EFFECT OF BURNISHING ON SURFACE TEXTURE OF Ni-Al PLASMA SPRAYED COATINGS

Robert Starosta

Gdynia Maritime University, Department of Marine Maintenance
Morska Street 81-87, 81-225 Gdynia, Poland
tel.:+48 58 6901249, fax +48 58 6901399
e-mail: starosta@am.gdynia.pl

Abstract

The purpose of this study was the selection of roller- burnishing parameters of surface Ni-Al coatings obtained by "PN 120" plasma torch. 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.

After turning, the average surface roughness of plasma sprayed Ni-5% Al coatings was R_a = 0.77 μm. Their average hardness was equal to the 253 HV 2. It was comparable to the hardness of flame sprayed Ni-Al coatings after the burnishing. Before machining, plasma sprayed alloy coatings were characterized by hardness 206 HV 2. After pre-treatment, plasma sprayed Ni-Al coatings were burnishing. Burnishing parameters were as follows: V_n=28.26 m/min, F_n=1100N, f_n=0,08m/rev. Burnishing reduces the surface roughness of coatings as compared to machining. The arithmetical mean deviation of the assessed profile of machined coatings was 0.78 μm. After the plastic working, the Ra parameter was reduced to a value of 0.28 μm. Total height of profile of machined coatings was only 2.63 μm. After burnishing, the value of W_t decreased by 0.16 μm, to the value of 2.47 μm. Studies burnished surface topography of coatings of Ni-5% Al overlaid by "PN 120" torch revealed the presence of defects stereometric structure. There is the folding. These folding are arranged in the direction of peripheral velocity vector. The observed high folding on the surface of alloy coatings sprayed by plasmatron were lower from the same geometric structure defects on the surface of coatings obtained by flame spraying methods. This follows from the fact that the plasma coating, after turning, characterized by higher hardness of the sprayed coating obtained by and "Roto-Teck 80" method. Thus, exhibit a lower propensity for plastic deformation. After plastic working of plasma coatings, decrease of parameters of the material ratio curve values were observed. For example, the reduced peak height of cut coatings were 1.38 μm, after burnishing R_{pk} value fell to 0.23 μm.

Keywords: *plasma spraying, burnishing, Ni-Al 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].

Plasma and 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 thermal sprayed coatings was proposed. In the literature found few data on the burnishing processes of thermal sprayed coatings. Burnishing is not used during the processing of thermally sprayed coatings, as is commonly believed that this technology causes damage to coatings. Low susceptibility of coatings to the surface plastic treatment arises from several reasons. These include:

a) low adhesion of coatings to the substrate,
b) high tensile internal stress,
c) embrittlement of coatings resulting from the presence of “in situ” oxides and the pore in the structure.

However, due to more modern torches technology for thermal spraying, the adhesion improvement and oxidation-reduction of the coating material are observed. This is due to obtain the higher speeds the movement of particles in the stream of sprayed.

Franzen [4, 5] proposes the use of burnishing to forming of geometric structure of coatings WC-Fe (50% tungsten carbide) obtained by arc spraying and WC-Co coatings imposed by supersonic spraying (HVOF). There are used as a coating to increase durability of press-forming dies. Efforts are also trying to obtain the relevant surface properties of thermal sprayed coatings by rolling and pressing. Plastic working of coatings based on nickel (Ni-Al, NiAl and Ni_3Al) allowed to reduce the roughness without loss of its adhesion [6]. Szczepanik [7, 8] proposes to use burnishing process as a finishing treatment and forming of Al-SiC composites sinters. After the surface plastic treatment R_a = 0.12-0.75 μm surface roughness were obtained.

Burnishing may also be used for surface treatment of materials prior to application of galvanic coatings, thermal sprayed and cladded. Nadasi [9] proposed the use of rolling of coatings to reduce their porosity.

In the articles [10], the use of burnishing to the surface finishing flame sprayed coatings are proposed. The Ni-5%Al coatings were studied. Coatings were deposited by oxy-acetylene „Roto-Teck 80” torch. 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. Influence of burnishing process parameters on the value of roughness reduction index (K_{Ra}) present the regression equation (1):

$$K_{Ra} = -0.03V_n - 3.6f_n + 0.013F_n - 3.2 \pm 1.6,$$

where:
V_n - burnishing speed, m/min,
f_n - feed, 0.08 mm/rev,
F_n - burnishing force, N,

The lowest value of surface roughness of Ni-5%Al coating were obtained, when the following parameters burnishing was used: burnishing force F_n = 1100 N, feed f_n = 0.08 mm/rev, burnishing speed V_n = 28.26 m/min. 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 R_a 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 [10].

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 [10].

In this article, the results of measurements of surface coatings roughness after the plastic working are presented. Coatings were obtained by plasma spraying method, using the “PN-120”. Coatings obtained using plasmatron 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 coatings obtained by "PN-120” plasmatron. 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) with diameter ϕ = 40 mm. To increase the adhesion of the coatings, the pivots were threaded. For spraying, was used a "PN 120 " torch. During plasma 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%), made by Castolin.

The following parameters of plasma spraying have been applied:
– argon pressure: 0.35 MPa,
– the distance of the nozzle from the surface : 70-100 mm,
– current: 450-600 A,
– voltage arc internal: 47-60V.

After spraying, the coating was subjected to initial treatment (turning) in order to reduce shape (roundness and cylindricity) deviations of the pivots shafts.

Ni-5% Al alloy coatings were machining by means of trigon inserts. As a tool, material borazon was selected. Its catalogue number is GC 3210 (Sandvig Coromant) [11]. GC 3210 is a material based on tungsten carbide with a supplement of titanium nitride, covered with a TiN coating obtained by CVD method. In the DWLNRL-2525M08 holder, a WMNG 080408-KM insert was mounted. Insert and the holder were manufactured by Sandvik Coromant. The geometry of the cutting tool, takes into account the insert and tool holder are follows:
– cutting inserts – $\beta = 80^o$,
– approach angle – κ_r -95^o,
– rake angle – $\gamma = -6^o$,
– clearance angle – $\alpha = 6^o$,
– nose radius – r_ε = 0.8 mm,
– without chip breaker.

Turning parameters were used:
– cutting speed – V_c = 110 m/min,
– feed rate f = 0.06 mm/rev ,
– cutting depth a_p =3 mm.

3. Methodology of research

Tab. 1. Parameters of burnishing process

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

The burnishing process was conducted with a one-roller Yamato SRMD burnisher. 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).

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

$$K_{Ra} = \frac{R'_a}{R_a}, \tag{1}$$

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 FM-800 device, at thrust force amounting to 20 N. On the basis of the results achieved, the relative degree of hardness Su was determined:

$$S_u = \frac{HV_2 - HV_1}{HV_1} 100\%, \tag{2}$$

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

4. Results

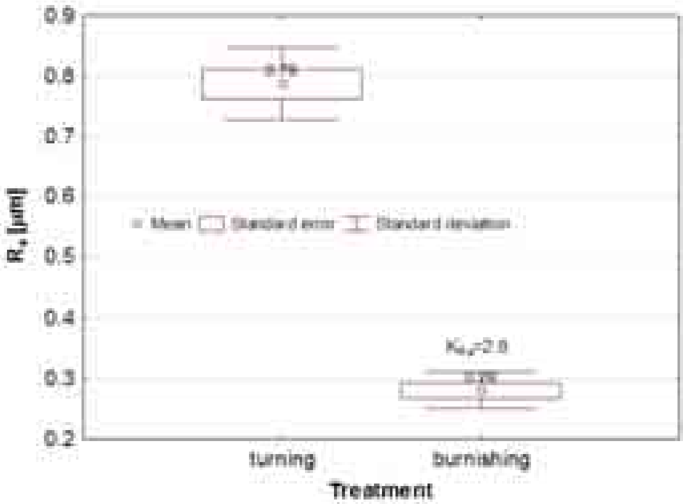

Fig. 1. Effect of treatment on R_a roughness parameter of surface Ni-Al coatings

After turning, the average surface roughness of coatings of Ni-Al plasma sprayed was R_a = 0.79 µm. Average hardness equalled 253 HV2. Before machining, plasma sprayed alloy coatings were characterized by hardness equal 206 HV2. There is strain hardening after machining of coatings was observed. Fig. 1 and Tab. 2 present the results of measurements of the parameters characterizing the geometric structure of the alloy coatings sprayed using the plasmatron, both after turning and burnishing. Burnishing allows get a surface, which is characterized by a lower surface roughness compared to the turning process. After the plastic surface treatment, the Ra parameter was reduced to a value of 0.28 µm. Roughness reduction index (K_{Ra}) equalled to 2.78. Processing tool SRMD contributes to nearly three times reduce the surface roughness of plasma sprayed Ni-Al coatings.

Average value of total height of roughness profile (R_t) of burnished coatings was equal to 4.91 µm and 9.45 µm after turning. Maximum height of roughness profile (R_z) value the after plastic surface treatment decreased from 6.55 µm to 3.6 µm. The difference is only 3 µm. Value mean of total height of waviness profile (W_t) of turned coatings was only 2.63 µm. After burnishing, the value of W_t decreased by 0.16 µm to the value of 2.47 µm. Statistical analysis (nonparametric tests

Tab. 2. Results of basic statistical analysis of roughness (R_t, R_z, R_{Sm}, R_{sk}, $R_{mr\ (50\%)}$), waviness (Wt) and material ratio (R_{pk}, R_k, R_{vk}) parameters of Ni-5%Al coatings obtained by plasma spraying

parameters	number of measurements	mean	Min.	max	sd	standard error
After turning-processing						
R_t[μm]	6	9.45	6	12.1	1.99	0.815
R_z[μm]		6.55	5.27	7.22	0.7	0.285
R_{Sm}[mm]		0.078	0.064	0.092	0.009	0.003
R_{sk}		-0.26	-0.85	0.14	0.36	0.15
W_t[μm]		2.63	1.97	3.47	0.58	0.24
R_{pk}[μm]		1.38	0.92	1.64	0.28	0.11
R_k[μm]		2.44	2.31	2.55	0.09	0.038
R_{vk}[μm]		1.38	0.89	1.77	0.3	0.12
$R_{mr\ (50\%)}$[μm]		3.84	2.89	4.38	0.6	0.24
After pressing processing: V_n=28.26 m/min, F_n=1100N, f_n=0.08 mm/revolution						
R_t[μm]	6	4.91	4.56	5.67	0.4	0.17
R_z[μm]		3.6	3.47	3.84	0.13	0.054099
R_{Sm}[mm]		0.02	0.018	0.027	0.0035	0.0015
R_{sk}		-1.74	-1.91	-1.51	0.15	0.061
W_t[μm]		2.47	1.65	3.6	0.71	0.29
R_{pk}[μm]		0.23	0.17	0.36	0.069	0.028
R_k[μm]		0.65	0.42	0.89	0.18	0.075
R_{vk}[μm]		1.11	0.8	1.36	0.19	0.078
$R_{mr\ (50\%)}$[μm]		1.12	0.78	2.35	0.61	0.247

for two dependent variables): Wilcoxon's test and sign test showed that the differences between the averages of the total height of waviness profile for both coatings of finishing processes , for a given level of significance $\alpha = 0.05$, is not statistically significant. The important observation is that the R_z takes the average parameter values greater than W_t. Thus, in this case the leakproofness condition is fulfilled.

There reduction of material ratio curve parameters was observed. For example, the reduced peak height of machined coatings was 1.38 μm, and the after plastic surface treatment of R_{pk} value decreased to 0.23 μm. Core roughness depth of machined coatings was 2.44 μm. The average value of the R_k parameter of coatings after plastic surface treatment was 1.11 μm.

a)

b)

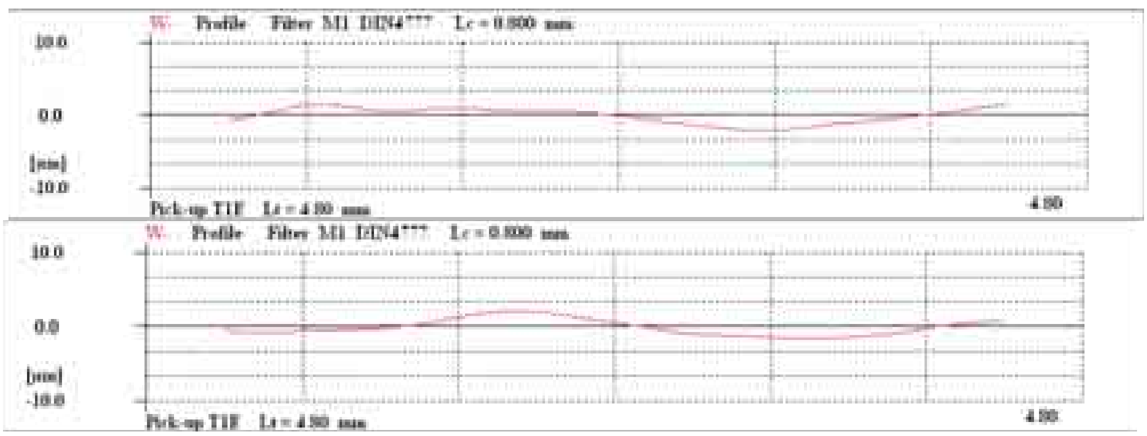

Fig. 2. Examples of waviness profiles of Ni-Al coatings obtained by plasma spraying: a) the turned (Wt = 3.47 μm), b) the burnished (Wt = 3.6 μm)

a)

b)

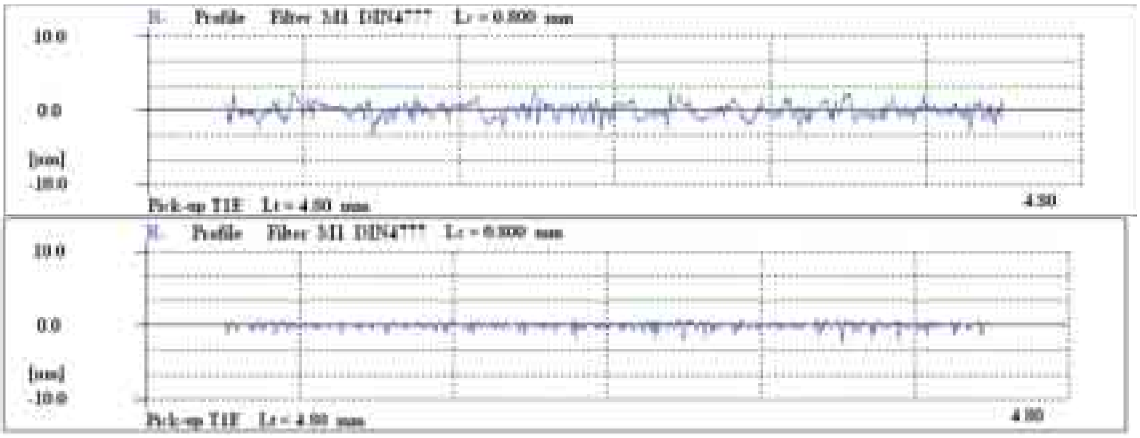

Fig. 3. Examples of roughness profiles of Ni-Al coatings obtained by plasma spraying:: a) the turned (R_a= 0.72 μm), b) the burnished (R_a= 0.26 μm)

a) b)

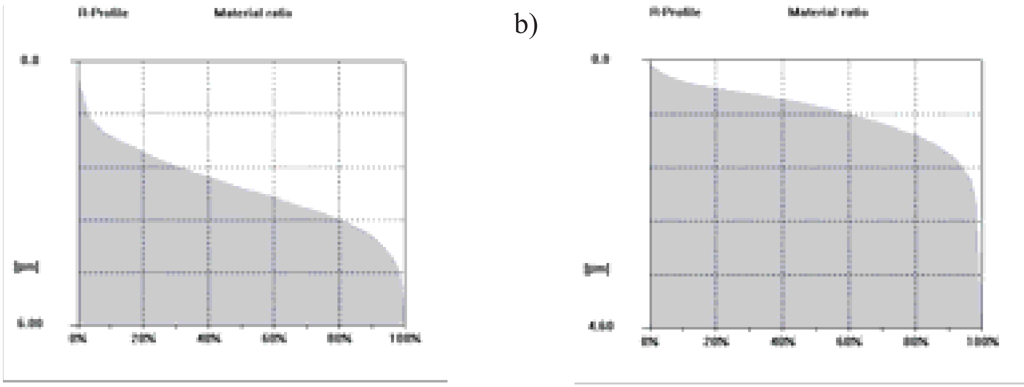

Fig. 4. Examples of material ratio curves of the surface Ni-Al coatings obtained by plasma spraying: a) the turned, b) the burnished

In Fig. 2-4 examples of profiles of surface roughness, waviness and material ratio curves of Ni-5% Al coatings plasma sprayed by PN120 torch are presented.

Studies burnished surface topography of coatings of Ni-5% Al overlaid by “PN 120” torch revealed the presence of defects stereometric structure. There are the folding (fig. 5). These folding are arranged in the direction of peripheral velocity vector. The observed high folding on the surface of alloy coatings sprayed by plasmatron were lower from the same geometric structure defects on the surface of coatings obtained by flame spraying methods [10].

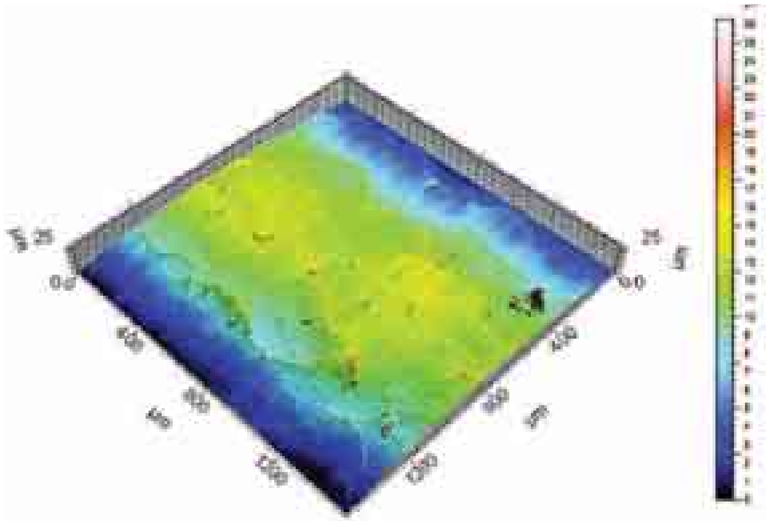

Fig. 5. Unfiltered topography of the burnished surface of plasma sprayed Ni-Al coatings

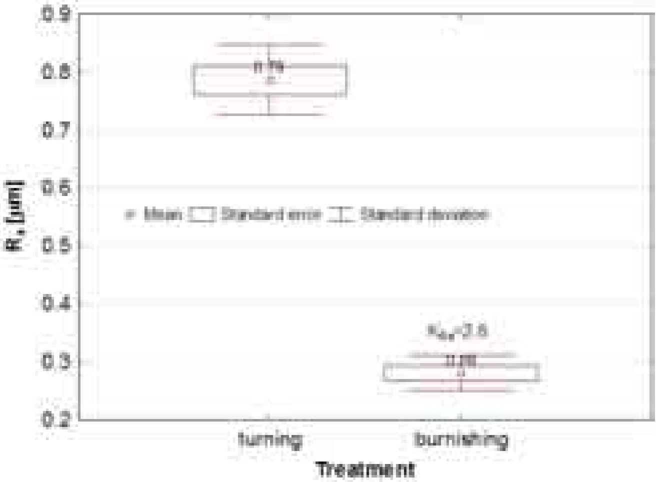

Fig. 6. Effect of treatment on hardness and relative degree of strain hardening (Su) of surface Ni-Al coatings

Figure 6 shows the results of hardness measurement and estimation of the relative degree of strain hardening of plasma coatings. The hardness of these coatings after machining was 254 HV2. After burnishing their hardness increased to 286 HV2. Relative degree of strain hardening (S_u) obtained a value of 12.6%.

5. Summary

- Burnishing can be used as finishing of plasma sprayed Ni-Al coatings .
- Applying to burnishing SRMD tool can be obtained to the coating surface roughness Ra = 0.28 μm. In comparison to the turned coatings is almost three times less the Ra value (KRa = 2.8).
- Burnished surface satisfies the tightness condition (Wt < Rz).
- The surface structure, characterized by the material ratio curve, burnished coatings testified about: a) a small wear of shaft neck in time grinding in mated machine parts, b) large area of contact between the surfaces of journal with gland's packing.
- After burnishing, plasma-sprayed Ni-Al coatings can be used to regenerate journals mated water sealed gland in torque pumps (due to the surface texture).
- After burnishing, almost 13% strain hardening (Su=12.6%) of Ni-Al coatings was observed

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