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Research on the design of the device for face milling, slotting, center drilling and chamfering equipment for roller shafts

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ABSTRACT :*This article presents a part of the results of research on the design of an automatic device for face milling – center drilling – slotting for roller shafts with the diameter from 20 mm to 40 mm and the length from 250 mm to 1,200 mm, with the requirements of face milling and slotting of the groove of shaft end, then flipping the workpiece 180^o to mill the other groove symmetrically, finally drilling the two center ends and simultaneously chamfering the two shaft ends. The author group have analyzed and selected the design of device to machine the roller shaft on one installation. The results of this study have successfully selected the design with suitable layout of machine heads to machine the roller shaft with the length varying from 250 mm to 1,200 mm and the machining diameter from 20 mm and 40 mm to ensure technical requirements and economic efficiency*

KEYWORDS: *Spot facing and centering lathe, machine tool, pneumatic clamping system*.

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I. INTRODUCTION

In fact, the roller shafts are used a lot in conveyor lines. This type of shaft often has different requirements in terms of length, diameter and grooves on the shaft [13]. In order to machine a complete shaft, it is often necessary to perform many operations, leading to low productivity and low economic efficiency. Currently, spot facing and centering lathes have been widely used in the machine building industry to machine axial parts in preparation for the next operation [9] [10] [11]. However, this device only performs two operations: post facing and center drilling. Therefore, this is a limitation to be studied to add more operations: slotting and chamfering of the shaft end. Stemming from practice, for a machining piece, there are often different requirements for length, diameter, groove depth, groove width and center hole on the two shaft ends [13]. The problem is to choose the design plan and arrange the appropriate machine heads so that the running time without cutting is the shortest, saving the time to finish a product. In addition, the workpiece flipping mechanism when cutting grooves is an issue to be studied to ensure the parallelism of the two groove bottoms after the completion of machining. Thus, the research on the design of the device for face milling, slotting, center drilling and chamfering equipment for roller shafts with different sizes in terms of length, diameter, groove depth, groove width and center on the two shaft ends ensures technical requirements of high practical significance, improving productivity and economic efficiency.

II. RESEARCHING THE LAYOUT PLAN OF MACHINE HEAD

2.1. Surveying the technical requirements of workpiece

Through detailed drawing analysis, it can be seen that we perform the following operations in order to perform roller shaft machining: Face milling and center drilling at both ends – Slotting with a width of 8 mm and reaching a size of 14 mm (Figure 1). Thus, the machining on universal machine will be performed on two machines with two operators, leading to an increase in labor force to operate the machine and a prolonged time for finishing a product, making low productivity, high cost of finished product and no economic efficiency [13].

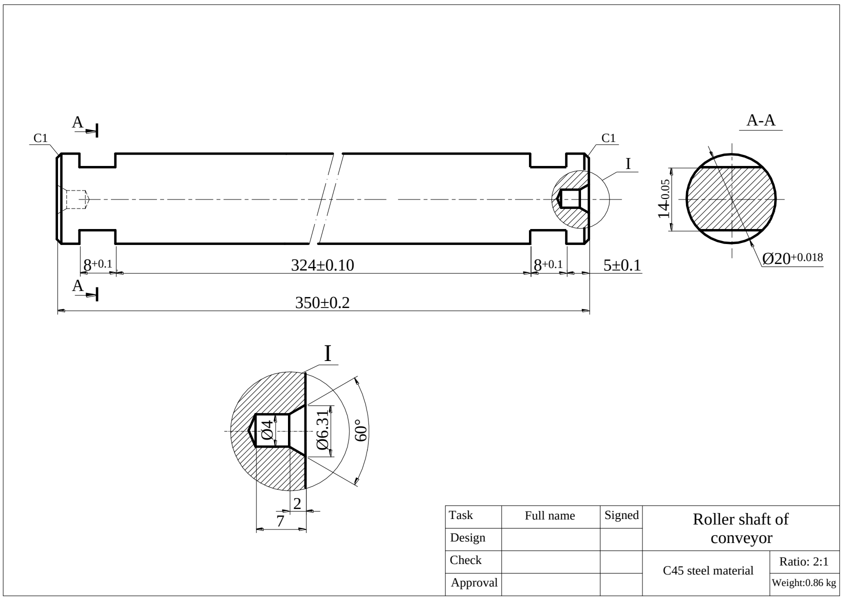

Figure 1. Detailed drawing of machining for a type of roller shaft

The problem here is to find a device design to perform all the machining steps on one machine such as face milling – center drilling – shaft chamfering – slotting to reduce extra time and operators, increasing labor productivity and economic efficiency.

Currently, some factories have used this combined device to machine roller shafts. However, these devices only stop at the combination of face milling and center drilling operations without any device combining slotting on the shaft with chamfering of the shaft end. This is the basis to research and find solutions to design a device meeting the requirements of the business such as face milling – slotting – center drilling – chamfering of the shafts to free up the operators, increase productivity and reduce the product costs.

2.2. Design plan for the layout of machine heads.

Based on the technical requirements of the drawings, the research team have analyzed and determined the machining steps including face milling – slotting – center drilling – chamfering. From that basis, proceed to develop appropriate machine head layout plans for each detailed machining step as shown in Figure 1 [1] [2] [3].

The general requirement of conveyor roller shaft machining device is to perform machining in one feed. Thus, the input is the workpiece and the output is the finished workpiece. Therefore, the machine heads must be arranged in accordance with each operation. Based on the cutting principle and the structure of machine head, the authors offer a number of layout plans as follows [4] [5] [6]:

* Option 1.

Arrange six machining machine heads in three stages, including: 1 – Face milling with a face milling cutter; 2 – Slotting with a disc milling cutter; 3 – Center drilling and chamfering of the shaft end. The machine head is arranged so that each stage has two machine headssimultaneously cutting both ends of the roller shaft. In this option, in the second stage, we use a horizontal machine head with two main shafts attaching two upper and lower disc milling cutters to cut and create two upper and lower grooves on each side of the shaft (Figure 2).

* Option 2.

Similar to option 1, the machine heads are arranged to machine in three stages, including: 1 – Face milling; 2 – Slotting; 3 – Center drilling and chamfering. However, in thesecond stage, we use a vertical machine head with two main shafts attaching two upper and lower cylindrical milling cutters to cut and create two upper and lower grooves on each side of the shaft (Figure 3).

* Option 3.

In this option, the device is arranged with six machining machine heads in three stages, including: 1 – Face milling; 2 – Slotting; 3 – Center drilling and chamfering. However, in the second stage, we use a vertical machine head with a main shaft attaching a cylindrical milling cutter to machine the first groove, then flip the workpiece 180^{o} to machine the symmetrical groove (Figure 4).

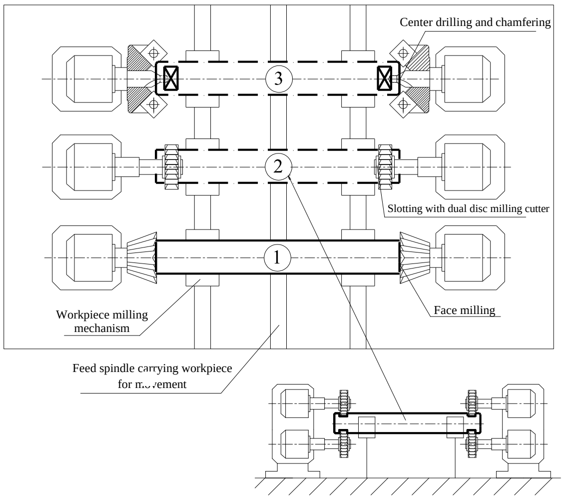

Figure 2. Arranging the machine head in accordance with Option 1

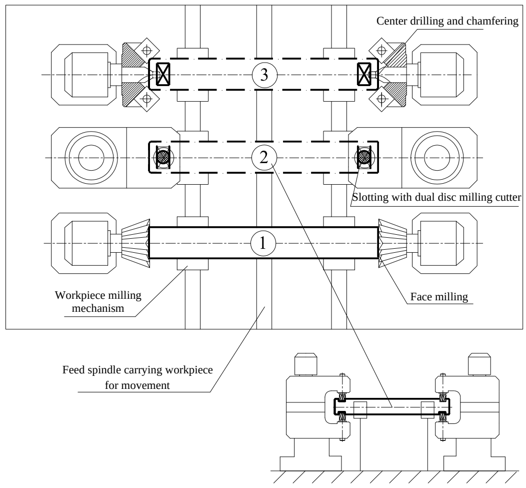

Figure 3. Arranging the machine head in accordance with Option 2

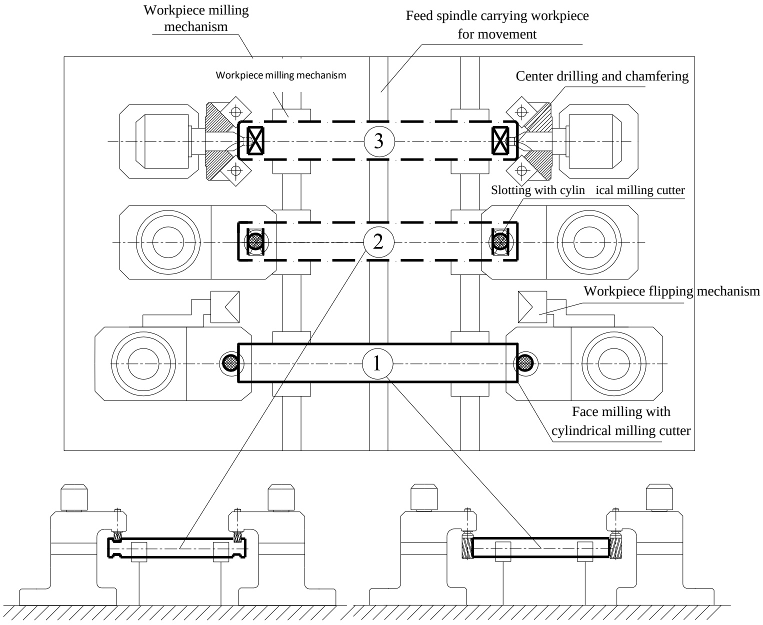

Figure 4. Arranging the machine head in accordance with Option 3

With the above 3 options, we draw some observations as follows:

- In options 1 and 2: The layout of a machine head with two main shafts to cut the upper and lower two grooves of the roller shaft will be very complicated. On the other hand, when four cutters simultaneously cut four grooves on two shaft ends, vibration due to large cutting force may occur, which may lead to damage to the cutting tool, poor surface quality and incorrect groove size. In order for the technology system not to vibrate when four cutterscut at the same time, we must use jigs as well as other structures of the machine must be rigid enough. However, the layout of machine head and other structures will be difficult and inappropriate.

For the machine head, it is equipped with a face milling cutter used for milling both ends of the shaft. The feature of milling process is that the cutting process is discontinuous with impact because the cutting edges are arranged evenly on the tool diameter. During the cutting process, the generated cutting force makes the impact occur. If the technological system is not rigid, the vibration will occur, causing the surface quality to be low and the tool life to be reduced. In fact, the face milling cutter is used to machine the surface of large parts for high cutting productivity. However, the machine structure requires high rigidity.

- Option 3: With the roller shaft diameter from 20 mm to 40 mm, the end has a small area, so the use of a cylindrical milling cutter to machine the two ends is perfectly suitable for this operation, because: The feature of cylindrical milling cutter has a twisted cutting edge on the cylinder. During the cutting process, the cutting edges always rest on the machined surface at different positions, making vibration appear not much during the cutting process. Therefore, the technological system does not need to be too large but still ensures its rigidity. On the other hand, with the current tool-making technology, alloy cutting pieces have been installed on the cylindrical helix groove to increase cutting productivity and tool life. During the cutting process, if the cutting edge is worn, we can replace with other cutting edge easily without re-sharpening.

With the slotting operation, it is possible to arrange the machine head attaching a cylindrical milling cutter for slotting then combine with the workpiece rotation mechanism to cut the opposite groove, because: the layout of machine head is simple and convenient in the process of machine adjustment and operation; the dimensions are controlled in the machining process; and the machine has a high stability.

From the above observations, the layout of machine head depends a lot on the cutting ability, the convenience in operation and the structure of machine. Of the options above, the option 3 is the most appropriate. Because the structure of machine meets the requirements of the machining process, such as: being convenient in the process of machine adjustment, limiting vibration during the cutting process, controlling product quality and easy automation during the production, the research team has chosen option 3 to design and build the machine.

III. DESIGNING IN 3D SIMULATION AND SELECTING BASIC TECHNICAL SPECIFICATIONS OF THE DEVICE

After agreeing on the layout plan of machine head, the author group has carried out a 3D design of the structure of machine shown in Figure 5. Technical specifications are shown in Table 1.

- At the face milling operation: Arrange two shaft ends with the face milling cutter. The machine head can be moved in and out to machine different shaft lengths thanks to the sliding table and feed spindle on the machine, and the machine head can be adjusted up and down with different heights so that the cutter stays in the machined surface. The main shaft speed adjustment mechanism is arranged by levers with 12 different speed levels from 125 to 2,500 rpm. It can be said that the machine head used for face milling of two shafts is easy to adjust and convenient in the machining process [1].

- At the slotting operation: Arrange two machine heads attaching cylindrical milling cutter to machine two grooves at two shaft ends simultaneously. The machine head can be can be moved in and out to machine different shaft lengths thanks to the sliding table and feed spindle on the machine, and the machine head can be adjusted up and down to adjust the cutting depth. The main shaft speed adjustment mechanism is arranged by levers with 12 different speed levels from 125 to 2,080 rpm. It can be said that the machine head used for slotting of two shafts is easy to adjust and convenient in the machining process [5].

- At the simultaneous center drilling and shaft chamfering operations: Arrange two machine heads attaching combination cutters including center drill and chamfer milling cutter to simultaneously center and chamfer the two shaft ends. The machine head can be moved in and out to machine with different distances thanks to the system of sliding cylinders and rack bars on the machine, and the machine head can be adjusted up and down to adjust the center of the machine to coincide with the center of the part. The main shaft speed adjustment mechanism is arranged by levers with 12 different speed levels from 125 to 2,080 rpm [6].

The moving workpiece carrying system is designed by ball slide rails and ball nuts and screws, the screw head is fitted with a servo motor with a workpiece carrying speed of 0 ÷ 15,000 mm/min to ensure the rigidity during the cutting movement and the fast movement.

The workpiece clamping system is used by a pneumatic system, automatically clamping through the central controller.

The workpiece flipping system for opposite groove machining is arranged on the machine head to flip the workpiece thanks to the pneumatic mechanism and the pneumatic system through the central controller.

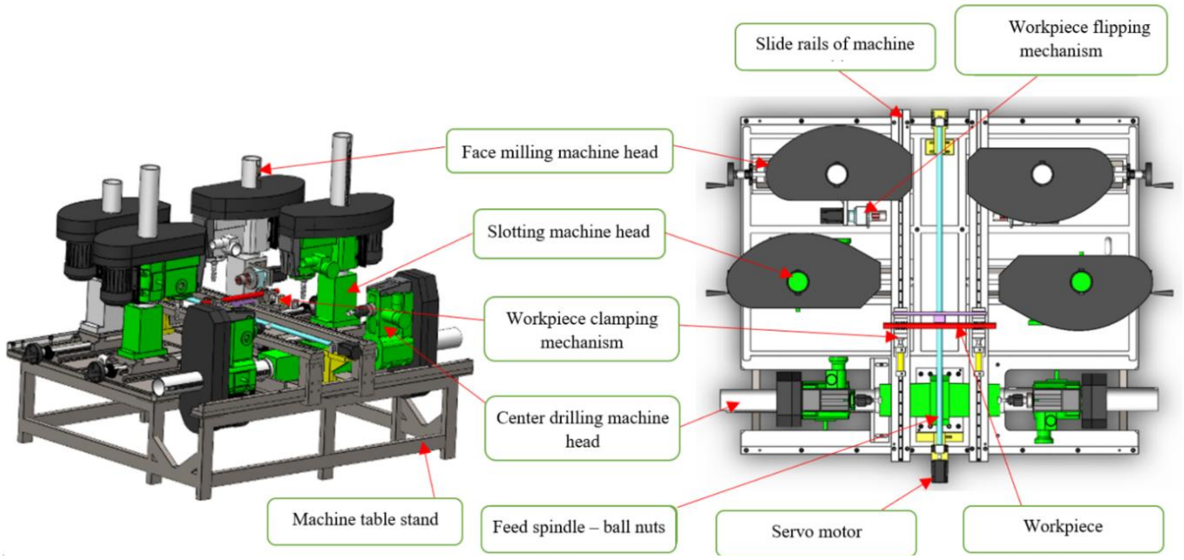

Figure 5. Some 3D design images of the device

Table 1. Specifications of device for face milling – slotting – center drilling & chamfering

No.	Items	Specifications
I	**General parameters of the device**	
1	Dimensions of the machine	2100 × 1800 × 1600 (mm)
2	Operational lighting	In accordance with the general lighting system of the production area
3	Compressed air	Working pressure: 5 bar
4	Safety sensor	There are 3 sensor positions: Workpiece zero point, center drill position and workpiece rotation position
5	Power system	3 phases / 380 V / 50 Hz
6	Control system	Programmable logic controller: Fx3G-60MT/ES and 7-inch HMI control screen
7	Cooling system	Circulating cooling water pump system for the cutting process
8	Product size during machining (mm)	Workpiece diameter: Φ 20 ÷ 40; Workpiece length: 250 ÷ 1200; Maximum face milling dimension: Φ40; Maximum slotting dimension: Φ18; Maximum center drilling dimension: Φ12
II	**Spot facing mechanism**	
9	Main shaft speed for face milling end	125 ÷ 2500 rpm
10	Spot facing engine power	1.5 kW; 50 Hz
11	Main shaft stroke for face milling end	250 mm
12	Main shaft taper	Morse taper No. 3
III	**Slotting mechanism**	
13	Main shaft speed for slotting end	80 ÷ 2080 rpm
14	Slotting engine power	1.1 kW; 50 Hz
15	Main shaft stroke for slotting end	250 mm
16	Main shaft taper	Morse taper No. 3
III	**Center drilling mechanism**	
17	Main shaft speed for center drilling end	80 ÷ 2080 rpm
18	Center drilling engine power	1.1 kW; 50 Hz
19	Main shaft stroke for center drilling end	200 mm
20	Main shaft taper	Morse taper No. 3
IV	**Workpiece clamping table**	
21	Workpiece clamping system	Tightening by pneumatic system
22	Workpiece travel during machining	Moving along the available shaft, stopped at the positions by sensors
23	Actuator for workpiece operation during machining	Using control system + servo motor with workpiece moving speed of 0 ÷ 5000 mm/min.

IV. DEVICE TESTING

After designing and simulating on 3D software, the research team has proceeded to build the detailed drawings and calculate technical parameters for each machine assembly. Carry out machining, assembly, commissioning and calibration of the device. Product machining testing is carried out as follows:

- Trial run time: 48 hours
- Number of machined products: 1,500 workpiece

- Take a trial run for the device with the following 3 specific cases:
  + Using a stable power source to run the workpiece with an average length of 1,000 mm
  + Using a power source with unstable voltage to run the workpiece with an average length of 1,000 mm
  + Turn off the compressed air source to run the workpiece with an average length of 300 mm.

Some test photos are shown in Figure 6.

Figure 6. Some test photos of product machining adjustment process

V. TEST RESULTS

Testing environment: Temperature (25 ± 3)^{o}C, Humidity (60 ± 5) %

Workpiece used: Diameter of 20 mm; 25 mm; 30 mm; 35 mm; 40 mm

No.	Testing items	Number of sampling times with frequency of 15 minutes/time	Average test results	Evaluation standard
1.	Noise while working	04	Being in compliance	QCVN 24:2016/BYT
2.	Ergonomic design	04	Being in compliance	TCVN 7302-1:2007
3.	Control system	04	Working only when being ready	TCVN 7384-1:2010
4.	Mechanical linkage (machine shaft, machine base, workpiece clap)	04	No abnormalities	TCVN 4725:2008
5.	Machining time for a product	20	29.8 seconds	

VI. CONCLUSIONS

This study has analyzed and successfully selected a suitable layout plan of machine head for machining the roller shaft of conveyor. Since then, the simulation has been built on 3D software and the technical specifications for each machine cluster have been selected.

Through the testing process, the device has met the criteria such as working noise, stable mechanical system without abnormalities, stable and ready-to-work control system, and the machining time for a product requiring 30 seconds/product.

The results of this study are used to apply in actual production to reduce the machining time, save labor, and contribute to improvement of economic – technical efficiency of the production process.

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