TEXTURE OF SURFACE OF COATINGS OBTAINED USING THE “Casto-Dyn 8000”, TORCH, AFTER BURNISHING TREATMENT

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Abstract

The flame sprayed coatings are characterized by porosity, oxide inclusions presence and large real area of surface. In order to obtain adequate surface roughness coatings must be applied finishing. For this purpose, the turning and grinding are used. In the paper a burnishing to finishing flame sprayed coatings was proposed. Burnishing is not used during the processing of thermally sprayed coatings, as is commonly believed that this technology causes damage to coatings.

The process of flame sprayed is a technology affordable and easy to implement. It does not require great skill of the operator. This method is not associated with expensive workstation equipment. It may therefore be used with success for the regeneration of machine parts by the crew of vessel engine room.

Coatings of Ni-5% Al and Ni-5%Al-15%Al_2O_3 *obtained by powder flame spraying were studied. Torch of "Casto-Dyn 8000" was used. After turning the average value of surface coatings roughness coefficient* R_a *=2.59* μ*m (for Ni—5%Al)* μ*m and* R_a *= 3.1* μ*m (for composite coating) was obtained. SRMD burnishing tool produced by “Yamato” company was used. Roller burnishing was performer on turning lathe. It was found that the increase in burnishing force and the reduction of burnishing speed and feed rate of less roughness of coatings are obtained.*

For Ni-5%Al coatings the lowest surface roughness, Ra = 0.3 μ*m was obtained after burnishing with the following parameters: the force - 1100 N, burnishing speed - 28m/min, feed - 0.08 mm/rev. During burnishing of Ni-5% Al-15%* Al_2O_3 *coatings applied force 700 N,* R_a *= 1.31* μ*m was obtained. Greater burnishing force caused coatings damage. Burnishing compared to turning has positive influence on the curve shape of the material ratio. It was found that the parameters* R_k *and* R_{pk} *were reduced.*

Keywords: *flame spraying, burnishing, Ni-Al coating, Ni-Al-*Al_2O_3 *coating, torque pump*

1. Introduction

Use of machines and equipments is associated with wear of machine parts by a process of corrosion, tribological and fatigue. This forces a periodical survey and verification of dimensional, sometimes replacement or regeneration of worn parts. The processes of wear can be reduced by shaping an appropriate surface layer of machine parts or applying coatings. In the construction of machines are commonly used electrolytic chromium coatings, cladded layer of stellite or nimonic alloys and chemical Ni-P coatings. Flame sprayed coatings can meet the performance requirements and extend the life of machine parts [1-3].

The process of flame sprayed is a technology affordable and easy to implement. It does not require great skill of the operator. This method is not associated with expensive workstation equipment. It may therefore be used with success for the regeneration of machine parts by the crew of vessel engine room [4].

Flame sprayed coatings are characterized by porosity, oxide inclusions presence and large real area of surface. In order to obtain adequate surface roughness coatings must be applied finishing. For this purpose, the turning and grinding are used. In the paper a burnishing to finishing flame sprayed coatings was proposed. Burnishing is not used during the processing of thermally sprayed coatings, as is commonly believed that this technology causes damage to coatings.

Korzyński and Przybylski [5-7] consider that burnishing may be applied to the finishing of galvanized and cladded coatings. Chromium coatings after burnishing very small surface roughness, R_a = 0.09 μm, are characterized. Burnishing for the treatment of electroplating chromium coatings placed on the piston rod and sleeve in hydraulic devices is used. The surfacing plastics working can also be used to treatment of electroplated coatings iron and nickel. The main purpose of burnishing galvanized coating is not only to low values of surface roughness, but also increase their fatigue strength. On the industry, this technology was applied to the finishing of cladding coatings (stellite or Nimonic 80A) on seat faces of the exhaust valves [3].

Numerous tests have concluded that the welding of high temperature resistant Ni-Cr alloy onto the stainless steel spindle will extend the time between overhauls considerably when the surface is work-hardened. The burnishing process (Fig. 1) dramatically improves the hardness of the seat. It also improves the spindle seat's resistance to cracks, compared to present hard-facings, including Nimonic 80A [3]. Due to the high hardness of stellite 50 - 60 HRC, while burnishing large forces 8 kN are used, obtaining 20% increase in their hardness. It can also use electro-mechanical treatment for 50% to increases hardness of stellite cladded layers [7]. The plastic forming of thermal nickel alloys (Ni-Al, NiAl and Ni3Al) coatings allowed reducing the roughness without loss of adhesion [8, 9].

Burnishing may also be used for surface treatment of materials prior to application of galvanic coatings, thermal sprayed and cladded. Nadasi [10] proposed the use of rolling of coatings to reduce their porosity.

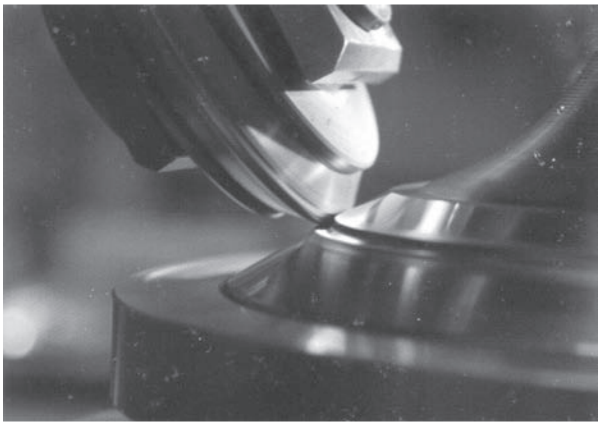

Fig. 1. High pressure on the welded (Nimonic 80A) spindle seat of MAN BW Diesel engines [3]

In the articles [9, 11], the use of burnishing to the surface finishing flame sprayed coatings are proposed. The Ni-5%Al and Ni-5%Al-15%Al_2O_3 coatings were studied. Coatings were deposited by oxy-acetylene „Roto-Teck 80” blowpipe. Finishing allowed obtaining a surface with small roughness for both types of coatings. Arithmetic mean roughness value of the surface alloy coatings was R_a = 0.27 μm and the composite layers R_a = 1.13 μm. The lowest value of surface roughness of Ni-Al coating were obtained, when the following parameters burnishing was used: burnishing force F_n = 1100 N, feed f_n = 0.08 mm/rev, speed burnishing V_n = 28.26 m/min. In the case of composite layers were used less burnishing force F_n = 700 N. Increased force burnishing caused detachment of Ni-5%Al-15%Al_2O_3 coatings from the steel substrate. It was found that the greatest influence on reducing the roughness of the surface coating has force burnishing. The greater the forces used during the burnishing operation, the arithmetic mean roughness value Ra is lower. Feed rate of roller is inversely proportional effect on the coatings surface roughness. Studies demonstrated a statistically insignificant effect of burnishing speed on surface roughness.

The roller-burnishing influences not only on the reduction of surface roughness, but also on strain hardening of the processed surface. The largest influence on the hardness of the coatings has burnishing speed. The relationship between these variables is inversely proportional. The least influences on the strengthening have the feed. When the feed is a smaller the coating surface hardness is higher. On the strain hardening is also influenced by the force of burnishing. The increase in the value of the burnishing force causes an increase in hardness of the coatings. The operation of burnishing caused an increase in the hardness about 20% for Ni-Al coatings.

In this article the results of measurements of surface coatings roughness after the plastic working are presented. Coatings were obtained flame spraying method, using the "Casto-Dyn 8000” torch. Blowpipe "Casto-Dyn 8000” comes with a set of different interchangeable nozzles and ejectors and a connector for connection to the compressed air. This additional medium of the compressed air stream narrows of sprayed coating and increases the speed of particles of coating material in the sprayed stream. Coatings obtained using the torch "Casto-Dyn-8000" should be characterized by lower porosity and the less numbers of interphases oxide inclusions from the layers obtained by "RotoTeck 80”.

The purpose of this study was the selection of roller- burnishing parameters of surface Ni-5%Al and Ni-5%Al-15%Al_2O_3 coatings obtained by "Casto-Dyn-8000 " blowpipe. Coatings with low surface roughness could be applied as layers increase the service life of torque pumps shaft used on vessels in the sea water systems.

2. Preparation of pivots for burnishing

The coatings were sprayed on steel shafts pivots (X5CrNi 18-10) degreased flame, with diameter f = 40 mm. To increase the adhesion of the coatings, the pivots were threaded. For spraying, was used a “Casto-Dyn-8000” torch made by Castolin. During flame spraying, was used powder ProXon 21021 (Ni- 93.45%, Al-5%, B-0.8%, Fe-0.34%, Cr-0.18%, Si-0.15%, C-0.08%), as well as its mixture with powder MetaCeram 28020 (Al_2O_3 – 97%, TiO_2- 3%). In composite coatings, the volumetric ratio of ceramic phase was 15%.

The following parameters of flame spraying have been applied:

- acetylene pressure: 0.07 MPa,
- oxygen pressure: 0.4 MPa,
- air pressure: 0.1 MPa,
- spraying speed: 25 m/min,
- feed: 3mm/rev,
- burner distance from the sprayed surface: 150 mm,
- number of applied layers: 6.

Spraying coatings were obtained on pre-heated steel substrate to a temperature of 60° C. Then, it was sprayed coating process with a so that the temperature of the shell shall not exceed 80°. In the case of the first layer of composite coating was applied without phase dispersion, in order to improve adhesion of coatings to the steel substrate.

After spraying, the coating was subjected to initial treatment (turning) in order to reduce shape (roundness and cylindricity) deviations of the pivots shafts. After turning, the surface of pivots shafts were observed to have an average value of roughness R_a = 2.59 μm and a hardness of 200 HV 5 in cases of alloy coatings, and R_a = 3.1 μm and the coating matrix hardness of 182 HV 5 for composite layers.

3. Methodology of research

The burnishing process was conducted with a one-roller Yamato SRMD burnisher. Alloy coatings were processed first. The application parameters of the technological process of surface plastic treatment are presented in Tab. 1. We decided upon an assessment of the impact of the burnishing on the surface roughness of the coatings by analyzing three factors associated with the operation – i.e.: pressure force Fn, speed of burnishing Vn, and feed fn. We’ve omitted the variables concerning the type of material (plasticity border, extension) and the tools (radius of rounding up of the burnishing element, surface roughness of the burnishing element).

Tab. 1. Parameters of burnishing process

Parameter		Values
Burnishing force - F_n	[N]	700, 1100
Burnishing speed - V_n	[m/min]	13.09, 28.26
Feed - f_n	[mm/rev]	0.044, 0.08

Surface roughness was measured with a profilometer HOMMEL TESTER T1000. The length of the measurement section was 4.8 mm, and the fundamental section was 0.8 mm. On the basis of the results achieved, the surface K_{Ra} roughness reduction index was defined:

$$K_{Ra} = \frac{R_a}{R_a}, \qquad (1)$$

where:
K_{Ra} - roughness reduction index,
Ra' - coating surface roughness after cutting,
Ra - surface roughness material after surface plastic processing.

The hardness measurement was performed by means of Vickers method with the use of WPM device, at thrust force amounting to 50 N. On the basis of the results achieved, the relative degree of hardness Su was determined:

$$S_u = \frac{HV_2 - HV_1}{HV_1} 100\%, \qquad (2)$$

where:
S_u - relative degree of strain hardening,
HV_1 - coating hardness before burnishing,
HV_2 - coating hardness after surface plastic treatment.

3. Results

Taking into account the results obtained in [9, 11] was to be expected that the use of smaller feed rates and speed burnishing will reduce the value of surface roughness and a greater strengthening of alloy coatings and composite materials. In the case of alloy coatings the surface roughness, depending on the conditions of burnishing, was in the range of R_a = (0.24-0.36) µm. Roughness reduction index was in the range of K_{Ra} = (7.18-10.78). However, statistical analysis performed (non-parametric tests: Ms and Kruskal - Wallis) showed that in the tested range of parameters of technological process to reduce the burnishing speed and feed do not affect significantly (established level of significance a = 0.05) on the value of K_{Ra} (Fig. 2). Fig. 3 presents examples of alloy coatings profilograms obtained during roughness measurements.

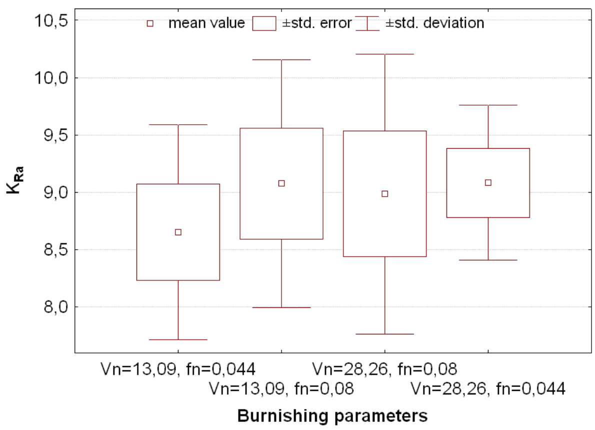

Fig. 2. Influence of burnishing parameters on the value of K_{Ra} index for Ni-15%Al coatings (V_n - burnishing speed, m/min; f_n – feed, mm/rev)

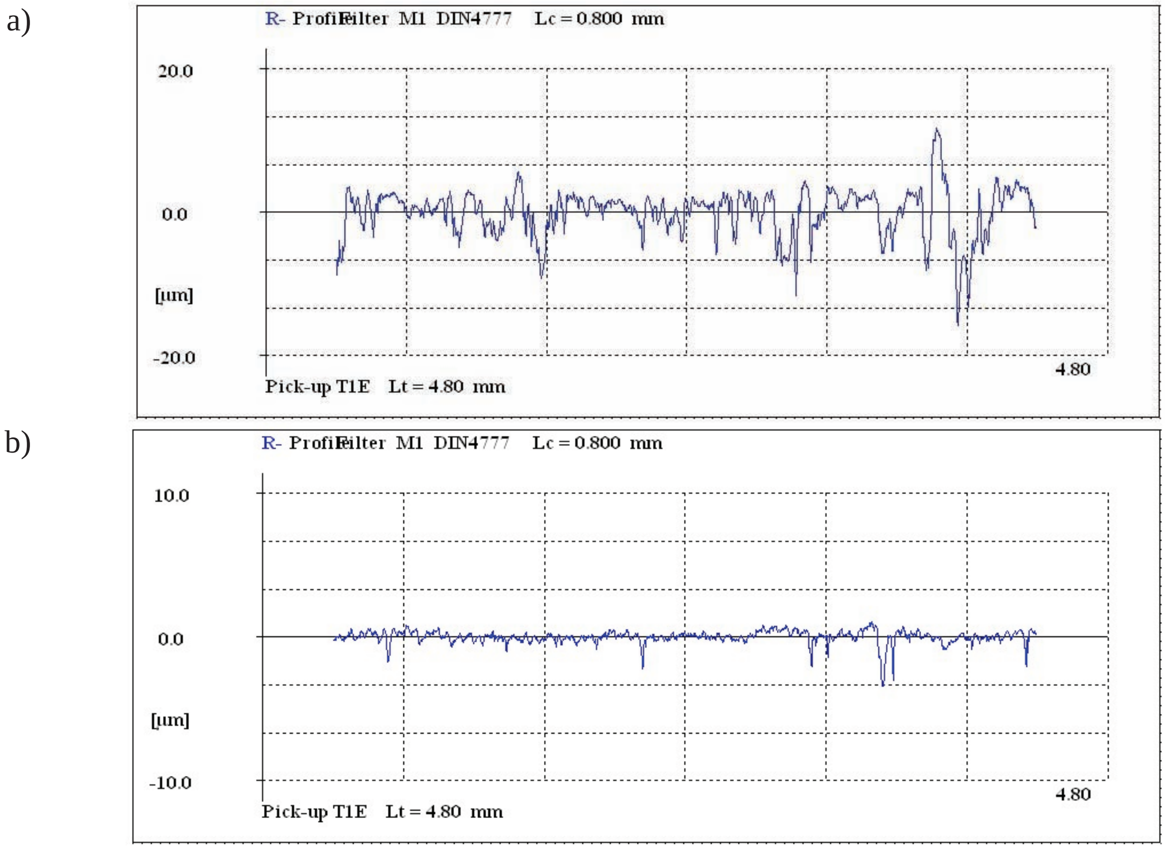

Fig. 3. Examples of alloy coatings profilograms after turning a) and burnishing b)

In the case of layers of Ni-5%Al-15%Al_2O_3, when using of burnishing force 1100 N, coating were damaged. Therefore, composite coatings were burnished with less force - 700 N. Execution of the burnishing process at low speed 13 m/min also resulted coatings are detached. Only the use of speed 28 m/min resulted in such a strain, at which there was no negative impact on the quality of coatings. The value of the parameter surface roughness R_a burnished coatings ranged 1.03 to 1.45 µm. Using the feed rate f = 0.044 mm/rev average R_a value was 1.26 µm. While greater feed f_n = 0.08 mm/rev was used, the average value of R_a was equal to 1.31 µm. Value of the roughness reduction index (K_{Ra}) ranged from 1.71 to 2.5. In the case of burnishing with a smaller feed rate, the K_{Ra} average value was 2.06. On the other hand, when the feed f = 0.08 mm/rev was applied, K_{Ra} was 2.00. Conducted statistical analysis (three nonparametric comparisons of two groups: Wald-Wolfovitz, Kolmogorov-Smirnov, Mann-Whitney tests) allows a 95% probability to conclude that the feed didn't affect the value of K_{Ra} (Fig. 4). Fig. 5 presents profilograms examples obtained during roughness measurements of composite coatings.

In Fig. 5 curves of the material ratio was showed. In Table 2 mean values of the material ratio curve parameters, such as R_{pk}, R_k, R_{vk}, M_{r1}, M_{r2} and $R_{mr\ (50\%)}$ were presented. The burnishing of surface coatings caused a change in the values of these parameters in comparison to the surface turned. Smaller values of R_{pk} indicate small participation of the peaks sticking out above the core profile section of surface compared to coatings turned. Very small value of R_k = 0.91 µm is related with obtaining the plateau surface of alloy coatings on the section (the difference M_{r2} - M_{r1}) equal 78.84% roughness profile dimension. Lower values of R_v can have a significant influence on the leaktightness of gland torgue pump. Parameter $R_{mr\ (50\%)}$ allows the estimation of the value of wear, which must occur to the real contact area of elements was 50%. For example, in the case of the turned composite coatings the wear must be as high as 14.77 µm, and the burnished coating only 3.66 µm.

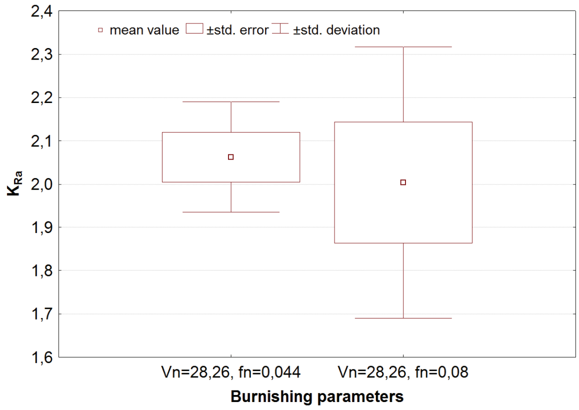

Fig. 4. Influence of burnishing parameters on the value of K_{Ra} index for Ni-15%Al- 15%Al_2O_3 (V_n - burnishing speed, m/min; f_n – feed, mm/rev)

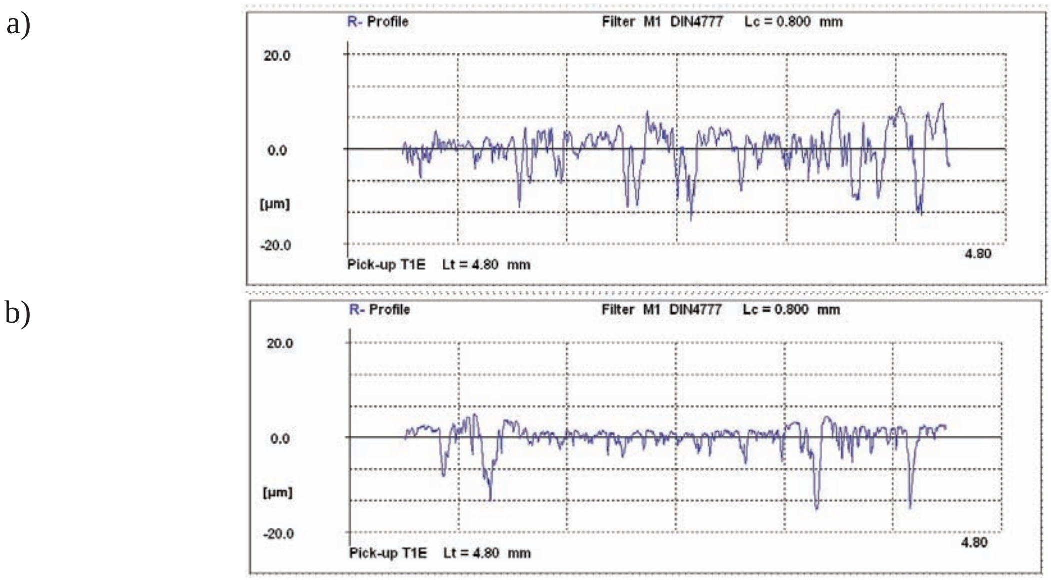

Fig. 5. Examples of Ni-15%Al- 15%Al_2O_3 coating profilograms after turning a) and burnishing b)

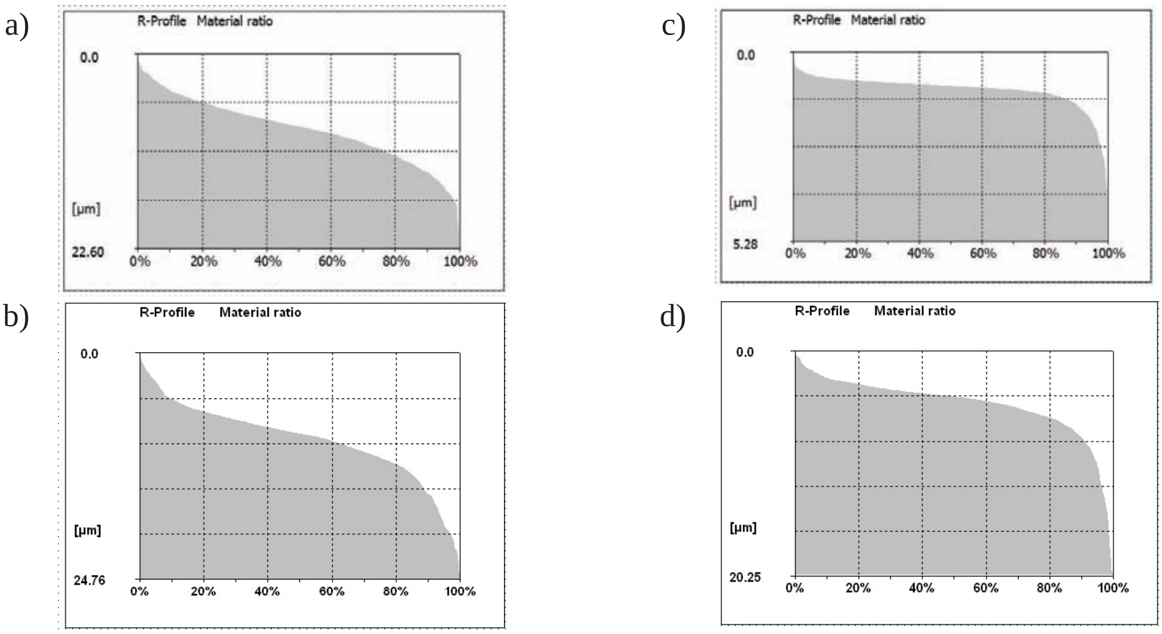

Fig. 6. Examples of material ratio curves of Ni-5%Al coating after cutting (a), Ni-5%Al coating after burnishing (b), Ni-5%Al-15%Al_2O_3 coating after cutting (c) and Ni-5%Al-Al_2O_3 coating after burnishing (d)

Tab. 1. The parameters of material ratio (average values)

Parameter / Coating	Ni-5%Al		$Ni-5\%Al-15\%Al_2O_3$	
	turned	burnished	turned	burnished
R_{pk} [μm]	1.37	0.38	2.99	0.87
R_k [μm]	7.39	0.91	8.49	3.16
R_{vk} [μm]	4.46	1.11	10.62	7.25
M_{r1} [%]	5.00	9.66	6.82	5.40
M_{r2} [%]	81.50	88.50	73.38	71.42
$R_{mr(50\%)}$ [μm]	6.63	1.27	14.77	3.64

Coatings during burnishing were strain hardened. The values of relative degree of strain hardening Su ranged from 17.5 to 39.26%. Lower values of Su for composite coatings were obtained. In the case of alloy coatings influence burnishing parameters on the strain hardening of the surface were found. Larger strengthening coatings were obtained when the smallest values of burnishing speed and feed rate were used. Burnishing of using the parameters V_n = 13.09 m/min, F_n = 1100 N, f_n = 0.044 mm/rev obtained the highest value of relative degree of strain hardening Su for Ni-5% Al coatings. Then the hardness of burnished coatings was 279 HV 5, so that, it increased by 39%.

4. Summary

The burnishing composite coatings should be done with less force - 700 N, than alloy coatings – 1100 N. Larger forces often cause damage to these layers.

In the tested range of burnishing process parameters change, there wasn't significant impact on the Ra value of the roughness of the surface coatings of Ni-5%Al and $Ni-5\%Al-15\%Al_2O_3$.
A significant influence of the technological parameters on the strain hardening of the coatings was observed. The use of large force low speeds and feeds during burnishing causes a greater strain hardening of the coatings. The greatest value of relative degree of strain hardening which was obtained is 39%.

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