Abstract: This paper describes the process of grinding and polishing of circular stainless steel tubes carried out by special centerless machines. It is a machine used for grinding and polishing of stainless steel tubes made by Surface Engineering, Italian company from Milan. The machine consists of four grinding and three polishing modules.

Key words: centerless, grinding, tube

1. INTRODUCTION

Centerless grinding process differs from other cylindrical grinding processes in that the workpiece is not mechanically constrained. On traditional, old design machines, a workpiece is either held between centers or chucked and rotated against the faster spinning grinding wheel by an external motor usually located in a workhead. Parts made using a centreless process do not require center holes, drivers or workhead fixtures. Instead, the workpiece is supported on its own outer diameter by a work rest blade located between a high speed grinding wheel and a slower speed regulating wheel with a smaller diameter. Centerless grinding is proper for grinding cylindrical tubes and bullion.

2. CENTERLESS GRINDING

Grinding is one of the most significant production operations within final processing, for it provides:
- highly accurate proportions
- high quality of the processed surface.

Most commonly, grinding is subsequent to thermal treatment whereby it eliminates any defects caused by thermal deformations during the thermal treatment.

The type of abrasive, machine performance and selection of the working parameters are of major importance for the final precision and surface quality of the machined components.

Centerless grinding makes it possible to quickly replace the processed parts with those to be processed. There are three main modes of centerless grinding:
1. Through-feed grinding
2. In-feed grinding
3. End-feed grinding.

Figure 1 shows the schematic view of through-feed grinding. [1]

As the figure shows, grinding and regulating wheel rotate in the same direction, a work-rest blade being in between. When centerless grinding is concerned, regulating wheel is usually rotated for \( \alpha \) angle that ranges from 0° to 8°. This provides the occurrence of workpiece horizontal velocity component, therefore the external mechanism for axial motion of the workpiece is needless. Owing to this axial motion, objects processed in such manner can have only circular cross-section which is constant along the whole workpiece.

During the grinding process, number of revolutions of regulating wheel is much smaller than the one of grinding wheel, and this difference regulates the number of revolutions of a workpiece and its axial motion. In order for this mode of operation to be feasible, the machine must be regulated by PLC controller whose role is to adjust both the number of revolutions and the workpiece force on grinding wheel.

During the process of centerless grinding, grinding wheel performs the main rotary motion. Secondary motion is performed by the regulating wheel, it is rotary and it provides longitudinal tube feed. The axis of grinding and regulating wheels can shift from 1 to 10 mm, as related to the axis of the workpiece. The feed of the workpiece can vary according to change in the dip angle \( \alpha \) and periferal velocity of the regulating wheel.

\[
S_{\text{workpiece}} = V_r \cdot \sin \alpha = D_r \cdot \pi \cdot n_r \cdot \sin \alpha \, [\text{mm/min}],
\]

wherein:
- \( S_{\text{workpiece}} \) presents feed of the workpiece
- \( V_r \) – periferal velocity of regulating wheel
- \( \alpha \) – dip angle of the regulating wheel in relation to grinding abrasive wheel
According to the diameter of the workpiece, two parameters of the operation mode are accepted: space between the grinding and regulating wheels, and change in the height of longitudinal work-rest blade. During the tube grinding process on the special centerless machine, grinding wheel is wrapped with changeable abrasive belt which is replaced after being worn out.

The process of centerless belt grinding is utilized for the outer grinding of cylindrical surfaces. It works after the principle of through-feed of the workpiece. Centerless grinding process setup is shown in figure 2.

Centerless grinding is on the increase because it eliminates the operation of centering both ends of the workpiece. The workpiece is completely supported in the grinding zone. That fact permits a higher efficiency of the grinding process.

2.1. Abrasive belt centerless grinding

During the abrasive belt centerless grinding, removal of material is achieved by the grinding head, which consists of the following main components:

- The regulating wheel,
- The contact wheel,
- The idler roll
- The work rest blade and
- Abrasive belt.

The workpiece is supported by an angular rest blade (through-feed support). Work rest blade can be adjusted for different heights, depending on the diameter of the workpiece. The abrasive belt is supported by a serrated rubber or plain-faced contact wheel and an idler wheel. The tension of the abrasive belt is achieved through a pneumatic device. The regulating wheel is placed opposite to the contact wheel. Its role is to ensure the contact between the workpiece and the grinding head. Its position is set under a certain angle to generate an axial feed and workpiece’s rotation. The surface speed of the regulating wheel is usually about 1/20 of the contact wheel speed. [2]

The cutting forces hold the workpiece against the rest blade. The workpiece rotates at the same surface speed as the regulating wheel. The rest blade supports the workpiece and can be adjusted at a proper height relative to the contact wheel.

Outlet of the abrasive belt grinding process is workpiece surface roughness. For the best results of the grinding process, working parameters of the process must be properly determined. The most important working parameters on abrasive belt grinding process are cutting speed, feed rate, contact pressure, contact wheel hardness etc.

Abrasive belt centerless grinding technology offers many advantages. The most important are:

- High feed rates can be utilized, commonly up to 20m/min
- Workpiece is supported both by the regulating wheel and the work rest blade. In this way, cutting process is intense, with no distortion of the workpiece
- Because there is no wear of the abrasive belt, the surface speed is constant
- The process is cooler
- Setup time is short [2].

3. MACHINE FOR GRINDING AND POLISHING OF CIRCULAR STAINLESS STEEL TUBES

The main purpose of advanced machine systems is to achieve high productivity in conditions of high accuracy and surface quality for the workpiece. One of the ways to attain this goal is to group more operations, commonly carried out on different machines, on the same machining system. Some recently made tests show a significant improvement in roughness and accuracy of tubes machined on this machine systems.
The machine for grinding and polishing of circular stainless steel tubes is a product of the Italian company *Surface Engineering* from Milan, and it is the result of long time experience and coorporation with *Siemens* company. Figure 3 shows the entire machine. The machine for grinding and polishing of stainless steel tubes comprises a set of several minor machines – modules. The total nominal output of the machine is 80kW and it requires constant water supply of 2 bars water pressure for its functioning.

The total machine length is 21m and it functions with the assistance of a crane whose lifting capacity amounts to 10t. It is mounted in a machine hall, and its role is to transfer raw material (unmachined tubes) and ready made products.

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The machine consists of an infeed, four grinding modules, three polishing modules and a part for automatic packaging of machined tubes into polyethylene foil. The assembled machine is controled by PLC Siemens company. It is the machine construction that enables shutting down some of its parts (according to circumstances or due to a failure/maintenance), which provides maximum working efficiency of the machine. [5]

The infeed is on the tube entrance into the machine, and it provides the entrance of the tubes 100mm – 6000mm long. Most commonly, 6000mm long tubes are utilized. The infeed is completely automatized and its maximum load is 2t, wherein the number of tubes it can receive depends on the diameters and thickness. The diameter of tubes varies between 10mm and 220mm.

The grinding modules ST 220 (Figures 4 and 5) are the first in the technological procedure of pipe grinding and polishing.

![Fig. 4. Interior of the ST220 module](image)

All the grinding modules are identical, however the power within particular modules varies, i.e. 17kW, 13kW, 10kW and 7kW. The first grinding module exerts the greatest power. Each of the modules may vary in the number of revolutions of the grinding wheel, within the range of 1500o/min to 3000o/min, which is governed by the PLC.

![Fig.5. Grinding wheel inside the grinding module](image)

The fineness of the abrasive bands of the grinding wheels also varies among modules. The fineness of the abrasive band of the first module is the lowest (400), and it grows with bands that follow, i.e. 600, 800 and 1000. [3]

Artificial materials, such as aluminium oxide, silicon carbide, cubic boron nitride and diamond are most commonly used for the production of grinding (abrasive) bands. For the different purposes, the ST 220 uses CBN (cubic boron nitride) and PCD (artificial diamond)-based bands produced by Klingspor.

![Fig.6. Interior of the PT 150 module](image)

Having being worked in grinding modules, tubes enter the polishing modules, the PT 150 type (Fig. 6). All the modules are identical, nonetheless they exhibit different power, i.e. 7kW, 5kW and 3kW.

![Fig.7. Polishing brushes](image)
Within each module, polishing brushes (Fig. 7) can have different number of revolutions (100 o/min – 300 o/min), which is regulated by the PLC. [4]

The fineness of the polish paste in each of the modules is 1200, 1400 and 1600. Brushes and pastes are combined, depending on quality requirements (high, moderate or low tube finish).

Subsequent to the above phase, tubes are automatically placed into a special carrier. They are then transferred by an automatic packaging machine into the 70μm thick polyethylene foil, whereupon these are considered as final products. The entire process of tube engineering can include finishing of maximum 25 tubes per hour, whereby the actual speed is approximately 10 tubes per hour, since the speed of the process depends on quality requirements. The materials used in the process (grinding bands, polishing brushes and polish pastes) are produced by the Klingspor and 3M.

4. CONCLUSION

The paper presents the process of abrasive belt centerless grinding and polishing of 6000 mm long stainless steel tubes worked on a special machine produced by the company Surface Engineering from Milan.

This process is carried out on a complex machine comprising four grinding and three polishing modules. Each of the modules ensures higher quality of the processed surface. Depending on quality requirements, some of the modules can be excluded.

This is the latest method of tube processing. It is highly productive, and it ensures high quality and accuracy of the processed surface. Multiple modules systems prove ability to obtain required specifications in a single pass.

5. BIBLIOGRAPHY

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