Research of the effect of shot peening vibro-abrasive machining on the properties of the steel NC11LV

Badania wpływu kulowania obróbką wibrościerną na własności stali NC11LV

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The article presents the results of the effect of vibro-abrasive machining using as a working medium balls of steel-check on the properties of disks made of steel NC11 (X160CrMoV121). Tribological tests using the tester T-01 made it possible to determine the relationship of time of shot peening on the coefficient of friction and wear linear-in. They were presented typical consumption profiles.

KEYWORDS: vibro-abrasive machining, tumbling, rotofinish, shot peening, tribological tests

Vibro-abrasive machining

Abrasive machining in vibrating containers is one of the finishing touches. This is a kind of mechanical-chemical processing [1], in addition to the machining medium - in the form of appropriately selected moldings - also abrasive pastes or polishing aid fluids [2]. It depends on the microscopic irregularities in the surface of workpieces. It can be used to remove: oxide layers, scales, traces of thermal treatment, and rust. On the other hand, sharp edges are often rounded after machining [3, 4]. Surface bleaching is also possible, often understood as improvement of reflectivity [5]. Two-stage processes (pre-smoothing followed by polishing using steel fittings) allow for more tangible effects of the shining process. This is followed by a distinct strengthening of the surface layer due to crushing [6].

Tribological studies

Roughness of the metal sliding surface is essential when it comes to the type of friction occurring [7]. In the case of very smooth surfaces, the dominant role in the friction process is the adhesion of the sample surface to the metal surface of the counter. This results in a high friction coefficient - about twice as much as friction on more rough surfaces. The presence of strong adhesion also adversely affects the wear intensity [8]. The phenomenon of adhesion during friction on smooth metal surfaces is even more pronounced as the pressure increases, resulting in an increase in the actual contact surface and approximation of the coherent particles [9].

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Like roughness, the hardness of the metal element has a
significant, though less intense [10] effect on the type of overlapping sliding surfaces. With increased hardness of the metal surface, which is a measure of the strength of surface layer, the surface energy increases [9]. From a tribological point of view, occurrence of free energy on the metal surface causes excitation of atoms of the surface layer and thus increasing their chemical activity. This has a certain effect on the interaction of surfaces in contact (sphere-ball), initiating diffusion, sorption and adhesion. The rise in temperature caused by friction, which cannot be avoided, additionally increases the proportion of adhesion phenomena. This, in turn, is related to the increase in energy of surface, but not to surface energy [8] (surface tension), which decreases with increasing temperature. The increase in surface energy causes an increase in the vibration amplitude of atoms on the metal surface in a direction perpendicular to the surface, which favors the formation of bonds with foreign atoms on the surface of material (adhesion, sorption).

Test parameters

Vibro-abrasive machining with the use of metal ball process is increasingly used. Its effect is to achieve a glossy, reflective surface with low roughness. The aim of the study was to evaluate the effect of vibro-abrasive machining using metal fittings on the technically dry friction (TTS) of disc-sphere interphase in T-01 tester. Consideration was also given to the cross-sectional character of the resulting wear depending on the processing time.

The Rollwasch SMR-D25 vibro-abrasive machine with a working tank capacity of 25 liters was used for the tests. In the tumbler, approximately 15 kg of SB-type lathe belts were used for polishing and strengthening. The impact of the fittings in vibration treatment resembles the process of balling. In addition, the process was carried out with FE L120-B32/R support fluid to wet the surface and protect it against the external environment. The vibration frequency of the container was set at 2500 Hz. Shields were placed in the tank for 60 and 120 min, respectively. The case was also considered, where both elements of the tribological association - shield and ball - were placed for 120 minutes.

Tribological studies were carried out at the Department of Mechanics at the Świętokrzyski University of Technology using the T-01M tribological tester, working in conjunction with the ball-disc in accordance with ASTM G 99 standards. The discs were made of NC11 steel (X160CrMoV121), while the balls were made of 100Cr6 steel with a diameter of 3 mm. The basis of the study was technically dry friction for the discs of material in question in the initial state, referring to 60 and 120 min discs; the case of the shield and balls affected in the vibrating container was considered for 120 min. The temperature during tests was 22.5 °C (±1 °C), the atmospheric pressure was 978.4 hPa (±4 hPa), while the air humidity was about 39.7% (±5%).

The tribological tester software continually collects information and presents it as a graph of friction and linear wear depending on the duration of the test (see Figure 1 for an example). Note that the coefficient of friction is the value of the friction force at a given moment related to the load of the steel ball (10 N).

Based on observations of the weld profiles formed after the tribological test using the Talysurf CCI Lite profiler - Taylor Hobson, exemplary profiles with cross-sectional examples are shown in Figure 2. Various traces of the resulting debris, which have a decisive effect on friction coefficient and linear wear, are evident. These factors increase with the duration of the reinforcement, while the wear field decreases and has a milder character, devoid of numerous recesses and hills.

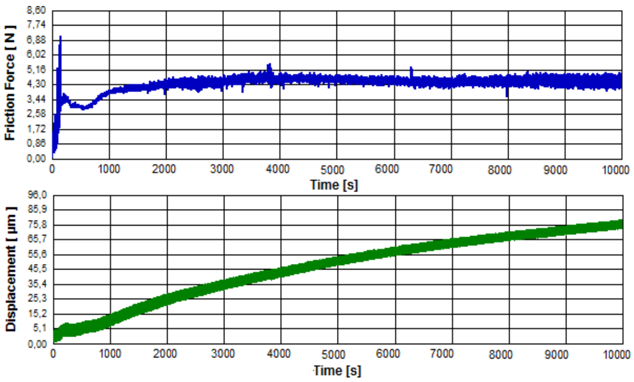

Fig. 1. Dependence of friction force and linear wear on time, obtained from the tester for a sample that has not previously been subject to vibro-abrasive treatment

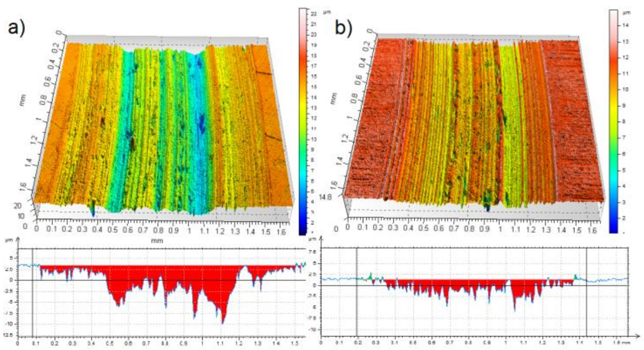

Fig. 2. The 3D wear views after tribological tests of discs subjected to vibro-abrasive pretreatment by: *a)* 60 min, *b)* 120 min

Based on the microhardness tests, Figure 3 shows the dependence of the hardness on balling duration. Hardness was measured on a Vickers scale with a constant load of 1 kg; the single measurement time was 15 seconds.

TABLE. Parameters obtained from SGP and tribological studies

Time, min	Max. depth, µm	Area of wear, $µm^2$	*Ra*, µm	Friction coefficient, *µ*	Wear, µm
00	6,33	4785	1,174	0,478	75,8
60	13,39	5693	0,452	0,480	38,8
120	11,53	3986	0,352	0,637	92,3
120T+K	7,26	2306	0,138	0,615	50,2

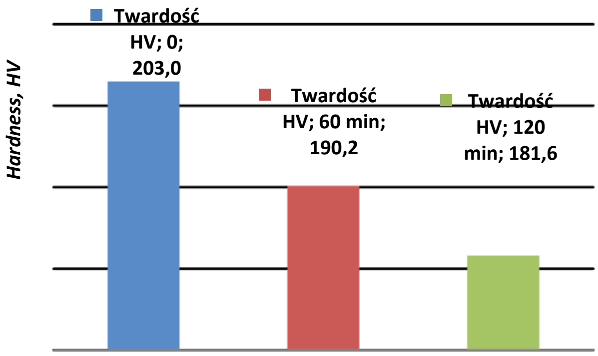

Fig. 3. Disc hardness dependence on vibro-abrasive machining time

Conclusions

Vibro-abrasive treatment using steel beads is an effective method of surface brightening.

Balling machining by vibration treatment increases the coefficient of friction *µ* from about 0.48 to 0.62. Linear wear also increases. It should be noted that at 120 min of balling of discs and spheres, the linear wear is nearly twice as small (50 µm) than in the corresponding test, where only the disc was strengthened by balling (92 µm).

Vibro-abrasive machining with steel beads reduces the hardness of discs. Before the impact of the vibrating balls, the hardness of discs was about 200 HV and decreased by about 10 HV for every 60 minutes of impact.

In the initial state, the discs had increased hardness, which was due to elastic-plastic deformation after machining. Balling relaxes the surface layer.

REFERENCES

1. Filipowski R., Marcinak M. „*Techniki obróbki mechanicznej i erozyjnej*". Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej, 2000.
2. Starosta R. „*Obróbka powierzchniowa*". Gdynia: Wydawnictwo Akademii Morskiej w Gdyni, 2008.
3. Spadło S., Pierzynowski R. „Zastosowanie obróbki wibrościernej do polerowania powierzchni elementów amunicji". *Machine Engineering*. 12, 1, Electrical Machining Technology, pages 70–77.
4. Spadło S., Młynarczyk P., Bańkowski D. "Analysis of the effect of processing vibro-abrasive finishing on the geometric structure surface scales ammunition and sharp edges". *Journal of Achievements in Materials and Manufacturing Engineering*. 66, 1: pages 39–44.
5. Kacalak W., Tandecka K. "Effect of superfinishing methods kinematic features on the machined surface". *J. Machine Engineering*. 4 (2012): pages 35–48.
6. Eric C. Ames. "Repair of high-value high-demand spiral bevel gears by superfinishing". *Gear Technology.* October (2012): pages 50–55.

7. Xiao L., Rosen B.-G., Naser Amini, Nilsson P.H. “A study on the effect of surface topography on rough friction in roller contact”. *Wear.* 254: pages 1162–1169.
8. Ozimina D., Madej M., Kałdoński T. “The wear resistance of HVOF sprayed composite coating”. *Tribology Letters*. 41, 1: pages 103–111.
9. Wieczorek J., Dolanta-Grosz A., Dyzia M., Śleziona J. „Właściwości tribologiczne kompozytowych materiałów o osnowie stopu aluminium AK12 zbrojonych cząsteczkami ceramicznymi”. *Kompozyty.* 1 (2001): pages 207–210.
10. Janecki D., Stępień K., Adamczak S. “Problems of measurement of barrel- and saddle-shaped elements using the radial method”. *Measurement.* 43, 5 (2010): pages 659–663.

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