greatly, depending on the work, and according to the literature may vary from one to twelve programmer hours per day and per machine the average being three hours. The amount of information that has to be processed in order to optimize the machining results and to programme in accordance with the piece specifications has had the result that the whole procedure of preparation and programming, up to the production of the tape, is carried out by computer. In this way it is possible to obtain punched tapes which are free from error within the minimum amount of time, which is one of the key factors in the intensive use of the machines.

It must be said once again that with a numerically controlled machine the preparatory work has to be very detailed and much more like large-series work. The punched tape has to be checked before it is finally put into use. Sometimes this is done by simulating the movements, in other cases a trial run is made with a rejected blank.

Execution

Although the work is carried out automatically, the operator must recieve plans and instructions well in advance so that he can mount the piece correctly, inspect it and intervene in the event of an error or other contingency. The first piece is usually inspected in the course of operation if the process permits this or by means of inspection machinery with digital reading when the parts are complex. The excellent repeatability of numerically controlled operations means that in general inspections can be dispensed with after the first piece.

The processes of handling and mounting the piece on the machine also have to be carefully studied and kept as far as possible to a minimum. Generally speaking, mountings are done away with, and simple fixing and reference devices are all that is used.

Maintenance

Numerical control has passed beyond the stage of scientific experiment and entered the field of industrial practice. The performance of the components - mechanical, electrical, electronic, etc. - is excellent and the problems are in general becoming less. However, the problem of maintaining and repairing the machines, particularly as regards the control system, and also the electro-mechanical, hydraulic and other parts which constitute the interface between the machine and the control system, is the main technical problem mentioned by numerical control users.

It is therefore recommended that the purchaser should be able to rely on a maintenance service which will put right any trouble that cannot be dealt with by a normal non-specialized unit.

Promotion of numerical control

In all countries where numerical control has achieved a high level of development there have been certain external factors that have encouraged it. The main such factor is action by the authorities to promote numerical control. The aim is to reduce the obstacles to its adoption. These obstacles are generally to do with lack of information, the large amount of investment involved, the changes inevitably required in the organization of the workshop, the need for staff training, etc.

In our country, as in others, numerical control needs to be more widely promoted. Perhaps most of the enterprises that consider it do not need it now, but a knowledge of it will surely lead to technical and organizational measures which will be of benefit to the company and will prepare the way for the future introduction of numerical control.

It is worth noting the fact that the European Economic Community has recognized the importance of developing numerical control. It has accordingly drawn up a promotion programme. The programme is designed to spread information directly or indirectly relevant to numerical control.

The education and training of qualified staff are also encouraged, as are efforts to reduce the difficulties encountered in introducing and applying numerical control in industry. At the same time, a programme of research into numerical control and its technology has been set up.

The introduction of numerically controlled machine tools is the start of a process which directly or indirectly leads to an increase in the enterprise's productivity. It also encourages the use of computers in planning, programming, launching production, optimizing results, etc.

These are the preliminary stages leading up to integrated production systems such as have been shown at the most recent machine-tool exhibitions, which the industrially advanced countries are already beginning to introduce.

This is a path on which we must set out, and we must help each other so that we can all follow it.

Conclusion

This Seminar offers an excellent opportunity for starting up a plan of co-operation in order to promote the study, dissemination and adoption of better techniques of production and the development of the corresponding equipment.

All sectors concerned should set themselves the basic long-term goal of making our industry more competitive, by taking the appropriate action. It should not be forgotten that technological progress, as a productivity factor, is only effective if the right kind of knowledge is adopted and put into practice.

The most effective means of achieving this end would seem to be co-operation between the producers and users of machine-tools, research and educational institutions and private and public organizations.

In conclusion, I should like to say that both the Department of Materials and Technology of the National University of Cordoba and the Materials Research Centre of the INTI System, to which I have the honour to belong, are interested in co-operating on these matters and making as much of a contribution as their means and resources permit.

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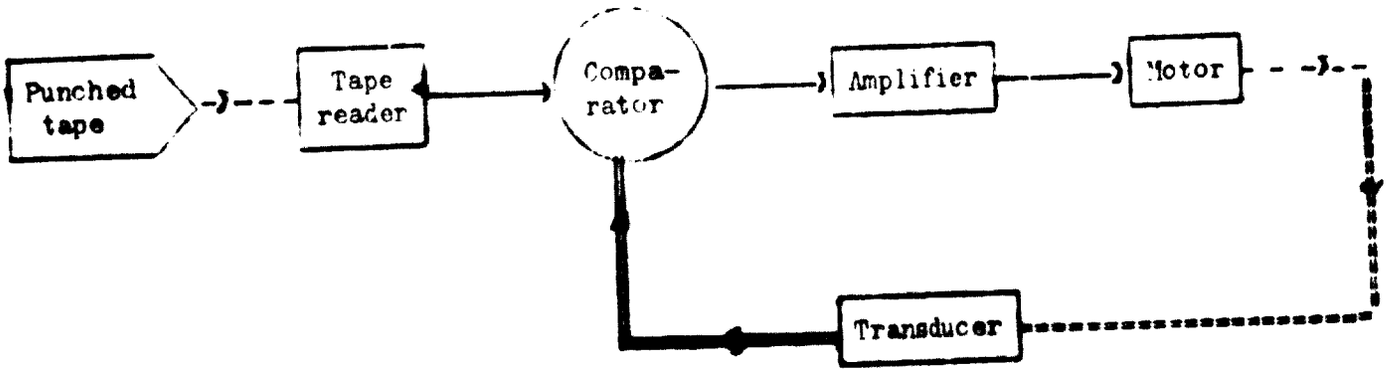


Electrical coupling

Mechanical coupling

Fig.1 Scheme for a closed-loop numerical control system

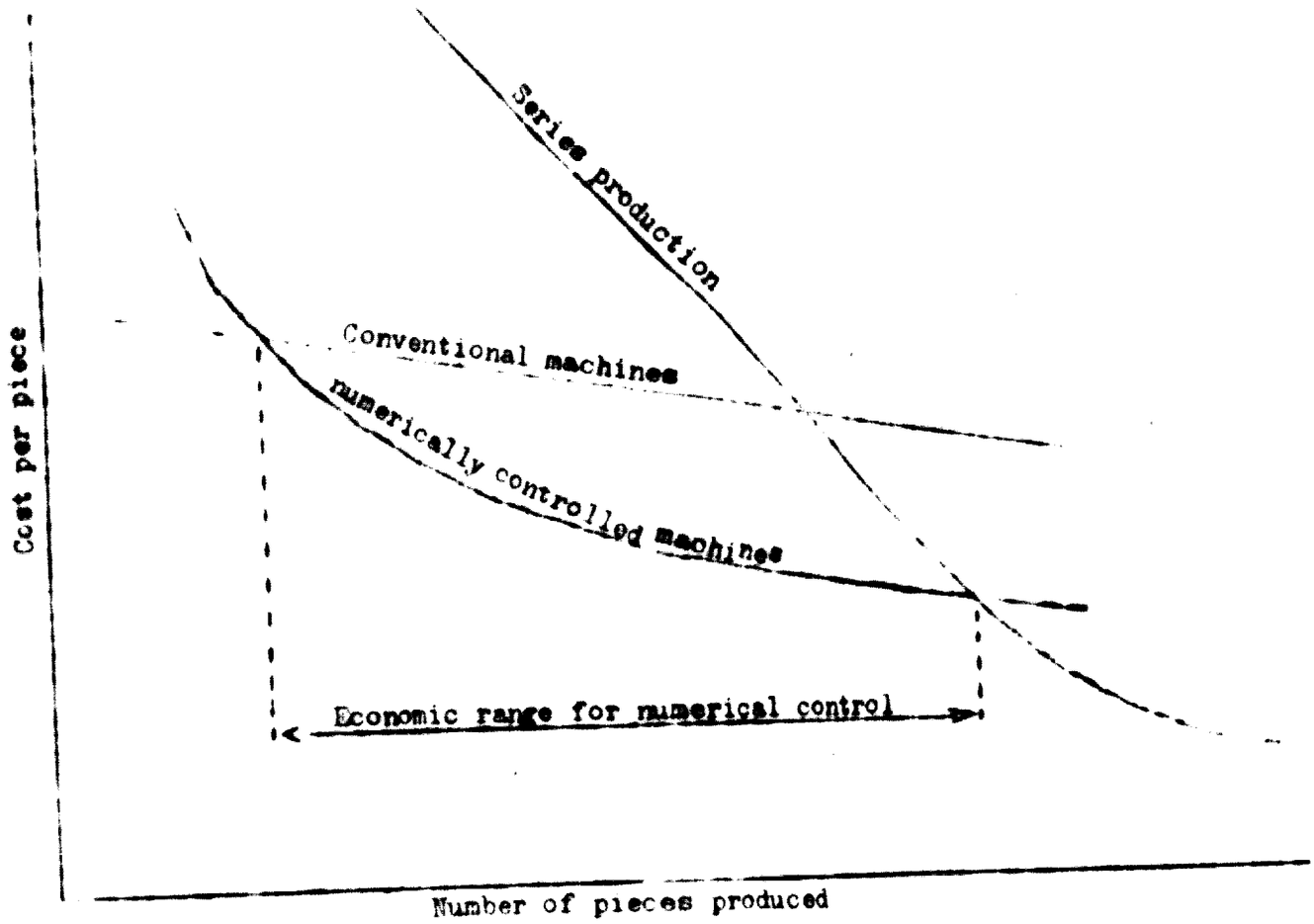


Fig.2 Economic range of application of numerically controlled machine tools

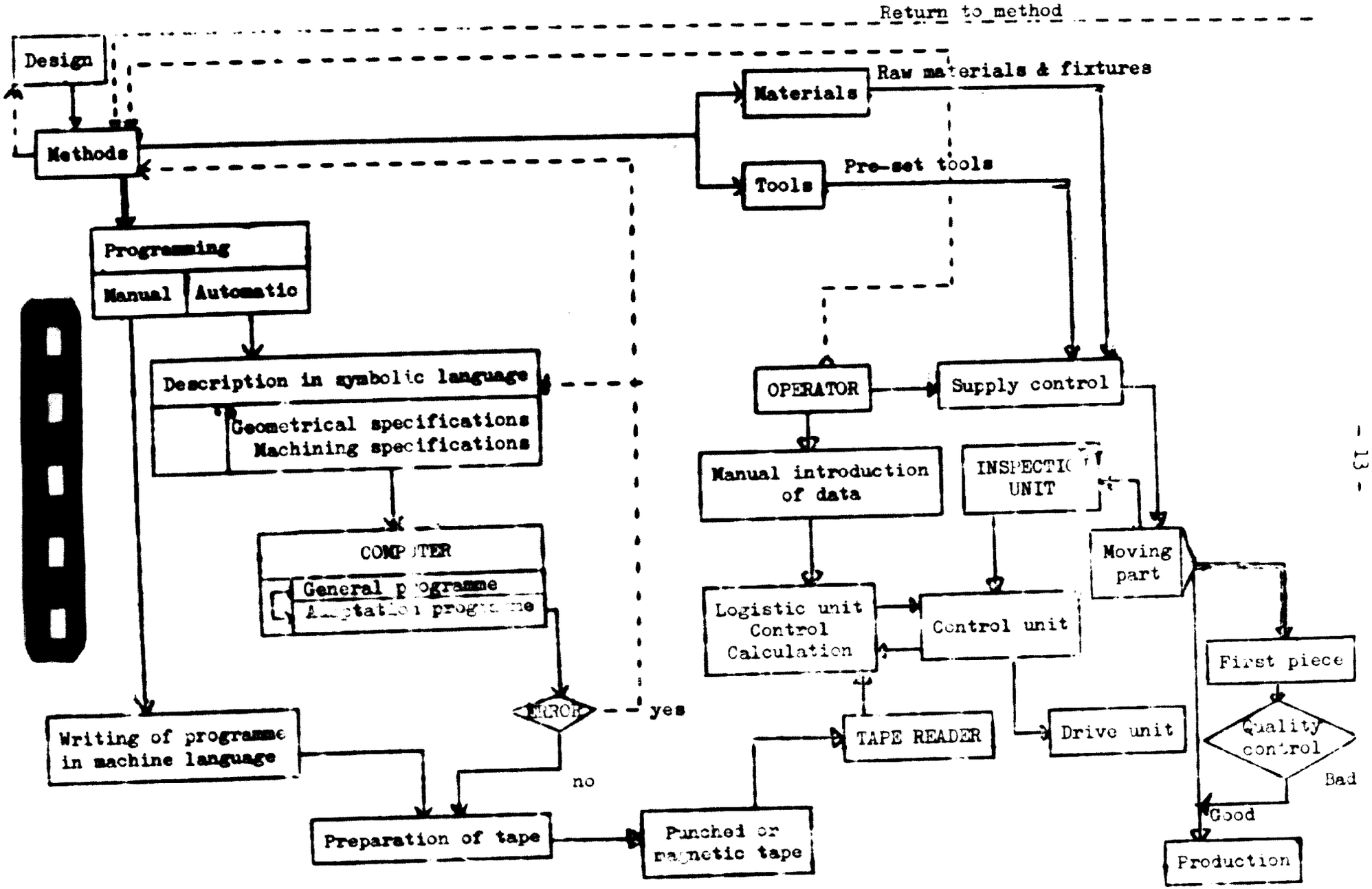
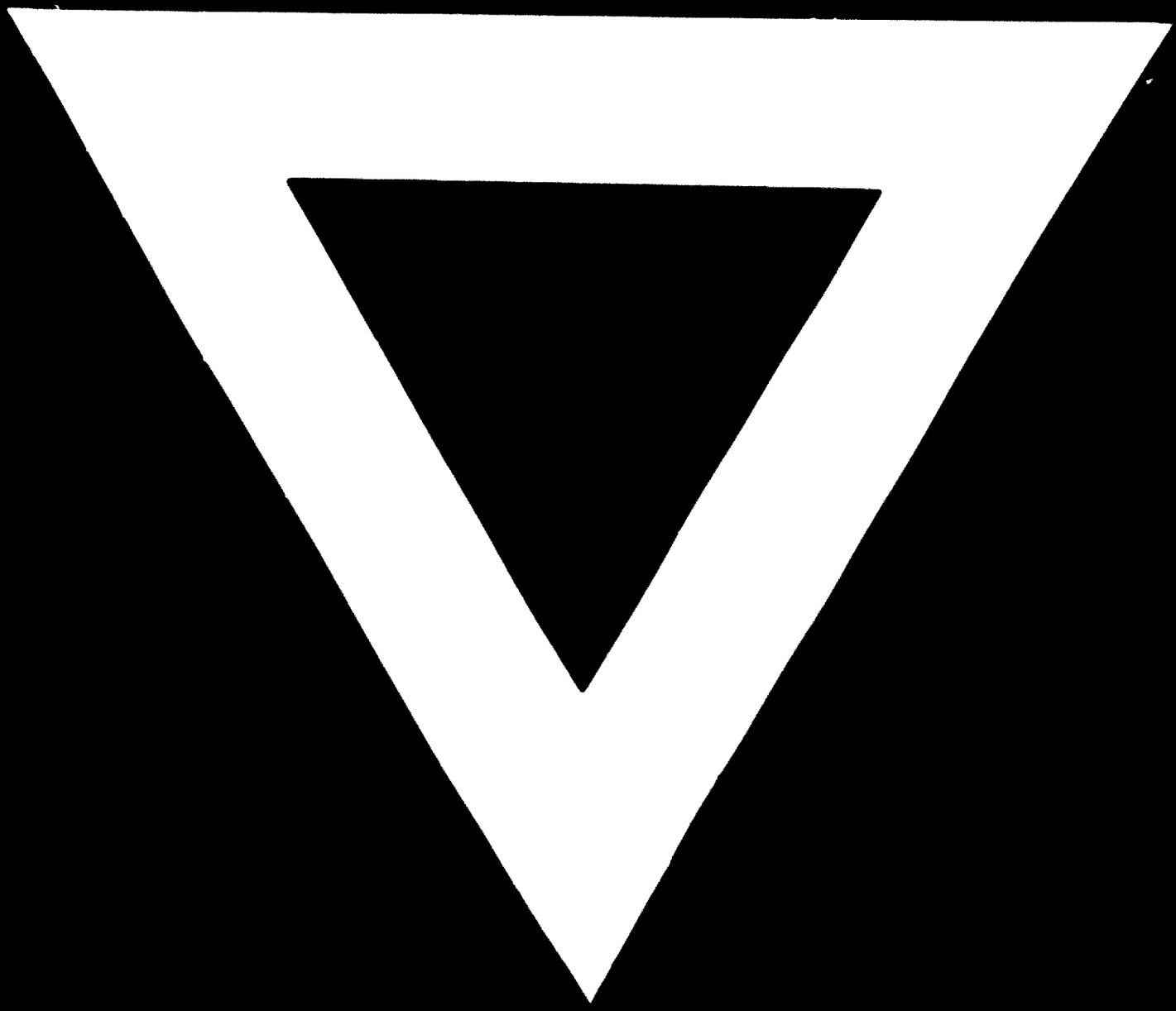


Fig.3 Interrelation between the preparation and execution phases in working with numerically controlled machine tools [1]



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