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**Stovpnyk O., student gr. I-22-TM-M**
**Leshchenko O.I., Cand. of Techn. Sc., Ass. Prof. of the Dep. of Mechanical Engineering Technology.**
*(Priazovsky State Technical University, Mariupol-Dnipro, Ukraine)*

# ENSURING GEOMETRIC ACCURACY WHEN GRINDING NON-RIGID SHAFTS

Low stiffness shafts are shafts with a length-to-diameter ratio of more than 10. Due to their low stiffness, when machining under the influence of radial cutting forces, the axis of the workpiece is distorted, forming a barrel-shaped profile with an increase in diameter from the edges to the middle of the cross-section. To achieve the required geometric accuracy it is necessary to make several passes, which reduces machining productivity. Developing techniques to ensure accuracy in machining such parts becomes important.

The occurrence of barrel-shape in machining of low rigid shafts is due to deflection of the workpiece under the action of mainly radial cutting forces. The solution to the part accuracy problem has two aspects: 1) reducing cutting forces; 2) increasing the stiffness of the machining system to reduce workpiece deformation.

The second aspect is most often solved by using movable or fixed lunettes that provide additional support to reduce workpiece deflection. Reduction of cutting forces can be achieved by changing the machining pattern to change the direction of the cutting force vector, using grinding wheels with suitable characteristics, ensuring high cutting capacity of the wheel and setting optimal cutting conditions.

The grinding process exhibits the same physical forces as other cutting methods, but their effects are greatly reduced due to small cut sizes and high cutting speeds. Cutting force R, decomposing into three components - Pz, Ry, Rx, is the sum of elementary forces due to the action of abrasive grains. The radial force Ru is of the greatest importance, exceeding the force Pz by 1,5...3 times. This is explained by the fact that the abrasive grains have a negative angle, which significantly increases the radial force Ry.

When grinding shafts, three basic methods are usually used: longitudinal feed grinding, plunge grinding and deep grinding (Fig. 1).

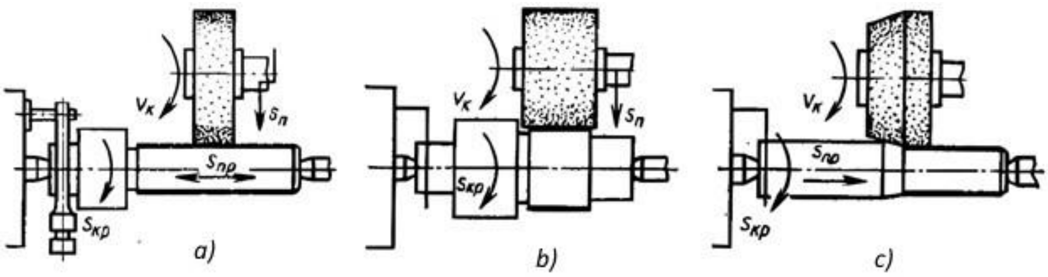


*Figure 1 - cylindrical grinding: longitudinal grinding (a), plunge grinding (b), depth grinding (c). [1]*

The first grinding method, which uses a longitudinal feed, is performed by moving the workpiece in a reciprocating motion relative to the grinding wheel. For each return stroke of the table with the workpiece, the wheel is displaced to the center of the workpiece by 0,005 to 0,02 mm. An illustration of this method is shown in Fig 1, a [1].

Plunge grinding is performed using a wheel whose width exceeds the length of the machined area (Fig. 1, b). In this case, the wheel has only transverse feed. This method is more efficient than grinding with longitudinal feed and is therefore used in mass and high-volume production [1].

Depth grinding (Fig. 1, c) allows removing a layer of material in one pass to the full required depth. A conical section with a length of 8 - 12 mm is formed on the grinding wheel. During grinding, the conical section removes the bulk of the cut layer, and the cylindrical section cleans the machined surface. There is no transverse feed.

According to [3], during depth grinding the forces Py and Pz decrease by a factor of 1,95...2,12, while the force Px increases. Experiments demonstrate that when grinding with longitudinal and transverse feeds at the same material removal rate, the tangential force is approximately the same. The ratio between radial and tangential forces is higher for longitudinal feed than for plunge grinding.

The characteristics of the abrasive tool have a significant effect on the cutting forces in grinding.

Self-sharpening of the wheel occurs during grinding. Dulled grains under the influence of forces acting on them are torn out of the surface of the wheel (ligament) or destroyed, and adjacent sharp grains or exposed sharp cutting edges come into play. The faster and more fully self-sharpened the wheel, the lower the cutting forces, but there is a large consumption of grinding wheels [2]. In general, as the hardness of the wheel increases, the grinding forces increase.

The structure of the wheel has almost no effect on the cutting forces [3].

The cutting ability of the wheel depends on the machining conditions (cutting and dressing mode, wheel characteristics, properties of the machined metal, etc.). The cutting ability changes during the durability period of the wheel [2]. When grains are blunted, their ability to penetrate into the machined surface decreases. Decrease in cutting ability slows down with increasing mode, with increasing diameter of the wheel and the workpiece, with increasing size of abrasive grains and impact toughness of the abrasive, with decreasing longitudinal feed during dressing. Reducing the cutting ability of the grinding wheel leads to an increase in cutting forces.

Significant influence on cutting forces during grinding is exerted by machining modes. On the basis of experimental data the empirical dependence [2] was obtained [2]

$$\chi = c_x V_{\kappa p}^{0,36} s_o^{0,1} V_\partial^{0,15} t^{0,22} .$$

where Vd - workpiece speed at external cylindrical grinding, m/min; cp - coefficient depending on workpiece material, heat treatment, grinding wheel; t - depth of cut, mm; s - longitudinal feed in fractions of wheel width; x, y, z - degree indices; values of x, y, z are given in reference books.

The degree indices in this formula show that the force Pz increases with increasing Vd, t, s and decreases with increasing $V_{kp}$.

The radial component of the cutting force has a decisive influence on the deflection of the workpiece during cylindrical external grinding. The ratio between radial and tangential grinding forces varies in the range of 1,6...3 [3].

To ensure geometric accuracy when grinding small rigid shafts, it is necessary to ensure a rational combination of machining conditions. During grinding it is necessary to reduce the value of the workpiece speed, feed and depth of cut and increase the wheel speed.

**List of references**

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