Researches Regarding the Improvement of Workpieces Surface Finish by Machining through Superfinishing Process

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Abstract: - In the paper is presented a machine for superfinishing external surfaces of cylindrical workpieces with diameters between 5 to 30 mm and length between 10 to 300 mm. The surface finish that is obtained for the workpieces is very high with the roughness values Ra between 0,4 - 0,2 µm. The parts are placed between two cylinders that have a rotational movement and with nonparallel axis. This feature allow for the parts to have a rotation motion and a transverse motion simultaneously while the abrasive stones which have a reciprocation motion make the abrasion action on the workpiece surfaces. The machine is automatically fed with parts and has a great productivity. An operator can work and control two these machines in the same time.

Key-Words: - superfinishing process, surface quality, productivity, accuracy.

1 Introduction

The quality of parts surface is an important condition to have products that will have a good reliability during their working life and success on the market. Many methods of producing parts have their contribution to the final goal: a part that fulfills all the condition required from the technical documentation. Between them, superfinishing operation is one of the most important because some time is the last method of machining in all the manufacturing process and therefore is the quality-determining process. This machining process gives the final surface quality and for this reason we must

be sure that all the process parameters are in the optimum values.
Some of the advantages of using superfinishing method as a finishing process are shown below:

- Time of processing is short;
- Increased workpiece life;
- Initial investment are low;
- Higher load bearing;
- Geometric improvement;
- Wear and tear are decreased;
- Decreasing of tool costs;
- Improving sealing capacities;
- Reduction of energy consumption;
- Decreasing of friction;

The reduction of surface peak-to-valleys is important and in this way is increased the bearing ratio over to 90 %, due to the plateau-like surface structure.
Superfinishing is a finishing process that machining the parts by three movements (Fig.1) [2].

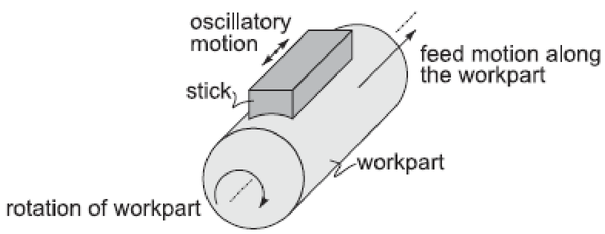

Fig.1 The principle of superfinishing process

The main movement is the rotation of the workpiece to be machined in a speed according with the part material and type of the abrasive stone used. The second and the third movements are doing by the abrasive stone and one is the oscillation of the stone and other is the pressure that the abrasive tool acts on the workpiece.
Depending on the type of part if the part is longer than the stone, the abrasive tool can have also a feed motion along the workpiece length parallel to the axis of the part.
The part passes by different phases during the superfinishing process. After the first contact with the part surface the abrasive dull grains fracture or pull away to produce a finish surface. Characteristic for superfinishing process is its self dresses and when is machining a new part is possible to use the abrasive tool without any truing or dresses. The cutting action terminates by itself when the pressure between the abrasive stone and part decreased because the area of contact increased, and a film of lubricant will appear in the work zone. For this reason during the superfinishing process only the surface finish is improving, having not influence on the dimensional accuracy.
The geometry of the workpiece is improved due to the curvature of the abrasive stone which is matched to the workpiece diameter, improving the its circularity and cylindricity. The result of the part surface is a cross-hatched surface due to an abrasive grain has a sinus curve moving direction and all the gains being in contact with the part produce marks which cross at a defined angle.
The processing time is short compared to other finishing operations, being between 35-50 seconds.

2 Studies and researches to superfinishing parts with cylindrical surface in a large production run

In Fig. 2 are shown some part with cylindrical surfaces that need a high roughness quality for a large production runs.

Fig.2 Parts with cylindrical surfaces that require a very high surface quality.

In automotive industry are a lot of parts with cylindrical surfaces that require a small roughness values with R_a between 0,020 to 0,012 μm. For this reason the grinding process is not enough and is needed to use superfinishing method. This type of finishing process can produce a surface finish as is required in technical documentation in a very small time, measured in seconds.
For superfinishing process is possible to use an abrasive tool with grains on a tape, or a solid abrasive stone.
In Fig. 3 is shown a scheme of using abrasive grains mounted on a tape for machining parts with cylindrical surface [5]. The stock removal is achieved by two simultaneously working motions, part rotation and short-stroke oscillation motion parallel to the part axis. The

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disadvantage of this method is that of abrasive grains wear and which are flattened and lose their cutting capacity. In this way the time needed to obtain the required surface finish is increased from part to part.

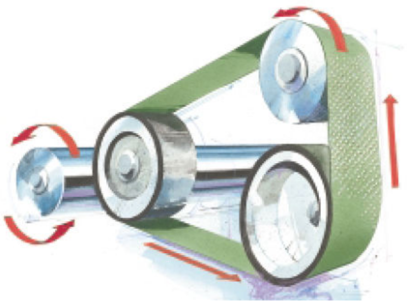

Fig.3 Schematic illustration of tape superfinishing.

For this reason was chosen superfinishing method with abrasive stone on a superfinishing centerless machine. In this way are achieved two goals: the time of processing is smaller because of the continuously system of parts feeding, and the required surface finish by using a number of abrasive stones that work together in the same time.

As it shown in Fig.4, the parts (2) come from the right side continuously from a feeding system and pass between two cylinders (5). From above a number of abrasive stones (1), have a cutting action on the parts surface by the reciprocating motion parallel to part axis with a stroke amplitude of 1-3 mm and a frequency of 100-1500 cycles per minutes under a pneumatic pressure.

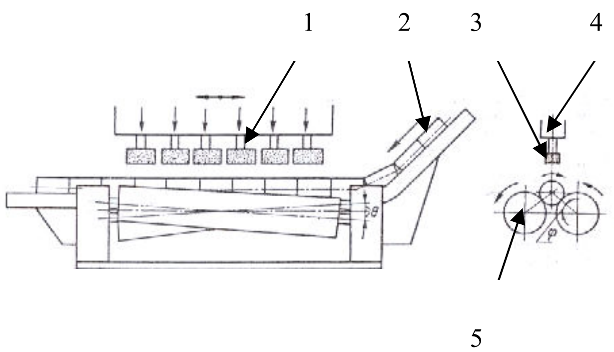

Fig.4 Scheme of a centerless superfinishing machine for cylindrical surfaces.

The axis of the two cylinders is not parallel, being an angle θ of 1-2^0 which ensure two movements for the workpiece: one of rotation and one of traverse motion. The size of these motions is according with the machining speed needed and the productivity required.

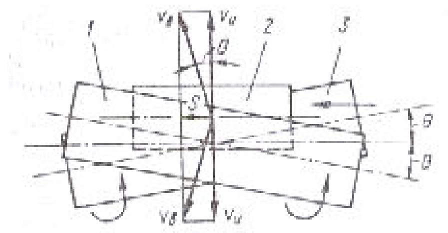

Fig.5 Scheme of the forces that give to the workpiece the two movements.

All the movements of the parts (2) to be machined come from the two cylinders (1) and (3) as is shown in Fig.5.

According with Fig.5 the motion V_B of rotation of a cylinder 1 is split in two components, namely:

(a) the radial component V_u;
(b) the axial component S;

The radial component V_u is given by:

$$V_u = V_B cos\theta \qquad (1)$$

and the axial component S is given by:

$$S = V_B sin\,\theta \qquad (2)$$

The radial component V_u will give the rotational movement of the workpiece and the axial component S will give the traverse motion of workpiece, which finally will establish the productivity of the process.

The first phases of the operation consists of the abrasion of the peaks and ridges of the workpiece, when the contact between the abrasive stone and the workpiece is on the isolated points. During the time processing the workpiece will have a surface nearer to a true cylinder and the area of contact increases that conduct to the decreasing of the pressure on unit area.

The path of the abrasive grain on the workpiece area is sinusoidal wave, and if we projected on a developed cylindrical workpiece surface will have the shape shown in Fig.6, [3]. The composition of the rotary motion and feed motion of the path of a grain give the trajectory motion PR.

This trajectory is a result of the periodic sinusoidal tool oscillation of an amplitude a and the wave

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length λ and the grain path motion passes through the points E-H-F-G-R.

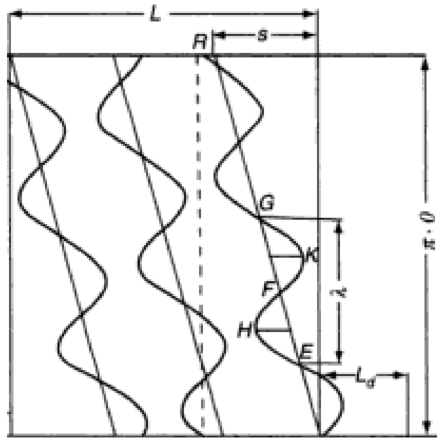

Fig.6 Path of the grain motion on work surface and cutting speed components in straight superfinishing.

The amplitude a of the oscillations can be controlled and the wavelength λ results from the condition that the number if waves along the periphery should not be full amplitude:

$$f\lambda = \pi dN \qquad (3)$$

where, f is the frequency of oscillation, N is the rotational speed in rpm, d is the workpiece diameter. The cutting speed of superfinishing process V_B is the sum of the peripheral speed of the workpiece V_u, the oscillation motion V_0 and traverse feed rate S, and is given by:

$$V_B = \sqrt{V_u^2 + (V_0 + S)^2} \qquad (4)$$

The oscillation motion V_0 is given by:

$$V_0 = 2\pi fa \cos(2\pi ft) \qquad (5)$$

The maximum oscillation occurs for the stick displacement equaling zero, e.g., for points E and F. The maximum cutting speed occurs at point E where V_{max} agrees with that of the longitudinal feed rate vector and thus:

$$V_{\max} = \sqrt{V_u^2 + (2\pi fa + S)^2} \qquad (6)$$

The minimum speed occurs when V_0 is zero:

$$V_{\min} = \sqrt{V_u^2 + S^2} \qquad (7)$$

The average speed which practically characterize the actual motion is given by:

$$V_0 = 2af \qquad (8)$$

In superfinishing process are three primary methods:

- through feed process;
- plunge process;
- superfinishing with wheels process;

For the machine that was designed was chosen the method of through feed process because is used for machining cylindrical parts, such as piston pins, shock absorber rods, shafts, needles. As is shown in Fig.4 the parts are transported and rotated between two rotating drive rolls and the rotating workpiece passes underneath a series of stone stations with stones of decreasing grit size that are mounted to an oscillator mechanism.

The abrasive stones are mounted in a support which is shown in Fig.7 [4].

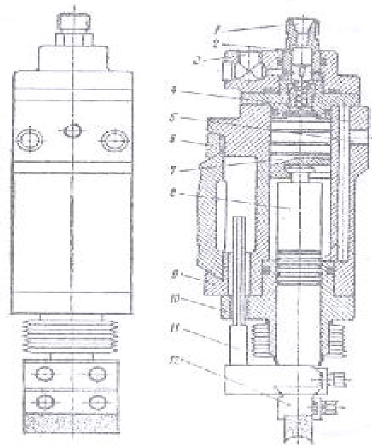

Fig.7 The support where are mounted the abrasive stones.

For the superfinishing machine that was designed were used five supports where the stone are located in decreasing grit size starting from the grit size 600 and finish with the grit size 6000, made by graphite. This arrangement of the abrasive stones ensure that is obtaining the required surface quality of R_a =0, 02 μm. These supports can be displaced parallel to workpiece axis according with the length and shape of workpiece.

Sometimes is happen that the cylindrical surface of the workpieces are not at the same diameter, and in these cases is necessary to make in a such way arrangements to lift the abrasive stone when come in the zone of different diameters, Fig.8 [1].

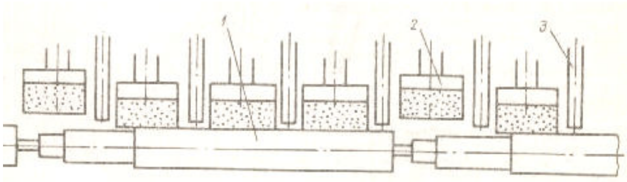

Fig.8 Arrangements of abrasive stones for workpieces with different diameters.

As is shown in Fig.8 the workpieces (1) that pass underneath the abrasive stones stations, have different diameters and is necessary a sensor (3) which will command the abrasive stone (2) to lift in upper position to not be broken. The abrasive stone will come down when workpiece will come with its maximum diameter that must be machined.
Superfinishing is not considered a stock-removal process, because it is utilized almost as a surface refining process with additional available in improvements to the geometric characteristics of the workpiece.
The superfinishing allowances are often contained within the limits of dimensional accuracy. The roughness obtainable offers high wear resistance and high load carrying capacity as compared to ground and precision turned surfaces.
Table 1 shows the amount of stock removed by superfinishing process.

Table1. Amount of stock removal by superfinishing [2].

Ground surface, RMS [μm]	Stock removal (per side or radius) [μm]
0,25	3,06
0,37	4,85
0,50	6,38
0,62	7,66
0,75	9,93
1,12	10,26

To achieve the desired surface finish during the tests that we have done was used fine grit sized materials using the device that is shown in Fig.9. It is a device with two units of abrasive stone where the oscillations are mechanically generated. We use two support for abrasive stone and for each one was tested different abrasive stone to find the process parameters that give us the best result in the smallest time of working.
The sizing of abrasive grains is determined by some organization as Federation of European Abrasive product (FEPA).

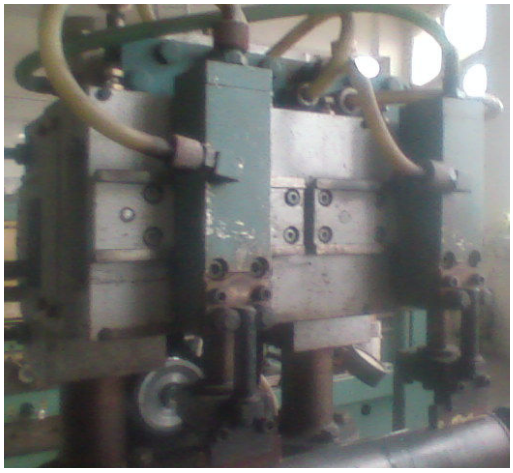

Fig.9 Device for testing the abrasive stones and for establishing process parameters.

It was used stone with grit size between 400 and 1200 grit on the FEPA scale. For some applications may require the use of sub-micron sized particles as in this case of our paper where as the last station is used as abrasive material graphite which ensure obtaining a very high surface quality and enhance the visual appearance of the workpieces.
The material of abrasive stone can be Aluminium oxide, silicon carbide, CBN and Diamond. For our tests we used silicone carbide with different grit size as 600, 800, 100, and 1200.
To achieve our goal regarding the superfinishing the workpieces with cylindrical surfaces it designed and realized a superfinishing machine that is presented in Fig.10.
As is shown in Fig.10, the workpieces are held between two cylinders (5) which have their axis not parallel and this kind of location produce two movements for parts to be machined: the rotation and the traverse feed underneath the stations of abrasive stones (3). The supports of abrasive stones are positioned in decreasing grit size starting with the size 600 and the on final station the abrasive stone is made by graphite.
Using this kind of arrangements for abrasive stones, the roughness of the part surfaces has very small values of R_a between 0,02- 0,012 μm, that are required for most of the workpieces in automotive industry.

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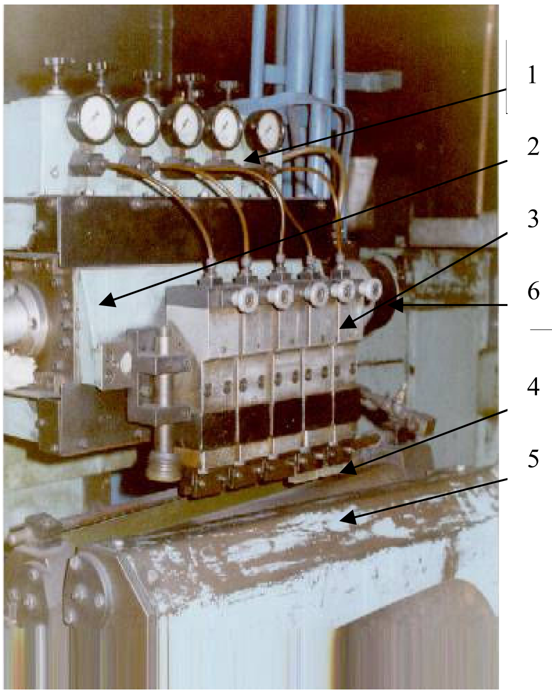

Fig.10 Superfinishing machine used to machining cylindrical surfaces.

The supports of abrasive stones are mounted to an oscillator mechanism (2) which produces reciprocating movements with a frequency of 45 to 70 cycles per minutes and amplitude of 5 to 15 mm. All these movements are mechanically generated. Above all these motions is superimposed other motion pneumatically generated by the device (6) which produce oscillations with a frequency of 100-1500 strokes per minutes and amplitude of 1-3 mm.
The pressure of the abrasive stones on the part surfaces is pneumatically generated and is controlled by the equipment (1).
The superfinishing process is continuously. The parts come from the right side from a feeding device and pass underneath the stones stations to the left side ready for delivering.
According with the diameter and the length of the workpieces that need to be machined is possible to change the arrangements of the abrasive stations and the grit size of each of stone mounted on the supports. Also the number of stations of abrasive stones can be different for each type of part to obtain the process parameters needed for required surface finish.
During the superfinishing process a lubricant made of kerosene oil is used to give fine finish for the part surfaces.

4 Conclusion

Superfinishing process is suitable for any material that could be finished with geometrically undefined abrasive blades. In addition to the most diverse metal alloys and grades, other materials can be finished, such as ceramics, plastics, non-ferrous metals. Through superfinishing is achieved for parts that require superior surface finishing a high workpiece quality in regards to load bearing capacity, efficiency, smoothness of running, operational safety, and longevity.
The superfinishing machine that was realized can be used for machining a lot of type of workpieces with cylindrical surfaces and is able to ensure a very high quality of surfaces.

References:

[1] Metzger, J.L., - *Superabrsive Grinding*. Stoneham, Mass.: Butterworths, 1986.

[2] Maroney, M. L., - *A guide to metal and plastic finishing.* New York, industrial press, 1991.

[3] Mckee, R. L., - *Machining with Abrasives.* New York, Van Nostrand Reinhold, 1982.

[4] Lepadatescu, B – *Superfinishing with abrasive stones*. – Doctoral thesis, Brasov, 1998.

[5] Rosca, D. M. –*Abrasive tools for engineering*. Lux Libris publishing house, Brasov, 1995.

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