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Experimental Research on Thermal Behavior of Feed and Positioning Kinematic Chain

Cleopatra Ceausescu
Machinery and Production Systems
Polytechnic University
Bucharest, Romania

Marian Cornel Ceausescu
Machinery and Production Systems
Polytechnic University
Bucharest, Romania

***Abstract*—The most important direction in CNC development can be considered high precision, fiability, quality improvement, the increase of productivity and reduction the production cost. An outstanding contribution in fulfilling these conditions was brought by attaching at CNC structures a ball screw driving feed drive system. The system is more efficiently, and had the advantage that replace sliding friction with rolling friction. In this way are obtained much lower screwing moments and up to 80% performance. But also this feed drive system need some improvements. The thermal errors from the system are caused by friction heat that is generated when parts as slide ways, screw shaft, end-bearing and nut are moving. In this case result thermal deformation in ball screw system. The friction heat generate errors on position accuracy on machine axis. The main purpose is to reduce the thermal deformation of ball screw for bringing accuracy in machine activity.**

Keywords: thermal behavior,CNC machine, ball screw system, structural and thermal deformation.

I.INTRODUCTION

The entire industry is seen as the most important need is the high quality of finishing processing. Those CNC machine-tools use high-speed ball screw. Also to have such high performance we need to reduce errors due to thermal moving elements, balls of bearings and support bearings, motors and balls crew nut has internal heat sources.

This affects the processing precision of the machines and at the same time positioning accuracy axis.

In section 2 are described the mechanical characteristics of ball screw and the importance for our researches. In section 3, explain the purposes of this study and the detailed methodology of the research are given in section 4.

II. MECHANICAL COMPONENTS OF A BALL SCREW SYSTEM.

Ball screw is a precision mechanical linear actuator that uses steel balls between a screw shaft and a nut to transfer the motion which convert rotary into linear movement when screw is rotated. Different from any conventional power transmission screw, which needs to overcome sliding friction between the screw and the nut threads, ball screw operates similar to bearing components could achieve high mechanical efficiency since it moves in relatively low rolling friction (Fig. 1).

As a tried and tested technology, ball screw drive systems are still used in a majority of machine tools which can meet the demands of higher productivity and tight part tolerances due to their low cost and high degree of stiffness. High speed ball screw drive system generates more heat and it results in greater positioning error, adversely affecting the accuracy of high precision machined parts.

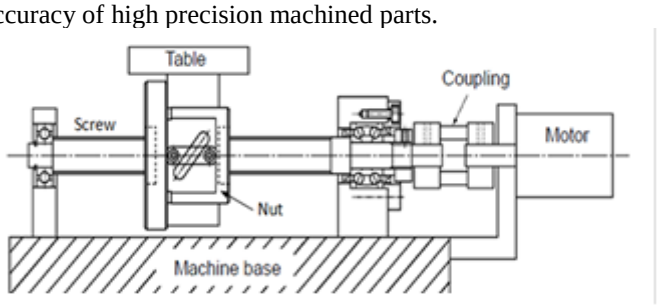

Fig.1 Mechanical components of a ball screw system.

In our research on the study of the thermal behavior of driveline advance / positioning, a defining role is the presence of ball screw (Fig.2).

Fig.2 Experimental stand

It was realized an experimental stand for testing ball screw and configured for thermal behavior experiments.

The experimental stand has the following components:

- electric motor with belt drive;
- incremental linear encoder LB 326;
- ball screw;
- measuring and processing data system;
- PC;
- laser;
- interferometer laser;
- incremental rotary encoder S 500 Fagor;
- numerical command equipment.

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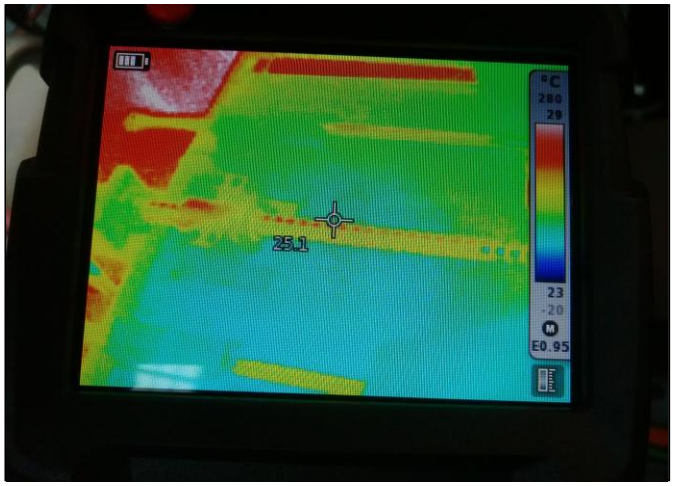
III. THERMOGRAPHY AND HEAT EXCHANGE SIMULATION

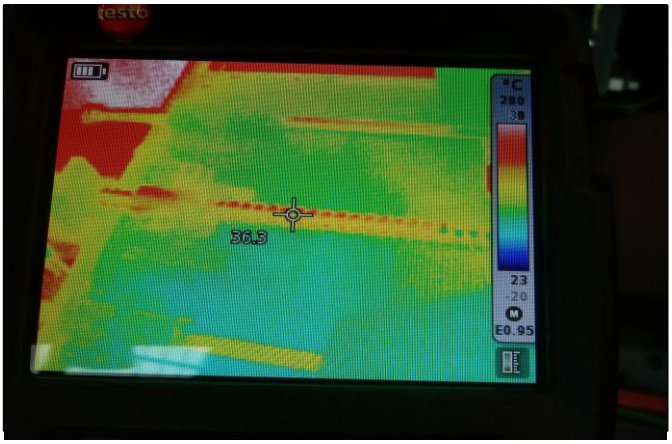
The main purposes of the research are improvements solutions of thermal behavior and heat exchange simulation [1].
To achieved the research goals of the feed and positioning kinematic chain it was made a thermography and ANSYS simulation.

A) Thermography

For thermography research was used a TESTO 870-2 camera [2] (Fig. 3 a - minimal temperature; b - maximal temperature).



a) Ball screw temperature after one cycle



b) Ball screw temperature after 1hour

Fig. 3. a) b) Thermography results.

B) Heat exchange simulation

To realize the heat exchange simulation, it will be used the algorithm that is presented in Fig.4

The model of the ball screw feed drive system will be develop in CAD software and running the optimization process using ANSYS program.

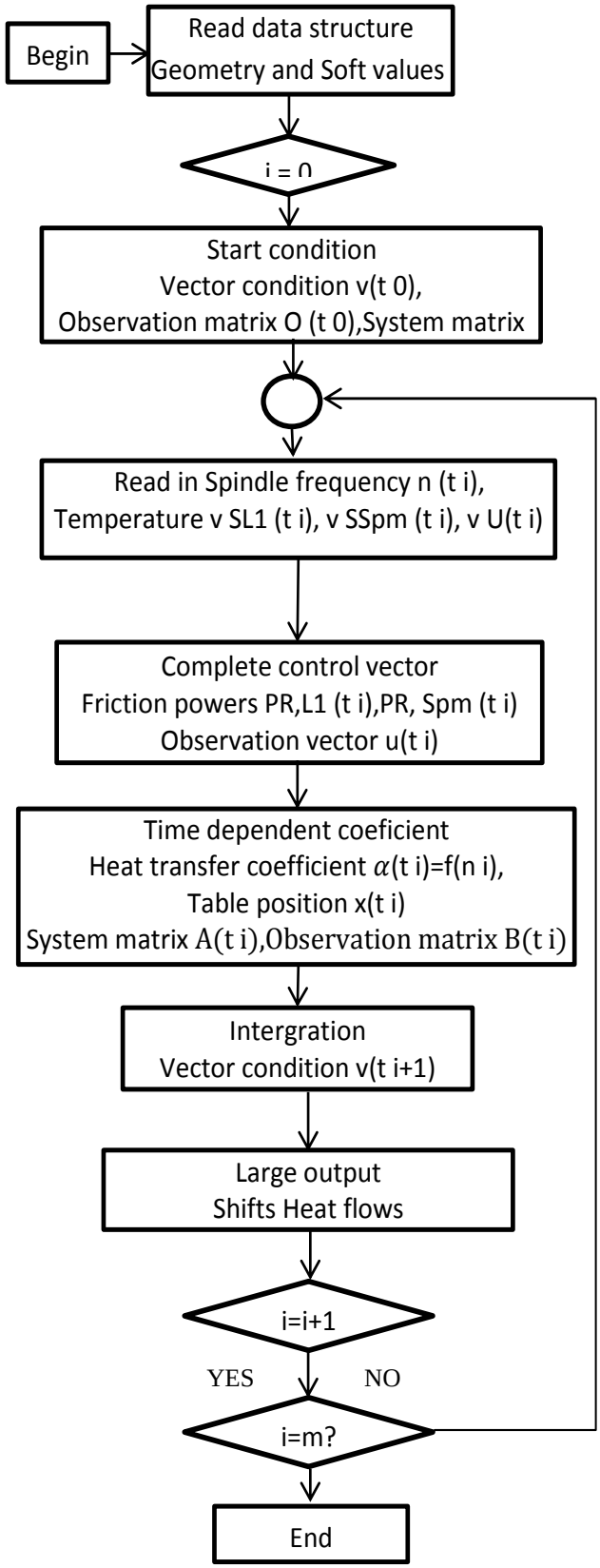


Fig. 4 Simulation algorithm.

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IV. FUTURE RESEARCH

As future researches we will analyze the possibility to choose the optimal linear encoder with full size scale housing from HEIDENHAIN Company. On table 1, are presented some possibilities.

The linear encoders with full-size scale housing are characterized by their sturdy construction, high resistance to vibration and large measuring lengths [3]. The scanning carriage is connected with the mounting block over an oblique blade that permits mounting both in upright and reclining positions with the same protection rating.

TABLE I.

HEIDENHEIN ENCODERS					
Features	*Accuracy grade*	*Measuring length ML*	*Increm. signals Signal period*	*Absolute position values*	*Model*
Absolute Linear Encoders for Safety-Related Applications	±5 µm ±3 µm	140 mm to 4240 mm	-	EnDat 2.2/22	✚LC 115 ✚LC 195 S
Absolute position measurement • Glass scale	±5 µm ±3 µm	140 mm to 4240 mm	-	EnDat 2.2/22 DQ 01 Fanuc 05 Mit 03-04	✚LC 115 ✚LC 185 ✚LC 195 S ✚LC 195 F ✚LC 195 M
Absolute position measurement for large measuring lengths • Steel scale tape	±5 µm	4240 mm to 28040 mm	- 1 V_{pp}; 40 µm	EnDat 2.2/22 EnDat 2.2/02	✚LC 211 ✚LC 281
Incremental linear measurement with very high repeatability • Steel scale • Small signal period	±3 µm ±2 µm	140 mm to 1240 mm	1 V_{pp}; 4 µm	-	✚LF 185

V. CONCLUSIONS

By comparing the experiment and the simulation, result a strong dependence between temperature distribution and ball screw displacement from 0 position to existing speeds in motion cycles.

Critical are the short cycles which occur for example in small pieces milling and lead to strong local ball screw warming.

Local movement are not linear as happens with other manufacturing processes.

Also we can discuss about numerous heat sources that influence the production process and CNC machine, especially in the cutting process .

Besides an increase in heat generation due to stronger application of each component of the machine, CNC are influenced mainly by the cutting process itself.

The heat generated at cutting is headed through tool, through piece and through splinters, which leads to the thermal influence of the other parts of the machine.

In case of long processing times, the heat that is released on cutting process can lead to a significant warming of workpiece. For the workpiece that was taken as example it appeared at onshore processing a heat increase until 39° C. The table had an independent increasing heat compared to workpiece temperature, because of direct contact with piece.
Cutting experiments show that toward empty operating, machine behavior is modified because of hot splinters and high load on the main bearing (due greater processing forces).
In addition to heating the machine, also workpiece heating had a significant influence on thermal deviations for worpiece dimensions

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