THE FINISHING OF COMPOSITE COATINGS IN ASPECT OF SURFACE ROUGHNESS REDUCTION

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Abstract

The influence of the shape and grade of inserts upon the geometric structure of the composite coatings Ni-5%Al-15%Al_2O_3 and alloy coatings of Ni-5% Al is considered in the paper. Nickel matrix coatings were sprayed by the Casto-Dyn 8000 torch on a steel substrate, and then subjected to straight turning. Determining of the optimum geometry of indexing is now synonymous with the selection of the optimum shape and dimensions of the insert and of an appropriate holder. According to cutting board it was selected square, triangular, trigon inserts, made of carbide and of cubic boron nitride (borazon). Machining of nickel-based coatings was carried out for the cutting speed v_c = 214 m/min in the case of treatment with borazon inserts, v_c = 107m/min in case of plates treated with tungsten carbide cutting, using the feed f_n=0.06mm/rev and the depth of cut a_p = 0.3 mm. Metal cutting the surface of steel samples coated with a composite coating containing 15% Al_2O_3 based on nickel, conducted for the cutting speed v_c = 157 m/min when machining with borazon inserts and for v_c = 83 m/min inserts with tungsten carbide for feed f_n = 0.06 mm/rev and depth of cut a_p = 0.3 mm. Highly precise finishing of flame spraying composite and alloy coatings was carried out using turning by tool with borazon inserts. Flank (VB) and attack (KB) wear coefficient of inserts while maintaining a constant spiral cutting length (SCL) were determined. Important elements parts (such as engines, pumps, centrifugal separators) are regenerated during long-term utilization. This paper proposes the use of regenerated technology subsonic flame thermal spraying and surface finishing by turning composite and alloy coatings of ship machinery parts.

Keywords: *composite coatings, flame spraying, cutting inserts, surface finishing*

1. Introduction

Composite coatings of metal matrix dispersion inclusions of non-metallic phase is characterized by high resistance to tribological wear. These materials are used in fields of technology, such as: aerospace, electronics, energy, industry, defense, automotive, aviation, shipbuilding, and more. Coatings obtained by flame spraying have a large surface roughness. Therefore, these coatings must be subjected to finishing most commonly used after-machining (eg, machine cutting, grinding). Flame sprayed coatings are applied taking into account the allowance for finishing. Machining should ensure not only the thickness of coatings related to the nominal dimension of the object, but also to obtain the required surface roughness and waviness. Choosing parameters (feed rate, depth, cutting speed) machining coatings, it must be remembered that the tool does not always cut sprayed particles, but may cause them breaking the surface. This occurs primarily in coatings of high porosity. On ships, there are outboard water systems (eg, a central cooling system), often used in centrifugal pumps. In the case of pump shafts, the most common disability is a wear of the shaft neck (corrosion and friction) at the location of installation seals (stuffing-box). Currently, the primary method of regeneration is the shaft bushing. As an alternative to the method used to repair worn shafts neck of centrifugal pumps the flame spraying was proposed. The flame sprayed technology is inexpensive and easy to implement. Therefore it can be successfully used for regeneration of machine parts by the crew of ship engine room. Flame sprayed coatings are characterized by porosities, oxide inclusions and the presence of a strongly developed surface float. In order to obtain a suitable surface texture coatings finishing must be used. For this purpose, turning and grinding can be applied. The paper proposes finish turning for the flame sprayed coatings. Alloy coatings Ni-5%Al and composite Ni-5%Al-15%Al_2O_3 were investigated, which substantial powders have been obtained by flame spraying using the "Casto-Dyn 8000" torch delivered by Messer Eutectic Castolin company. In practice, the thermally sprayed coatings are machined using the same tool as for machined surface. For example, a company Messer Eutectic Castolin proposed multi tool with a square or cylindrical inserts. Cutting knives, cutting elements should be made of cubic boron nitride or diamond. Also the insert tool made of tungsten carbide is allowed [6]. During the turning of alloy and composite coatings the durability of the insert is usually short. It is therefore important to determine the spiral cutting length. This is the length cutting, which are chosen for recommended cutting, thus allowing for a reliable process. Spiral cutting length is dependent on the insert geometry and grade, depth of cut and material that shall be subject machined [7].

The processes of production and regeneration of products with applied metal matrix composite coating are recognized among engineers, technologists, because of the possibility of increasing the performance characteristics of the surface layer (strength, tribological and corrosion resistance and decorative aspect). Metal matrix composite and metal alloy and coatings containing in-metal matrix dispersion inclusions of non-metallic phase is characterized by high resistance to tribological and corrosion wear [1, 3, 5, 11, 12]. Metal matrix composite are used in such fields of technology, such as: aerospace, electronics, energy, industry, defense, automotive, aviation, shipbuilding, and more. Based on a literature review, in the study it has been considered composite coatings based on nickel with aluminum [4, 8, 9, 10, 13].

2. Methodology of research

Composite coating material consisted of a matrix of Ni-5%Al and 15% of the disperse phase volume fraction of alumina (Al_2O_3). The “Casto-Dyn 8000” spray torch, delivered by the company Castolin was used. Flame spraying alloy coatings and composites were carried out assuming the following process parameters: pressure flammable gas-acetylene: 0.07MPa oxygen pressure: 0.4MPa, air pressure equal: 0.1 MPa, the speed of the torch equal 25m/min, feed rate equal: 3mm/rev, the distance from the torch surface to be sprayed: 150mm, the number of superimposed layers: 6. Steel substrate was pre-heated in the temperature range 333-373 K. Flame spraying was carried out at temperatures exceeding 523 K. Then the coating have been subjected to very precise straight turning. To determine the parameters of machining the alloy coatings and composites based on nickel flame sprayed onto the substrate steel, the preliminary study was conducted for straight turning of high precision. Such turning has been realized with different cutting speed (v_c = 45-214 m/min), feed rate (f_n = 0.06-0.2 mm/rev) and depth of cut (a_p = 0.05-0.3 mm). Based on analysis of test results, it was determined that the best surface quality was obtained for samples of coated steel, nickel based alloys, using the cutting speed v_c = 214 m/min in the case of treatment with inserts of borazon, v_c = 107 m/min in the case of plates treated with cemented carbide cutting. Then it was determined that the best gain of the sample surface quality of coated steel composite was obtained for cutting speed v_c = 157 m/min, in the case of treatment with CBN inserts, v_c = 83 m/min in the case of treatment with cemented carbide inserts. For machining of alloy coatings and composites it was used the feed f_n = 0.06 mm/rev and depth of cut a_p = 0.3 mm.

Straight turning were subjected to a precise external cylindrical surfaces of steel samples with alloy and composite coatings, which samples were of diameter ϕ41mm and of thickness equal 2 mm. The determination of the optimal geometry of the cutting tool is synonymous with the selection of the optimum shape and dimensions of the insert.

The appropriate holder and edged tiles were chosen, which could be square, round, triangular, trigon, made of tungsten carbide (with grades: GC2015, GC3205, GC3210, GC3215, GC4015, H10F) and cubic boron nitride (CBN, grade CB7015).

Tab. 1. The research program and shape and grade inserts

Insert Type	Holder Type	Insert Grade	Insert Shape
SNGA 120408 S01030A	DSDNN 2525M 12	CB7015	Square
N123J1-0600-RE	RF 123J13-2525BM	CB7015	Round
TNMX 160408-WM	DTGNR 2020K 16	GC4015	Triangular
TNMG 160408-23	DTGNR 2020K 16	H10F	Triangular
WNMG 080408-WF	DWLNRL 2525M 08	GC2015	Trigon
WNMG 080408 S01030A	DWLNRL 2525M 08	CB7015	Trigon
WNMA 080408-KR	DWLNRL 2525M 08	GC3205	Trigon
WNMG 080408-KM	DWLNRL 2525M 08	GC3205	Trigon
WNMG 080408-KM	DWLNRL 2525M 08	GC3210	Trigon
WNMG 080408-KF	DWLNRL 2525M 08	GC3215	Trigon

The research program and shape and grade inserts is presented in Tab. 1. Surface texture of the alloy and composite coatings was measured with a Hommel Tester T1000 profilometer. During the turning of alloy and composite coatings the insert durability is usually short. It is therefore important to determine the spiral cutting length. This is the length cutting, which are chosen for recommended cutting, thus allowing for a reliable process. Spiral cutting length is applied to the insert, geometry, and grade, depth of cut and material that shall be subject machined. Spiral cutting length (SCL, m) can be calculated from the formula in paper [2].

3. Results of research

The study allowed for determination, that there are relationships between the surface texture of composite and alloy coatings and the type of grade used and the shape of the inserts. Trigon insert WNMG 080408 S01030A of CBN was characterized by a smaller flank wear as compared to a square insert with SNGA 120 408 S01030A 7015 (Fig. 1).

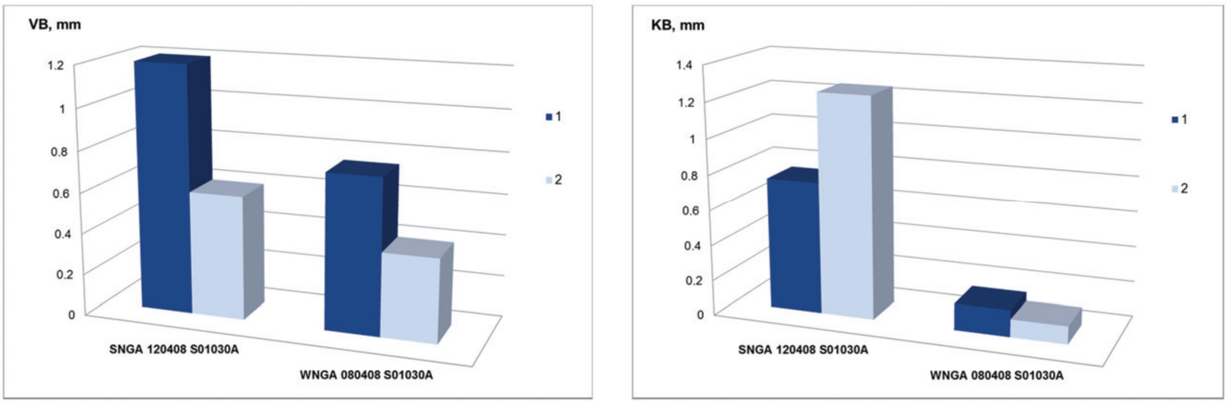

Fig. 1. The flank (VB) and attack (KB) wear coefficient of square and trigon inserts of CBN (CB7015) where: 1 – alloy coatings Ni-5%Al and 2 – composite coatings Ni-5%Al-15%Al_2O_3

After turning of composite coatings using square insert SNGA120408S01030A 7015, it was specified that the arithmetical mean deviation of the assessed profile reached a lower value of Ra = 1.08 μm (Fig. 2) in comparison to the roughness of the surface texture obtained with the trigon insert made of the same grades (CB7015) and also with the trigon of tungsten carbide (about the grades: GC2015, GC3205, GC3210, GC3215) and tungsten carbide (for grades: GC4015, H10F) for triangular inserts. Turning composite coating by the round insert N123J1-0600-RE 7015, the lowest surface roughness Ra = 0.65 μm (Fig. 2) was achieved. Round insert after turning composite coatings are characterized by the lowest flank wear compared to the square, trigon and triangular. Surface roughness (Fig. 2) of the surface texture of alloy coatings turned by trigon insert (Ra = 0.47 μm) and by round one (Ra = 0.39 μm) is nearly three times lower than the roughness of the coatings obtained with a square insert (Ra = 1.07 μm). Using the trigon insert made of tungsten carbide, it was determined that the minimum surface roughness of alloy coatings was obtained for grade GC3215 (Ra = 0.54 μm).

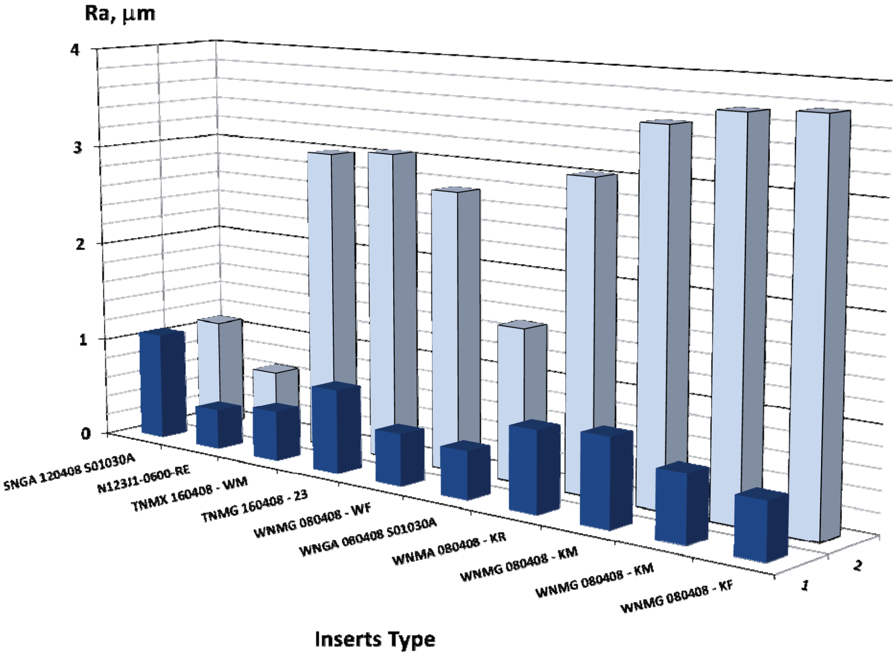

Fig. 2. The arithmetical mean deviation of the roughness for coatings: 1 – alloy Ni-5%Al and 2 – composite Ni-5%Al-15%Al_2O_3 after turned for various type inserts

For Fig. 2 shown the arithmetical mean deviation for nickel-aluminum alloy coatings and nickel matrix composite coatings after turned for various type inserts.

Parameter (Rpk) of the reduced peak height (which should be the lowest) is characteristic for the upper surface layer that quickly undergoes abrasion after start of i.e. engine running. Reduced depth of roughness profile valley is described by (Rvk) parameter (which should be the highest). It is a measure of the working surfaces ability to keep the lubricant in the valleys created mechanically. Parameter (Rk) defines the core roughness depth (which should be the lowest) (Fig. 3).

After turning the external cylindrical stainless steel samples with coating of alloys and composites, it was determined, that there were relationships between surface texture and the type of material used and the shape of the tool inserts. Based on analysis of test results, it was determined, that due to obtaining the smallest surface roughness of alloy coatings, it was expedient to use trigon inserts made of tungsten carbide with grade GC3215 and trigon inserts made of cubic boron nitride grade CB7015 and round inserts (CB7015).

For alloy coatings Ni-5%Al subjected to turning, it was determined, that the arithmetical mean deviation of the assessed profile and the material ratio curve (Abbott-Firestone curve) surface roughness parameters took the smallest value (Fig. 2-4).

The material ratio curve indicates the material ratio as a function of the section height. On the basis analysis of test results, it was determined, that due to obtaining the smallest surface roughness for turned alloy coatings of Ni-5% Al, with the least wear on the insert flank face and tool face, for a constant spiral cutting length equal thousand and seventy three meters, it was recommended the use of trigon inserts made of cubic boron nitride on the grade CB7015 and of an insert grade GC3215 and of the round profile of the CB7015. Roughness of the surface texture of Ni-5%Al subjected to turning by trigon insert with CBN is three times smaller than the roughness of the alloy coatings obtained with a square insert. Thus, it is advisable not to use square inserts for machining the alloy coatings.

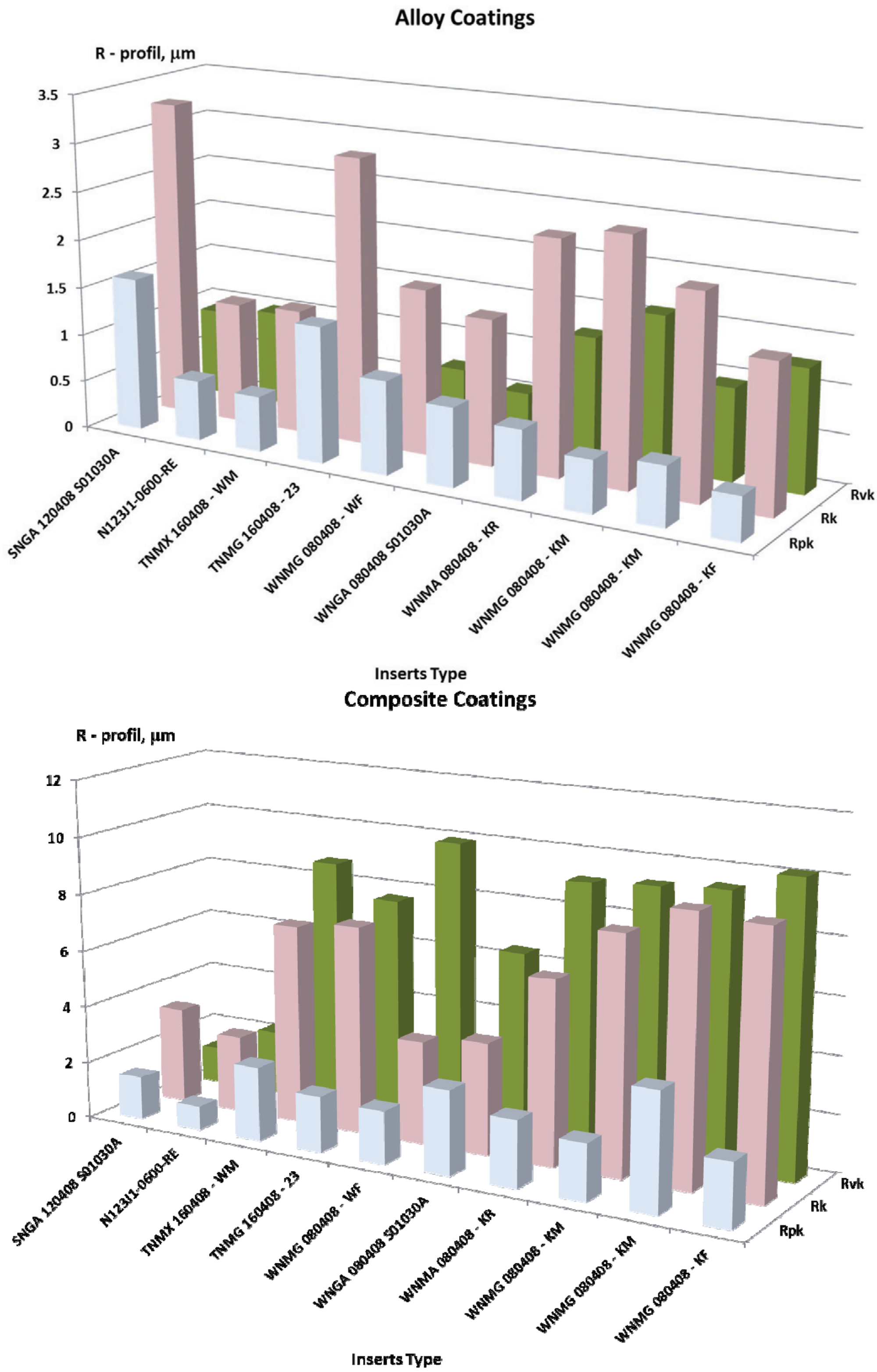

Fig. 3. The characterised parameters of the material ratio curve for alloy Ni-5%Al coatings and composite coatings Ni-5%Al-15%Al_2O_3 after turned for different type inserts

Figure 4 and 5 shows the material ratio curve surface roughness alloy coatings Ni-5%Al and composite coatings Ni-5%Al-15%Al_2O_3 for different type inserts. On the basis of analysis of experimental results after turning composite coatings for insert by the round profile of the grade CB7015, it can be determined, that the roughness profile parameters and parameter values of the material ratio curve reached the lowest values (Fig. 2, 3 and 5).

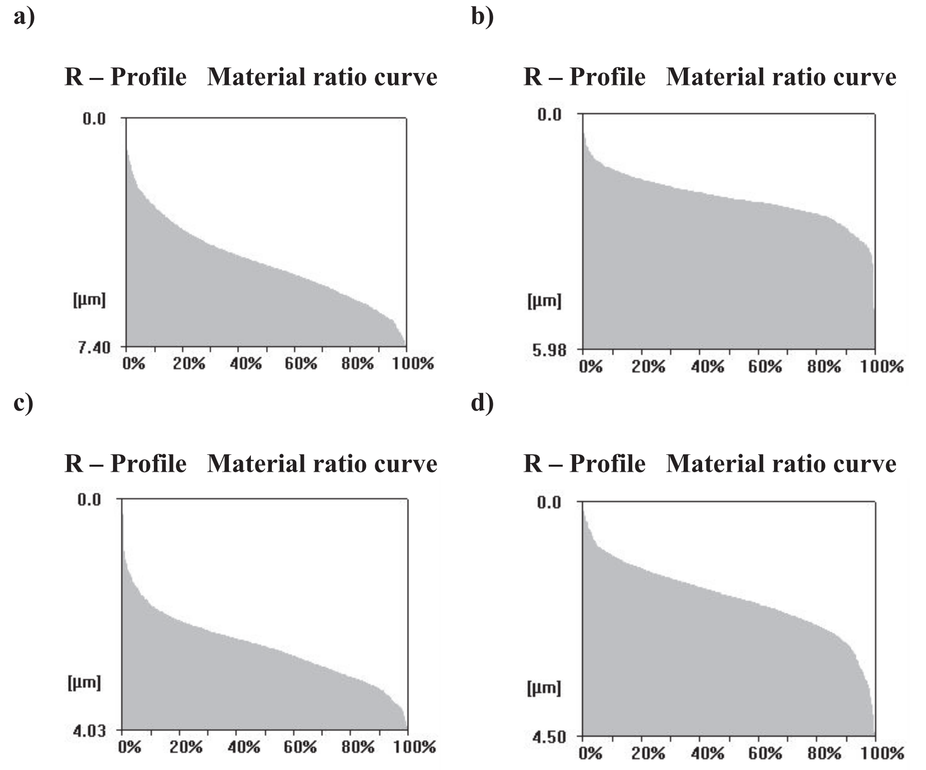

Fig. 4. The material ratio curve (Abbott-Firestone curve) surface roughness alloy coatings Ni-5%Al for inserts square SNGA 120408 S01030A CB7015 and b) round N123J1-0600-RE CB7015 and c) trigon WNMG 080408 S01030A CB7015 and d) trigon WNMG 080408-KF GC3215

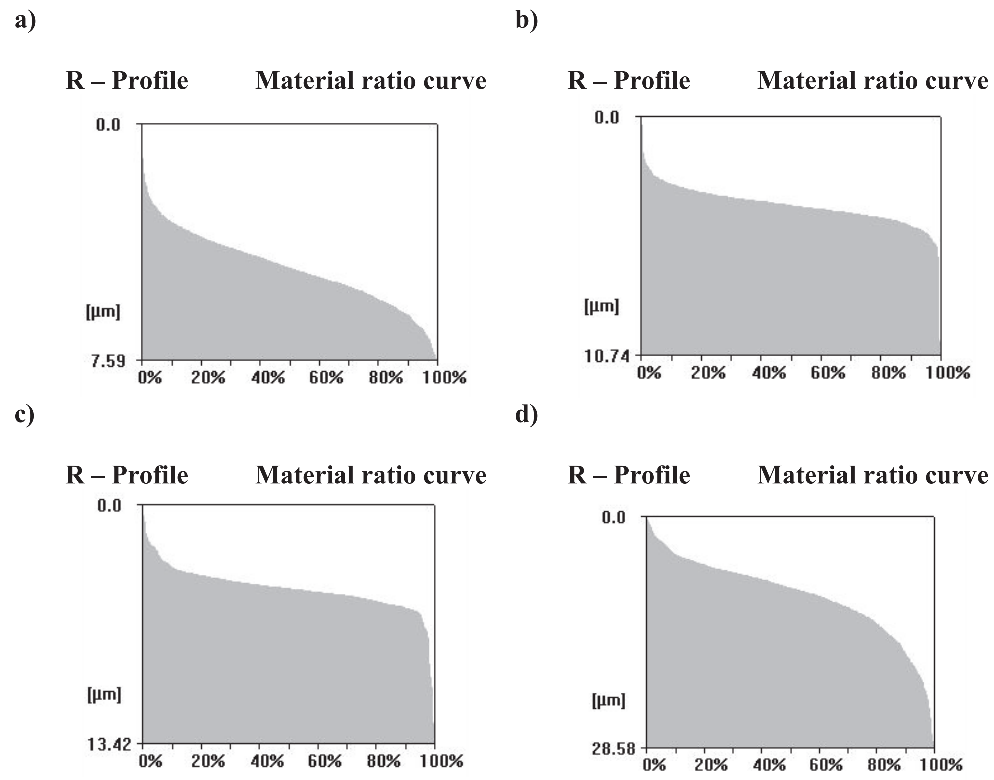

Fig. 5. The material ratio curve surface (Abbott-Firestone curve) roughness composite coatings Ni-5%Al-15%Al_2O_3 for inserts a) square SNGA 120408 S01030A CB7015 and b) round N123J1-0600-RE CB7015 and c) trigon WNMG 080408 S01030A CB7015 and d) trigon WNMG 080408-KF with GC3215

Conclusions

Nickel matrix composite coatings can be used for production and regeneration of the surface layer of the machine parts.

Due to the surface quality coatings and durability of the turning inserts for alloy coatings, such insert should be round or trigon one with grade CB7015 or trigon one with grade GC3215.

Due to the surface quality coatings and durability of the turning inserts for composite coatings, only round inserts with grade CB7015 should be applied.

Surface texture is very important, as it has a direct influence on the quality of the machined parts. It has to be defined as precisely as possible with the help of standardized surface texture parameters.

From the study for the finish turning of alloy and composite coatings, it was determined, that due to obtaining the smallest surface roughness, with the least wear on the insert flank face and tool face, for a constant spiral cutting length, it is recommended to use round inserts with CBN.

References

[1] Chang, J. T., Yeh, C. H., He, J. L., Chen, K. C., *Cavitation erosion and corrosion behavior of Ni–Al intermetallic coatings*, Wear, 255, pp.162-169, 2003.

[2] Dyl, T., Starosta, R., *Determining the effect of the geometry and type of inserts on the geometric structure of turned composite coatings*, Inżynieria Materiałowa, No. 6, pp. 701-704, 2012.

[3] Dyl, T., Starosta, R., *Effect of the ceramic dispersion in the nickel matrix composite coatings on corrosion properties after plastic working*, Solid State Phenomena, 183, pp. 43-48, 2012.

[4] Dyl, T., Starosta, R., *The influence of treatment parameters on the quality of MMC coatings surfaces applied to recondition parts of ship machinery*, Journal of POLISH CIMAC, Vol. 3, No. 2, pp. 39-46, 2008.

[5] Grądzka-Dahlke, M., Bukrym, A., Choińska, E., *Effect of TiN coating on functional properties of implant titanium alloy*, Solid State Phenomena, 147-149, pp. 782-787, 2009.

[6] *Machining powder of sprayed layers 19000, 21000, 12000*, Materials of the company Castolin Eutectic, 2001.

[7] *Manual machining*, AB Sandvik Coromant, Sandviken, Sweden 2010.

[8] Molins, R., Normand, B., Rannou, G., Hannoyer, B., Liao, H., *Interlamellar boundary characterization in Ni-based alloy thermally sprayed coating*, Materials Science and Engineering, A351, pp. 325-333, 2003.

[9] Sampath, S., Jiang, X. Y., Matejicek, J., Prchlik, L., Kulkarni, A., Vaidya, A., *Role of thermal spray processing method on the microstructure, residual stress and properties of coatings: an integrated study for Ni-5 wt.%Al bond coats*, Materials Science and Engineering, 364, pp. 216-231, 2004.

[10] Sierra, C., Vazquez, A. J., *NiAl coating on carbon steel with an intermediate Ni gradient layer*, Surface and Coatings Technology, 200, pp. 4383-4388, 2006.

[11] Starosta, R., *Corrosion of Ni-Al and Ni-Al-Al_2O_3 flame sprayed coatings of CastoDyn8000 system in 0.01MH_2SO_4 and 3.5%NaCl solutions*, Solid State Phenomena, Vol. 183, pp. 185-192, 2012.

[12] Starosta, R., Skoblik, R., Dyl, T., *The influence of plastic working on the selection properties of the nickel – aluminium alloy coatings*, Journal of KONES Powertrain and Transport, Vol. 14, No. 2, pp. 441-448, 2007.

[13] St-Georges, L., *Development and characterization of composite Ni-Cr+WC laser cladding*, Wear, 263, pp. 562-566, 2007.