RESEARCHES ON IMPROVING THE MANUFACTURING ACCURACY OF CNC CUTTING MACHINES

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Abstract: This paper presents the experimental researches results carried out to optimize the dynamic behaviour of a NC machine-tool regarding the cutting precision. The aim is to detail the influence of the numerical control equipment setup on the size of the contouring errors and on the smoothness of the movement, factors that have a direct influence on the accuracy. Based on the experimental results, recommendations are made to increase the cutting machine's accuracy and to find where it's optimal performance lies.
Keywords: contouring accuracy, NC machine-tool, cutting precision.

1. INTRODUCTION

The processing through profiling with energy beam of oxyacetylene flame, plasma or laser type, represents a relatively new technology, both on national level and on international level.

Realised in the structure of numerical control machines, after the model of the CNC milling machines and lathes, the profiling equipment are tributary to the control structure of the movement of numerical axis type with synchronous servomotor, position and speed transducers and performing transmissions of ball screw-nut couple type. Also, the numerical command system is adapted with very few modifications, from the CNC machines for cutting. This closed architecture surpasses in terms of performances, in most cases, the technological requirements imposed to the profiling procedure, raising, unjustifiably, to prohibitive levels the price of an equipment for small and medium-sized companies from the domain of machine manufacturing.

The project's topic concerns the realizing of processing equipment capable of realizing profiling operations with an energy beam such as oxyacetylene flame, plasma or laser. It is intended to realize the processing equipment in a variant with exchangeable power heads, for each type of energy beam.

The approach intended in this work is to improve the contouring accuracy of the profiling equipment by a joint simulation and experimental process.

2. FEED DRIVES MODEL

Feed drives control the positions and velocities of machine tool slides or axes in accordance with commands generated by CNC interpolators.

The requirements on feed drive performance include: control over a wide range of speeds, precise control of position, ability to withstand machining loads while maintaining accuracy of position control, rapid response of drive system to command inputs, precise coordination of the control of multiple axes in contouring systems.

Direct current brushed, brushless servomotors and permanent magnet synchronous motors are usually used as driving units for machine tools feed drives.

Servo-driven contouring machine tools are capable of producing high quality precise parts. However, tracking and/or contouring errors often limit the accuracy.

Tracking/contouring errors result from various kinds of sources, including mechanical hardware deficiencies, cutting process effects and drive dynamics.

A major problems when using CNC machine tools is that after some operation time, the contouring errors are significantly increasing. The recommended solution in this case is to adjust the control parameters of the feed drives. However, this operation requires a close understanding of the position control process and, moreover, in order to improve the performance, the use of a mathematical model of the feed drive, combined with a computer simulation process is recommended.

There are a large number of mathematical models reported in the literature concerning the CNC feed drives using dc motors as actuation device. However, some of them are oriented to the mechanical drive dynamics, which is justified when dealing with large or medium size machine tools, but has no significant importance with profiling machine tools, where the machine slides masses are quite small.

Other authors presented elaborate friction models, suited when the machine slides have large masses. Another approach is to use advanced control methods such as feed-forward or cross coupling control, which lead to high contouring accuracies, but are quite hard to implement ate the level of the CNC controllers.

A model of the feed drive was built, which is presented more accurately in the papers. The model is built as a NC feed drive seen as a position control system using dc motor as actuation device.

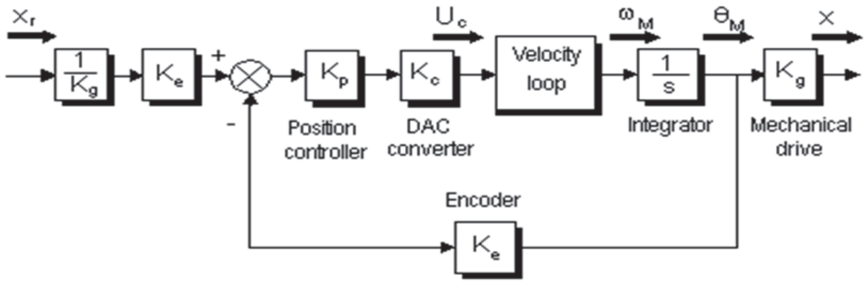

Fig. 1. Block diagram of a NC feed drive.

A simplified block diagram for a NC feed drive is shown in Figure 1, where: K_g – gear ratio [m/rad]; K_e – encoder gain [pulses/rad]; K_p – position gain; K_c – DAC gain [V/bit]; x_r – reference position [μm]; U_c – voltage command [V]; ω_M – motor velocity [rad/s], θ_M – motor angular position [rad]; x – actual position [μm].

Figure 2 shows a detaileddiagram of thebehaviour of themechanicalsystem.

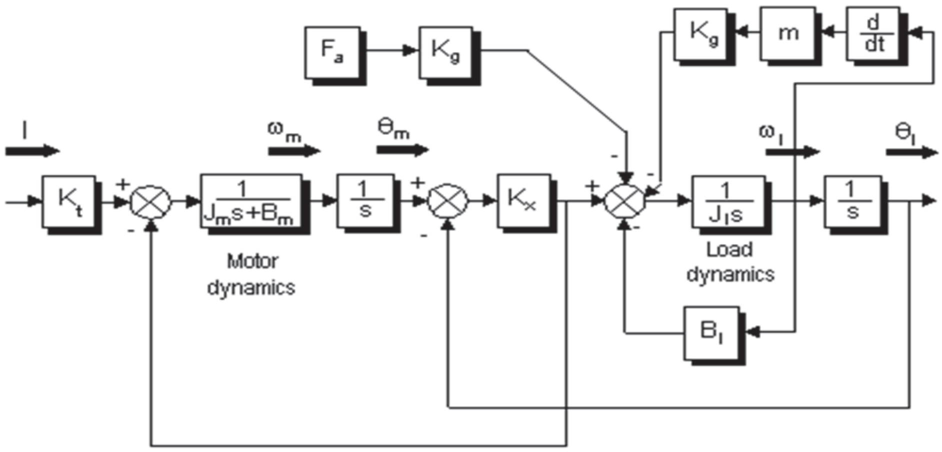

Fig. 2. Block diagramused for thestudy of thebehaviour of themechanicalsystem.

3. MODELLING AND SIMULATION OF THE INTERPOLATION PROCESS

In order to drive the tool on various trajectories, the common requirement of all CNC systems is to generate coordinated movements of the separately driven axes of motion to achieve a desired path of the tool relative to the workpiece.

The interpolation algorithms for generating the reference pulses were implemented as programs in MATLAB software package. The reference pulses generated by running those programs were stored in two one-column matrixes (A and B) and were available in MATLAB's workspace.

A simulation diagram was also developed in the SIMULINK software package in order to simulate and visualize the generated trajectory by composing the signals on both axes. The diagram is presented in figure 3. Two “sampled read from workspace” blocks are used in order to read the data from matrixes A and B at sampling intervals equal to the interrupt frequency.

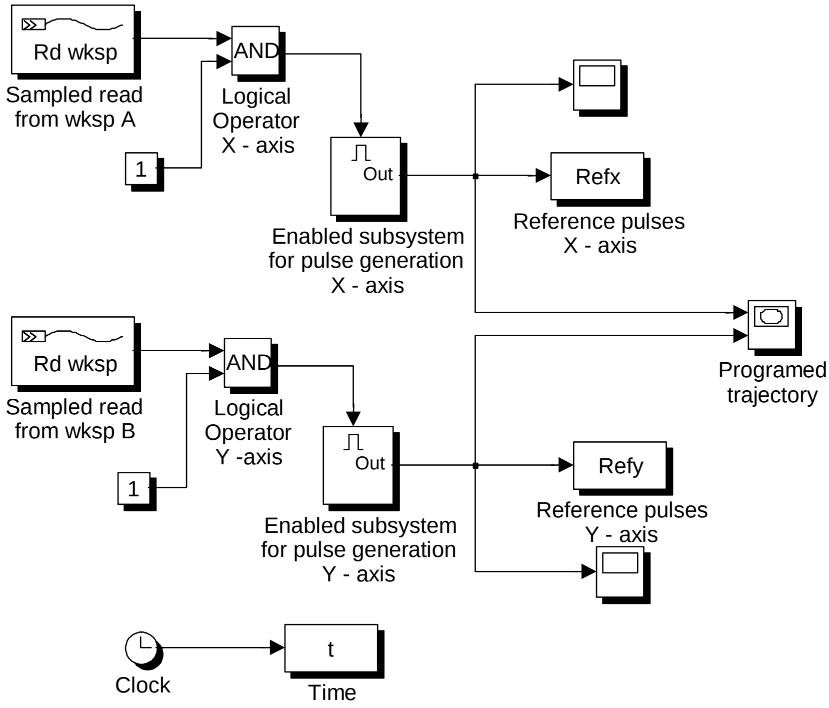

Fig. 3. Simulation diagram of the interpolation process.

Conditionally executed subsystems (enabled subsystems) were used for reference pulse generation on both axes. These are subsystems whose execution depends on the value of an input signal.

The signal that controls whether a subsystem executes is called the control signal. An enabled subsystem executes while the control signal is positive. It means, in our case, that pulses are generated only when an “1” is read from the matrixes A or B. To avoid reading errors, a logical gate AND is used for confirmation, by comparing the result of reading with the 1 value.

Figure 4 shows the reference pulses generated for interpolating a circle arc by DFC method. In that figure, the sampling period and the increment of motion are of no importance, only the pulses succession having relevance at this time.

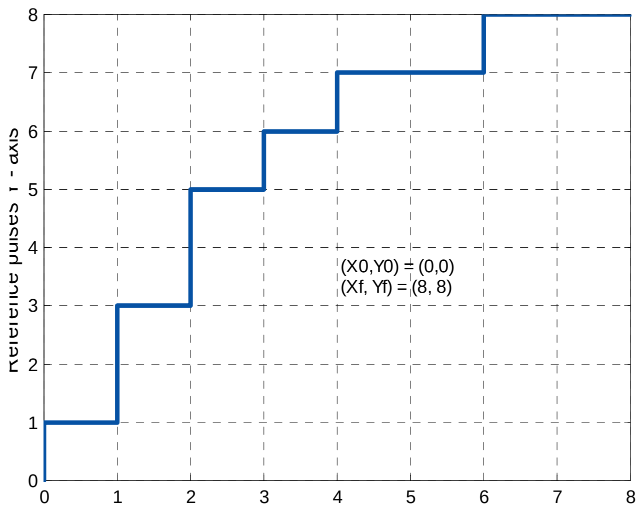

Fig. 4. Simulated reference pulses for a circle arc by DFC method.

4. EXPERIMENTAL RESEARCHES

In order to test the contouring accuracy of the experimental system, both simulation and experimental researches were performed.

Figures 5 and 6 show the simulation results before and after tuning the system (the programmed circle and the simulated trajectory).

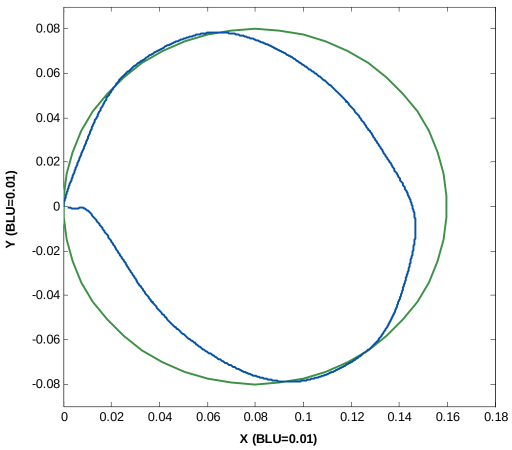

Fig. 5. Simulated results (before tuning).

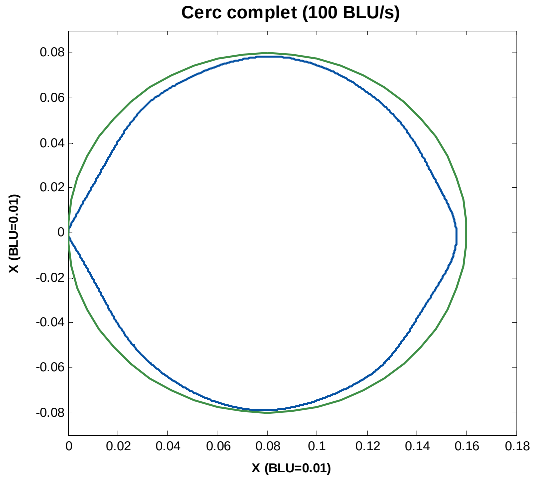

Fig. 6. Simulated results (after tuning).

Using the simulation results, the control parameters of the feed drives were modified according to the calculated values. Figures 7 and 8 shows the circular error (measured on a coordinate measuring machine before and after tuning the position controllers.

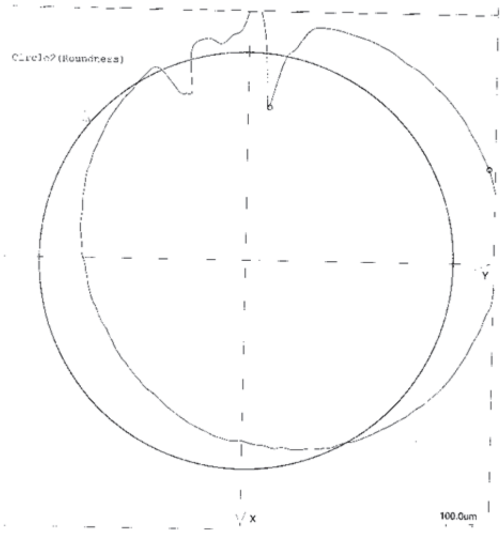

Fig. 7. Experimental results (before tuning).

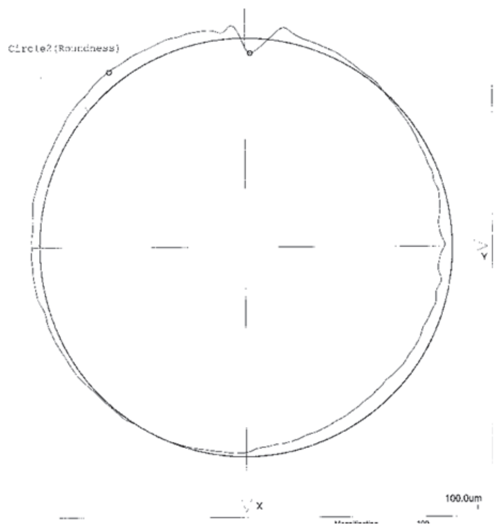

Fig. 8. Experimental results (after tuning).

5. CONCLUSION

This paper presented a joint simulation and experimental approach for studying the behaviour of the feed drives of profiling equipment, seen as mechatronic motion control system. A model of the feed drive was built, which was used for the simulation process.

The effects of the technological forces, friction and pre-tensioning of the ball screw system were also taken into consideration by introducing disturbance torques.

The controllers within the system were tuned by a combined method using both analytic relations for the position controller and also a trial-and-error simulation process for the other ones. The main goal of the tuning process was to achieve a good dynamic behaviour of the system.

The experimental results presented in figures 7 and 8 shows the experimental results before and after tuning the system, which validate the proposed approach.

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CERCETĂRI PRIVIND PRECIZIA DE PRELUCRARE A MAȘINILOR DE DEBITAT CNC

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Rezumat: Aceasta lucrare prezinta rezultatele cercetării experimentale efectuate pentru a optimiza comportamentul dinamic al mașinilor de debitat CNC în ceea ce privește precizia de prelucrare. Scopul este de a detalia influența configurării echipamentului de control asupra erorilor de conturare și asupra preciziei de mișcare, factori care au o influentă directă asupra preciziei rezultatelor. Pe baza rezultatelor experimentale sunt făcute recomandări pentru a mări precizia mașinii de debitat și pentru a determina configurarea corectă a echipamentului pentru performante optime.