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

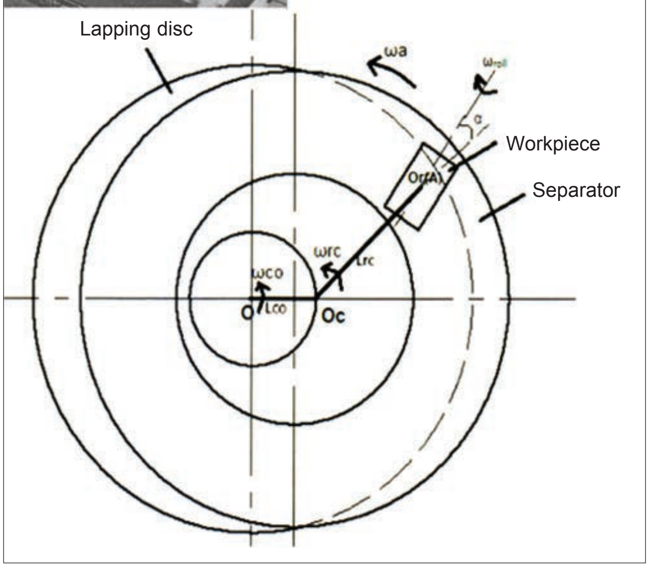

Fig. 1. Peter Wolters AL00-1-Z two-disc lapping machine (445 mm diameter, top/bottom blade speed of 100/60 min^{-1}) [8] and its circuit diagram

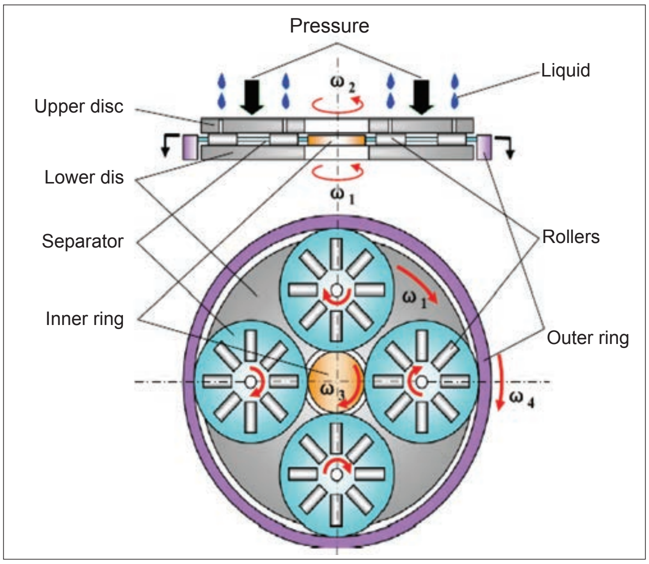

Fig. 2. Diagram of the planetary actuator system in the lapping of the shafts (angular velocity: ω_1 – lower disc, ω_2 – upper disc, ω_3 – internal ring, pinion or toothed drive); ω_4 – outer ring, usually ω_4 = 0)

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 ω_a arriving disc and the separator ω_{rc} with respect to its center *O* and the angular velocity ω_{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 ω_{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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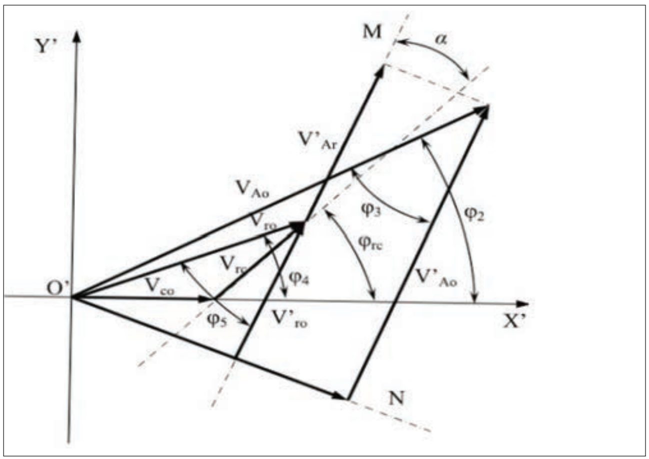

Fig. 3. Speed vectors in eccentric configuration: M – direction of rolling motion of the shaft (perpendicular to its central axis N), v_{Ao} – point velocity vector located on the lower disc reaching the center O', v_{co} – vector of separator center velocity O_c relative to point O', v_{rc} – center 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.

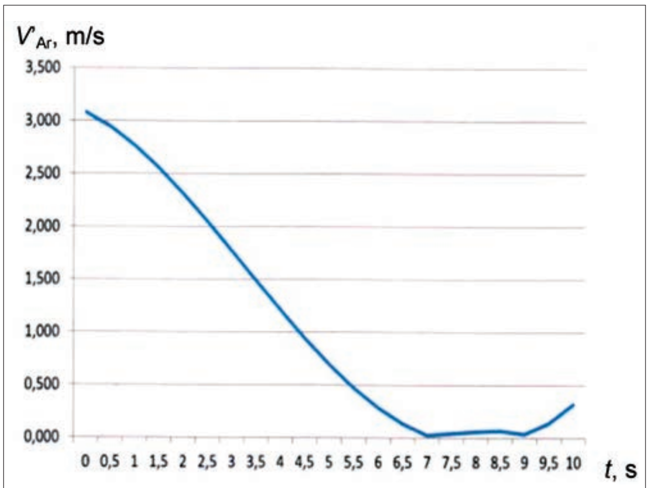

Fig. 4. The relation of velocity V'_{Ar} as a function of time t (L_{co} = 156 mm, L_{ro} = 160 mm, α = 0.349 rad, ω_a = 10.5 rad/s, ω_{rc} = 0.350 rad/s, ω_{co} = 0.339 rad/s)

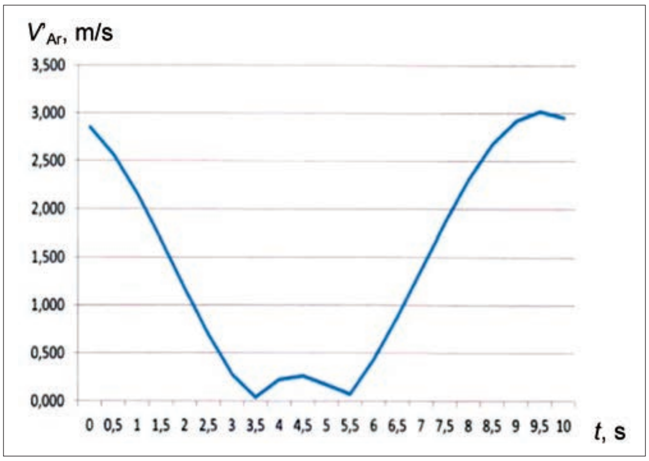

Fig. 5. The relation of velocity V'_{Ar} in time function t (L_{co} = 156 mm, L_{ro} = 140 mm, α = 0.349 rad, ω_a = 10.5 rad/s, ω_{rc} = 0.628 rad/s, ω_{co} = 0.339 rad/s)

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]

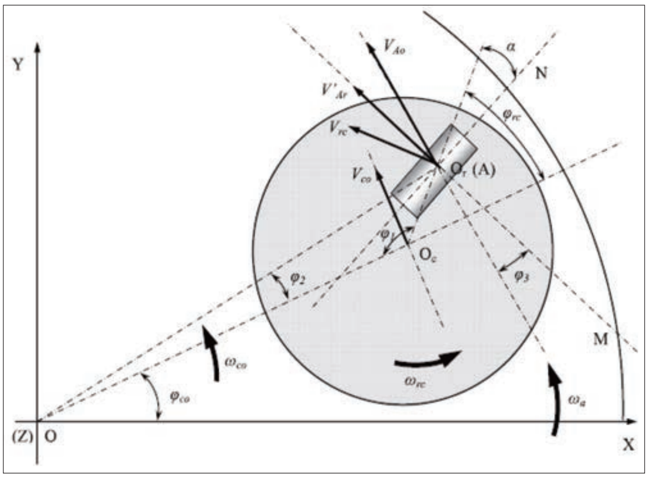

Fig. 7. Schematic diagram of the kinematic system in the planetary drive (designations, see fig. 3)

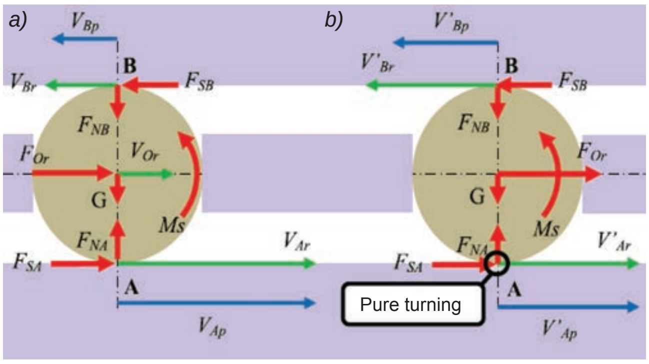

Fig. 8. Schematic of forces and velocities in the planetary system of the rollers (G – gravity, M_s – friction moment, A – point of contact of the shaft with the lower disc, B – point of contact with the upper deflection disk, F_{or} – normal component of shaft force and separator, F_{SA} and F_{SB}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

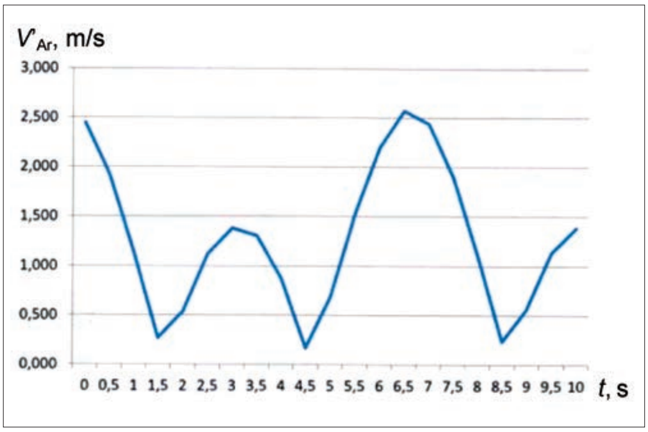

Fig. 9. Speed dependence of V'_{Ar} versus time t (L_{co} = 250 mm, L_{rc} = 180 mm, α = 0.314 rad, ω_a = 8 rad/s, ω_{rc} = 0.9 rad/s, ω_{co} = 0.5 rad/s)

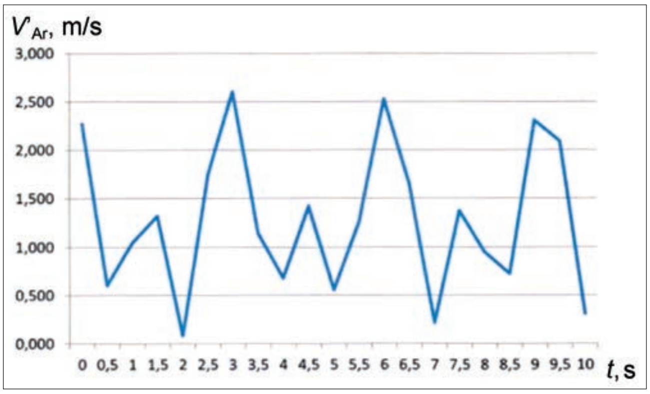

Fig. 10. Speed dependence of V'_{Ar} versus time t (L_{co} = 250 mm, L_{rc} = 180 mm, α = 0.436 rad, ω_a = 8 rad/s, ω_{rc} = 2 rad/s, ω_{co} = 0.5 rad/s)

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.

REFERENCES

1. Barylski A. „Analiza kinematyki docierarek tarczowych". *Inżynieria Maszyn*.18, 2 (2013): s. 97–104.
2. Barylski A. *„Obróbka powierzchni płaskich na docierarkach"*. Gdańsk: Wydawnictwo Politechniki Gdańskiej, 2013.
3. "*Cylindrical Lapping and Polishing Machines*". Materiały nr 06/2017 firmy Stähli.
4. Doi T.K., Ichikawa D. „Lapping and lapping machines". *Handbook of lapping and polishing.* Eds.: Marinescu L.D., Uhlmann E., Doi T.K. Boca Raton: CRC Press, 2007.
5. Jiang L., Yao W., He Y., Cheng Z., Yuan J., Luo J. "An experimental investigation of double-side processing of cylindrical rollers using chemical mechanical polishing technique". *International Journal of Advanced Manufacturing Technology.* (2015). doi: 10.1007/s00170-015-7370-1.
6. Materiały informacyjne nr 7200 (a) firmy Hommelwerke.
7. Materiały informacyjne firmy Lapmaster.
8. Materiały informacyjne firmy Peter Wolters.
9. Materiały informacyjne firmy Stähli.
10. Stähli A.W. "*The Technique of Lapping*". Pieterlen/Bienne (Szwajcaria).
11. Yao W., Yuan J., Zhou F., Chen Z., Zhao T., Zhong M. "Trajectory analysis and experiments of both-sides cylindrical lapping in eccentric rotation". *International Journal of Advanced Manufacturing Technology.* 88 (2017): s. 2849–2859.
12. Yuan J., Yao W., Zhao P., Lyu B., Chen Z., Zhong M. "Kinematics and trajectory of both-sides cylindrical lapping process in planetary motion type". *International Journal of Machine Tools and Manufacture.* 92 (2015): s. 60–71.