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Wear of vibrating disc working bodies of smoothing machines

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Wear of vibrating disc working bodies of smoothing machines

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Abstract. The issues of wear of disk vibrating working bodies of smoothing machines are considered. It is shown that during friction of the working body against the concrete mixture, mainly abrasive and less oxidative wear occurs. In this case, the amount of wear is proportional to the smoothing capacity of the working body, the operating time, the specific pressure of the working body on the surface of the concrete mixture and the coefficient taking into account the working conditions. It was found that the position of natural and forced vibrations of the working body on the smoothing process leads to significant changes in the magnitude and nature of the disc wear. It was determined that the general one-sided character of the disk depends on the parameters of forced vibrations generated by the working body. The presence of localized zones with an expressed wear of the disc was revealed. The latter reduces most significantly the quality of the surface treatment of the concrete mixture. The relationship between the presence of wear of localized wear zones and natural vibrations of the metal structure of the portal of the smoothing machine is shown. It is suggested that the issues of vibration protection (vibration isolation) in the broad sense of controlling the dynamic state of the smoothing machine as a technological complex are of decisive importance for the prevention or significant reduction of local localized wear of the working body.

1. Introduction

In the works [1, 2, 15], the economic feasibility of using rigid concrete mixtures is justified, as their use allows reducing the consumption of cement by 10-20% while maintaining the specified strength of concrete, reducing the hardening time and increasing the durability of concrete products. At the same time, the surface treatment of products formed from rigid concrete mixtures is associated with the application of significant dynamic loads to the treated environment.

Studies [11, 12, 13] showed that the most promising way to improve the working processes of machines for surface treatment of concrete products is an additional vibration effect of the working body of the machine on the treated surface. The effectiveness of the vertical oscillations of the disk of the working body is experimentally confirmed, in which the concrete mix is a mechanical redistribution of components in the most dense packing and sand-cement paste and the milk necessary to smooth the irregularities is displaced to the friction surface, whereby the surface quality is significantly improved.

In the last three decades, a number of authors, including those at the Department of Construction and Road Machinery of the Bratsk State University [6, 10, 14], have developed and studied a fairly large number of various vibration working bodies of smoothing machines, including disk ones. However, the proposed designs have not found wide practical application yet.

2. Materials and methods

A comparative review (not intended to be exhaustive) of concrete finishing machines offered on the Russian market shows that they are mainly represented by foreign manufacturers: Barikell (Italy), Masalta Engineering CO., LTD (China), Tremix LTD Tremix (Sweden), Schwamborn GmbH (Germany), etc. This equipment is self-propelled and manual, one and two-disc (two-rotor) concrete finishing machines with diameters of smoothing discs from 600 to 1600 mm. The drive is electric or from the internal combustion engine, which provides rotation of the disk working body with a frequency within 40-140 rpm. Hydraulic or mechanical transmission provides progressive movement of the working body along the treated surface, and the working bodies themselves do not contain vibration exciters and, accordingly, do not have an additional vibration effect on the treated surface. Among the main reasons that disk vibrating working bodies containing a kinematic or inertial type of vibration exciter as part of their design do not find sufficient application in the mass production of concrete finishing machines, the following can be noted: the large metal consumption of such working bodies; the presence of a larger number of mating rubbing pairs and, accordingly, a lower resource and additional costs for their maintenance. Another main reason that significantly reduces the operational properties of vibrating working bodies is their greater and often uneven wear, which negatively affects the quality of surface treatment of the concrete mixture.

The problems of wear of vibration-free working bodies of concrete-finishing machines, including disk ones, are considered in the works of Professor AV. Bolotny [4, 5]. It is established that when the working body is rubbed against the concrete mixture, mainly abrasive and to a lesser extent oxidative wear occurs. Taking into account that the physical state of the mixture under the influence of the velocity gradient remains constant in the first approximation, and the magnitude of deformations is relatively small, it was suggested that in this case processes similar to those described in [16] take place. Under this assumption, the amount of abrasive wear is proportional to the friction path and the specific pressure:

$$I = K_p \cdot \Delta P \cdot S \tag{1}$$

where $K_p = K_1 \cdot K_2 \ldots K_n$- coefficients that take into account the influence of the material and surface temperature, the size of the gap between the working body and the surface, etc.; ΔP- the value of the specific pressure of the working body on the surface;; S- friction path.

In its physical sense, the smoothing ability of the working body S_{p0} is the length of the line during which the working body acts on the elementary surface of the processed surface, and for disk working bodies can be determined by the dependence:

$$S_{\text{d}} = 1.05 V_d \cdot R \cdot \frac{1}{V_з}, \tag{2}$$

where V_d- the peripheral velocity of the disk; V_d- progressive velocity of the disk along the surface; R- disc radius.

At a known operating time T of the working body, the friction path is determined:

$$S = S_d \cdot T, \tag{3}$$

In relation to the process of smoothing concrete mixtures, on the basis of measurements of wear and working bodies and the time T of their operation before И wear, knowing the specific pressure ΔP of the working body on the surface, the dependence (1) allows setting the values of the coefficient K_p:

$$K_p = \frac{И}{\Delta P \cdot S_d \cdot T} \tag{4}$$

This allows predicting the amount of wear of working bodies of different sizes made of different materials when processing the surface of concrete mixtures with different stiffness.

This approach, based on the measurements made and their subsequent analysis, allowed to A.V. Bolotny came to the following conclusions: it is advisable to use hard disk working bodies with an easily removable steel rubbing surface; linear wear of the steel disk working body is 1 mm for 30-40 hours of operation; the disk working body wears out relatively evenly and provides stable surface treatment quality throughout the entire service life.

3. Research results

Long-term experience in the operation of disk working bodies allowed establishing that the imposition of own or forced vibrations of the working body on the process of smoothing the surface of the concrete mixture leads to significant changes in the magnitude and nature of wear of the working body. In this case, self-oscillations are understood as vibrations caused by malfunctions of the machine components (disk deformation, bending of the disk drive shaft) or their limiting state (the presence of excessive gaps in the mating pairs), and under forced vibrations, vibrations that occur when the disk interacts with the surface to be processed. Figure 1 shows the cross-sections of the disc, which before the start of operation had a thickness of 8 mm, was installed on the basic smoothing machine of the bridge type SMR-13 and treated the surface of the concrete mixture with a stiffness of 60 s. Table 1 shows the results of wear measurements in sections 1-10 of the working body. The operating time to wear was 85 hours.

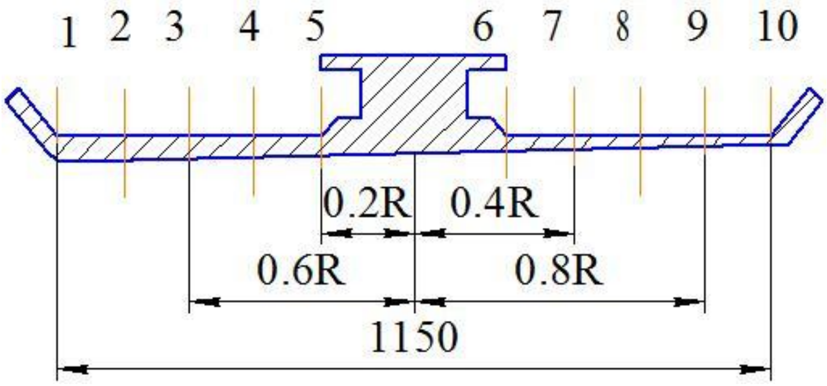

Figure 1. Position of the cross sections of the disk working body.

Table 1. The amount of wear in the sections of the disk working body.

Section number	1	2	3	4	5	6	7	8	9	10
Wear rate, mm	7.5	7.1	6.3	5.5	4.9	3.3	2.4	1.2	0.8	0.6

The maximum wear value of 7.5 mm in section 1 with its gradual decrease to a minimum value of 0.6 mm in section 10 indicates the unilateral nature of disc wear. At the same time, linear wear of 1 mm in the presence of vibration effects is achieved in 20-25 hours of operation, which almost halves its service life. The appearance of forced vibrations is caused by a change in the force or coefficient of friction under the disk and is not associated with the action of any external periodic disturbing force. Forced vibrations, in the absence of a constant source of energy for these vibrations, appear when smoothing products formed from rigid inhomogeneous concrete mixtures, the surface of which can have a significant number of bumps and depressions. These vibrations contribute to accelerated and uneven wear of the disk and individual mechanisms of the machine, which generates the occurrence of natural vibrations of the system and leads to even faster wear of the disk surface.

To date, various disc vibration working bodies have been developed in their design, which differ mainly in the parameters of the vibration effect on the treated surface and the type of vibration exciter. However, there are practically no studies of wear of such working bodies. The relevance of research in this area is due not only to the fact that the vibration effects imposed on the rotational and translational movements of the disk can almost halve its service life, but also significantly reduce the quality of surface treatment due to accelerated and uneven wear of the disk.

It is known [4,5,6,10,12,14] that defect-free smoothing of the surface of the mixture is provided under the condition of maintaining the continuity of the material flow in the boundary layer of the mixture during its flow under the working body. It is evident that the nature and degree of wear of the vibrating working body will largely depend on the characteristics of the boundary layer flow in the zone of vibration effects of the working body. Under the conditions of application of vibration effects, the shear flow begins only when the shear stress exceeds the limit shear stress. After overcoming the limiting shear stress, the process of rapidly increasing mobility of the boundary layer of the concrete mixture and turning it into a heavy liquid with a gradually decreasing viscosity begins. In this process, two components should be distinguished: actual liquefaction, which occurs due to the displacement of free, physically unbound water to the surface of the mixture; pseudo-liquefaction, which occurs due to the linearization of dry friction under the influence of vibration and is expressed in the replacement of dry friction with viscous one.

To obtain information about the actual size and nature of wear of the disk vibration working body, according to the method of Professor A.V. Bolotny, measurements of the removable disk of such a working body were made. The design of the disk working body was developed on the basis of the patent for invention No. 21825136 "Working body of the smoothing machine". Before the start of operation, the disk had the same thickness of 8 mm, as previously described, and was installed on the same basic machine SMR-13. Concrete mixes with a hardness of 60-65 s were treated. The smoothing capacity of this working body $S_д$ =40 m, the vibration intensity $J=A^2\omega^3$ was 25-30 m^2/s^3. The operating time T before reaching wear was about 75 hours. Figure 2 shows the position of the disk sections, and table 2 shows the results of measurements of disk wear in these sections of the working body.

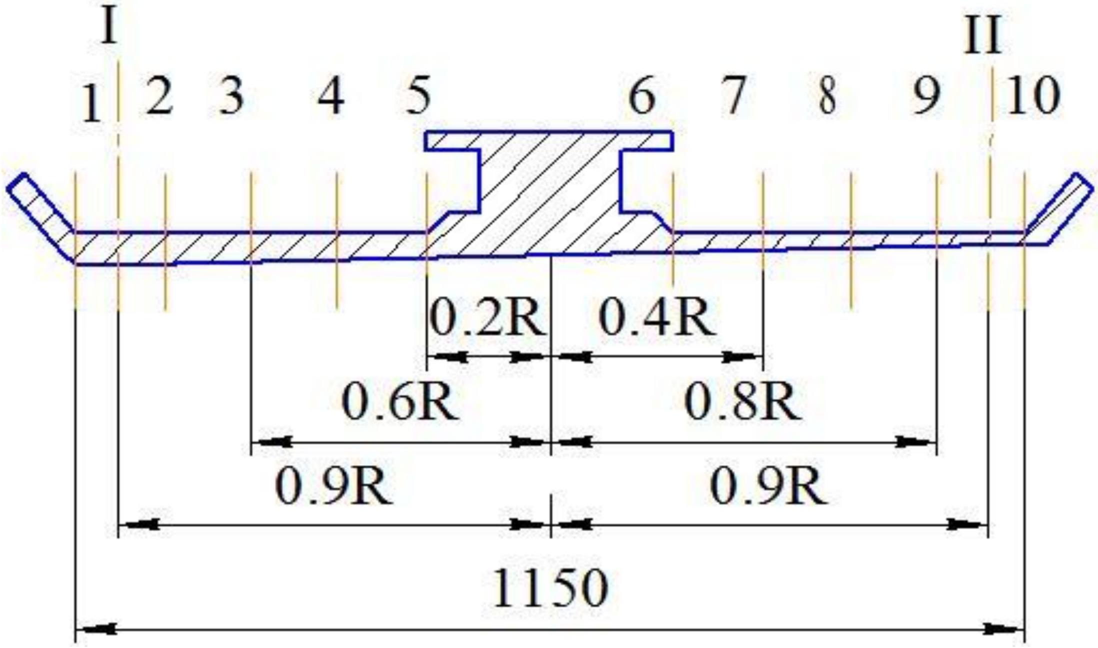

Figure 2. Position of the sections of the removable disk of the vibrating working body.

Analysis of the results obtained with a difference from the maximum wear values of 7.1 mm in section 1 to the minimum 0.9 mm in sections 9 and II indicates the general one-sided nature of wear of the working body. It can be assumed that this type of wear depends on the parameters of forced vibrations generated by the working body. A comparison of the results presented in tables 1 and 2 indicates a slight decrease in the overall wear of the vibrating disk working body in sections 1-8, which can be explained in this case by replacing dry friction with viscous one, when the mixture flows under the working body.

At the same time, localized zones with a clearly expressed local wear of up to 0.5 mm appear between sections 1-I, 2-I and 10-II, II-9. It can be assumed that the occurrence of localized wear zones is due to the natural vibrations of the portal of the smoothing machine due to insufficient vibration isolation of the working body from the main metal structure of the machine.

Table 2. The amount of wear in the sections of the disk working body.

Section number	1	2	3	4	5	6	7	8	9	10	I	II
Wear rate, mm	7.1	6.8	6.0	5.1	4.4	2.9	2.2	1.1	0.9	1.0	7.0	0.9

Manual smoothing machines occupy a significant share in the total number of concrete finishing machines in operation. The experience of their operation indicates two features: their use is most appropriate for surface treatment of moderately hard concrete mixtures with a stiffness not exceeding 40s, and the specific pressure of the working body on the surface to be treated is constant and is determined by the weight of the machine distributed over the surface area of the working body. In accordance with the above procedure, the value and characteristics of wear of the disk working body with a diameter of 800 mm and a thickness of 8 mm of a manual vibration smoothing machine were estimated. The design of the machine is made in accordance with the patent for invention No. 2147513 "Working body of a manual smoothing machine of an oscillating type". Concrete mixtures with a hardness of 35s were treated. The disk working body had a smoothing capacity $\boldsymbol{Sd} = \mathbf{30}$m, and the vibration intensity $\mathbf{J} = \mathbf{A^2\omega^3}$ was 23-24 m^2/s^3. The operating time T before reaching wear was 80 hours. Figure 3 shows the position of the disk sections; table 3 shows the results of wear measurements in these combinations of the working body. The obtained results of measurements of disk wear in combinations 1-10 confirm the general one-sided nature of wear of vibrating disk working bodies, due to the contribution of forced vibrations generated by the working body. However, a comparison of these results with the results shown in table 2 indicates significantly lower values of absolute wear of the working body in sections 1-10 for manual smoothing machines. The latter can be explained by the fact that the specific pressure of the working body on the surface of the mixture in manual machines is significantly less than in stationary ones, and the process of linearization of dry friction under the influence of vibration and replacement of dry friction with viscous flows faster due to the displacement of large volumes of liquid phase to the friction surface during processing of moderately rigid mixtures.

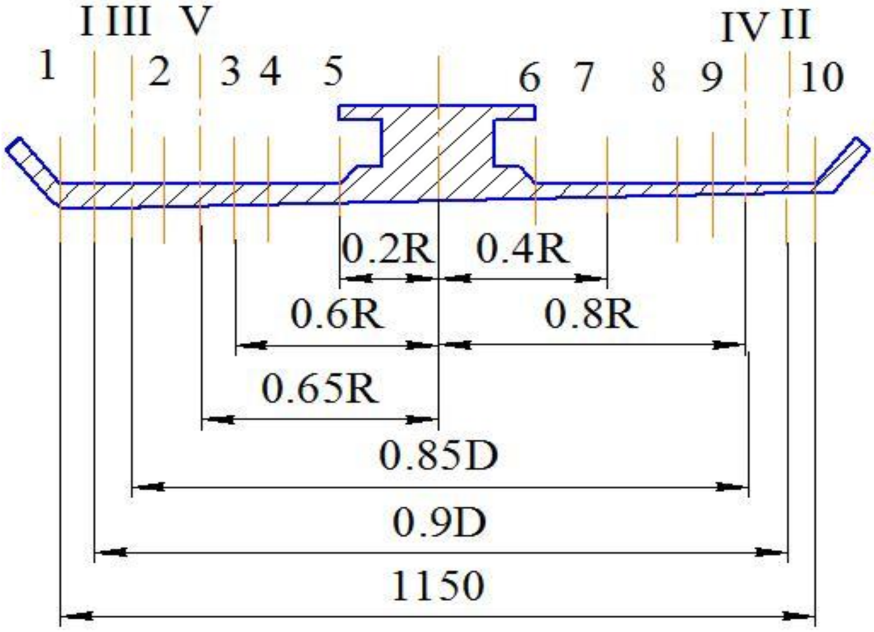

Figure 3. Position of the sections of the removable disk of the vibrating working body of the manual smoothing machine.

When the working body reached the operating time T=60 hours, the quality of surface treatment noticeably deteriorated due to the accelerated formation of local localized wear in sections I, II, III, IV, V. At the same time, for manual smoothing machines, their value in comparison with the value of wear in adjacent sections 1, 2, 3, 9 and 10 exceeds the values recorded for vibrating working bodies of stationary machines. The one-sided nature of wear becomes more expressed due to the additional localization of local wear in section V. In this case, the occurrence of localized wear zones is also due to its own vibrations of the manual machine body, which were clearly expressed during its operation due to insufficient vibration isolation of the working body, structurally represented by elastic elements in the form of rubber seals. The latter emphasizes the need to take into account the issues of vibration protection of vibration working bodies of manual machines, as a factor that significantly affects the magnitude and nature of their localized wear.

Table 3. The amount of wear in the section of the vibrating disc working body of a manual smoothing machine.

Section number	1	2	3	4	5	6	7	8	9	10	I	II	III	IV	V
Wear rate, mm	6.4	6.0	5.2	4.3	3.5	2.1	1.7	1.00	0.8	0.65	6.9	0.95	6.7	0.85	5.1

4. Summary

The results obtained and the assumptions made are preliminary and indicate the need for more extensive experimental studies in the field of wear of vibration working bodies with different geometric dimensions, in a sufficient range of their smoothing ability, when processing mixtures of different stiffness and when varying the parameters of the vibration effect on the treated surface of the mixture. However, as localized areas of local wear most adversely affect the quality of surface treatment, it can be concluded that the issues of vibration and overall control of dynamic as smoothing machines as a technological complex, are of fundamental importance to prevent or significantly reduce the magnitude of localized wear of the working body. In the general case, lower levels of self-vibrations of shells and manual smoothing machines and the basic structures of stationary machines, allowing for the difference in their mass-inertial characteristics, size and features of operation may be implemented for manual smoothing machines with structural study of a method of vibration control of the working body, and for stationary machines the most appropriate one is the installation of dynamic absorbers on the main metal machine. The issues of vibration protection and control of the dynamic state of technological machines based on the structural theory of vibration protection systems are widely considered in the works [3, 7, 8, 9]. However, the development of technical solutions in relation to a particular type of vibrating working body working as part of a smoothing machine, which has its own mass-inertia characteristics and its own spatial metric, requires additional theoretical and experimental research.

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