FLAME SPRAYING "ROTO-TECK 80" OF Ni-Al AND Ni-Al-Al_2O_3 COATINGS SURFACE TEXTURE AFTER ROLLER BURNISHING

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Abstract

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.

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.

Coatings of Ni-5% Al and Ni-5%Al-15%Al_2O_3 obtained by powder flame spraying were studied. Torch of "Roto-Teck 80" was used. After turning the average value of surface coatings roughness coefficient Ra = 3 μm was obtained. SRMD burnishing tool produced by "Yamato" company was used. Roller burnishing was performer on engine 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 μm was obtained after burnishing with the following parameters: the force - 1100 N, rate - 28m/min, feed - 0.08 mm/rev. During burnishing of Ni-5% Al-15% - Al_2O_3 coatings applied force 700 N, Ra = 1 μm 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 Rk, Rpk and Rpk were reduced.

Keywords: *thermal spay coatings, burnishing, roughness, material ratio, torque pump.*

1. Introduction

On vessels, one often uses torque pumps. They are used for drying load bilges and power plants, emptying ballast tanks, in engine cooling systems, as well as for the water supply of boilers. In many cases the material pumped or lifted with torque pumps is sea water. Owing to the difficult operating conditions, for construction of this type of pump, one uses materials resistant to cavitation, consumption, and electro-chemical corrosion caused by sea water. Then the impellers of the pumps are made of bronze, aluminum, manganese or silicone. On the other hand, the shafts are made of steel resistant to corrosion. In spite of the application of the aforementioned materials, it has been observed, in operational practice, the presence of faultiness of the previously mentioned elements of the torque pumps. In the case of the shafts, you often encounter the consumption of the pivots (contact corrosive, frictionm and fatigue) at the point of installation of the sealings (packing). In practice, the worn-out shafts are replaced with new ones or the pivots are regenerated by rotating or polishing them to repair their dimensions, application of a galvanic chromium coating, as well as placing a sleeve over a damaged shaft. However, application of the above methods of regeneration causes a decrease of the active section of a shaft, which may lead to reduction of its strength [3, 4].

This study, as a method of regeneration of shafts of torque pumps, has suggested hot-spraying a coating of nickel on the base. Owing to the structure of hot-sprayed coatings (high porosity among other things), the surface is strongly developed and characterized by substantial roughness [7-9]. The traditional method of shaping the geometrical structure of coatings is cutting (turning and polishing). This study proposes the application of surface plastic processing (burnishing) for receipt of optimal surface geometry of coatings containing 5% Nickel and Aluminum, and then flame sprayed using a burner “Roto-Teck 80” [3, 10, 11].

2. Preparation of pivots for burnishing

The coatings were applied on flame degreased steel rollers (steel C45), with diameter f = 50 mm. To increase the adhesion of the coatings, threads were cut on the surface of the pivots.

For spraying, use a burner “Roto-Teck 80” made by Castolin. During flame spraying, use 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,
- spraying speed: 25 m/min,
- feed: 3 mm/rev,
- burner distance from the sprayed surface: 150 mm,
- number of applied layers: 6,
- maximum temperature of surface during spraying: 150°C.

After spraying, the coating was subjected to initial treatment (turning) in order to reduce deviations in the wheelness of the rollness of the pivots. After turning, the surface of pivots was observed to have an average value of roughness Ra = 2.92 mm and a hardness of 190 HV in cases of alloy coatings, and Ra = 3.1 mm and the coating matrix hardness of 181 HV 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). According to literature, the analysed parameters of burnishing Fn and fn (independent variables) do not always affect linearly the value of the dependent variable (K_{Ra}) [5]. For this reason, it was decided to assume a three-value experiment plan (3^3). In order to restrict the number of tests, the impact of the burnishing parameters on reduction in surface roughness has been evaluated using the Hartley’s plan of research [2], including executing eleven tests.

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 obtained results, we’ve determined the ratio of surface roughness change K_{Ra} (1):

$$K_{Ra} = \frac{Ra'}{Ra}, \quad (1)$$

where:
K_{Ra} - ratio of surface roughness change,
Ra' - coating surface roughness after cutting,
Ra - surface roughness material after surface plastic processing.

Tab. 1. Ni-5%Al coatings burnishing parameters

Pivot No.	Layout of Hartley's plan [2]		
	Burnishing force, Fn [N]	Burnishing speed, V_n [m/min]	Feed, f_n [mm/rev]
1.	700	28.26	0.08
2.	1100	28.26	0.08
3.	700	111.47	0.08
4.	1100	111.47	1.04
5.	700	70.65	0.52
6.	1100	70.65	0.52
7.	900	28.26	0.52
8.	900	111.47	0.52
9.	900	28.26	0.08
10.	900	28.26	1.04
11.	900	70.65	0.52

The results determining the indicator of surface roughness reduction have undergone statistical – regression multiple analysis, in order to determine the impact of the applied parameters of the burnishing technological process on its value. The calculations were made by means of the computer software Statistica 5.5. Owing to different values of independent variables, the impact of particular parameters was analyzed on the basis of standardized factors of multiple regression (BETA). The assumed level of significance was = 0.05.

After selecting the process parameters, the alloy composite coating was subjected to burnishing with 4 moves of the tools. Comparison of geometrical structure of turned and burnished coatings was made using the parameters of material ratio curve i.e.: Rpk, Rvk, Rk.

4. Test results

Figure 1 and 2 present the effect of the parameters of burnishing on the ratio of change of roughness of alloy coatings Ni-5% Al. While analysing the obtained values of standardized factors of multiple regression for independent variables, one can state that the greatest impact (BETA = 0.72) on the indicator of surface roughness change K_{Ra} has burnishing force (Tab. 2). The greater force value used in the operation of burnishing, the smaller value is of arithmetic average of deviation of unevenesses profile Ra. The other parameters of burnishing, i.e. feed and speed, exert inversely proportional impact on the indicator of surface roughness reduction of coatings, and hence are favourable for obtaining greater values of parameter Ra.

The value of the indicator of change of roughness of coatings can be determined from multiple regression equation (2):

$$K_{Ra} = -0.03V_n - 3.6f_n + 0.013F_n - 3.2 \pm 1.6. \quad (2)$$

Tab. 2. Results of multiple regression analysis for K_{Ra} parameter (R^2=0.75, F(3.7) = 7.29, p<0.015, estimation error = 1.61)

	BETA	B	level p
Free word		-3.2	0.35
Burnishing speed – V_n	-0.41	-0.03	0.07
Feed – f_n	-0.47	-3.6	0.06
Burnishing force - Fn	0.72	0.013	0.008
BETA - standardized regression coefficient, B - regression coefficient, p - significance level			

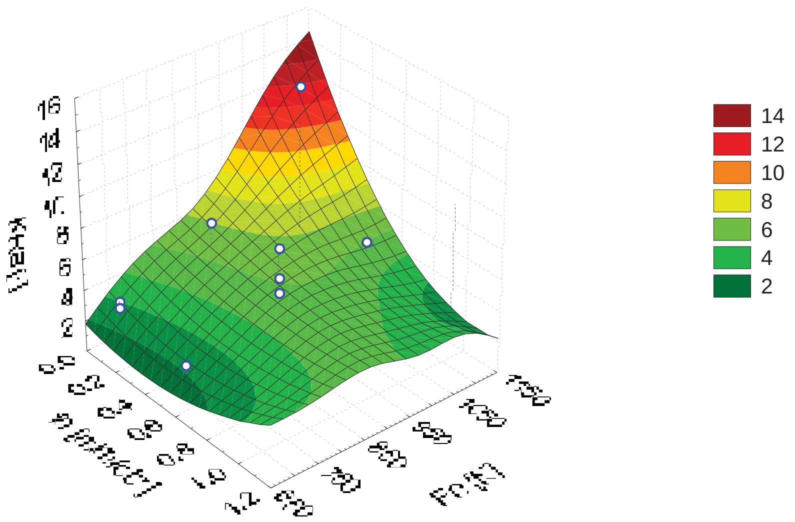

Fig. 1. Effect of burnishing feed and force on the K_{Ra} value K_{Ra} of Ni-5%Al coatings

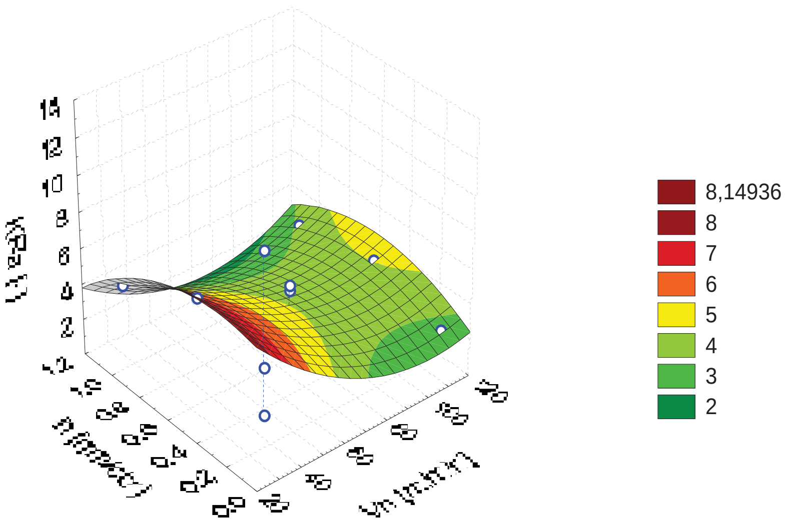

Fig. 2. Effect of burnishing speed and feed rate on the K_{Ra} value of Ni-5%Al coatings

Variance analysis F = 7.29 at the level of significance p<0.015 allows rejection of zero hypothesis that no independent variable has significant impact on dependent variable. Determination coefficient value R^2 proves that 75% of the obtained results are described with equation 2.

However, significance level p = 0.06 for burnishing speed is relatively large (larger than the assumed α = 0.05) and may prove it has a statistically small influence on the value K_{Ra}. For this reason, the analysis of multiple regression was repeated without independent variable Vn (Tab. 3)

Tab. 3. Results of multiple regression analysis for K_{Ra} parameter without Vn (R^2=0.60, F(2.8) = 5.92, p<0.026, estimation error = 1,94)

	BETA	B	level p
Free word	-	-5.15	0.2
Feed - f_n	-0.57	-4.36	0.04
Burnishing force - F_n	0.76	0.013	0.01

On the basis of the data from Tab. 3, the regression equation assumes the following form (3):

$$K_{Ra} = -4.36f_n + 0.013F - 5.15 \pm 1.94. \quad (3)$$

The results of the repeated analysis of regression prove that one can predict the value of the indicator of surface roughness reduction, ignoring the burnishing speed. But the quality of fitting the equation (3) to the measurement data is smaller. This fact is proved by lower determination coefficient value (R^2=0.6) and greater estimation error (1.94).

The hypothetical reasons for only 75% of explanation of general variability of the dependent variable K_{Ra} by equation (2) are: lack of a linear relationship between the dependent variable and the independent variables (Fn, Vn, f), or (i) recurring values of independent variables [6].

Square sum of remainders calculated in the variance analysis may be split into two components: clean error and lack of fitting [1, 6]. Square sum of remainders of the result of multiple regression presented in Tab. 2 equal 18 from the overall square sum of deviations 74.8. However, the obtained values of clean error are greater than 18 for the particular independent variables. Thus, lack of fitting adopted negative values. Large values of clean error prove that a mismatch of equation (2) is, above all, related to random error, and, to a smaller extent, with a non-linear relationship between independent variables and a dependent variable.

Figure 3 presents the relationship between the observed values (measured) and the estimated ones (calculated from equation 2). There is no basis to assume that the relationship between the observed values of the indicator of roughness reduction and its prediction is non-linear.

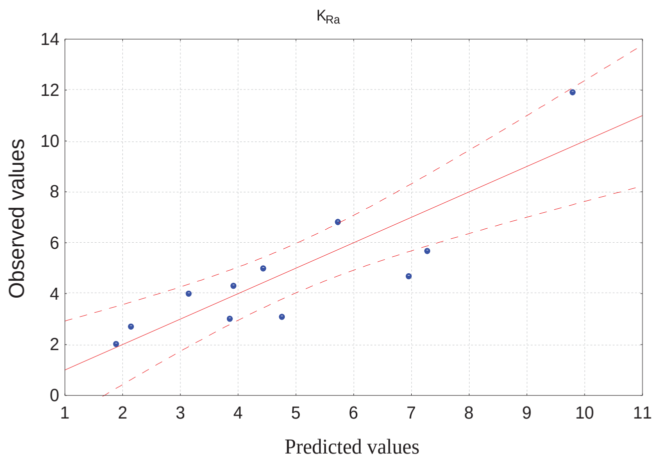

Fig. 3. The relationship between observed and predicted K_{RA} values on the basis of equation 2

The largest value of the indicator of roughness change (K_{Ra} = 11.9) to the surface was obtained for a burnished pivot by application of the following parameters: Fn = 1100 N, fn = 0.08 mm/rev, Vn = 28.26 m/min. The burnished surface was characterized by roughness Ra = 0.27 μm.

This pivot was burnished many times. Altogether, three moves of the tool were exercised. However, during the last move of the tool, the coating was damaged (Fig. 4a)

a)

b)

Fig. 4. Coatings surface (Fn = 1100 N, fn = 0.08 mm/rev, Vn = 28.26 m/min) [9]: a) Ni-5%Al after three burnishing, b) Ni-5%Al-15%Al_2O_3 after a single burnishing

Average values of parameters of surface roughness Ra and Rz and parameters of material ratio of alloy coatings have been presented in Tab. 4. Multiple burnishing affects surface roughness to a small degree. In case of the analyzed parameters of material ratio, one can note that the greatest impact on reduction of their value was the first move of the tool. The second burnishing resulted only in a decrease in the value of Rpk by 50%.

Also, the composite coating Ni-5% Al-15% Al_2O_3 were subjected to burnishing. When the following parameters of burnishing were applied: Fn = 1100 N, fn = 0.08 mm/rev, Vn = 28.26 m/min, the coating fragment fell off (Fig. 4b). Therefore, one decreased the value of burnishing force to 700 N. After the first burnishing, one diagnosed a 2.28 (K_{Ra}) times reduction of Ra parameter. Arithmetic average deviation of the profile of roughness after the first burnishing was 1.13 μm and after the third it was 0.97 μm (Tab. 5). During the fourth move of the tool, the coating was damaged.

Tab. 4. Effect the number of tool move on roughness surface and parameters of material ratio curve of Ni-5%Al coating (μm)

Parameter	After turning	Burnishing – one move	Burnishing – two moves
Ra	3.25	0.27	0.25
Rz	16.82	3.7	3.67
Rpk	1.66	0.32	0.16
Rk	10.7	0.49	0.49
Rvk	5.89	1.18	1.17

Tab. 5. Effect of the number of tool move on roughness surface and parameters of material ratio curve of Ni-5%Al-15%Al_2O_3 coating (μm)

Parameter	After turning	After burnishing		
		1 - move	2 - moves	3 - moves
Ra	2.56	1.13	0.98	0.97
Rz	16.36	10.62	9.24	8.92
Rpk	2.04	0.39	0.39	0.46
Rk	5.81	1.7	1.67	1.77
Rvk	7.17	5.26	4.8	4.47

Figure 5 presents the example profiles of roughness, and Fig. 6 presents the curves of material ratio of the surface of alloy coatings after turning and burnishing.

5. Summary

- It is possible to apply burnishing to shape the geometrical structure of coatings Ni-5% Al, as well as Ni-5% Al-15% Al_2O_3.
- An almost twelve-times reduction of surface roughness, as compared with the turned coatings Ni-5% Al, can be obtained by burnishing with the tool SMRD, using the following parameters: Fn = 1100 N, fn = 0.08 mm/rev, Vn = 28.26 m/min.
- In the case of burnishing with composite coatings Ni-5% Al-15% Al_2O_3, one should use a smaller burnishing force value (Fn = 700 N).
- Burnishing, as compared with turning, causes decrease of the value of the reduced height of vertices (Rpk) and core roughness (Rk), and at the same time, increases the load ratio of the profile. This should result in growth of coating resistance to tribologic consumption.
- The impact of subsequent moves of a burnisher on the geometric structure of treated coatings is small.

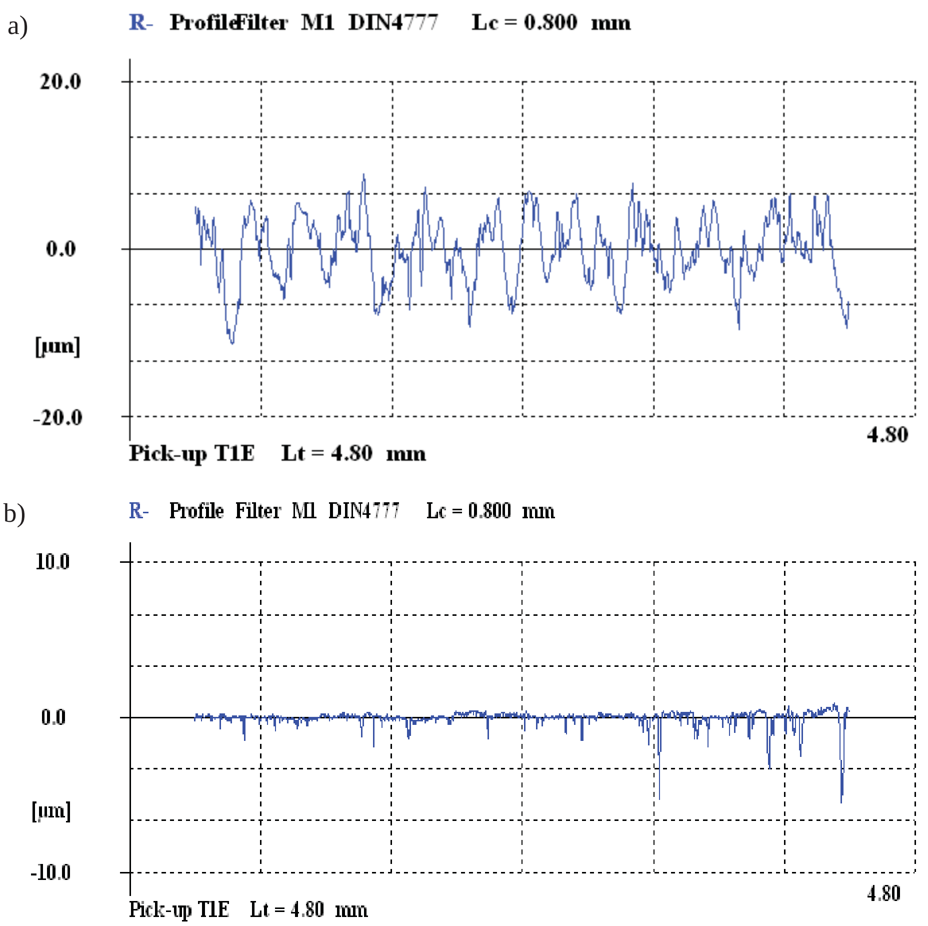

Fig. 5. Examples of coating roughness profiles of Ni-5%Al a) after turning , b) after burnishing

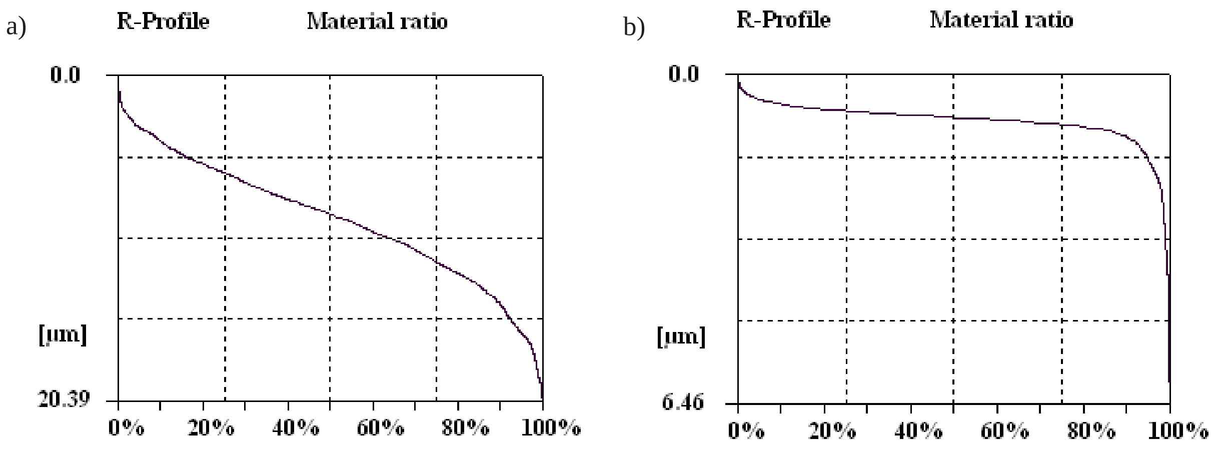

Fig. 6. Examples of material ratio curves of Ni-5%Al coating surface: a) after turning , b) after burnishing

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