Considerations about command system for lathes with numerical controls, adaptive controls and copying system with hydraulic modules or computer assisted

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Abstract. One of the most complex situation in establishing the principles of modern complex lathes design is that the tool machine has to fulfill special purposes, like working with computer numerical controls and commands, adaptive cutting force control system and use in some manufacturing phases copying functions. The main issue in this case is choosing between adding an additional axis to the basic CNC machine or equipping the machine with a special subsystem purposed for the task. This paper compares the two possibilities mentioned above from the point of view of their capacity to satisfy the needs of the copying process, the complexity, and the cost of the machine, the precision achieved in the manufacturing process, and the complexity and cost of the process itself.

1. Introduction

In order to clarify the content of this paper it is necessary to have a general image of our team research field, that mainly involves the goal of ”perfect” cutting (splinter) tool machine manufacturing. Our directions are oriented towards:

a) developing a sustainable frame, not implying necessarily a very rigid one, but a structure for which we can predict (anticipate) the deformations, different movements and vibrations, in order to be able to correct them right the moment they are to begin acting \cite{1, 2, 3}.

b) creating sources of movement for small and very small displacements (like magneto-strictive engine) able to create the compensation movement of the tools \cite{4, 5, 6, 7}.

c) analysing (comparing) and improving command systems able to coordinate the process in order to obtain maximum results, which in our field means high precision manufacturing.

When the first two issues are solved, the command system must ”keep the rhythm” with the whole machine.

In this case we tried to match the right command system with the most complex manufacturing conditions that we consider to be when the machine is working with adaptive control of the cutting forces and the processed surface is a particular one ”coping” a particular profile or matching a profile generated by a complex equation.

The second factor to be considered is how often we are changing the type of profile manufactured.

It is obviously that if the profile manufactured is repetitive, even in short series, with limited variants of particular profiles, we prefer to use a quite simple command system based on a physical
materialized profile, each change of type of manufactured piece requesting the change of the template. This system is based mostly on hydraulic components able to develop together a sort of hydraulic "computer" limited in complexity and flexibility but very reliable and easy to use.

The opposite case is when the surface manufactured is changing frequently, sometimes piece after piece, in this situation the command system must be composed of a hydraulic part that is developing correct forces in right time connected with a computerised part that is offering the flexibility of the system.

2. Methods and materials
Case A: Limited configuration of the manufacturing product in mass production. This type of command system is presented in Figure 1.

![Command system case A.](image-url)
By analysing the advantages and disadvantages of these conditions our conclusion is the system that fits better is the simplest one, in this type of production changes of manufacturing piece being relative rare, the main changes in the settings of the tool machinery consisting in the change of the piece profile and dimensions, all pieces belonging to the same ”family”, that means limited range of profiles and dimensions.

We can simply observe the ”spartan” conception obtained by eliminating supplementary functions in order to get a simple structure with increased reliability and short times for adjustments when changing the manufacturing program, thing that is done very simply by changing the generation of templates of the piece SA.

The cutting tool is actioned by a linear hydraulic engine (cylinder) in charge with the movement $f_u$.

It is obvious that the $f_u$ movement is controlled by a relative simple hydraulic system composed by a hydraulic pump group (completed of course with filters, supercharge protection, etc.) offering the advantage of low costs, reliability and easy maintenance. The movement of the main hydraulic cylinder (which is acting directly to the cutting tool) is controlled by a hydraulic tracking device $Su$ in charge of converting physical information from the generating template of the piece SA in hydraulic input for the movement $f_u$. Other common hydraulic and mechanic components are included in order to complete the system.

Case B1: When the type of the processed pieces is changing frequently it is compulsory to complete the command system with a computer section that will increase the flexibility of the machine, an example for this category being presented in Figure 2.

The system consists of two parts: the hydraulic part responsible of developing manufacturing movements and forces and the computerised part in charge with the logical process and the sequence of phases. This command system is fitted with adaptive cutting force control $F_{ret}$ able to maintain constant (in the limits of a narrow margin) cutting force, feature allowing the use in a constant mode the full energy developed by the machine and having as a consequence the maximization of the production capacity. The adaptive force control was developed to react almost instant at changes in cutting depth of the manufactured material, the cutting tool was fitted with a sensor that outputs a signal related with the value of the force, signal processed electronically (derivate) , in this way the trend of increasing or decreasing the cutting force being predictable fact that allows the computer to anticipate the fluctuation of the value of the cutting force and command corrections to keep the force as constant as possible.

In this command system, in order to be able to compare it with the case A some information about the geometry of the piece is taken from the model SA through a hydraulic tracking device and transmitted to the hydraulic system. The same hydraulic system acquires information from adaptive cutting force command electronic system and is combining the two channels of incoming data (input information) in the command decision system and after a logical algorithm delivers the correct parameters (output information) to the machine subsystems that are responsible with the movements, corrections and any action involved in the direct cutting process.

It is obviously that in our days it is normal to input the geometry of the piece by using a computer [8, 9], but in our solution B1 it was adapted to a system like the one used in solution A (a mechanical copying system) in order to be able to compare the performance of the command system A and B1 in similar manufacturing conditions.

Case B2: It was mentioned above that the structure of the command system B1 was chosen for the purpose to be able to make a comparison with the structure of the system A. This system is presented in Figure 3, where the hydraulic part from B1 is not detailed anymore being symbolized as SH, the hydraulic part is used to amplify the electronic signals and to generate forces and movements contributing to cutting process itself. The geometric parameters for the manufactured piece (shape, dimensions, quality of surfaces, dimensional deviations, etc.) are introduced into the system using a standard computer (CNC), acting together with the adaptive force control CA (functioning similar with B1 and having a reference value for the cutting force $F_{ret}$ ) the final result is transmit to the hydraulic system in charge with the cutting movements and forces. [10, 11, 12, 13]
Figure 2. Command system case B1.
3. Experimental work
The main challenge was to establish the right structure for the command system with the cutting tool machine operating in various conditions, beginning with a structure similar to case A that was fitted for a classified project for the military industry, the machine working in very hard conditions (heat, dust, sand, unqualified operators, etc.) without any maintenance problems, passing through intermediate solution presented in case B1 and finishing with the B2 system presented on a CNC complex lathe machine at the Milan fair, Italy.

4. Results and discussions
Each command system presented was designed and then assisted in practical implementation on the tool cutting machinery by a member of our team, here to be mentioned that the complete production of the machines was done in Romania, each of them representing at the time a success, the brief description of the A solution being a result of its final destination (the elements presented are not anymore classified, the whole machine is still unavailable) [14].

5. Conclusions
After presenting briefly the two solutions for command systems (case A and case B) we can conclude depending on particular needs of manufacturing conditions that the simple solution (case A) is suitable
for mass production, relative simple manufactured pieces generating lower costs for the tool machinery and for the manufacturing process itself. Involving more electronics and computers in command systems (case B) offers wider flexibility for the tool machinery (wider range of shapes and dimensions to be manufactured) but also raises the costs and probably due to its complex structure the reliability of case B is less than the reliability of case A. As a final conclusion both cases have to be considered, relating them to manufacturing requests about range of shapes and dimensions of products manufactured. This subject will be further analysed in a future paper.

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