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Rationalisation in the injection moulding shop

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Preface

This book is addressed to all those concerned with injection moulding technology and its application.

Special importance must be attached to the subject of "Rationalisation in the injection moulding shop" in these times of rising prices and rising unemployment. Any attempt at rationalisation in a moulding shop must be carried out systematically if it is to be successful. This presupposes a works-related cost analysis. Accordingly, the underlying tasks of rationalisation and the importance attached to them will vary from one factory to the next. The various chapters in this book deal with different points relating to rationalisation and the ways in which this can be achieved, which are of interest to all injection moulders.

The use of microprocessors in injection moulding is a much discussed subject. The possibilities which will be realised in the foreseeable future are discussed. Programmable computers have achieved growing importance for design as well as production, also for small and medium-size concerns. The use of computers in deciding on the most important design features is an important contribution towards rationalising design operations. The mathematical determination and representation of processes provides the processor with new knowledge and therefore with a method of matching design against processing parameters at the preparatory stage, instead of "practical experience".

Injection moulding is a process which takes a particularly heavy toll of the machine. One rationalisation reserve of interest to many concerns is the improvement of machine utilisation. Reducing the set-up time is of special importance for firms making a wide range of different products, with varying productions runs.

The subject "Use of handling equipment" is of special topical interest in view of the exceptional development of handling technology. The advantages with regard to fully automatic operation, machine utilisation and quality are obvious. Beyond this, the moulder is interested in the flexibility of the equipment as well as the removal of moulded parts generally.

Reduction of raw material costs is an interesting and constantly recurring theme. For the injection moulder, the need to reduce costs has once more become important because of raw material price increases. Sprueless injection moulding, a method of saving raw material that is of immediate interest, and used so far with varying degrees of success, is treated in two chapters.

Finally, another cost factor has become important in relation to rationalisation, due to the developments that have taken place in the cost of energy. The injection moulding process is a heat process and it is absolutely essential for the processor to examine different possibilities of reducing energy consumption and of energy recovery, and to put these into practice. This important subject is discussed in three chapters.

Baden-Baden, March 1981

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The use of microprocessors in injection moulding

Jürgen Conrad

Only five years have passed since injection moulding machine manufacturers changed over to electronic control systems from the contactor control systems used hitherto. The electronic components of these controls, initially consisting of transistors and resistances but soon including higher integrated circuits, replaced the switch and logic functions of a large control cabinet with many relays and took up no more space than a suitcase.

There is a continual and absolutely essential need to rationalise production, the aim being to have a fully automatic injection moulding machine operating on a three-shift basis. Additional possibilities of rationalising are opened up by the logical use of modern data processing components. Of these, microprocessors form an essential part.

The interest shown by machine manufacturers in this modern technology was evident at the K'79 in Düsseldorf. Microprocessor systems were one show in which processing data input is possible via a display screen, lines of print as well as complex control panels. Microcomputer technology provides help for machine setting. To reduce downtimes

a) it offers the possibility, when changing moulds, of feeding in the new processing data via a data carrier and

b) in case of breakdown, faults can be located quickly via a fault locating program.

Microprocessor control

The development of microprocessors goes back to 1969, when the American firm Intel found that it was possible to accomodate the entire logic of a small computer on a single silicon chip. The basic idea behind this development was to develop a universal logic element to replace the many specifically developed logic circuits which involved costly research work for each circuit. Such a universal logic element can be given a program produced by the user. This marked the birth of the system Intel 8008, which proved to be the pioneer for a whole range of microprocessors. Other manufacturers subsequently also introduced microprocessor technology.

The necessary peripheral units were then developed around the central processing unit (CPU), the microprocessor forming the central part of the minicomputer and ever increasing capacities achieved through greater integration. Today, many highly developed microcomputer systems are on the market and finding and ever widening range of uses.

Structure and construction of a microcomputer

Hardware

Fig. 1 [1] shows a block diagram illustrating the structure of a microcomputer. The microcomputer is a system consisting of a microprocessor (the so-called central processing unit or CPU), a number of necessary memories to accomodate programs and data, as well as a number of input and output modules. The microprocessor in this system fulfills the task of the central unit of a conventional digital computer. It contains the control and computing units. The task of the control unit is to process the program instructions, i. e. it controls the exchange of data between periphery (inpit/output) and memories. In the computing unit, these data are linked through the arithmetic and logic functions prescribed by the program.

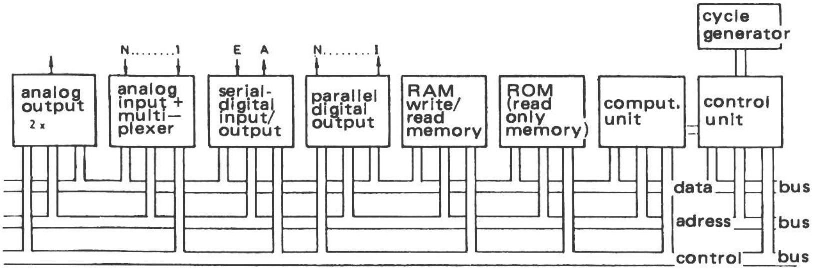

Fig. 1. Structure of a microcomputer system.

Memory

The memory is made up of the program memory and the data memory. The program memory is made up of so-called EPROMS whose content is fixed and is not lost if the power supply is switched off. The data memory must be a read-write memory, i. e. new setpoint inputs or messages from the machine must be capable of overwriting it. In this memory are always found the data originating from the process at that particular moment. It is made up of so-called RAM's which normally lose their contents when the power is switched off. In order not to have to load in the processing program every time the current is switched off, these RAM memories are provided with a buffer battery so that the memory contents remain intact even if the current remains switched off for several weeks.

Input and output modules

These modules form the interface for the data exchange of the central processor with instruments connected outside, e. g. limit switches and solenoid valve drivers. Special conversion assemblies are necessary for the input and output of analog signals such as actual temperatures or the control voltage for the proportional valves. The computer is a digital system, which is why figures not available in digital form first have to be converted.

Bus-bars

These are collector bars on which all memory contents (data), memory addresses as well as control signals between all the modules of a microcomputer communicate.

Additional logic, adaptor modules

These are standard modules for application-related special functions, especially for the data exchange with master computers, terminals, printing units and programming instruments.

Peripheral instruments

In injection moulding machines these are, on the input side, limit switches, selector switches, electronic sensors etc., and on the output side solenoid valves, displays or relays.

Software

To be able to control an electrohydraulic plant such as an injection moulding machine, various input and output signals, counter readings, expired periods and measured strokes must be linked with one another according to a certain pattern. This "sequence program" in a conventional injection moulding machine control system consists of a wiring scheme, in which the different signals are linked with each other via separate wires through logic elements (or formerly via relays). In a microcomputer control system, this wired-up programme is replaced by what we call the software, i. e. by instructions which tell the microprocessor how it must link signals coming from the machine or the control panel with other processing data which have been deposited in electronic memory modules, and what functions must be produced as a result, e. g. activation of solenoid valves to initiate a new movement.

The software is divided into:

- operation software which makes it possible for the microcomputer to function. This is independent of the problem in hand, and the user does not have access to it.
- application software, which is influenced by the controls manufacturer or also by the user. This is problem-related and with it, for example, one produces the machine sequence program.

The microcomputer is not only capable of replacing conventional logic elements. Since it can carry out arithmetic functions – i. e. since it can calculate – it is also in a position to carry out more complex tasks.

Hitherto, special heater controls were used for heating the cylinder and mould of an injection moulding machine. The microprocessor system takes over these complex tasks just like the entire timing and stroke system. The monitoring of limiting values and instructing the operator in feeding in processing data for the injection moulding machine are likewise very easy and can be realised with the application software since ready-made "software modules" are available for such functions in modern microcomputer systems.

What data have to be processed in the case of an injection moulding machine?

Temperatures Pressures Speeds Strokes	analog inputs/outputs	approx. 36
Limit switches Command switches Sensors	digital inputs	approx. 85
Indicator lamps Digital displays Display screens Relays Solenoid valves	digital outputs	approx. 85

The user is interested especially in the applications of this new technology.

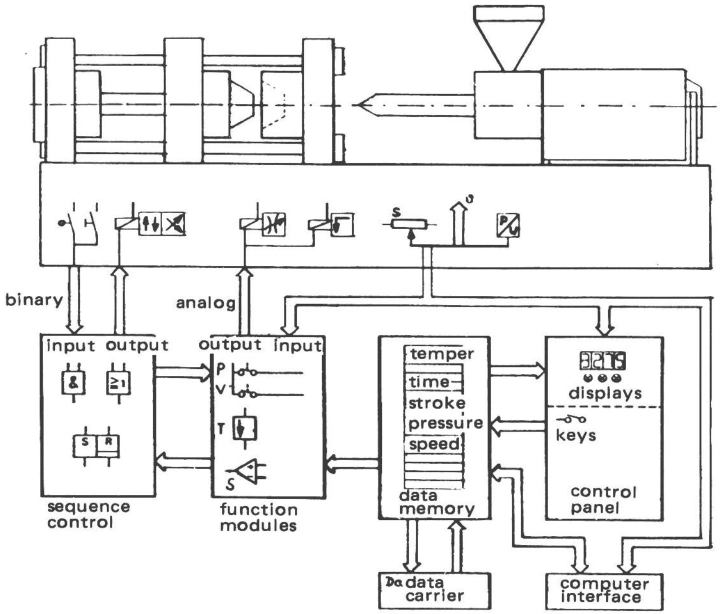

Fig. 2. Block diagram for the microprocessor controls of an injection moulding machine.

Cost/performance and problems in the use of microcomputer systems for injection moulding machines

This is illustrated in fig. 3, which shows the drastic reduction in price of pocket calculators. It does, however, tend to give a false impression. Although the cost of microcomputer systems has dropped steadily and will probably continue to do so, the cost of microcomputer peripheral unit can hardly be reduced any further. These include, for example, the command units, power drivers, digital-analog and analog-digital converters as well as the necessary mechanical structures.

Most of the "true" microcomputer controls being offered now (non-programmable sequence controls) are more expensive than the electronic machine controls used hitherto. They do, however, offer considerable technical advantages as well as multi-functions. These advantages include, for example, setting aids for the set-up operation, the output of processing parameters via a display screen or lines of text and numbers, self-diagnosis in case of production breakdown, as well as the input of processing

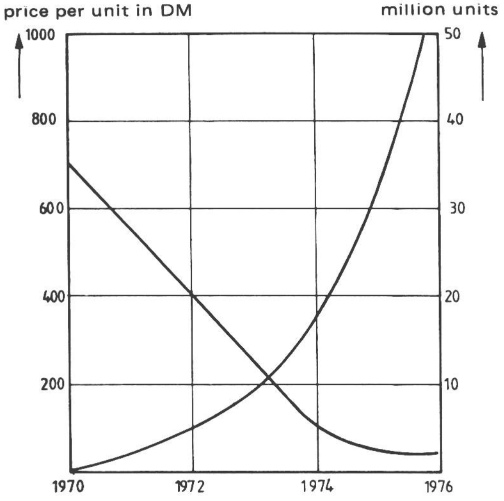

Fig. 3. Development of price of electronic pocket calculators in relation to the number made.

data via memory media, e. g. tape, magnetic cards or integrated EPROM data carriers.

Setting aids for the set-up operation

Since the data of all required and actual values are stored in the microprocessor controls, there are advantages for setting-up which are absent in conventional control systems.

The entire setting-up operation can be fashioned in such a manner, using so-called "operator guide", that the machine controls guide the operator without pause and in the correct order from one processing parameter to the next and ask him to feed in required values.

Here, the plausibility checks have been arranged in such a way that the computer recognises wrong inputs and prevents them. At the same time, the operator is informed of possible errors via the indicators or the display screen, the information being presented symbolically or as text.

For a large number of required values, e. g. in the case of cylinder temperatures, speeds, strokes, clamping force, the computer is capable of automatically suggesting values which can be accepted or altered by the setter.

Automatic limit value checks are possible, which means that maximum temperatures or pressures cannot be exceeded, an alarm signal being produced immediately. A check is also kept on maximum strokes or minimum braking strokes which depend on the type of machine being used.

Mathematically dependent values can be automatically determined by calculation, e. g. clamping force from the clamping pressure, the metered volume from the screw stroke or the melt pressure from known machine data.

In view of the many different values which must be fed to the machine control system when setting-up a new mould, the use of a microcomputer offers very considerable advantages.

Input of machine data when changing moulds, via data carriers

The biggest advantage from the point of view rationalisation is in the reduction of mould changing time. Ideally, this is what happens:

The new mould is quickly clamped in position, a data carrier, a magnetic tape cassette or a magnetic card containing the mould-dependent processing data is pushed in and the mould is ready to produce perfect mouldings without any start-up waste.

The data carrier, which is a memory medium, is made possible only through microelectronics. The time taken to change machine components is reduced through newly programming via the data carrier and transfer errors such as can occur when feeding in processing data from a data sheet are avoided.

There is one false assumption which every injection moulder must guard against; once the new machine settings have been fed in via the data carrier, one must not assume that the machine will produce in exactly the same way as before, when these machine settings were found to be the most suited.

Accuracy and reproducibility in an injection moulding machine

- The *machine* must be adjusted so accurately that the former pressures, amounts of oil and strokes are again reproduced accurately. This requirement forces the machine manufacturer to build an accurately reproducible machine.
- The *mould* must be in exactly the same condition as during the earlier production cycle, especially the parting surfaces and cooling channels.
- The *mould temperature control instrument* must have the same data as before – or, better still, accurate mould wall temperature control must

ensure that the mould temperature is the same as before. The same applies to hot runner systems.

- The *plasticising unit* must be in the same condition as before, especially the non-return valve.
- The *heater* for the plasticising unit deserves special mention. The location and condition of the thermocouples are frenquently at fault. Additional errors are produced by fluctuations in the ambient temperature, e. g. if the doors of the moulding shop are opened. These have a negative effect upon the cylinder heaters and here it would be a sensible idea to cover the plasticising unit.
- The effect of *flange cooling* in the entire feed area is often underestimated. Here, care must be taken that the feed characteristics of the plasticising unit are accurately reproduced.
- The *effect of the material* is often considerable, being determined not only by batch variations due to technical reasons, but also by the initial temperature and moisture content.

In order to be able to control these peripheral influences, considerable demands are made on the developers of the microprocessor controls of tomorrow.

Microelectronics will, in future, help in achieving improved processing techniques and faster process optimation. Work in this direction has proved that this aim can be achieved. Microprocessor systems are also capable of carrying out extensive closed-loop control operations, although this is still a costly and complex undertaking.

Fault indication, self-diagnosis

One clear advantage of microcomputer controls is that faults can be indicated through the program, making it easier for the operator or maintenance engineer to check the machine movements more easily. The machine itself indicates why the moulding cycle has been interrupted. In the case of alpha-numeric displays this takes place through the display of a letter/numeral code with whose help the operator can find a detailed description of the extent of the damage in a table. Display screen systems indicate the nature of the fault in clear text, although more detailed description is limited according to the size of the display screen.

Thanks to service programs which can be fed additionally into the computer system, there is also the possibility of localising the fault in case of a machine defect. The control system will then give the necessary instructions for remedying the defect. Likewise, instructions for maintenance measures to be taken to prevent damage are conceivable.

The possibility of linking a machine installed in a customer's moulding shop with a central service computer at the machine manufacturer's factory in case of breakdown, using a transfer module, a so-called Modem, and a telephone line, is no Utopian dream. Engineers can thus carry out a fault analysis or make program changes without having to visit the moulder's factory.

Adaption of controls to special purpose functions

Apart from the above mentioned advantages, microelectronics will drastically reduce the mechanical part of control systems. In the ideal case, the entire microcomputer controls are accomodated on a large printed circuit board to which a number of cables leading to and from the machine are connected. In case of breakdown, this means that the entire control system can be exchanged in a matter of minutes.
Since the machine sequence program is no longer wired up, but has been replaced by software in the memories, the control system is freely programmable. If there is a change in controls, it is not the wiring that changes but the software, the program.

Now, at the start of this technology, this means, however, that the machine operator must have the program memory re-programmed by the machine manufacturer. Otherwise, he will require his own programming device and appropriately trained staff. A few years will pass before this happens, however.

For the machine manufacturer, the idea of microcomputer control offers the advantage of being able to work more quickly on control changes demanded by the costumer, or on special functions, even if the machine is already producing. The preparation of the necessary documentation for such special functions still requires a great deal of time in the design department. When altering software, the actual state of the control program can be documented via a linked printer, after the machine has been tested, simply by pushing a button.

Central production data acquisition

Data combination with a central computer

The idea of centrally connecting all the machines in a moulding shop to a control and monitoring computer is an attractive one. Here, all production data, as well as the faults occurring in the various machines, are determined. All mould-related machine settings are stored in a data bank and recalled via a code when moulds are changed. This offers the following advantages:

– reduced labour costs
– clearer and easier checking of production.

The condition for such a central computer is met by microcomputer controlled machines. All required and actual data are accessible in the machine controls and can be recalled via an interface to which the central computer is connected.

The following should, however, be noted if this is to be accomplished:

All the machines should be completely equipped with the same microcomputersystems. Because of the different ages of the plants and, possibly, different makes, this can only be achieved right at the start, i. e. at the initial planning stage, and a great deal of work is involved in adapting the software of the different kinds of machine systems to the central computer. It is hardly possible to equip old machines with microcomputers. Rationalisation becomes fully effective however, only when all machines have been included.

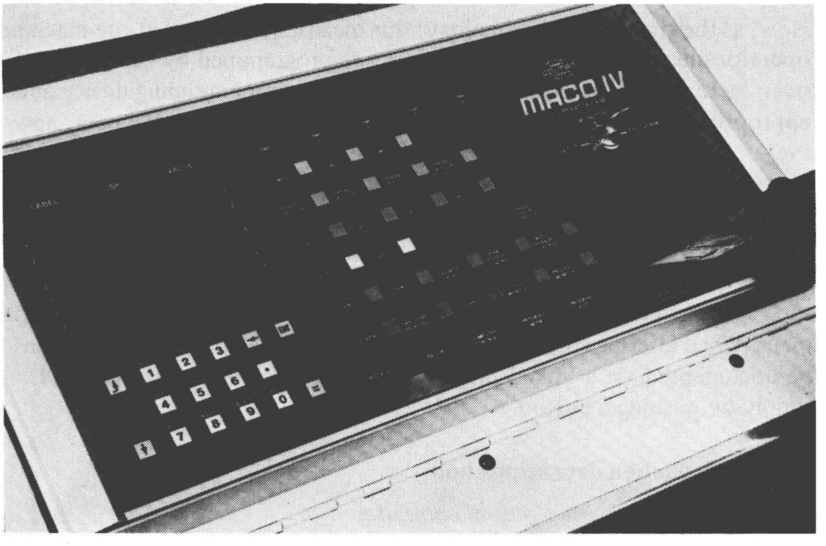

Fig. 4. Microprocessor control with display screen, made by the American firm Barber-Colman.

Operational concept of modern microcomputer controls

The operator is more often confronted with operation of the injection moulding machine than with sequence control. How is a microcomputer-equipped injection moulding machine operated? Different machine manufacturers use different systems, as detailed below.

1. Operation via display screen and keyboard. Using a code list, the operator calls up the various program steps of the parameter input, and feeds in the various figures via a numeric keyboard. Here he must forget the familiar appearance of the control panel of a conventional control cabinet, fig. 4.

2. Control panel with a alpha-numeric line of letters, as well as a keyboard. This system is,in principle, a display screen with only one line. The operation of required value input is similar to the use of a display screen systems.

3. Control panel, which gives a complete picture of all the data and operations that have to be programmed.
   Machine settings are effected by means of the operator instruction unit which automatically calls up the processing parameters to be fed in, one after the other, fig. 5.

Future outlook

The above remarks have demonstrated the advantages brought about by the use of microelectronics. The prevention of long downtimes when changing moulds, the automatic indication of faults and breakdowns, as well as the possibility of operating microcomputer-controlled machines in a data combination with a central computer – all these are notable considerations with regard to rationalising an injection moulding shop.

Since injection moulding machines equipped with microcomputers permit acess to all processing parameters, as well as the actual and required values, it will be possible in future to carry out extensive optimisation processes by connecting central process computers, provided the appropriate programs and necessary data (e. g. relating to the materials) are available. Graphic representations of process sequences (storable), automatic fault location, operating instructions or spare parts lists via a display screen will be a welcome help for processors as well as machine manufacturers.