ANALYSIS OF FLAT COMPENSATOR LAPPING IN AN ASSEMBLY PROCESS

Analiza docierania kompensatora płaskiego w procesie montażu

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DOI: 10.15199/160.2020.2.7

Abstract: An approach to analysis of lapping of flat compensator during the assembly of the structural connection was demonstrated. Machining main time and the costs of single-disc lapping process were presented.

Keywords: assembly, compensator, lapping, analysis

Streszczenie: Przedstawiono sposób analizy docierania kompensatora płaskiego podczas montażu połączenia konstrukcyjnego. Wyznaczono czas główny obróbki i koszty operacji docierania jednotarczowego.

Słowa kluczowe: montaż, kompensator, docieranie, analiza

Introduction

Abrasive machining, mainly grinding and lapping, is often applied in the process of the assembly of machine structures, in the case of individual fitment of the components of a given joint or application of the technological compensation [2, 3]. When compensative assembly method is employed, the required length of the closing link is achieved by changing the dimension of one of the component links of the chain of dimensions. It is very important to specify the offset correctly, so as it is not too large because it would extend the time consumption of the assembly process. The advantages of this compensative assembly method include the possibility of producing the components with larger tolerances. The time consumption of the compensator lapping in the link assembly process makes this method applicable in piece production and low-rate production. Machine lapping is being applied in order to shorten the machining time as much as possible.

In case of unilateral lapping of flat surfaces, a single-disc lapping machines are used, including both machines with weight ballast (Fig. 1a and 1b) – placed in specially designed separators (Fig. 1.e) and machines featuring pneumatic assemblies ballasting lapped parts – through elastic supports (Fig.1c and 1d).

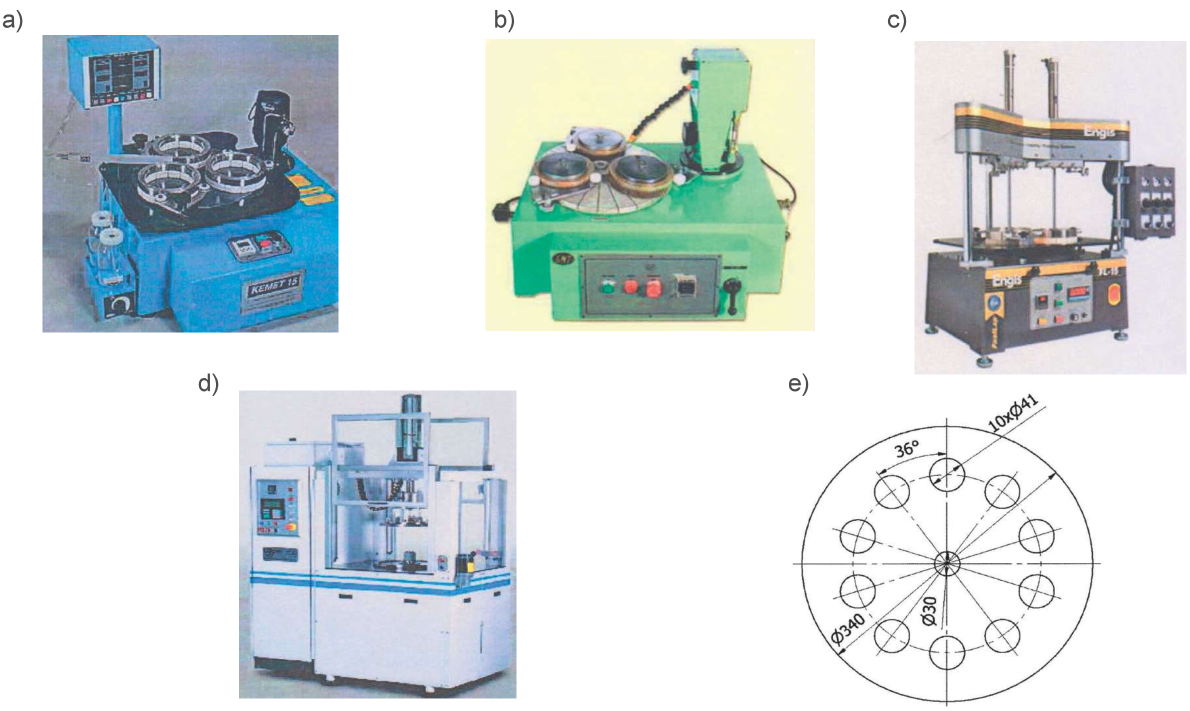

Fig. 1. Single-disc lapping machine: a) model 15 produced by Kemet [6], b) model 06-01 produced by GMT [5], c) model FL-15 produced by Engis [4], d) model LSP-6 produced by Lapmaster [7], e) sample separator

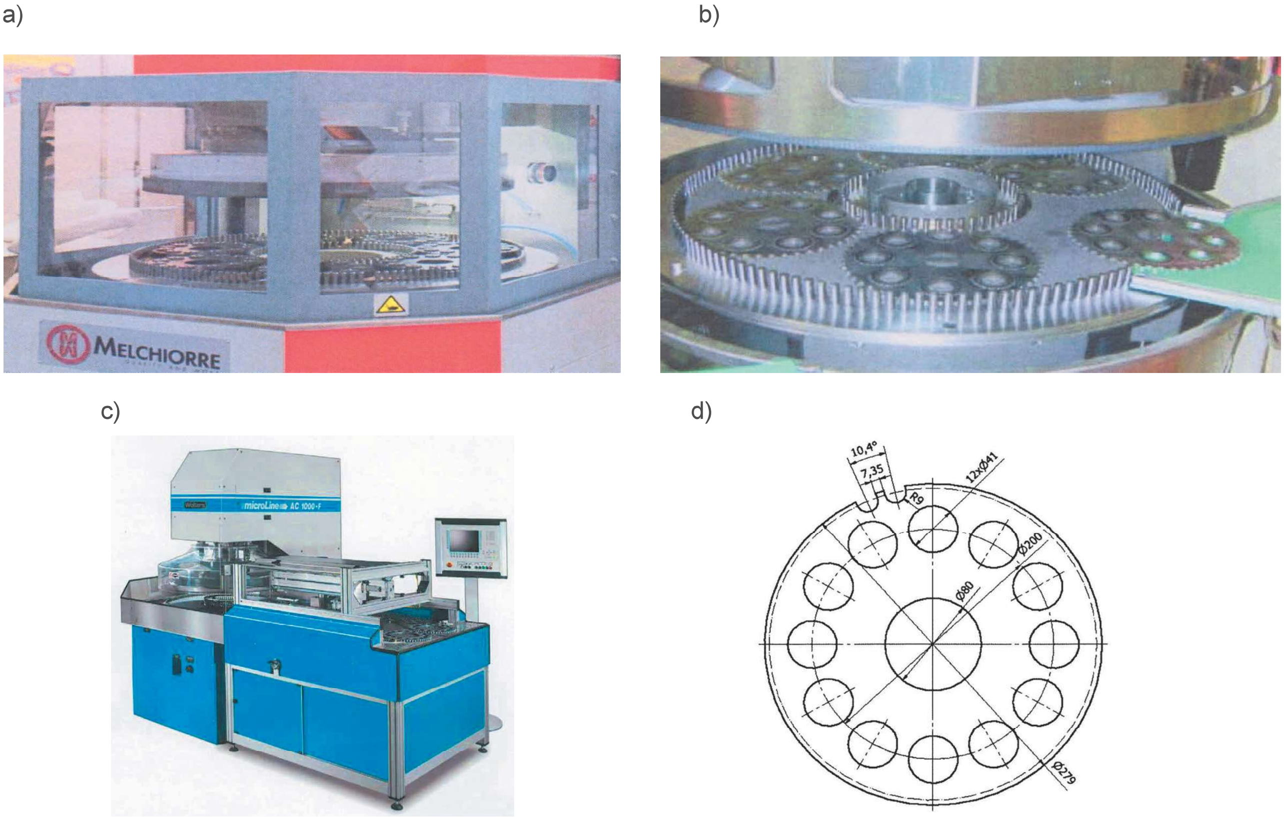

Fig. 2. Double-disc lapping machine: a) model ELC 900 produced by Melchiorre [8], b) model DLM 705 produced by Stähli [10], c) model AC1000-F produced by Peter Wolters [9], d) sample separator

When flat-parallel elements are being machined, it is possible to use double-disc lapping machines (Fig. 2a - 2c), in this case the separators (Fig. 2d) are, at the same time, elements of the circulatory drive system. Due to the piece and low-rate production of the wares, machining of the compensators should be carried out with lapping machines featuring lapping discs of the appropriate diameters (usually of small dimensions), so that a single leading ring (in case of a single-disc lapping machine) or at least four separators (in case of double-disc lapping machines) contain at least four machined pieces. In a double-disc system it is possible to place only one machined element in each separator. Such a situation can also occur in case of a single-disc lapping machine when the dimensions of a machined compensator are relatively large (in relation to the outer diameter of the leading ring).

The paper presents a method of selecting the conditions of lapping of a single-disc flat compensator. Due to the fact that each lapping machine allows precise setting of the duration of machining, it is vital to set this basic parameter in such a way as to avoid frequent breaks for measuring the height of a compensator.

Lapping technology

In order to develop the guidelines for machining conditions, lapping experiments were conducted on a single-disc lapping machine with standard (ring) kinematic system (Fig. 3). Actuating system of the lapping machine consists of three leading rings *1*, cast-iron (EN-GJL250) grooved lapping disc *2* (outer diameter 380 mm), abrasive suspension dispenser *3*, rollers *4* – keeping the turning leading rings in a specific position on the disc *2* and reflective sensors *5* measuring the rotational speed of the rings *1*. Lapping disc features stepless adjustment of the rotational speed and machining duration in with the precision of 1-second.

The time consumption of machine lapping is influenced by many factors, including mainly material and technological conditions associated with the machined element, abrasive suspension, lap and exerted pressure, as well as kinematic parameters resulting from the applied actuating system of the lapping machine.

Fig. 3. Single-disc lapping machine Abralap 380

Main time of lapping tg of a single filling of separators with workpieces (a batch of elements machined at the same time) can be specified with this formula:

$$t_g = q(A \cdot v \cdot p \cdot kv \cdot kp \cdot kz \cdot kc)^{-1} \qquad (1)$$

where:
q – lapping offset (unilateral) [mm],
A – constant depending on the type of a machined material [mm²/daN],
v – average lapping speed [m/min],
p – unit pressure [kPa],
k_v – coefficient of the influence of lapping speed,
k_p – coefficient of the influence of unit pressure,
k_z – coefficient of the influence of the size of abrasive grains,
k_c – coefficient of the influence of the liquid components of abrasive suspension.

Table 1 contains the experimentally determined values of the constant A and coefficients in the formula (1) during lapping with a suspension based on normal artificial corundum.

For example, in the case of the considered unilateral offset for lapping a ring flat compensator (made of carbide construction steel in a mild condition) with q = 0,05 mm, an element whose surface roughness after lapping should not exceed Ra = 0,16 μm, a suspension of micro-grains of artificial corundum 95A number F360/23 was selected. For the adapted unit pressure p = 100 kPa, average lapping speed of 60 m/min and application of liquid suspension (volumetric composition: 50% of machine oil and 50% of petroleum) table 1 yields: $A = 448 \cdot 10^{-8}$, $k_v = 0{,}73$, $k_p = 0{,}54$, $k_z = 0{,}62$ and $k_c = 0{,}84$ (determined average value). Therefore, bearing in mind formula (1), main time of lapping t_g is 10,8 min. As it was exhibted in further experiments, when abrasive suspension based on green silicone carbide (the same grain number) and p = 80 kPa were applied, main time obtained was t_g = 13,5 min. When lapping is underway, it is necessary to measure the height of compensator, disturbing the process before the calculated time t_g (approx. two minutes earlier). Afterwards, the machining process should be completed in order to obtain the required assembly dimension. When suspension is constantly supplied, it can be assumed that linear performance of lapping is maintained throughout the operation at undeviating level.

In the case of a single-disc lapping, the applied kinematic system (Fig. 4) includes a lapping disc *1* (outer diameter R_3) rotating with angular velocity ω_t and workpiece separators *2* (fitted in a leading ring with inner radius r_2) rotating concurrently with velocity ω_2 (angular velocity of an imaginable yoke $\omega_j = 0$). Speed of a specific point P located on the surface of a machined workpiece 3 is described (in time function t) by relation [2]:

Table 1. Data for calculating the lapping time

Values of the A constant and coefficients in the formula for calculating the main time of lapping							
Machined material	**A [mm²/daN]**						
Steel in mild condition	$448 \cdot 10^{-8}$						
Hardened steel	$374 \cdot 10^{-8}$						
	Lapping speed v [m/min]						
	10	20	30	40	50	60	
	Coefficient k_v						
Steel in mild condition	1	0,92	0,86	0,81	0,77	0,73	
Hardened steel	1	0,85	0,76	0,70	0,64	0,60	
	Unit pressure p [kPa]						
	50	60	70	80	90	100	
	Coefficient k_p						
Steel in mild condition	1	0,83	0,74	0,66	0,59	0,54	
Hardened steel	1	0,81	0,73	0,65	0,58	0,52	
	Size of an abrasive grain						
	180	F240/45	F280/37	F360/23	F400/17	F500/13	F600/9
	Coefficient k_z						
Steel in mild condition	1	0,91	0,85	0,62	0,55	0,45	0,38
Hardened steel	1	0,89	0,82	0,60	0,51	0,41	0,33
	Liquid component of abrasive suspension						
Type of liquid	**Coefficient k_c**						
Machine oil	1						
Petroleum	0,67						

$$v_P(t) = \omega_t [R^2 + r^2 \cdot k^2 + 2R \cdot r \cdot k \cdot \cos(\omega_2 \cdot t)]^{-1/2} \quad (2)$$

where coefficient

$$k = (\omega_t - \omega_2)/\omega_t \quad (3)$$

Figure 5 presents, for example, the variability of lapping speed for a standard single-disc lapping machine at various distance r of the center of a lapped workpiece to the center of the separator (Fig. 4).

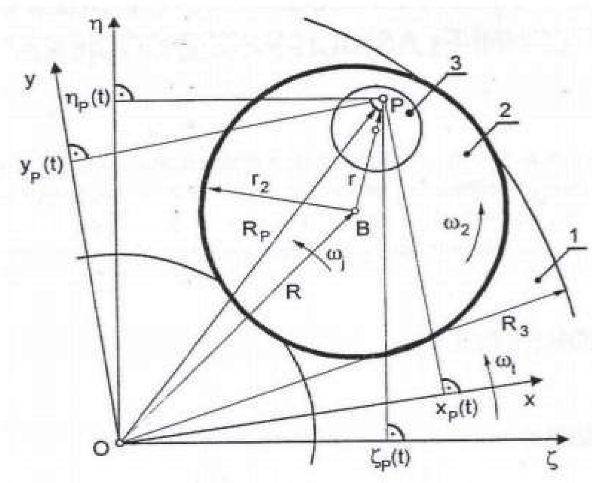

Fig. 4. Kinematic system of single-disc lapping

Knowing the arrangement of lapped compensators in separators and other geometrical and kinematic parameters of the system (including the location of the separator center) formula (2) can be used to determine the value of angular velocity (thus rotation speed) of the lapping disc as a mean value – calculated from the initial and final value of the cycle of variations.

Material costs of lapping are mainly influenced by the output of abrasive suspension which, in the analysed case, is 1.65 ml/min. Taking into consideration the costs of man-hour amounting to 23.70 PLN [11] it is possible to determine a price of lapping a flat technological compensator amounting to 11.06 PLN if normal artificial corundum grain is applied in the process or 13.54 PLN if the suspension of green silicone carbide (with the same grain number) is used.

General remarks

Lapping is not the only machining method applied in the assembly process with technological compensation or in individual fitting of components. Standard grinding or cutting is also applied. In the case of time-consuming manual grinding, the duration of the operation is significantly longer than the duration of machine lapping and, in approximation, it is proportional to the dimensions of the machined surface of a compensator. One of

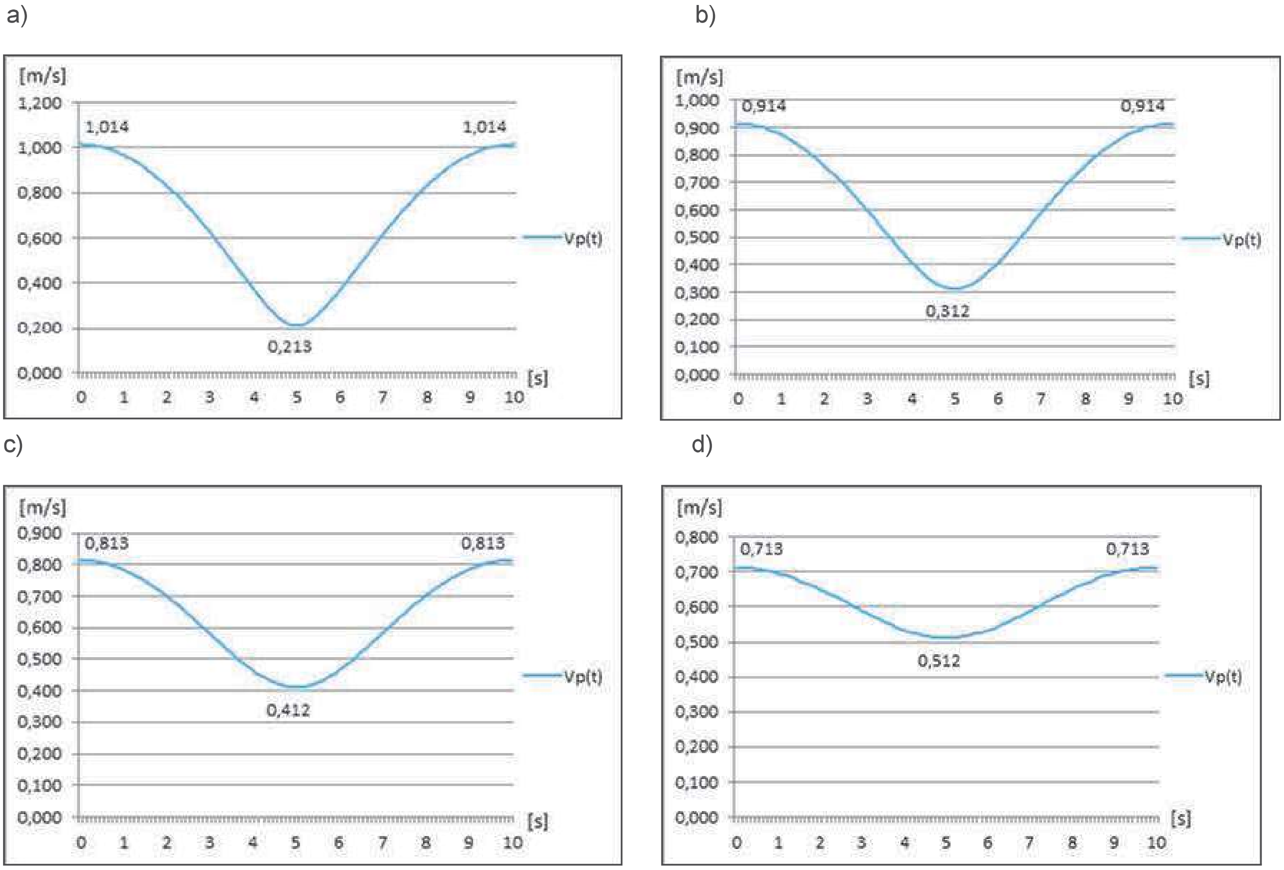

Fig. 5. Values of the instantaneous lapping speed in a system of a standard single-disc lapping machine for: a) r = 40 mm, b) r = 30 mm, c) r = 20 mm, d) r = 10 mm (R = 65 mm, ωt = 3π rad/s, ω2 = 0,2π rad/s)

the advantageous solutions includes the application of grinding with lapping kinematics [1,12,13], which is a method that allows a significant increase of performance – at comparable shape-dimension precision and quality of the machined surface. An important advantage of this innovative machining method on lapping machines, mostly double-disc type, for flat surfaces lies in facilitating the post-process cleaning of workpieces and minimizing the risk of contaminating the surface of workpieces with grinding micro-grains. Successive decreasing of (still high) costs of uniform and segment disc tools for lapping also as far as single-disc lapping machines are concerned, will probably allow finishing machining of flat compensators on a single machine without the need for applying initial grinding. In case of the individual fitting of the components of assembly joint, lapping with a loose abradant is still a correct machining process, especially when a high precision of a construction node is required.

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