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NUMERICAL CONTROL SERIES

POST PROCESSORS

BY

ALWALID ElSHAFEI

OPERATIONS RESEARCH GROUP

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CAIRO

3. MOHAMED MAZHAR - ZAMALEK

INTRODUCTION:

Before we can employ a computer, to generate tapes for numerically controlled machine tools we need to be assured that we have a complete programming system available for the machine tools, control systems and computer, we intend to use. In almost every case, one of the elements of the programming system will be a postprocessor.

The postprocessor is needed whether we are intending to use 2CL, EXPAT,, ADAPT, APT or any of the other general purpose computer programmes now available for NC. More than likely, we need different ones for different machine tool and control system combinations. Why this is so, and exactly what functions the post-processor performs in a complete computer programming system is explained in this article.

In this article, we are going to discuss the postprocessor in relation ONLY to general purpose computer programmes like 2CL, APT and ADAPT, but the principles are valid for most other general purpose programmes as well.

COORDINATION OF WORK WITHIN NC SYSTEMS:

General purpose programming systems for numerically controlled machine tools, such as APT, ADAPT and 2CL consist of two parts: a programming language and a number of computer programmes.

The programming language is used by the part programmer to describe the geometry of the part to beproduced, the tools to be used and the tool motion to cut the desired part. The computer programmes in turn are divided in two sets:

The processor is the first set of programmes. This is used within the computer to interpret the statements written in the programming language by the part programme, evaluate them and calculate a general solution.

The general solution, called cutter location data, is the result of geometric calculations which were executed to solve the problem of calculating the path of one geometric body, the tool, over another geometric body, the part. The general solution is machine tool independent. It will be stored on an intermediate storage device such as magnetic tape or disc.

For the APT system the data are generally stored on a tape, called the CLTAPE (cutter location tape).

The post processor is the name given to the second set of computer programmes.

The postprocessor will adapt the general solution generated by the processor to a specific machine tool with a specific control unit (3).

This procedure of processing of a part programme in two steps, by a processor and then by a postprocessor may seem lengthy. But it has many advantages. The main one is that of increased flexibility and standardization. The separation makes it possible to use only one programming language to programme parts for numerically controlled machine tools having point-to-point as well as multi-axis controls. It requires a large and powerful processor which is not easy to develop. But this in turn also makes it very easy to develop postprocessors to adapt the general solution generated by the processor to a specific machine tool/controller combination.

As an example, it took more than 100 man-years to develop the APT programming system. To develop postprocessors for this system may take an effort of only two to three man-months for a point-to-point postprocessor or of two to three man-years multi-axis postprocessors.

Under these conditions it is now possible to include in the programming language, requirements from users with a wide range of types of machine-tools. This helps to standardize the programming language. Since the format of the interface between processor and postprocessor may easily be standardized, for any new machine tool or any new controller only a new postprocessor has to be written. This then relieves the user or the manufacturer of the new equipment of an enormous programming burden.

PROCESSING AND POSTPROCESSING:

The use of the postprocessor is not very difficult to understand. The postprocessor is the second of two major steps in taping,

(1) Main processing. In the first step, the path that the end of the cutter must take to produce the part is calculated in detail and described numerically. The cutter path is calculated 'in space', as more or less abstract lines.

This first major step is essentially one of solving solid geometry probelems. The programmer, working from the drawing, writes out step by step a detailed mathematical description of the required cutter movements. He writes these procedures in English-like words. If the geometry problems are complex, such as precisely locating the intersection of straight or curved lines and planes, the computer is used. The computer also automatically calculates and compensates for cutter offset.

In America there are at least two large-scale general-purpose computer programmes widely used for this main processing work-APT (Automatic Programmed Tools) and ADAPT (a subset of APT). These two programmes will shortly be supplemented by the British 2CL programme and the German EXAPT I and II programmes. One outstanding feature of all these programmes is that only a few words are required to effect the most complex computer calculations.

The programmer's detailed procedures, are punched on cards, one card to a line. These are then fed into the computer along with the APT or similar programme, which is on magnetic tape. The output of this processing is a second tape, the CLTAPE. The 'CL' means cutter location, the establishment of which is the principal purpose of the first major processing step in producing an NC punched tape.

When the programmer writes up his procedures, he also includes the feeds and speeds for the various cuts to be made. He provides for such instructions as coolant on and off, intensity of spray, direction of the spindle rotation and so on.

Knowing how much stock is to be removed, the programmer must also determine the exact cutter to be used and the number of passes that will be required. All these machining instructions are fed into the computer along with the part description and its geometry problems. However, the computer ignores such machining details at this point. These are simply passed along and included in the CLTAPE.

(2) Postprocessing. In the second major step of the procedure, the CLTAPE and the postprocessor (usually in the form of another magnetic tape) are fed into a computer together.

Here the postprocessor takes the data defining the previously calculated path of the cutter and adapts it:

(A) to the specific machine tool that is to produce the part and

(B) to the specific make and model of numerical control system used to run that machine.

FUNCTIONS OF A POST PROCESSOR:

The statements in a part programme may roughly be divided into two main groups: the first being those which describe the geometry of the part and the tool motion, the second being those statements which describe the functions of the machine tool.

The first group of statements will be processed in the computer by the processor of the programming language. Their evaluation results in geometric calculations which are independent of any machine tool.

The second group comprises what we call the postprocessor commands. They can only be handled in the computer by the postprocessor after the geometric calculations have been performed because their evaluation depends on the machine tool and control system to be programmed.

Postprocessor commands are:

- turning coolant on or off,
- programme end,

- rewinding the control tape,
- position of the indexing table,
- feed,
- spindle speed,
- tool select command,
- tool load command,
- tool length,
- position of the turret,
- machining tolerance, and
- delay time and so on.

The statements for the processor and the postprocessor commands are fed into the computer on the same set of punched cards. In the processor stage of computing the postprocessor commands are however not acted upon. They might be checked by the processor for correct spelling, but otherwise they are simply stored on the intermediate storage tape or disc without any processing.

Basically it may be said, that a postprocessor must cover all programming possibilities that the combination of controller and machine tool is capable of. In that sense it must be a true simulator of this combination.

Within the postprocessor all calculations and all functions executed by the postprocessor are completely machine tool dependent. That means that as many machine tools may be programmed with one programming language as there are postprocessors available for that programming system. (Unless different machine tool/controller combinations have been designed with interchangeable postprocessors in mind.

In other words, the postprocessor does automatically what a human would do if he were an expert in the particular combination of machine tool and control system involved. 'Knowing' the capabilities, operating procedures and limitations of the machine tool, and the format and coding that the control requires, the postprocessor takes the data from the CLTAPE and tailors it to the particular metalworking equipment to be used.

It checks the limits of travel (to make sure the programmer hasn't programmed the work table off the slides of the machine), checks the speeds and feeds and dynamics of acceleration (to make sure the machine will be operated efficiently, yet not exceed its limitations), and at the same time interprets the auxiliary commands such as coolant control, spindle control, tool change, rewind, and the like.

Further, it recognizes any conflicts between the part programme and the machine tool and makes compromises if possible. Finally, the postprocessor encodes all this information into the special language of the particular make and model of control that is to be used. Typically, a postprocessor will consist of some 8,000 to 10,000 computer commands.

In the following presentation, we are going to discuss elaborately the functions of the postprocessor.

GENERATION OF CONTROL BLOCKS

Cutter path information (co-ordinate values, codes for auxiliary functions, and feed and speed values have to be combined in control blocks on the control tape. The postprocessor forms the control blocks in the core memory of the computer in the format that is required for the control unit.

If for instance a control block format with word addresses is used, the postprocessor places the word address before the values to be inserted into a control block ('X' before the X co-ordinate, 'Y' before the Y coordinate, 'N' before the sequence number, and so on). If the values of a certain word are equal in consecutive blocks, the postprocessor omits this word in the second and following blocks (in the case of word addresses).

When a control block has been assembled it will be punched out or written out if it is not required any more.

If the postprocessor runs on a small or medium sized computer, the control block will be punched 'online' into the control tape, using a tape punch connected to the computer. If the postprocessor runs on a large computer, an 'image' of the generated block will first be written on magnetic tape. After the postprocessor has written all control blocks on tape the control tape will be punched 'off-line', using a small and therefore cheaper satellite computer, from the information on the magnetic tape. When writing the magnetic tape the postprocessor already considers the number of channels the tape to be punched will have, and the code the characters are to be coded in, for example EIA code or ASCII code. (One exception to this procedure is the Ferranti Multiax control system which is designed to operate direct from the computer's magnetic tape output.)

CHECKING LIMITS

An important task of the postprocessor is to test that the calculated tool path co-ordinates do not exceed the limits of machine table travel or the limits of the tool head travel. Since the processor of a programming system only performs machine tool independent calculations it is possible that because of a programming error in the part programme tool path co-ordinates are calculated which exceed these limits. This error may only be discovered by the postprocessor which is aware of these limits.

In case such an error occurs, the postprocessor should issue a warning to the part programmer on the verification listing and it should terminate the generation of the control tape because the tape will be false and might lead to machine tool damage.

CODING MACHINE TOOL FUNCTION

It depends on the control unit how the data for programming machine tool functions are put into the control tape. The postprocessor therefore evaluates the postprocessor commands for the auxiliary functions such as turning a coolant on or off, for machine stop, for programme end, and so on, after they have been read in from the intermediate storage device, according to the requirements of the respective control unit. The postprocessor determines the correct code and inserts the data into the appropriate control block.

Spindle speeds programmed in the part programme often have to be changed by the postrpocessor to values actually attainable by the programmed machine tool. The changed values will be put into the control block either directly or coded by a spindle speed number.

CONSIDERATION OF TOOL LENGTH

The intermediate results, computed by the processor of the programming system and stored on an intermediate storage device, represent the path of the tool tip or that of the tool centre. The postprocessor for certain machine tools has to reference the z co-ordinate of the tool path co-ordinates to the control point of the tool head. This is done by using the length of the tool which was passed on from the part programme.

This recalculation of the z coordinate is especially important in case a machine tool with automatic tool change has been programmed and if tools of variable length are utilized. After each tool change the postprocessor has to use the length of the new tool in order to correctly perform the recalculation of the z co-ordinates. The referencing of the z co-ordinate of the control point of the tool head will involve intricate calculations if a multi-axis machine tool is involved.

TOOL CHANGE

The postprocessor for machine tools with automatic tool change capability often has to perform extensive work.

If the postprocessor is designed for a machine tool with tool magazine it generates from the tool select command in the part programme a command necessary for the search in the magazine. For machine tools with a magazine or a turret the command in the part programme to a new tool causes the postprocessor to generate commands for the withdrawal of the last used tool to a position where the tools may be exchanged without endangering either the work piece, the last used tool or other tools. This tool change position may be indicated in different ways:

(1) There may be only one position on the machine tool where a tool change may be performed; in which case the co-ordinates of this point are best programmed into the postprocessor.

(2) The tool change position may change from one part programme to the next. The postprocessor then automatically retrieves the co-ordinates of this point at each tool change command.

(3) The tool change position may change frequently within a part programme. It may in this case either be programmed by a

postprocessor command before each tool change command, so that the postprocessor can generate all necessary control information for the withdrawal of the tool, or the part programmer himself may programme each move in the part programme.

(4) The postprocessor itself may calculate the tool change position. To perform this calculation it takes into account the length of the last used tool, the length of the new tool, the length of tools that have to pass the workpiece before the new tool is in the correct position, and a safety distance or safety plane.

MACHINE TOOL DYNAMICS

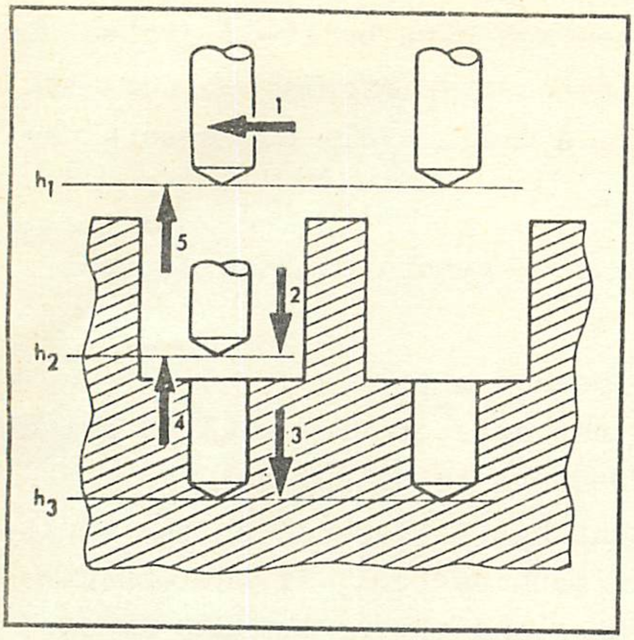
A part programmer will always try to keep the production time for the part as short as possible. This is formally achieved by programming the highest possible feedrates. To obtain these feedrates on the machine tool all movable parts of the machine tool have to be accelerated or decelerated as much as possible. Because of the reading time of the tape reader of the control unit, because of the processing time of the data in the control unit, and because of the construction of the machine tool (power of the drives, movable masses and so on) only certain maximum values for acceleration or deceleration for the change of feedrate between two successive control tape records, are possible considering the given limits or, failing that, that the highest possible feedrate will be maintained for as long as possible.

EVALUATION OF CYCLE COMMANDS

A cycle is a fixed sequence of instructions for a machine tool issued by a control unit. In general, cycles are used to programme point-to-point or straight-cut problems like drilling, tapping, face milling and so on. Such a cycle is programmed by giving in the part programme a cycle command, such as a drilling operation, which contains all necessary data and the points at which this cycle is to be executed. The processor does not evaluate the command since its evaluation depends on the machine tool and on the control unit, but it stores the cycle command with its data and the points on the intermediate storage device.

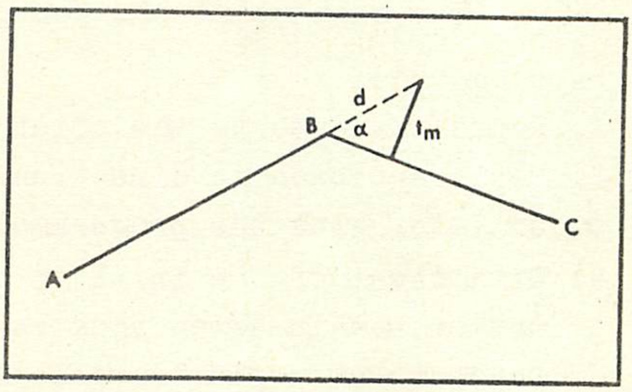
It is the task of the postprocessor to evaluate the cycle command. The evaluation may be done in two ways. The control unit may be equipped with 'canned', that is, built-in, cycles which enable it to execute a complete sequence of instruction for a machining operation in response to a function code read in from the control tape. The postprocessor for such a control unit generates from the general cycle command a control block which contains such a function code and together with all necessary data, followed by a series of control tape records which contain the co-ordinates of the points to be machined under this cycle.

The control unit when reading the first record, stores all information and applies it to the following co-ordinates of points until it reads the command 'Cycle Off'. This function code may either be programmed in the part programme as a postprocessor command or it will be generated by the processor or the postprocessor on encountering the command to begin a new cycle.



◀ **Fig. 1. When evaluating** the drill cycle for one hole the post-processor may have to generate five control tape records.

Fig. 2. **With t_m as machining** tolerance the largest permissible overshoot at corner B is $d = \frac{t_m}{\sin \alpha}$



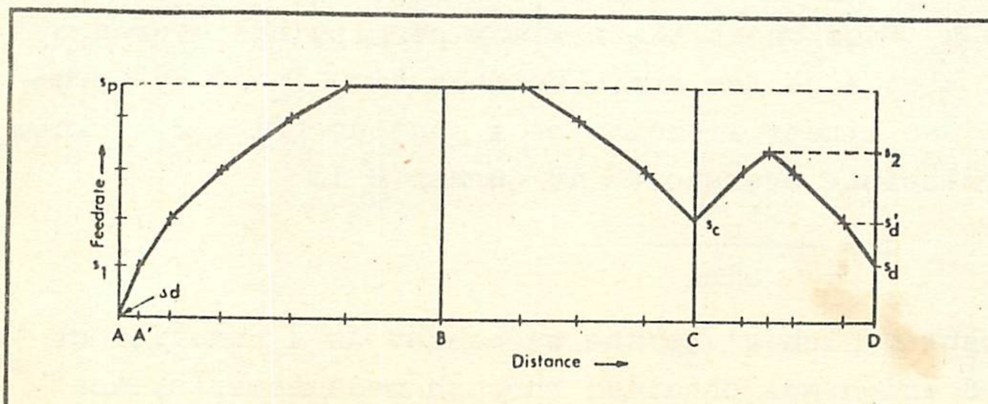


Fig. 3. **Postprocessor** must assure that the programmed feedrate is reached as fast as possible or that the highest possible feedrate will be maintained for as long as possible.