# Analysis of the possibility of double-disk lapping of rollers in the aspect of the kinematics

## Analiza możliwości docierania dwutarczowego wałków w aspekcie kinematyki

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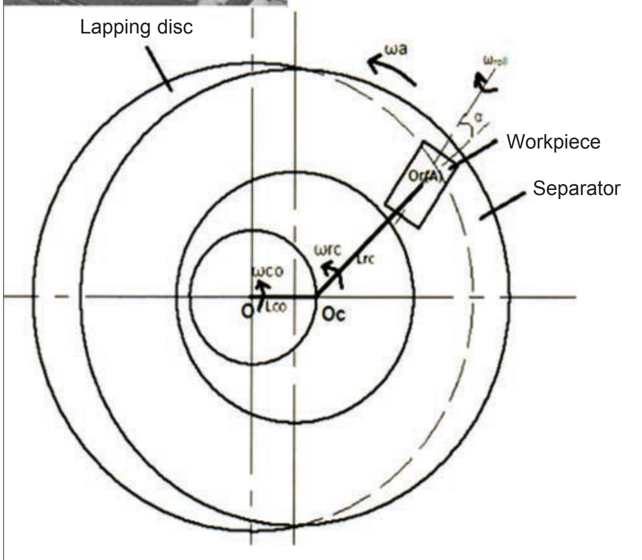
Kinematics of shafts machining was described. An eccentric and planetary implementation arrangement of double-disk lapping machines was analyzed.

KEYWORDS: cylindrical lapping process, kinematics, analysis

Technological lapping of external cylindrical surfaces can be made manually, machine-hand or machine [1, 2, 7]. In the case of machining, the machine is machined with two-disk machines and eccentric drive [3, 4, 10] in one separator (fig. 1).

It is also known to lap rollers between rotating rollers [6], e.g. on CLM 150-500 from Stähli. In this case, it is possible to process single unpaired rollers or several shorter ones of the same diameter [9]. Due to the widespread use

Fig. 1. Peter Wolters AL00-1-Z two-disc lapping machine (445 mm diameter, top/bottom blade speed of 100/60 min$^{-1}$) [8] and its circuit diagram



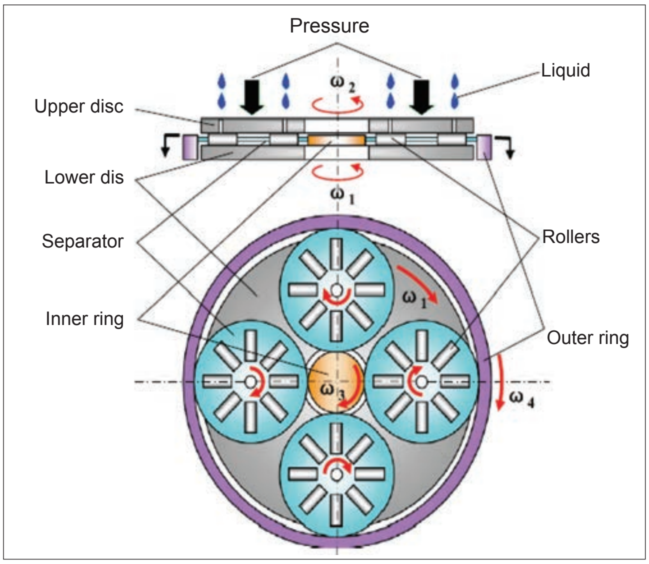




Fig. 2. Diagram of the planetary actuator system in the lapping of the shafts (angular velocity: $\omega_1$ – lower disc, $\omega_2$ – upper disc, $\omega_3$ – internal ring, pinion or toothed drive); $\omega_4$ – outer ring, usually $\omega_4$ = 0)

of disc milling machines for machining flat-parallel elements with the planetary system, the question of their applicability in the machining of the unmolded rollers (fig. 2) [5, 10, 11].

The purpose of this analysis was to compare the variability of the basic kinematic parameters of these systems.

### Analysis of the eccentric system

In this kinematic arrangement of lapping rollers with radius *r* (fig. 1), when considering the point (*A*) located halfway in the object, the angular velocity of the $\omega_a$ arriving disc and the separator $\omega_{rc}$ with respect to its center *O* and the angular velocity $\omega_{co}$ with respect to the center. In addition, the angle of inclination of the object axis in the separator socket α, the angular velocity of the lapping shaft $\omega_{roll}$, the distance $L_{co}$ of the center of the separator $O_c$ from the center of the disc *O* and the distance $L_{rc}$ of the point *A* (*A*) from the center of the separator $O_c$. The point $O_r$ lying on the axis of the shaft *N* is away from the center of the disk reaching the value $L_{ro}$. The temporal position of the respective velocity vectors in relative lapping motion is shown in fig. 3.

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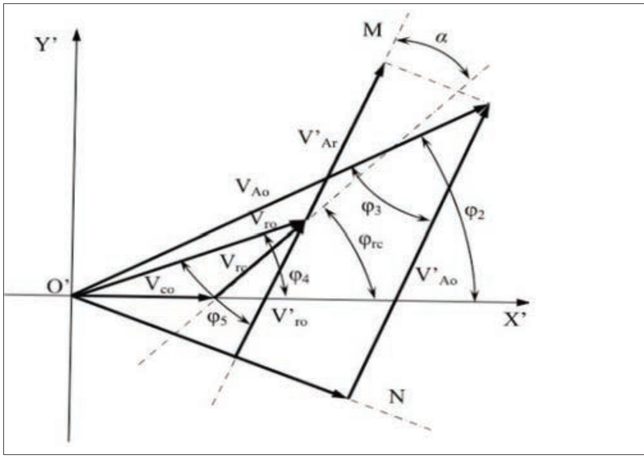


Fig. 3. Speed vectors in eccentric configuration: $M$ – direction of rolling motion of the shaft (perpendicular to its central axis $N$), $v_{Ao}$ – point velocity vector located on the lower disc reaching the center $O'$, $v_{co}$ – vector of separator center velocity $O_c$ relative to point $O'$, $v_{rc}$ – center velocity vector of shaft $O_r$ ($A$) relative to center $O_c$, $v_{ro}$ – vector of velocity $O_r$ (point $A$) relative to $O'$, $v_{Ar}$ – the velocity vector of the center of the shaft forming relative to the point $O_r$ located on the axis $N$ of the penetrating shaft ($v'_{Ar}$, $v'_{Ao}$ and $v'_{ro}$ – respectively projections of the vectors on the axis $M$)

Since the lapping speed (slip of the shaft) is determined by the formula:

$$|V'_{Ar}| = |V_{Ao}|\cos\varphi_3 - |V_{ro}|\cos\varphi_5$$

In addition, (t is the time):

$$\varphi_{co} = \omega_{co}t,\ \varphi_{rc} = \omega_{rc}t,\ \varphi_1 = 180 - \omega_{co}t$$

$$L_{ro} = [(L_{co})^2 + (L_{rc})^2 + 2L_{co}L_{rc}\cos(\omega_{rc}t)]^{1/2}$$

$$|V_{Ao}| = \omega_a L_{ro}$$

$$|V_{ro}| = [(\omega_{co}L_{co})^2 + (\omega_{rc}L_{rc})^2 + 2\omega_{co}L_{co}\omega_{rc}L_{rc}\cos(\omega_{rc}t)]^{1/2}$$

$$\varphi_2 = \arcsin[L_{rc}\sin(\omega_{rc}t)/L_{ro}]$$

$$\varphi_3 = \alpha + \varphi_{rc} - \varphi_2$$

$$\varphi_4 = \arctan[|V_{rc}|\sin\varphi_{rc}/(|V_{co}| + |V_{rc}|\cos\varphi_{rc})]$$

$$\varphi_5 = \varphi_{rc} + \alpha - \varphi_4$$

therefore:

$$\omega_{roll} = V'_{Ar}/r$$

Fig. 4 and fig. 5 illustrate the results of calculations of the lapping speed on the AL 00-1-Z lathe machine with a diameter of 20 mm and a length of 60 mm.

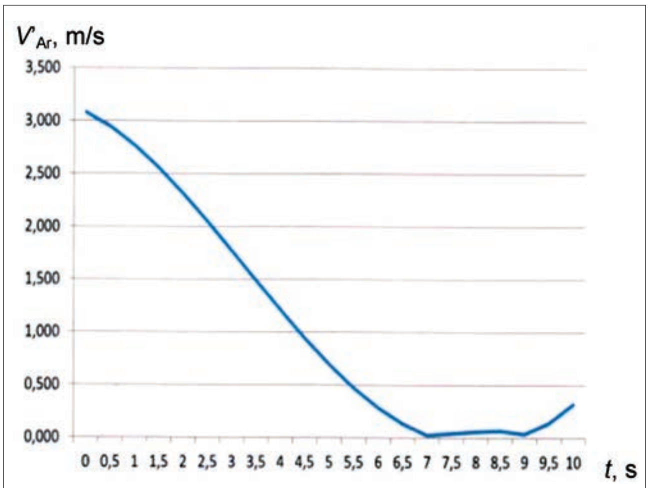


Fig. 4. The relation of velocity $V'_{Ar}$ as a function of time $t$ ($L_{co}$ = 156 mm, $L_{ro}$ = 160 mm, $\alpha$ = 0.349 rad, $\omega_a$ = 10.5 rad/s, $\omega_{rc}$ = 0.350 rad/s, $\omega_{co}$ = 0.339 rad/s)

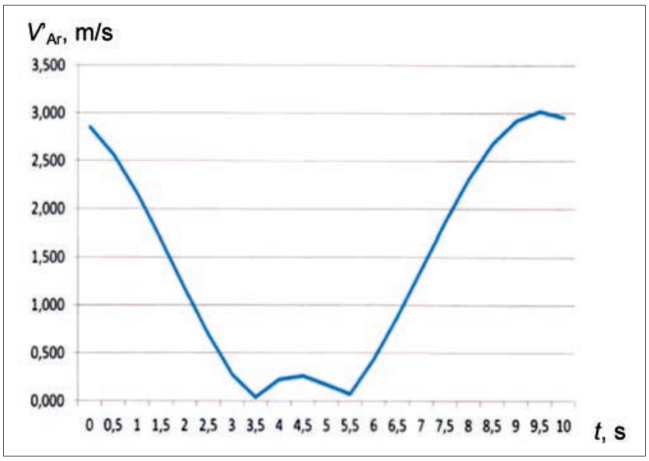


Fig. 5. The relation of velocity $V'_{Ar}$ in time function $t$ ($L_{co}$ = 156 mm, $L_{ro}$ = 140 mm, α = 0.349 rad, $\omega_a$ = 10.5 rad/s, $\omega_{rc}$ = 0.628 rad/s, $\omega_{co}$ = 0.339 rad/s)

## Analysis of the planetary system

In the case of the planetary system (fig. 6 and fig. 7), the pattern of forces and velocities is given in fig. 8. To find the position of the „pure" rolling motion, the velocity vectors (fig. 8a) the spindle to the coordinate system associated with the center of the lapped shaft (fig. 8b)


Fig. 6. Executive elements of the planetary system and the view of the Microline AC700 lathe by Peter Wolters [8]

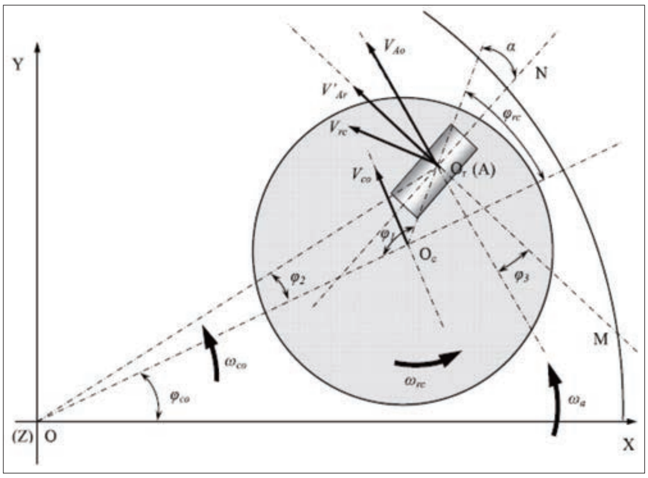


Fig. 7. Schematic diagram of the kinematic system in the planetary drive (designations, see fig. 3)

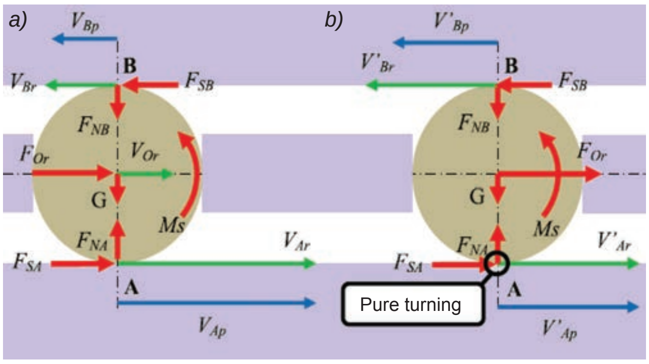


Fig. 8. Schematic of forces and velocities in the planetary system of the rollers ($G$ – gravity, $M_S$ – friction moment, $A$ – point of contact of the shaft with the lower disc, $B$ – point of contact with the upper deflection disk, $F_{or}$ – normal component of shaft force and separator, $F_{SA}$ and $F_{SB}$ – friction forces, $F_{NA}$ and $F_{NB}$ – normal components of shaft and disc impact force)

Due to the similarity of analyzed kinematic systems, the equations given earlier can be used to determine the values of individual velocities.

Examples of such calculations are given in fig. 9 and fig. 10. They concern the machining of shafts with a diameter of 20 mm and a length of 60 mm on the Microline AC700 lathe by Peter Wolters (outer diameter of the target discs 720 mm, inner diameter of the disc 320 mm, rotational speed of the lower disc 100 min$^{-1}$, and the top plate – up to 60 min$^{-1}$) [8].

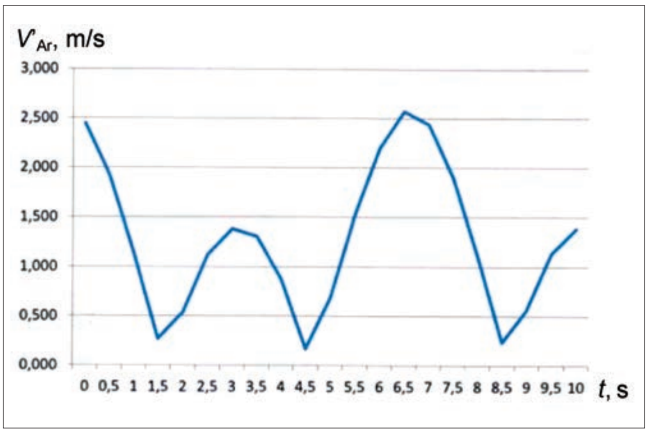


Fig. 9. Speed dependence of $V'_{Ar}$ versus time $t$ ($L_{co}$ = 250 mm, $L_{rc}$ = 180 mm, α = 0.314 rad, $\omega_a$ = 8 rad/s, $\omega_{rc}$ = 0.9 rad/s, $\omega_{co}$ = 0.5 rad/s)

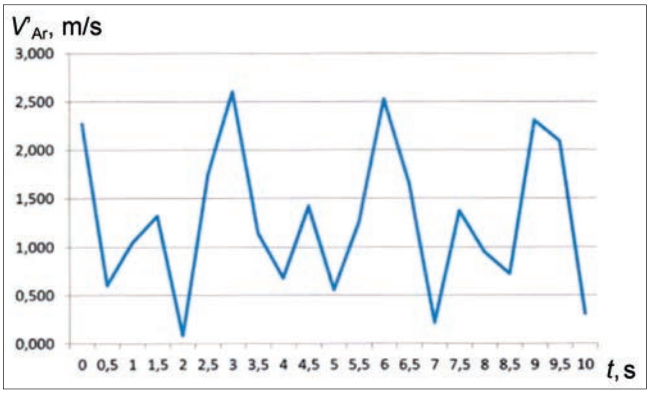


Fig. 10. Speed dependence of $V'_{Ar}$ versus time $t$ ($L_{co}$ = 250 mm, $L_{rc}$ = 180 mm, α = 0.436 rad, $\omega_a$ = 8 rad/s, $\omega_{rc}$ = 2 rad/s, $\omega_{co}$ = 0.5 rad/s)

## Conclusions

The calculations show that the kinematic conditions of the machine rollers depend not only on the speed and dimensions of the discs and the rotational speed of the separators, but also on the position of the geometric center of the separator and the angle of inclination of the shafts α. With lower values of this angle, the speed for the planetary drilling machine in question varied from about 3 m/s to about 0.1 m/s in 6 seconds. With the increased pitch of the object it was much shorter, because only about 3.5 s. In the case of eccentricity, there is a slight reduction in the variation of the shaft breaking speed (2.5÷0.2 m/s) for the same speed of the discs. In the planetary system there are also large gradients of these changes. Determining how it will affect the wear of the discs and thus the deviation of the shape of the workpieces will require further modeling and testing, taking into account the favorable process dynamics (another in metal and other lapping in ceramic lining). Due to the common use of double-disk lathes for flat-parallel surface treatment, the determination of the scope of their potential use also in the lapping of unconverted shafts is a concept that is not only technological but also economic.

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