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DESIGN SOLUTION OF ROTARY TILTING TABLE FOR FIVE AXES MACHINING

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***Abstract*—** The paper presents the solution for the feed mechanisms of the rotary-tilting table with a 250 mm diameter that is used in the 5-axis machining centers.

Rotary-tilting table are equipped with synchronous worm gears duplex, timing belts get moving through the actuator drive. Gear ratios of duplex worm gears are 1:40, and timing belts transmission gear ratios is 1:1. For tension timing belts are use the excentric tensioners. Tilting movement servomotor is located on the motherboard of the rotary-tilting table and feed rotary servomotor is located in the tilting axis.

The result is a table with small footprint, low cost, without diminishing performance.

***Keywords*—** rotary-tilting tables; Feed mechanism; 5 axes machining)

I. INTRODUCTION

The project was performed under research contract nr.7037/10.05.2011 with the goal of achieving a family of rotary-tilting tables, used at transforming 3-axis CNC machining centers into 5-axis CNC machining centers.

The rotary feed of these tables must assure the elimination of rotary backlash, elimination of vibrations during processing, high positioning accuracy and high repeatability. In addition, an advance speed of at least 20 RPM [1], [2].

Solving these problems in terms of a minimum required size is a problem that needs to be solved.

II. DESCRIPTION

The solutions adopted for the advance mechanisms of the rotary-tilting tables are based on two main types:

−feed mechanisms with gears, provided with various solutions to remove the backlash;

−torque, or built-in motor mechanisms, which do not have gears, the motor casing being in the frame of the rotary table.

Choosing a solution for the rotary feed mechanism was made taking into account both functionality and the associated costs. The Direct Drive solution with built-in motors, which although are recommended for these applications due to its functionality an reliability, was abandoned because of the high cost [7] [8], [9], [10].

Ensuring a high operating accuracy even under a considerably lower reliability, but with lower cost lead to equipping the rotary-tilting table family with duplex worm gears feed mechanisms [3] [4] [5], [6].

The kinematic schematic diagram of the rotary-tilting table is presented in Fig.1.

To ensure a balanced load of the rotary feed mechanisms, two synchronously operated worm gears were used.

During the rotation of the table, due to the use of a gear provided with a worm wheel and two diametrically opposite wheels, to ensure the movement, the wheels will rotate in the opposite direction.

This can be done using a gear with spur gears and a transmission with a toothed belt, as in Fig 2.

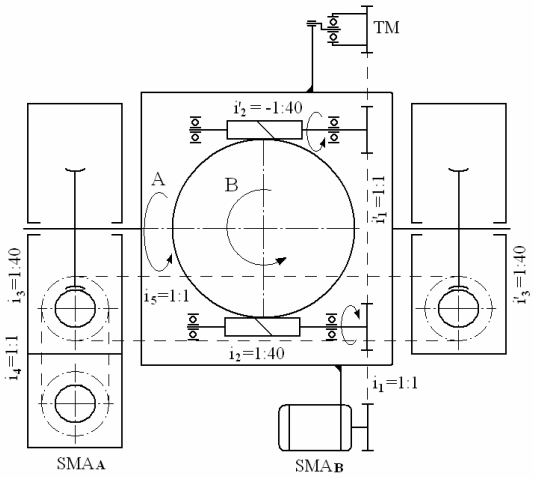

Fig.1.Kinematic schematic diagram of the rotary-tilting table family RTT-5

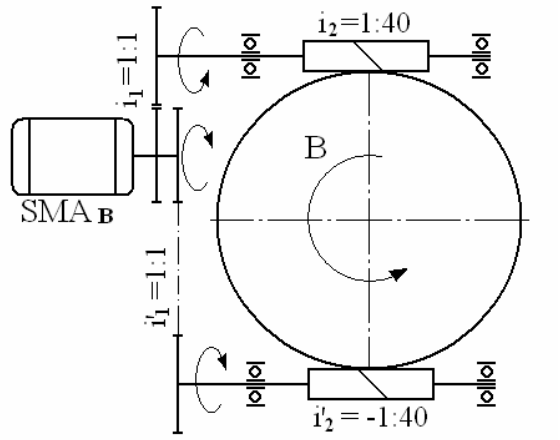

Fig.2.The kinematic schematic diagram for the spur gears and the toothed transmission belt.

Removing the backlash when changing the direction in the case of the spur gears is difficult and expensive. For this reason, the solution of driving the two worm gears with a single toothed belt was chosen [12], as shown in Fig.1. For this purpose, a synchronous twin toothed belt was used, manufactured by the Gates company. (Fig.3).

Fig.3.TWIN POWER BELT – synchronous toothed belt.

The rotary-tilting table with 250 mm table diameter has the goal of equipping the 5-axis machining centers with the possibility of processing sculptural profiles. For this purpose, a rotary-tilting table with the following characteristics was realized:

–Table diameter	250 (mm)
–Maximum shelf rotation speed	75 (rot/min)
–Maximum torque at the worm gear	420 (Nm)
–Positive tilt angle	135°
–Negative tilt angle	10°

In order to increase the tilt angle in the conditions of low height of the table, a solution with an SMS_B servomotor was adopted, placed coaxially with the tilt axis B, as shown in Fig.4.

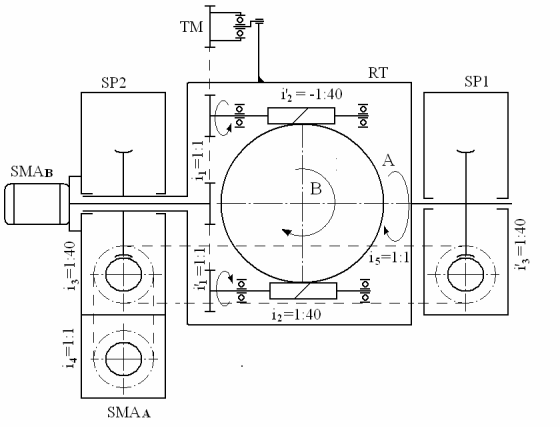

Fig.4.Kinematic shematic diagram of the rotary-tilting table RTT-5 with 250 mm shelf diameter

The design of the rotary-tilting table is presented in Fig.5, where the positioning of the tilting servomotor SMA_A and the rotary servomotor SMA_B can be observed.

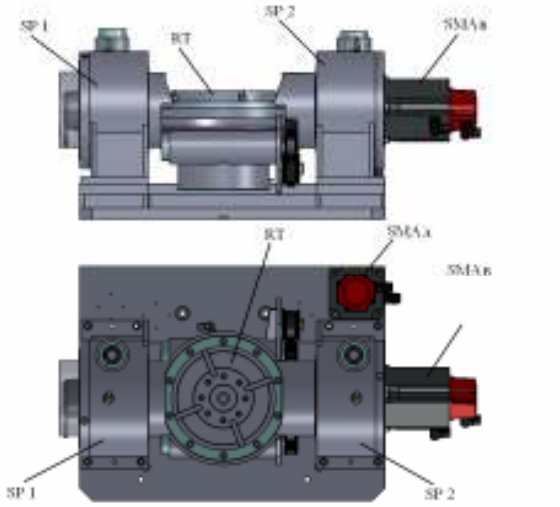

Fig.5.Rotary-tilting table RTT-5 with 250 mm shelf diameter

As shown, the SMA_A servomotor is placed on the base plate.

The circular tilting movement is taken from the SMA_A servomotor through a synchronous belt, and transmitted to the duplex worm gears, positioned on both sides of the table shelf, and has the role of tilting the RT rotary table around the SP1 and SP2 swivels. The SMA_B servomotor, placed coaxially with the B rotation axis, generates a continuous rotary movement of the RT table.

From the servomotors, to the worm gears, the movement is transmitted through synchronous toothed belts with a gear ratio of i=1:1
thus:

$$i_4=i_5=1:1$$

The circular rotary movement of the shelf is taken from the servomotor SMA_B through a synchronous TWIN belt, and transmitted to the duplex worm gears. The gear ratio of the synchronous TWIN toothed belt transmission is also i=1:1
thus:

$$i_1=i'_1=1:1$$

Duplex worm gears by STIMIN company were chosen, having the following characteristics:

TABLE I

WORM GEAR	Size	40	WORM WHEEL	40
	Distance between axes	104		104
	Gear ratio	1:40		1:40
	Direction	Right		Right
	Pitch diameter	48		160
	Number of teeth	1		40
	Diametral coefficient	12		12
	Module	4		4
	Large step of worm screw	12,816		12,816
	Small step of the worm screw	12,315		12,315

Gear ratio of the spur:

$$i_2=-i'_2=i_3=-i'_3=1:40$$

the maximum speed of the servomotors is calculated:

$$i_2=n_p/n_{max} \quad (1)$$
$$n_{max}=i_2 \cdot n_p \quad (2)$$

n_p-the rotary speed of the shelf [rot/min]
n_{max}-maximum speed of the servomotor [rot/min]

$$n_{max}=40 \cdot 75=3000$$

For the drive, the following servomotors were chosen: Ais12/3000 A06B-0078-B203 manufactured by the firm Fanuc (Fig.6), with the following characteristics [11]:
- nominal power.....2,8 (kW)
- torque.....12 (Nm)
- maxumum speed.....3000 (rot/min).

Verifying the motor torque is done with the relation

$$T_{max}= i_2\ Tm_{max} \quad (3)$$

T_{max}-maximum torque at the rotary table, given by the motor
Tm_{max}-maximum torque of the driving servomotor SMA

$$T_{max}= 40\ 12=480 \text{ (Nm)}$$

The SMA servomotors ensure a torque that covers the maximum required at the rotary-tilting table (400Nm).

Fig.6.Servomotor Ais12/3000 A06B-0078-B203

In the kinematic schematic diagram in Fig. 7 the path of the belt required to ensure the opposite direction rotation of the two worm gears is presented.

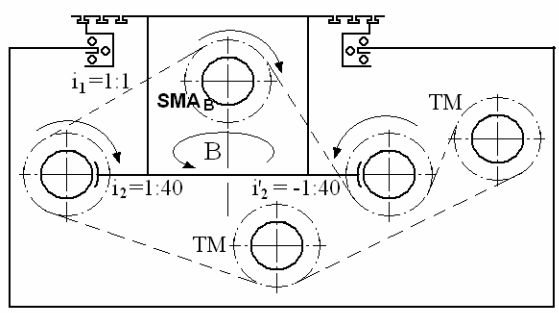

Fig.7.Kinematic drive schematics of the worm gears at table rotation.

The design for the synchronous toothed belt transmission at axis A is shown in Fig.8 and for axis B in Fig.9.

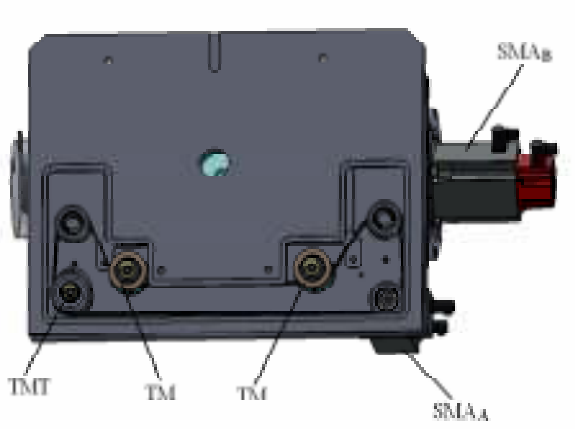

Fig.8.The synchronous transmition solution at the tilting axis.

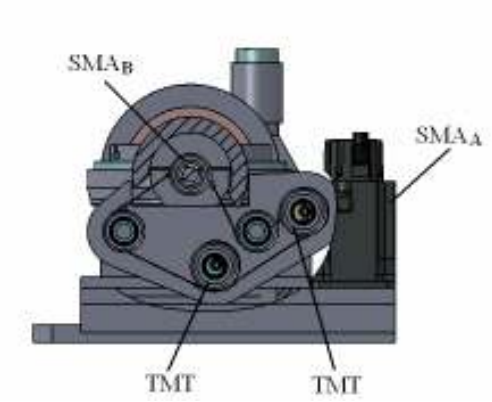

Fig.9.The synchronous transmition solution at the continuous rotation axis.

The TIM and TMT tensioners are excentric tensioners, used both to draw the path of the toothed belt, and to stretch the belt to the value set by the manufacturer.

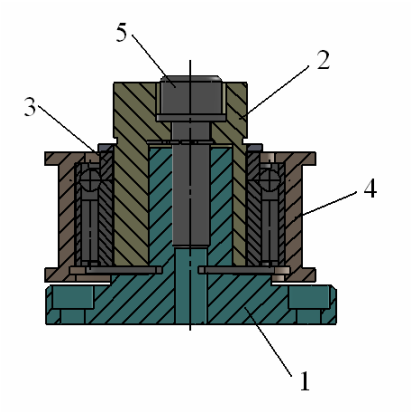

Fig.10.Eccentric tensioner.

This version was chosen because it has a small size and is stiff. They are made of body 1, eccentric 2, which is rotated by roller 4 hold in position with the axial bearing. Blocking is done with screw 5. Two types of rollers are used, as shown in Fig.11

a b

Fig.11.Tensioner rolls

TMT tensioner will be used, when the contact of the roller with the belt is on the teeth, the roller used will be toothed (Fig.11a), respectively TM tensioner is used if the the roll is in contact with the smooth side of the belt, the tensioner being equipped with smooth roller.

III. CONCLUSIONS

Drive solution applied to the rotary-tilting table with 250 mm table diamater is suitable for equipping 5-axis CNC machining centers, having a high advance speed, and elimination of reversing backlash. A large tilt angle is achieved, so the range of applications of the rotary table may also satisfy the processing of sculptural surfaces. Reduction of costs were taken into account, without diminishing the performance of the table.

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