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PROCESS CENTERLESS RECESS GRINDING

Andrej MALÍK, Augustín GÖRÖG

Abstract

The article deals with special centerless grinding using various methods, particularly the centerless grinding recess methods. The results of measuring the surface roughness of frontal and cylindrical areas of a workpiece, as well as the roundness of the cylindrical surface of the workpiece are presented in the paper. Qualitative parameters of the machined surfaces are supplemented by the course of the grinding process. The change in the shape of the workpiece in the process of grinding causes also the change of position of the workpiece in the work zone.

Key words

centerless grinding, quality parameters, the grinding process

Introduction

The principle of each method of grinding is withdrawal of material by abrasive grain. Abrasive grain is a cutting wedge with random geometry and orientation. When grinding, the workpiece material is removed by a hard flint grinding wheel at high cutting rates. [1]

Centerless grinding is used for grinding smooth cylindrical components, which are inserted between two discs. One of them is a grinding wheel and the other a regulating wheel. Workpiece rotates at a peripheral speed of the rotating regulating wheel.

Centerless radial grinding (Recess)

Recess grinding is used for machine parts that have a recess, shaped or conical surfaces, or, where appropriate, more coaxial cylindrical surfaces without centres. Workpieces are inserted into the backstop between the grinding and regulating wheels, the axes of which are parallel [1].

Andrej Malík, MSc. Eng., Augustín Görög, Assoc. Professor, PhD. – Institute of Production Technologies, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology Bratislava, J. Bottu 25, 917 24 Trnava, Slovak Republic, e-mail: andrej.malik@stuba.sk, augustin.gorog@stuba.sk

Specific features of centerless recess grinding

Specific features of centerless grinding recess method are:

1. Movement (feed) of one of the discs in the radial direction of grinding. At the end of this movement (feed), the workpiece receives the final dimension;
2. Axis of the wheels are parallel with the surface of the leading slide;
3. Smooth procedure, since there is no axial movement of the workpiece.

However, in the real procedure, the regulating wheel forms a minute angle (0.5 °) with the surface of the leading slide. This arrangement, which is typical for this method, is here to prevent the workpiece from oscillating in the axial direction. The inclined axis of the regulating wheel is pressed against the front of the piece backstop.

Wheels are converging either manually or automatically. In this method, we can grind the parts of various shapes to a certain length and $l_{max} \leq H$, where l_{max} is the maximum length of the piece of ground. Workpieces are inserted and removed manually or by using tanks.

Grinding process is usually carried out with a surface of the workpiece pressed to surface of the leading slide and regulating wheel. The change of the shape of the workpiece in grinding leads to the change of the location of this workpiece in the work zone.

Recess grinding process

In Fig. 1 is a scheme of instant positioning the workpiece during a single revolution when in-feed grinding.

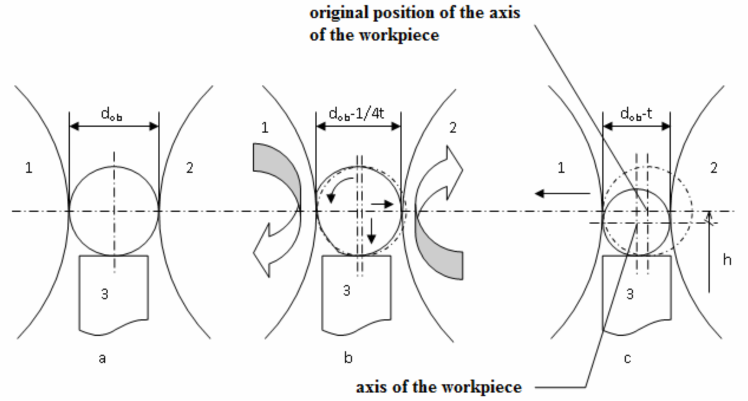

Fig. 1 *Scheme of instant positioning of the workpiece when in-feed grinding*
a – starting the process; b – intermediate position of the workpiece; c – position after one revolution of the workpiece; 1 – grinding wheel; 2 – regulating wheel; 3 – leading slide. [2]

The tool path feed rate is marked t.

If allowance is taken with certain parts of the surface, the workpiece decreases and is shifted to the regulating wheel Fig. 1 b).

Thus, the workpiece does not have a correct cylindrical shape after one revolution, because the depth of grinding over the turn varies. To receive the workpiece of a precise circular shape, it must be kept rotating without lateral feed.

When grinding, the geometrical axis of the workpiece position is constantly changing while remaining parallel to its initial position Fig. 1 c).

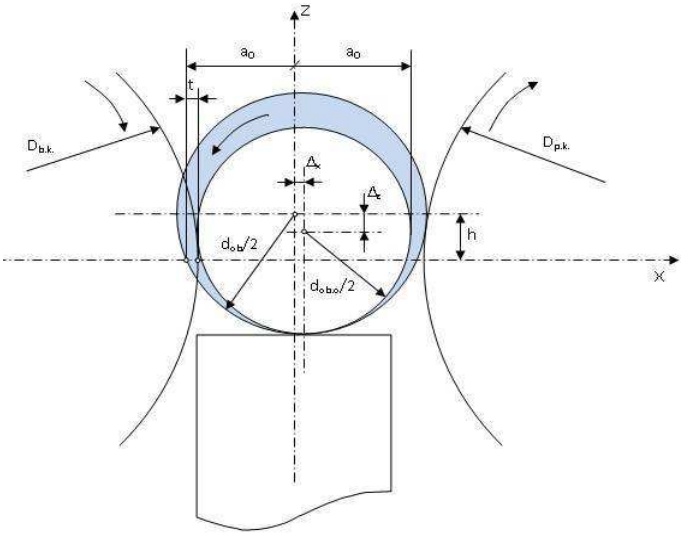

Fig. 2 *The ratio of diameters of the workpiece before and after grinding [2]*

$D_{b.k}$ – grinding wheel diameter, $D_{p.k}$ – regulating wheel diameter, d_{ob} – workpiece diameter before, $d_{ob.o}$ - workpiece diameter after, h – height of the workpiece axis connecting the wheels centers, a_0 – half of a chord limited by an intersection line between the centers of wheels with the outer surface of the workpiece, Δ_x – center displacement of the workpiece axis X, Δ_z – center displacement the workpiece axis Z.

$$a_0 = a_0 \tag{1}$$

$$\sqrt{\left(\frac{D_{p.k}+d_{ob}}{2}\right)^2 - h^2} = \sqrt{\left(\frac{D_{p.k}+d_{ob.o}}{2}\right)^2 - (h-\Delta_Z)^2} + \Delta_X \tag{2}$$

$$\Delta_Z = \frac{1}{cos\varphi}\left(\frac{d_{ob}-d_{ob.o}}{2}\right) + \Delta_X \frac{sin\varphi}{cos\varphi} \tag{3}$$

$$\left(\frac{D_{b.k}+d_{ob.o}}{2}\right)^2 = (h-\Delta_Z)^2 + \left(\frac{D_{b.k}}{2} + (a_0 - t) + \Delta_X\right)^2 \tag{4}$$

The system of equations (2), (3), (4) must be solved wit regard to $d_{ob.o}$, Δ_X ,Δ_Z. In a special case when φ = 0, h = 0, the system takes the following shape:

$$\frac{D_{p.k}+d_{ob}}{2} = \sqrt{\left(\frac{D_{p.k}+d_{ob.o}}{2}\right)^2 - \Delta_Z^2} + \Delta_X\,; \tag{5}$$

$$\Delta_Z = \frac{d_{ob}-d_{ob.o}}{2}\,; \tag{6}$$

$$\frac{D_{b.k}+d_{ob.o}}{2} = \sqrt{\Delta_Z^2 + \left(\frac{D_{b.k}+d_{ob}}{2} - t + \Delta_X\right)^2}\,. \tag{7}$$

When substituting the expression for Δ_Z in equation (6) in equations (5) and (7), and take them to the power of two, we get:

$$\left(\frac{D_{p.k}+d_{ob}}{2} - \Delta_X\right)^2 = \left(\frac{D_{p.k}+d_{ob.o}}{2}\right)^2 - \left(\frac{d_{ob}-d_{ob.o}}{2}\right)^2\,; \tag{8.1}$$

$$\left(\frac{D_{b.k}+d_{ob.o}}{2}\right)^2 = \left(\frac{D_{b.k}+d_{ob}}{2} - t + \Delta_X\right)^2 + \left(\frac{d_{ob}-d_{ob.o}}{2}\right)^2 . \qquad (8.2)$$

After further adjustments, we will have a system of equations (8) in the form:

$$\frac{d_{ob}-d_{ob.o}}{2} = \Delta_X - \frac{\Delta_X^2}{D_{p.k}+d_{ob}} ; \qquad (9.1)$$

$$\frac{d_{ob.o}-d_{ob}}{2} + t - \Delta_X = \frac{(t-\Delta_X)^2}{D_{b.k}+d_{ob}} . \qquad (9.2)$$

When omitting the members $\frac{\Delta_X^2}{D_{p.k}+d_{ob}}$ a $\frac{(t-\Delta_X)^2}{D_{b.k}+d_{ob}}$ in the system (9) , which do not affect the required accuracy of calculation, from equations (3) and (9) we get:

$$d_{ob.o} \cong d_{ob} - t ; \qquad (10)$$

$$\Delta_X \cong \frac{t}{2} ; \qquad (11)$$

$$\Delta_Z \cong \frac{t}{2} . \qquad (12)$$

It is evident that dependences (10), (11), (12) are valid for the addition of the removal of any thickness, however only with the difference that variable *nt* will be substituted for *t*, where *n* is the number of revolutions of the workpiece within the period of removing the allowance.

The property of centre workpiece displacement is taken into account when setting the grinders. It should be noted that with increasing *h*, difference d_{ob} - $d_{ob.o}$ is also growing fast. Line height *h* can be determined from the geometrical relationships.

Similarly, this applies to centerless grinding-through manner, yet the nature of the workpiece movement is much more complex. Workpiece is rotated and thus its axis stops to be parallel with its original position.

These movements in the piece-through grinding lead to reducing the workpiece diameter approximately by variable *t*, which was previously set up in the grinding machine. With the same setup in center grinding, the workpiece diameter would decrease by *2t*.

In centerless grinding, the variable-through d_{ob} - $d_{ob.o}$ is usually called the *depth of cut*. A double depth of cut for grinding center is indicated *t*, respectively *2t*.

To avoid misunderstanding, variable *t*, which can only be regarded an instantaneous depth of cut will called allowance of angle [2].

Change profile and qualitative parameters surfaces workpieces

To determine the impact of in-feed centerless grinding on a circular profile and the parameters of the surface (roundness and surface roughness), we carried out a series of experiments within which the parts shown in Fig. 3 were manufactured. Components were made of ST 37 - 2K. Their diameter was ø $9.96^{-0.01}$ (diameter of semi-product before grinding ø$10.04^{+0.06)}$. Grinding was made on MULTIMAT 208 machine while using the grinding wheel 400x30x203 99BA/96A 60N7V (STROH flat diamond), regulating wheel 300x30x127 A120RL152R7 and leading slide was straight. Grinding machine working time was 9.8 sec.

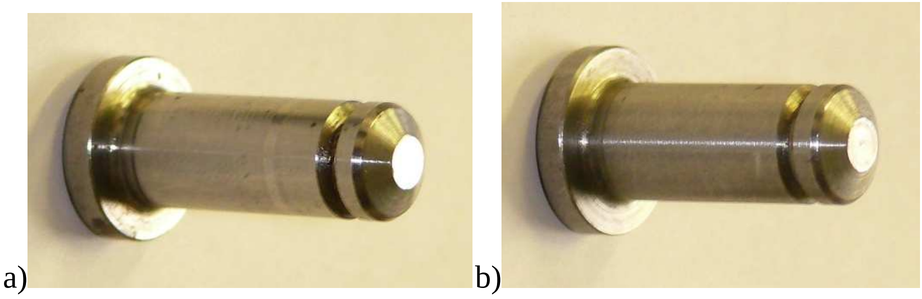

Fig. 3 *Workpiece a) before and b) after grinding*

Fig. 4 shows the round profile section measured for a selected part before grinding. Below the picture, specific parameters of measured round profile and surface roughness are listed.

For comparison, Fig. 5 shows one of the measured profiles after grinding and the measured parameters.

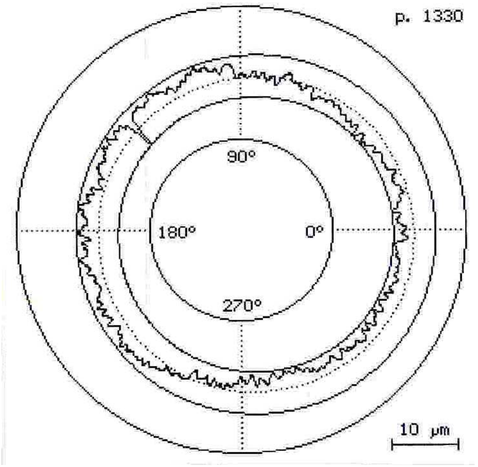

Fig. 4 *Profile before grinding*

ΔZ 6.34µm; P 3.28µm; V 3.05µm; R_R 7,03µm

Roughness before grinding: Ra 1.59µm; Rz 8.99µm; Rq 1.97µm

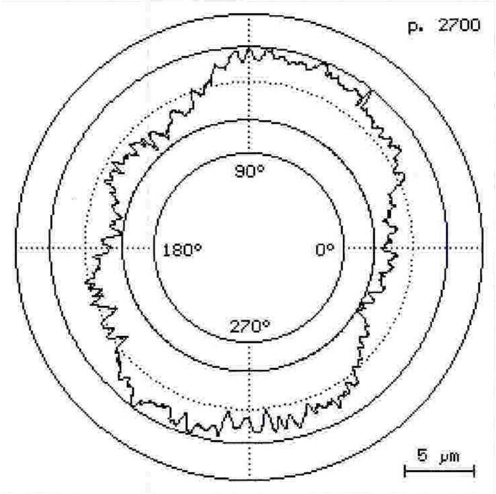

Fig. 5 *Profile after grinding*

ΔZ 5.25µm; P 2.50µm; V 2.74µm; R_R 5.79µm

Roughness after grinding: Ra 0.55µm; Rz 4.37µm; Rq 0.70µm

Both displayed profiles (Figs. 4, 5) have representation parameters – the parameter values are the closest to the average values. Roundness (*ΔZ*) was reduced by grinding in average by 17%, while the part in the region of mounts (*P*) was reduced by 24% and the depressions (*V*) by 10%. Radial wheel run-out (R_R) was reduced in average by 17%. All the surface roughness parameters observed were reduced significantly (different parameters of 51 to 65%).

Conclusion

The experiments proved that the centerless plunge grinding improves the parameters of circular profile and surface roughness. However, there are cases where grinding can worsen a qualitative parameter. It concerns particularly an accurate mutual positioning of the workpiece surfaces. For example, in a way-through centerless grinding of outer surfaces (especially with a small of length/diameter ratio of a component, i.e. ring-shaped components) nonuprightness of the cylindrical surface of the workpiece regarding its face can be a bit bigger. This will not happen with plunge grinding.

All the methods of centerless grinding may cause that the outer (grinding) surfaces and the inner surfaces of the workpiece are not exactly in alignment. Coaxiality of surfaces is changed by pass-through grinding along the length of the workpiece.

This abaxial is usually considered a *random deviation*. In fact, this phenomenon is caused by specific features of centerless grinding and it can be affected. If the grinder is properly adjusted, a larger amount of appliance is used and the optimum allowance of grinding is retained, it is possible to achieve the accuracy to the extent of the prescribed tolerances after grinding.

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Reviewers:

Zdenko Lipa, Professor, PhD. - Institute of Production Technologies, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology Bratislava

Dana Stančeková, Assoc. Professor, PhD. - Department of Machining and Automation, Faculty of Mechanical Engineering ŽU, Žilina