Enhancing the Performances of the Abrasive Circular by Designing a Pneumatic System for Automatic Control of Workpiece Clamping and Tool Auxiliary Motion

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The paper presents the reconstruction of the factory clamping mechanism for abrasive circular in order to improve the technical characteristics. Reconstruction was done because of the disadvantages of this mechanism in operation. Instead of the mechanical clamping mechanism on the abrasive circular, the newly designed pneumatic clamping mechanism is integrated. The reconstructed work has significantly improved the operation of the abrasive circular. In the previous paper the first solution for the reconstruction of the abrasive circular clamping mechanism was presented. In this paper, the newly designed solution of the clamping mechanism has been improved by enabling the function of automatic motion of the abrasive grinding wheel. Also, the paper has been extended with calculating models of old and new clamping systems and representations of old and new fixture.

Key words: abrasive circular, factory clamp, pneumatic clamp, reconstruction, enhancement

1. INTRODUCTION

The possible division of the maintenance method is given in [1]. According to this division, the reconstruction, in addition to modification, is a basic activity that is carried out in order to improve the technical characteristics of the technical system. Reconstruction of technical systems implies an activity by which it replaces the whole subsets, subsystems and systems with technical solutions that represent the current level of technical development. In modern production there are technological problems due to the obsolescence of the means of production and the development of new products that the existing technological systems are unable to follow. That is the problem with the abrasive circular from the title which was no longer able to respond to the technological requirements of the manufacturing process. In accordance with the new technological requirements it was necessary to reconstruct the given technological system in accordance with production needs. Reconstruction is an activity that improves the technical characteristics of the system. In other words, the reconstruction of te-

chnical systems implies an by which it replaces the whole subsets, subsystems and systems with technical solutions that represent the current level of technical development. Some examples of solving this problem are given in the papers [2-4].

It was concluded that the diagnosed disadvantages can be solved by replacing the existing clamping solution with a pneumatic clamping method. Then the reconstruction of the clamping of the abrasive circular began. First, mechanical clamping was presented. Then a newly-designed solution of the pneumatic clamping method was introduced. The analysis of the reconstruction results, the results and the analysis were presented with the appropriate certificate and tests. The final verification of the reconstruction was confirmed by ten years of exploitation without any problems or delays in operation.

The main products of the company AutoValve J-SC from Užice are valves for internal combustion engines. The valve consists of two parts of different materials (austenitic steel - X53CrMoNiN219 and martensitic steel - X45CrSi93), which are joined together by friction welding [3]. Preparation of the surface of the valve head for connection with the valve body is carried out on the abrasive circular saw.

In its production line the company AutoValve has AC-300 type circular of the FAM manufacturer from Novi Sad. During the exploitation on the circular saw

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some disadvantages were noticed. The cause of these disadvantages was the mechanical clamping of the work piece or the pressure of the leg on the pedal respectively. In order to define the disadvantage of the mechanical clamping mechanism, the substrates placed in the paper [3] are used.

The disadvantages of the mechanical clamping mechanism were identified in the following:

- Gradient cutting surface of the workpiece in the mono variant of the valve due to the imperfection of the clamping system,
- Unbalanced clamping force due to the geometrically irregular shape of the workpiece (bimetallic variant),
- The inability to clamp the bimetallic variant of the valve due to the cone on the neck of the valve (the gradient surfaces appeared which caused further problems in the technological process - bimetal welding), such a piece created problems in the technological process,
- Such a piece created problems in the technological process,

All this led to the fact that this operation has become a bottleneck in production and the cause of a poor quality operation, which further led to poor quality in the technological process. A search for a new solution that would meet the existing technological requirements has begun. While searching for the new solution both the parameters of the machine and the economic justification of the cost-effectiveness of the investment has been taken into account. The designing of new solution was preceded by the reviewing Refs. [5-11].

2. DESCRIPTION OF THE ORIGINAL MECHANISM FOR CLAMPING

Figure 1 shows an abrasive circular design with original (mechanical) clamping mechanism [12].

Main parts of the abrasive circular with factory clamp are: 1 - electric motor, 2 - panel, 3 - console, 4 - axle, 5 - screw, 6 - button for adjusting the pendulum, 7 - button for lifting/lowering the clamp, 8 - clamp, 9 - spring, 10 - pedal, 11 - nut, 12 - plate, 13 - hole, 14 - pan, and 15 - door.

The electric motor (1) is located on the plate (2), which, along with the console (3), rotates around the axle (4). The drive from the electric motor (1) is transmitted by the main shaft using the conveyor belt. The main shaft with the abrasive disc is located on the front part of the console. The screw (6) is used to adjust the final limit to which the pendulum can be lowered. By rotating the screw (7), the movable vise is raised or lowered, which allows the starting position for different diameters to be set. The spring (9) returns the

moving vise to the open position. The workpiece is placed in the vise (8) to the limiter. By pressing the pedal (10) the necessary clamping force is achieved. Then the abrasive disc is started and the workpiece is cut back to the specified dimension. The sparks formed during the cutting process pass through the opening (13) and fall into the pan (14)

Figure 1 - An abrasive circular design with original (mechanical) clamping mechanism [12]

Performance of the abrasive circular are: power of electric motor - 7.5 kW, number of revolutions of electric motor - 1890 o/min, number of revolutions of abrasive grinding wheel - 5100 o/min, diameter of abrasive grinding wheel - $\varnothing 300$ mm and cutting speed i.e. of speed of abrasive grinding wheel 80 m/s.

Figure 2 shows the model of a two-spoke lever at the factory clamping mechanism. It is activated using the leg.

Figure 2 – Model of the lever - factory clamping mechanism

The starting data for the clamping force calculation are:

- leg force, $F_l=150$ N [5],
- the distance between the point of action of the leg force and the sleeve, $L=420$ mm,
- the distance between the location of the action of the clamping force and the sleeve, $l=150$ mm,
- diameter of the sleeve, $r=9$ mm,
- coefficient of friction in the sleeve, $\mu=0.1$ [13].

Based on the static conditions of equilibration, defined leg force and defined geometric relations, the clamping force equals to:

$$F_c = F_n \frac{L - \mu \cdot r}{l - \mu \cdot r}. \quad (1)$$

Replacing the initial data in the expression (1) the clamping force is $F_c = 416.6$ N.

Figure 3 shows an example of an old fixture, which was used on a circular with a factory clamping mechanism.

Figure 3 – Old fixture

3. DESCRIPTION OF THE DESIGNED A PNEUMATIC SYSTEM FOR AUTOMATIC CONTROL OF WORKPIECE CLAMPING AND TOOL AUXILIARY MOTION

In the previous paper [14], the first solution for the reconstruction of the clamping mechanisms in the abrasive circular was given. In other words, this solution is the first step to improve the technical characteristics of the given abrasive circular. In this paper, have designed an advanced clamping mechanism of the abrasive circular, which includes the automatic feeding of the wheel.

The layout of the abrasive circular design with a advanced newly-designed clamping mechanism for the cutting operation is shown in Figure 4.

Main parts of the abrasive circular for newly-designed clamp are: 1 - electric motor, 2 - panel, 3 - console, 4 - axle, 5 - screw, 6 - button for adjusting the pendulum, 7 - pneumatic cylinder, 8 - lever-clamp, 9 - fixture carrier, 10 - limiter fixed carrier, 11 - limiter movable carrier, 12 - limiter, 13 - safety nut, 14 - distributor 3/2, 15 - activation bar, 16 - feed unit, 17 -

back up limit stop switch, 18 - sealed beam limit stop switch, 19 - control unit, and 20 - cock.

In the first phase of designing a new valve clamping solution for the observed technological operation, some solutions of automated clamping systems were considered. Based on the clamping time diagram for different types of clamping, [3], a pneumatic solution with a pneumatic clamp was selected, which was most optimal from the aspect of clamping time.

The newly-designed system of clamping of the workpiece (the valve head) was made so that the existing constructive form of the machine was retained, only the newly-designed clamping mechanism (pneumatic clamp) was integrated instead of the mechanical clamping mechanism.

Figure 5 shows a scheme of the advanced pneumatic system, in relation to the solution in [14].

Figure 4 - Abrasive circular design with newly-designed pneumatic system

The pneumatic clamping device is a set of pneumatic components connected in one whole, which uses compressed air from the industrial network and compressor aggregate to perform its task.

The model of the newly-designed abrasive circular clamping mechanism consists of transformational-pneumatic and transmission-mechanical part. The transformational part of the abrasive circulation clamping mechanism consists of the control unit (2) and (3), the distributors, the linear cylinder (1.1) and the feed unit (1.3) connected in the pneumo-static circuit. The linear cylinder (1.1), the mechanical arm (1.2) and the feed unit (1.3) belong to the portable part of the abrasive circular clamping mechanism. The cycle starts (start) by pressing the handle on the distributor 3/2 (3.2). Since the diaphragm distributor (3.1) is open, the distributor 5/2 (3.5) is activated and thus the left cylinder chamber (1.1) is activated. When the cylinder (1.3) is activated, the left part of the pneumatic scheme is triggered, thereby releasing the distributor 3/2 (2.2) and activating the distributor 4/2 (2.1), which results in the clamping of the working piece (valve). Next, on the

right side of the pneumatic scheme, the piston rod of the cylinder (1.3) activates the membrane distributor (3.3) and connects it to the atmosphere. When the pressure in the diaphragm distributor (3.3) disappears, it is connected to the supply pressure and activates the distributor (3.5) via the double non-return valve (3.6) so that the pressure is obtained by the right side of the cylinder (1.3). All the time the workpiece (valve) is clamped. In the next step, the pressure decreases gradually so that the piston is pulled out and the diaphragm distributor (3.1) connects to the atmosphere. When the cylinder (1.1) and grinding wheel returns to the upper position, then the distributor 3/2 (2.2) is activated, which leads to the release of the valve. The cycle can be stopped at any time by pressing the distributor 3/2 (3.4).

By turning off the right part of the pneumatic scheme, the machine can work with the manual receiving of the wheel. The transformation part of the clamping mechanism of the abrasive circular can be realized by an electromagnetic method and through the final microswitches.

Figure 5 - Scheme of the pneumatic system

As a fixture for the valve clamping operation, the existing worn-out fixture from the friction welding machine manufactured by „Kuka“ was used because it is technologically fit for the operation. Because it was not necessary to construct a new fixture the financial savings were achieved.

Figure 6 shows the model of a two-spoke lever at the newly-designed clamping mechanism. It is activated using the pneumatic cylinder.

The starting data for the clamping force calculation are:

- air pressure in the pneumatic cylinder, $p=0.6$ N/mm²,
- the distance between the point of action of the force in piston rod of the pneumatic cylinder and the point of action of the clamping force, $L= 200$ mm,
- the distance between the point of action of the force in piston rod of the pneumatic cylinder and the sleeve, $l= 110$ mm,
- diameter of the sleeve, $r=6$ mm,
- coefficient of friction in the sleeve, $\mu=0.1$ [13].

The force on the piston rod of the pneumatic cylinder equals to:

$$F_{cr} = p \cdot D^2 \frac{\pi}{4} \eta. \quad (2)$$

Replacing the initial data in the expression (2) the force on the piston rod of the pneumatic cylinder is $F_{cr}=716.283$ N.

Figure 6 – Model of the lever – newly-designed clamp

Based on the static conditions of equilibration, calculated the force on the piston rod of the cylinder and defined geometric relations, the force clamping equals to:

$$F_c = F_{cr} \frac{l - \mu \cdot r}{L - l + \mu \cdot r}. \quad (3)$$

Replacing the force on the piston rod of the pneumatic cylinder (2) and initial data in the expression (3) force clamping is $F_c=864.916$ N.

Figure 7 shows an example of an new fixture, which was used on a circular with a newly-designed clamping mechanism.

Figure 7 – New fixture

4. ANALYSIS AND EVALUATION OF THE DESIGNED A PNEUMATIC SYSTEM FOR CONTROL OF WORKPIECE CLAMPING AND TOOL AUXILIARY MOTION

Reconstruction of the clamping device significantly improved the operation of the device itself. Figure 8 shows the abrasive circular saw after the reconstruction of the clamping mechanism in the execution of the technological operation on the valve. Analyzing the implemented solution, it was established that by using the pneumatic clamp in the technological process in mass, serial and medium series production, a significant decrease in the additional time is achieved.

Figure 8 - Technological operation of the surface of the valve head for connection with the valve body on the abrasive circular saw after reconstruction

Analyzing the expressions (1) and (3) it can be concluded that from the point of view of the utilization of the external force, the case of a lever clamping method in the old solution is more favorable, that is, when the external force acts at the end of the lever. This is true if the the same source of external force is used. The lever model in the old solution was not

suitable for use in the pneumatic clamping system. On the other hand, in terms of the size of the produced external force, the new solution of clamping system is much more favorable. Also, from the aspect of the possibility of maintaining the clamping force constant, a new clamping solution is more favorable.

Besides reducing the additional times, it has been found that the work with the newly-designed clamping device has the following advantages in comparison to the original solution:

- Additional time in mass, serial and medium-serial production is significantly lower,
- Processing accuracy increase,
- Small clamping force is needed without worker's body stress,
- 2.08 times the higher force of the clamping force,
- Constant clamping force,
- A more adequate solution for clamping device,
- Higher efficiency of machine of the machine is achieved,
- Seating work position was obtained from the standing work position,
- Reduction of the processing time resulting in a larger number of finished pieces,
- No physical stress of the worker,
- Quick replacement and positioning of the clamping device,
- Easy and smooth adjusting of the limiter to the desired length of the valve,
- Easy distribution of the clamping force which is particularly important in clamping the thin wall pieces,
- The automatic motion of the abrasive grinding wheel was achieved.

Positive assessment of the performed reconstruction has been confirmed by appropriate tests and approvals.

5. CONCLUSION

By replacing the original clamping solution with a newly-designed clamping solution, the technical characteristics of the abrasive circular saw have been improved. With the finalised reconstruction, the abrasive circular has become a semi-automatic machine, which means the inserting and ejecting of the valves are done only manually. In other words, diagnosed disadvantages in the production process were eliminated. Using a newly-designed clamping system, a number of advantages were obtained. The abrasive circular saw with a newly-designed clamping system responded to the requirements of the technological process in the company Autoventil from Užice. The

appropriate tests and attests first showed that the reconstruction of the circular was successfully performed. Finally, the performance of the reconstruction of the abrasive circular is illustrated by the fact that in the exploitation of more than ten years after the first improvement and two years after the second improvement, there were no registered stalls or congestions caused by the failure of the clamping device.

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REZIME

POBOLŠANJE PERFORMANSI ABRAZIVNOG CIRKULARA PROJEKTOVANJEM PNEUMATSKOG SISTEMA ZA AUTOMATSKO UPRAVLJANJE STEZANJA RADNOG PREDMETA I POMOĆNOG KRETANJA ALATA

U radu je prezentovana rekonstrukcija fabričkog mehanizma za stezanje kod abrazivnog cirkulara u cilju poboljšanja tehničkih karakteristika. Rekonstrukcija je izvršena zbog uočenih slabosti ovog mehanizma u radu. Umesto mehaničkog mehanizma stezanja na abrazivni cirkular je integrisan novoprojektovani pneumatski mehanizam za stezanje. Izvedenom rekonstrukcijom znatno je poboljšan rad abrazivnog cirkulara. U prethodnom radu prikazano je prvo varijantno rešenje rekonstrukcije mehanizma za stezanje abrazivnog cirkulara. U ovom radu je unapređeno novo-projektovano rešenje mehanizma za stezanje tako što je realizovana funkcija automatskog primicanja tocila. Takođe, rad je proširen sa proračunskim modelima starog i novog načina stezanja i prikazima starog i novog alata.

Ključne reči: abrazivni cirkular, fabrički mehanizam, pneumatski mehanizam, rekonstrukcija, poboljšanje