PRECISE ROTARY TABLE INDEXING SYSTEM USED ON MILLING MACHINING CENTRES

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Abstract: Growing performance demands in the mechanical manufacturing field have lead to a great development of the machine tools domain, regarding especially the productivity and the manufacturing precision. When equipping a machine tool with an automatic tool changer and an automatic pallet mechanism, the obtained result is a machining center. For small series products, milling machining centers fulfill the precision and productivity requirements, through the advantages of a reduced auxiliary time and reduced operating errors. This paper presents a new technical solution of the rotary table indexing mechanism used on milling machining centers, which offers a very high positioning precision, by using a curvic coupling and a hydraulically driven table clamp/unclamp mechanism.

Keywords: machining center, rotary table, indexing system, clamp/unclamp mechanism

1. INTRODUCTION

Recent developments in the machine tools domain are determined by the necessity for new and improved constructive solutions, which are capable of leading to an increased manufacturing precision and productivity of the machine tools [1, 2].

The trends of performance requirements for mechanical manufacturing are characterized by the constantly growing demands for the machine tools positioning precision, the challenge also consisting in the ability to produce mechanical pieces with very high precision and also at reasonable production costs [3].

In order to meet these ambitious demands, it is necessary to find solutions regarding the shortening of the process time, which can be accomplished by increasing the productivity of the manufacturing process, since increasing the precision of the procedures is in many cases limited by the physical principles which underlay these procedures and by the performances of the mechanical part of the machine tool [4].

The machining centers present the advantage of an increased productivity, due to the reduced auxiliary time, through concentrating a higher number of operations needed for changing the workpiece position and avoiding the removal, transport, setting and alignment of the work piece, which in many cases represents the source of many errors [5].

Another main advantage is represented by the increased machining accuracy, achieved through eliminating the errors caused by setting the work piece on the machine tool table, by a human operator. These advantages are made obvious when having to produce single or small series workpieces, which require several and complex operations. In this context, an important role in accomplishing a high positioning precision and productivity is

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held by the machine tool table as part of the machining center. In the past decades, the demand of productivity and accuracy of work pieces is being fulfilled by milling machining centers, which consist of linear and rotary feed axes. Regarding the rotary axis, there are a number of features such as backlash, rotational fluctuation, stiffness etc. that affect the positioning precision [6].

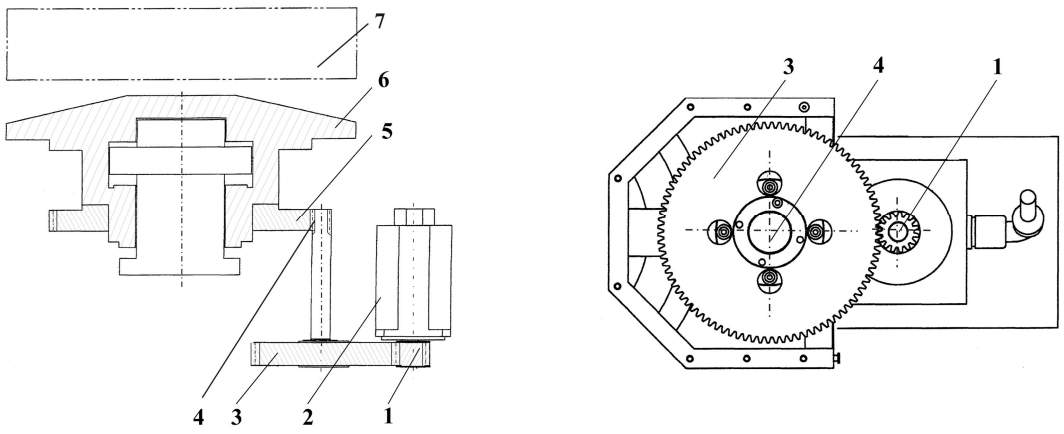
The subject of this paper is a technical solution of a precise rotary table indexing system used on milling machining centers, which represents a critical element in the rotary axis structure. In this solution, a high precision curvic coupling, with a 1º minimum indexing angle and a hydraulically driven table clamp/unclamp mechanism is used.

2. MECHANICAL STRUCTURE OF THE ROTARY TABLE INDEXING MECHANISM

The table indexing mechanism has the main purpose of ensuring the relative angular position of the workpiece set on the machine tool pallet, against the cutting tool tip. The manufacturing precision of the machining center is directly affected by the positioning precision of the rotary axis, given by the indexing mechanism.

As regard to its structure, the table indexing mechanism comprises several main components, beginning with the servomotor 2 - Figure 1, having an attached pulse coder, which monitors the position and speed of the machine tool table. The servomotor transmits the rotation motion over to the curvic coupling, through the gearing systems, composed of gear 1 with gear 3 and gear 4 with gear 5.

The curvic coupling has a precision external toothing, which allows it to interlock with the pinion shaft and rotate the machine tool table. The upper part of the curvic coupling is connected to the rotary support 6, and the bottom part is connected to the machine tool frame. The curvic coupling used in this technical solution meets the need for the highest accuracy at maximum load capacity, after the pallet 7 and workpiece were set and locked on the table rotary support. The curvic design of the coupling has the major advantage of ensuring a precise, low weight and compact connection, in which the curvic toothing shape facilitates the self-centering of the coupling, thus increasing the indexing precision of the machine tool table, under high loadings.



a. b.

Fig. 1. General structure of the rotary table: a. block-scheme of the driving mechanism; b. bottom view of the driving mechanism.

3. FUNCTIONING PRINCIPLE OF THE ROTARY TABLE INDEXING MECHANISM

3.1 Table unclamp and indexing mechanism

A top view of the rotary table is presented in Figure 2a, which emphasizes the four positioning cones used for centering and clamping the pallet on the machine tool table. A partial view of the rotary table, focused on the table unclamp mechanism is presented in Figure 2b. The sequence of operations for unclamping and indexing the rotary table has the following order: when the machine controller gives the table unclamping command, the

solenoid valve 5 is de-energized, changing its position from a to b. The hydraulic oil driven from the hydraulic unit 7 enters area "A" of the hydraulic cylinder, determining the rotary support 2 to move upward and the curvic semi-coupling 3 also moves upward. As a result, the curvic semi-couplings 3 and 8 disengage, the proximity switch detects the table unclamp and sends a signal to the machine controller, which confirms the completion of table unclamping. Next, a command signal is being sent to the servomotor which drives the kinematic chain, to index the machine tool table in the required position, by rotating the pinion shaft 4, which is engaged with the external toothing of the curvic coupling. The check valve 6 keeps the pressure level in area A and prevents the hydraulic oil from leaking back to the hydraulic unit in case of power failure. The speed and position of the rotary table are monitored by a pulse coder, ensuring a 2" positioning precision and a mean repeatability of 1", for a minimum indexing angle of 1º.

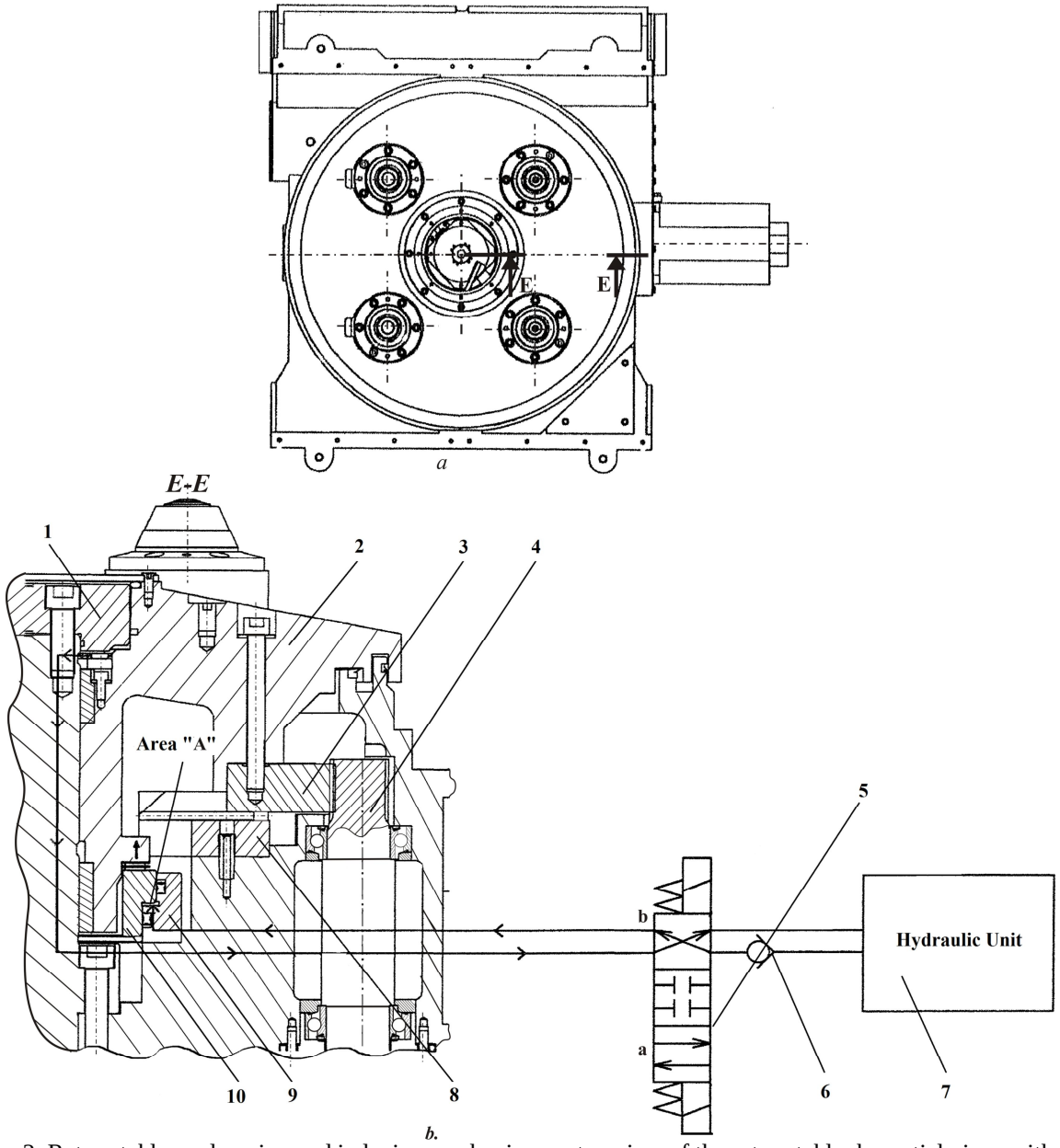


Fig. 2. Rotary table unclamping and indexing mechanism: a. top view of the rotary table; b. partial view, with the E-E plane.

3.2 Table clamp mechanism

During the manufacturing process, the rotary kinematic feed chain needs to execute several angular positioning displacements in order to provide the required position of the workpiece, relative to the cutting tool tip, specified in the worpiece manufacturing programme.

In Figure 3 it is represented the table clamp mechanism, which secures (clamps) the rotary support 2. The table clamping and unclamping are performed by hydraulic pressure, provided by the machine hydraulic unit 7, the same used for the pallet clamp and unclamp operations. The completions of these operations are confirmed by two pressure switches, which send appropriate signals to the machine tool controller.

When the table clamping is commanded, the solenoid valve 5 is de-energized, changing its position from *b* to *a*.. The hydraulic oil supplied by the hydraulic unit 7 enters area "B" of the cylinder 9, which causes the rotary support 2 to move downward by hydraulic pressure and curvic semi-coupling 3 also moves downward. Consequently, the curvic semi-couplings 3 and 8 are engaged and a proximity switch detects the table clamp, sending the signal to the machine controller, which confirms the completion of the table clamping. The check valve 6 has the purpose of maintaining an adequate pressure level in case of machine tool power failure, preventing the oil from leaking back to the hydraulic unit and accidentally unclamping the table.

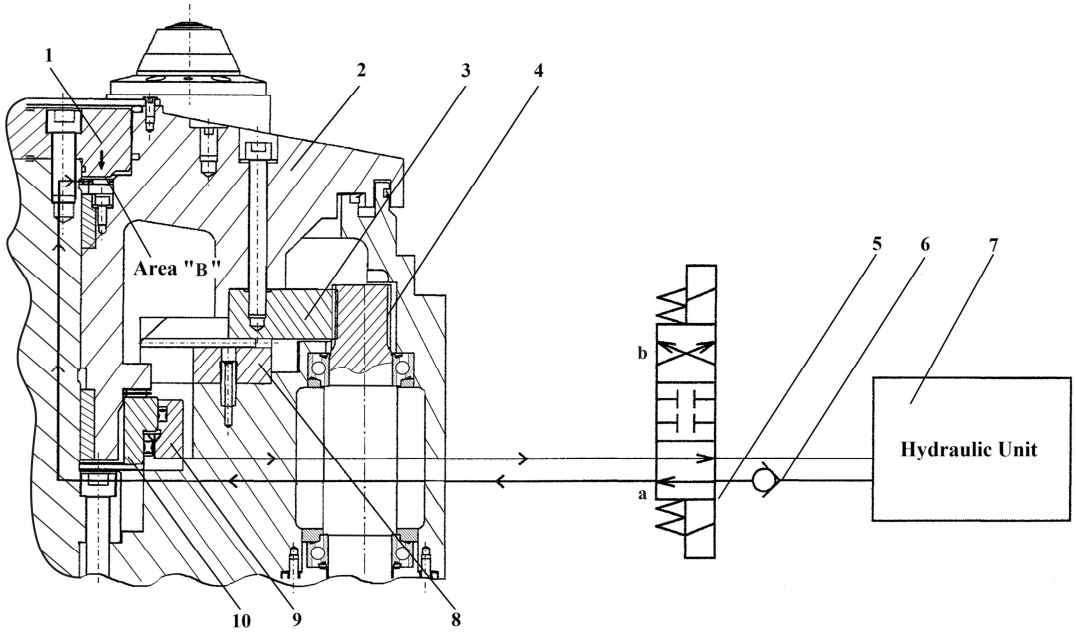


Fig. 3. Structure of the table clamp mechanism.

4. CONCLUSIONS

Equipping the numerically controlled machine tools with automatic tool changers and automatic pallet changers has lead to the development of machining centers, which include linear and rotary feed axes in their structure.

In this paper, a precise rotary table indexing and clamping/unclamping system was presented, which plays a very important role in obtaining a high manufacturing precision of the machining center. The indexing mechanism of the rotary table offers a high positioning precision and also a high repeatability, by making use of a precise curvic coupling in the mechanism's structure, which has a minimum indexing angle of one degree. Also, the gears and the pinion shaft used in the transmission system are manufactured in a high accuracy class.

Together with the machine's paletting system, this technical solution significantly reduces the auxiliary time of the manufacturing process and also the errors caused by setting the workpiece on the machine tool table. The table clamp/unclamp mechanism is hydraulically driven, ensuring a fast and accurate table position. The hydraulic unit used for the table clamping and unclamping operations is the same used for securing and releasing the pallet on the machine tool table, leading to a more compact design of the machining center.

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