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PROTOTYPE STAND FOR TESTING THE PRECISION OF POSITIONING USING KINEMATIC CHAINS OPERATED BY AC SYNCHRONOUS MOTORS

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Rezumat. *Lucrarea constă în proiectarea şi construcția unui stand prototip pentru testarea preciziei de poziționare a lanțurilor cinematice acționate cu motoare electrice sincrone de curent alternativ. Acest dispozitiv are la bază o masă rotativă în două axe, A şi C, cu comandă numerică. Pentru determinarea preciziei de poziționare standul se va monta pe masa de lucru a unui centru de prelucrare prin frezare în 3 axe şi se va prelucra o piesă de probă prin interpolarea celor două axe ale standului. Prin scanarea 3D a piesei de probă obținută se vor obține date despre erorile de prelucrare, respectiv despre precizia de poziționare a arborelui motor.*

Abstract. *The paper consists of designing and building a prototype for testing the precision of positioning using kinematic chains operated by AC synchronous motors. This device is based on a two-axis CNC rotary table, A and C. In order to determine the precision of positioning, the device is mounted on the work table of a milling centre with 3-axis and a sample piece will be processed by interpolating the two axes of the device. By the 3D scanning of the piece the processing errors and the positioning accuracy of the motor shaft will be obtained.*

Keywords: prototype, stand, accuracy, positioning, interpolation.

1. Introduction

High precision machining requires advance kinematic chains with more axes to accurately track the specified contours. The contouring errors usually occur in groups of axes X-Y and A-C (for 5-axis milling machines) [1].

With the increase of demands for precision of operations, several methods were proposed which increase the accuracy of positioning for each axis, separately, through different methods of control.

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A good positioning performance for each individual axis does not guarantee the reduction of contouring errors for a movement system on several axes, and the poor synchronization of the motion of the axes may result in a reduced accuracy of tracking the trajectory [2-6].

To achieve complex trajectories, the interpolation method of motion axes is used. It consists in the continuous movement of 2-axes and their synchronization to achieve a flat or spatial trajectory.

This work aims to design and build a stand prototype for testing the positioning accuracy and kinematic chains operated with AC synchronous electric motors.

2. Description of the Stand

This device is based on a tilting rotary table in 2 axes, A and C, with numerical control and it can be mounted on the workbench of a processing centre by milling in 3 axes, thus turning it into a processing centre by milling in 5 axes.

The stand consists of bed 1 which supports the tilting table 2 with two lateral axes 3, the bearing being made with a deep-groove ball bearing 6207 series for each axis. The bearing of the shaft of the rotary table 4 is made with two single-row conical roller-bearing, 30210 series, mounted in "O". The rotary table is driven by an AC actuator Siemens 5, 1FK7 series, through a belt gearing 6 from HTD series, with a gear ratio of 1: 1. This motion transmission variant was chosen because the space is limited and there is no backlash.

The tilting table is driven by an identical actuator, mounted directly on the shaft of the table, by means of the mounting bracket 7. The displacement lift of the table is $+90^{o}/-90^{o}$.

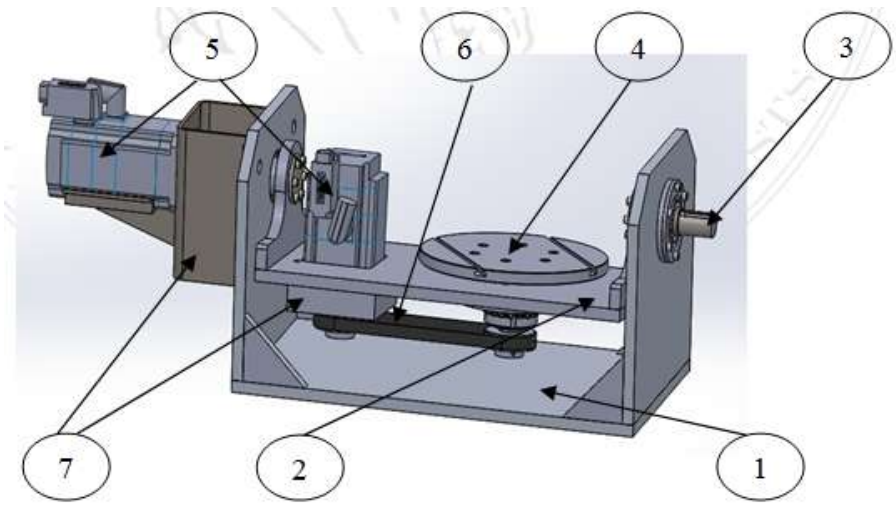

Fig. 1. Components of the stand.

The control equipment for actuators contains:

1. Sinamics S120 converter
2. Simotion D410-2 control unit
3. 5 A Stabilizing source
4. Motor switch

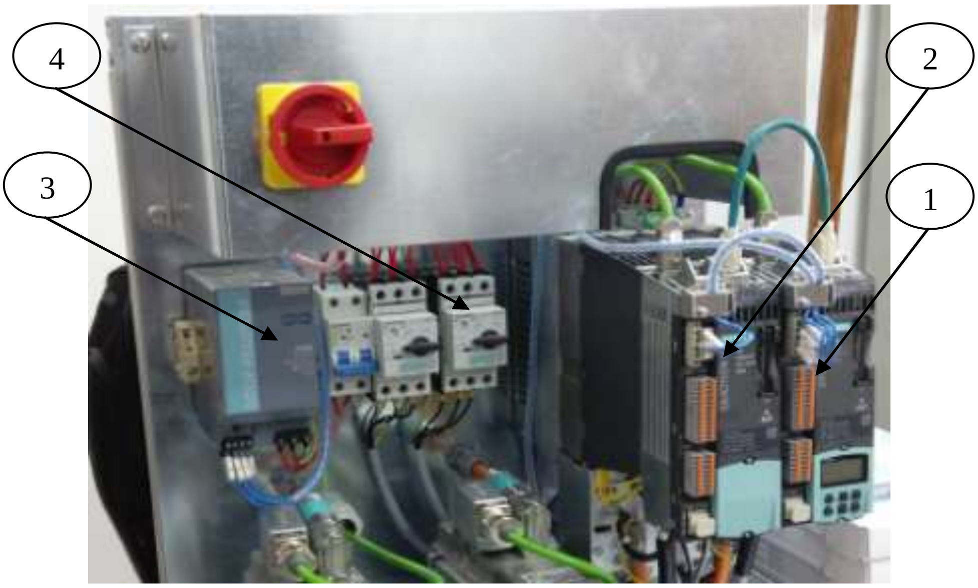

Fig. 2. The control equipment of the stand.

3. Operating Principle

SINAMICS S120 Servo Control is used for precision cyclic processes and at the same time with position control. Together with SIMOTION D410-2 it may control simultaneously two axes of motion, and it can track complex trajectories by interpolation.

The basic functions of the equipment are the speed control, torque and positioning. These can be made using the SIEMENS STARTER software.

This software imports data from the converter and offers the opportunity to achieve a faster parameterization for the desired process. The set points and the actual values can be tracked in real time.

- **Setting the time of acceleration / deceleration**

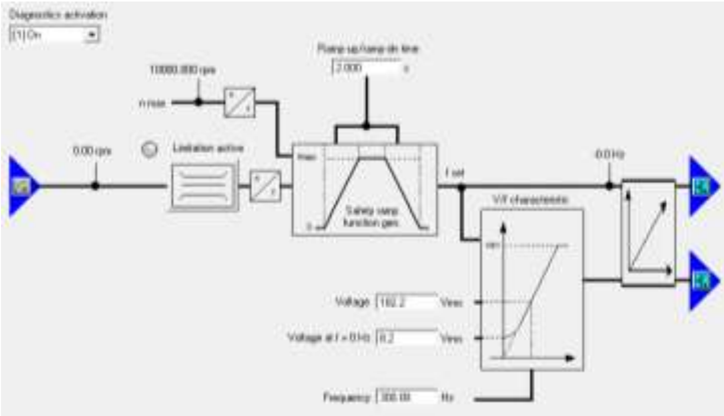

Fig. 3. Setting the time of acceleration / deceleration.

In the menu "V/f control" the acceleration and deceleration time can be changed. The set time will be the same for acceleration and deceleration.

- **Setting the speed**

For speed setting it activates the menu "V / f control" → "Limitation active". On "n_max" is set the maximum speed with which we want the motor to work. These settings prevent the use of the motor at a speed higher than the allowed one.

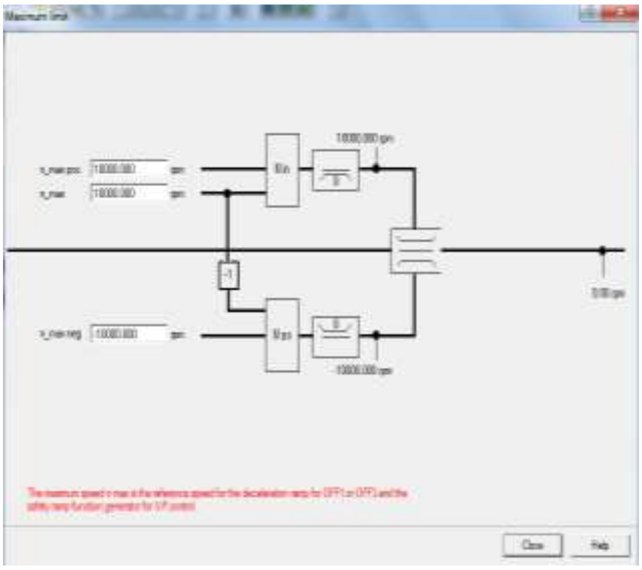

Fig. 4. Setting the speed.

- **Setting the position using the "traversing blocks" method**

The position can be controlled by closed loop, setting the lift limit or by setting the traversing blocks (for each block the position, speed, acceleration and deceleration can be set; maximum 64 blocks).

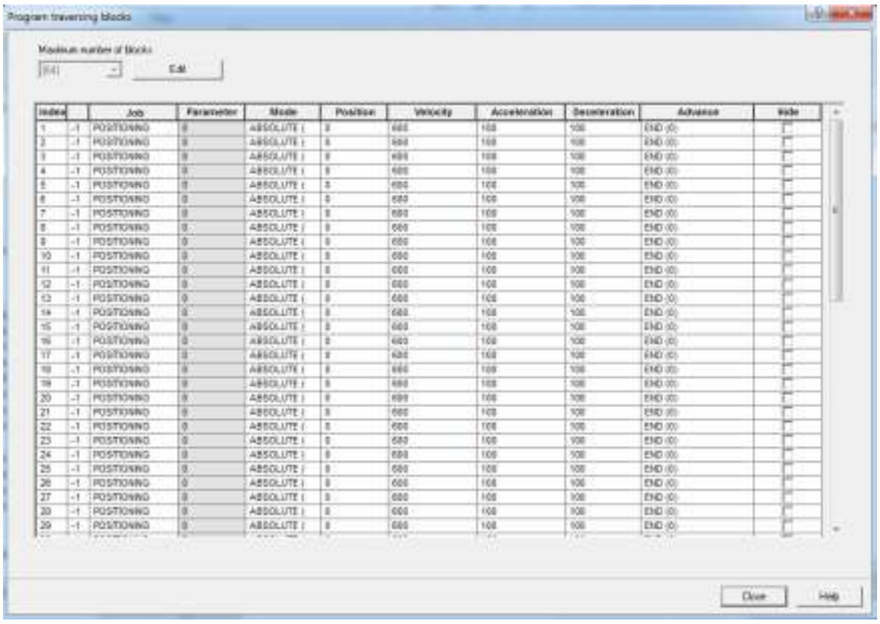

Fig. 5. Setting the position using the "traversing blocks" method.

For more advanced control the DCC module of the SIEMENS STARTER software is used. The Drive Control Chart (DCC) means the graphic configuration and the extension of the functionality of the device, using computing and control logic blocks. The graphical editor for the control of functions in open loop and in closed loop can be operated without programming skills. The functionality control of the closed and opened loop is defined by the use of several logical blocks from a predefined library (DCB library) which are selected and connected by dragging and dropping. Testing and diagnostic functions allow the verification of the behaviour or the identification of causes in case of errors.

4. Evaluation of the Positioning Accuracy of the Motor

To determine the positioning accuracy, the stand will be mounted on the workbench of a processing centre by 3-axis milling and a test piece NAS 979 will be processed of aluminium alloy in two stages, roughing and finishing.

Fig. 6. Test piece NAS 979.

Measurement of the test piece can be done by:

- **3D scanning**

By the 3D scanning of the test piece obtained, it will get data on processing errors, respectively on the positioning accuracy of the motor shaft. The interpretation of results will be done using the GOM Inspect software.

- **Measuring made with coordinate measuring machine**

Circularity error

According to the definition, the deviation from circularity is a deviation from the nominal profile of the piece and is defined as the distance between the actual profile of the cross-section, resulted from the junction of the piece of revolution with a plan, and the adjacent circle of the same section, drawn from the outside of the work piece material.

For the test piece we will determine the difference between the maximum and minimum radius of the points located to an angle of 30° on the measuring circle, the centring being performed in relation to the axis of rotation.

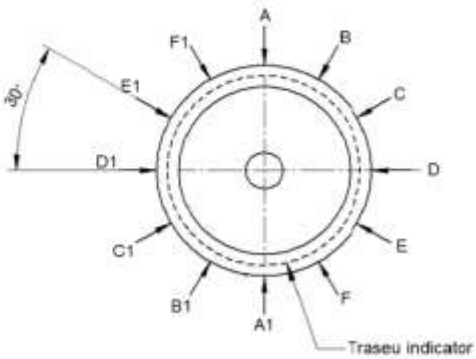

Fig. 7. Measurement scheme of circularity.

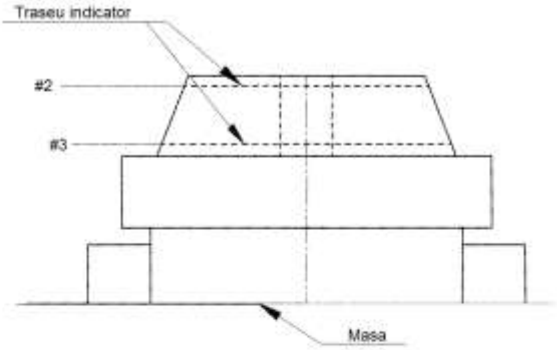

Fig. 8. Verification scheme of the tilt angle.

Checking the tilt angle

The deviation from the tilt of two lines or of two rotation surfaces is equal to the difference, measured within the reference length between the angle formed by the adjacent lines to the actual profiles, respectively by the axes of adjacent rotation surfaces and the nominal angle.

Checking the tilt angle is done from the same clamping of the piece on the coordinate measuring machine table, according to the scheme presented in picture 8 [7].

Conclusions

Achieving the purpose of the **stand prototype for testing the positioning accuracy and of the kinematic chains operated with AC synchronous electrical motors** involves 3 phases of research:

- execution and testing of the table's stand
- machine tool preparation and its testing in order to equip with 5 simultaneous axes;
- integration of these two parties and processing technology implementation in the five axes machining concept.

Of all the above mentioned phases, the first is the one that refers to the objective of this research, respectively the implementation of the test device.

The second phase is conducted at Politehnica University of Bucharest, the Faculty of Engineering and Management of Technological Systems being equipped with an MCV 300 processing centre.

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