Research paper

Evaluation of the surface activation of stainless steels using sandblasting and mechanized for the coatings covered by atmospheric plasma spray (APS)

Evaluación de la activación superficial de aceros inoxidables usando sanblasting y mecanizado para la aplicación de recubrimientos mediante aspersión de plasma atmosférico (APS).

M. Ramos[1], S. Sánchez[1], J. Giraldo[1], J.A. Gutiérrez[1], Sa. Sánchez[1], A. Gutiérrez[1], A. Zapata[1], L. Olmos[1], I. Zuluaga[2], A. Toro[2]

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Resumen

En el presente trabajo se realizó una evaluación de la preparación superficial de sustratos metálicos con chorro de alumina (sandblasting SB) y mediante el uso de herramientas de corte (HC) sobre aceros inoxidables AISI 304 para después aplicar un recubrimiento por APS. Se utilizó la estación de rugosidad de la Universidad Nacional de Colombia Sede Medellín con el apoyo del grupo GTS de superficies, para analizar la textura y así comparar los perfiles de rugosidad y sus respectivos parámetros de rugosidad tomando de referencia los parametros más usados en contexto metalmecánico nacional. Como resultado de ejecutar ambas técnicas sobre inoxidable 304, se evidenció que existe un efecto significativo en la activación superficial cuando se combinan el sandblasting y los procesos de mecanizado para activar la superficie ya que la componente polar de energía libre disminuye de manera significativa al aumentar las variables de rugosidad.

Palabras clave: *APS, mecanizado, Activación Superficial, Sandblasting, recubrimientos***.**

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1 Institución Universitaria Pascual Bravo, Medellín

2 Universidad Nacional de Colombia, sede Medellín
E-mail seb.sanchez@pascualbravo.edu.co

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Abstract

In this work was carried out the evaluation of the surface preparation of metallic substrates with alumina (sandblasting SB) and by the use of cutting tools (HC) on stainless steels AISI 304, after which an APS coating was applied. The roughness station of the National University of Colombia at Medellin was used with the support of the GTS group of surfaces, to analyze the texture and comparing the profiles of roughness and its respective parameters of roughness taking of reference the parameters most heavily used in the metal-mechanical national context. As a result of running both techniques on these materials it is evident that there is a significant effect on surface activation when sandblasting and machining are combined to activate the surface due to the parameters that increase surface roughness result in decreasing values of the polar component of surface free energy.

Keywords: *APS, mechanizing process, Surface Activation, Sandblasting, Coatings.*

1. Introduction

By means of the evaluation of the surfaces it is aimed to quantify the topography of the material in order to be based on parameters of roughness, waving and errors of shape, taking into account that the roughness of a surface is of vital importance in order to have a total control of the quality of de mechanized piece [1]. In the stage of surface preparation, a process is highlighted, which is generally recommended to rise the surface energy and to increase the contact area between the coating and the substrate. It is a sandblasting process, where certain characteristics are very important, such as the processes of generation of surface texture (pressure, size, type of particles, among others) [2]. However, this process involves certain type of inconveniences in the surfaces due to contamination by the incrustation of fine particles (sands or powders). The particles act as stress concentrators that laminate the coating [3].

The preparation of the surfaces is a very important aspect, because it is the main mechanism of adherence, and has to do with the mechanical interference between peaks and valleys of the surface and the sheets of the material deposited on them [2]. By evaluating the surface and the preparation with cutting tools, it is sought to have a greater number of roughnesses that are similar to those generated by sandblasting and thus avoid having problems with the incrustation of the particles that lead to the failure of the coating. With the preparation of the surfaces, it is sought to have the necessary standards of roughness to maintain the cleanliness in the finishes, which are essential to perform a coating process where the material must be completely decontaminated and without inlays to avoid failure. Finally, the surfaces can be covered by APS (Atmospheric Plasma Spraying), with this process the life cycle is sought to be increased.

The thermal protection techniques allow the tribiological properties of the pieces to be modified through the generation of coatings, whose surfaces must be subjected to very specific and in some case extreme conditions. In this technique, the thermal and kinetic energy is transmitted to a material with shape of powder, wire or rod, which is melted and projected to the substrate (previously sandblasted), where it arrives in a pasty or semi-paste state. The contraction of the particles during solidification gives rise to a mechanical type anchoring with the substrate [4].

In recent years, the study of this technique of thermal projection APS, has generated different ideas such as: obtaining self-lubricated coatings to replace the liquid lubricants. In this study, a Ni-Graphite coating was used, which has an ideal behavior capable of competing with traditional liquid lubricants [5].

In the aerospace industry, there are needed lightweight materials that have high mechanical performance combined with low density. The silicon carbide, the carbon fiber reinforced with carbon fiber and the silicon carbide reinforced with carbon fiber are materials that meet these requirements, but at high temperatures they have oxidation problems. One of the most effective ways to prevent this phenomenon is the use of ceramic coatings, whose correct adhesion on the different substrates is essential to guarantee its operation [6]. There also were found studies showing the relationship of the microstructure and micro hardness on the wear resistance of coatings widely used in the thermal projection by atmospheric plasma [7].

There is another method called supersonic APS, the speeds of this type of method to reinforce are very high overcoming the sound barrier [8]. Hou et al. [9] conducted a study where they compared the supersonic APS and the traditional APS method; but for this type of projection to work in optimal conditions, it is necessary to know the true optimum values of the spray distance, chamber pressure, speed of the stream, flow and hydrogen gas flow. To facilitate this, a hybrid artificial intelligence (AIM) method has been studied, which is used to optimize the atmospheric plasma spraying and the processing parameters (APS) [10]. Then, it is necessary to analyze the porosity of the coating to avoid future failures [11]. This procedure has also been used in stainless steel M42C improving the properties of cast iron avoiding its oxidation at high temperature [12].

In many metal-mechanical processes it is very important to measure the roughness and surface finishing [13]. Roughness is defined as the state and micro-granulometric variation of the surface of a material that has been manufactured. The vast majority of machines and tools such as lathe, milling machine and boring machine, can generate roughness at the end of the manufacturing process, but in order to ensure a better finishing, there are procedures used to generate roughness, some of which are: brushing, grinding, extrusion and stamping, drilling, sandblasting, coarse polishing, fine polishing and electro-polishing [14]. Achieving a quality of measurement of the surface of average roughness, according to the process used.

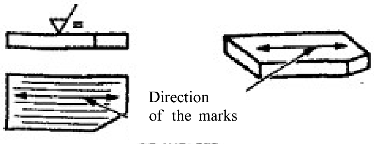
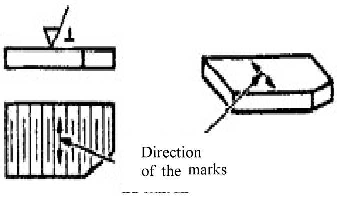
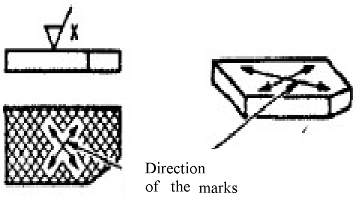
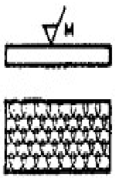
The roughness of surfaces recommended to apply a coating by means of APS, is of 4 microns according to the manufacturer of the ceramic powders that will be applied. This is due to the average granulometry generated in the manufacture of the ceramic substrates but this variable is not enough to characterize the texture of a substrate since two very different textures can have the same Ra, which has generated the need to look for a method to measure the surface activation of a substrate to see if it has adhesive potential, in this process the surface of free energy (ys) is measured, which consists of two components, one dispersive (ysd) and another polar (ysp) relating them as: ys=ysd+ysp and according to the theory the larger the variables Ra, Rz, Rp, Rv, the dispersive component will increase and the polar component will decrease, which will increase or decrease the free energy surface [15].

In the industry there is a large number of products whose main parameter is to present a surface with certain roughnesses, such as the company SKF [16], which is responsible for making bearings of different roughness according to the operation to be performed or the type of lubrication that is going to be adopted. Another application of roughness can be observed in plastic materials such as PEEK (polyether ether ketone) which belongs to a group of high performance thermoplastic polymers that is widely used in structural components [17].

2. Materials and methods

The different orientation proposed in the literature were studied and a type C orientation was used, as shown in Table 1, to generate the geometry of the test tubes that were later mechanized. P40 and P20 burins with tungsten carbide insert with V-sharpening were used to generate a texture of high peaks and deep valleys. A mechanizing protocol was designed to organize the variables and parameters of mechanizing based on parameters of the workshop of the Pascual Bravo University and some data from Mikell Groover's modern manufacturing book [18] see Table 2, thus obtaining detailed information (see Table 3) to create a work path and calculate the mechanizing time.

TABLE 1. SUMMARY OF ORIENTATIONS [17]

Symbol of the orientation	Surface pattern	Description
=		Parallel to the projection plane of the view in which the symbol is used.
⊥		Perpendicular to the projection plane of the view in which the symbol is used.
X		Crossed in two inclined directions in relation to the projection plane of the view in which the symbol is used.
M		Multidirectional

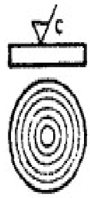
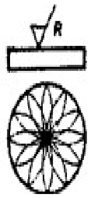
Symbol of the orientation	Surface pattern	Description
C		Approximately circular in relation to the center of the surface on which the symbol is applied.
R		Approximately radial in relation to the center of the surface on which the symbol is applied.

TABLE 2. STAINLESS MECHANIZING PARAMETERS [17]

Material	Cutting depth		Advance by revolution		Cutting speed	
	Inches	mm	Inches	mm	ft./min	m/min
Stainless Steel	.005-.015	0.15-0.4	.002-.005	0.05-.015	375-500	115-150
	.020-.090	0.5-2.3	.005-.015	0.15-0.4	300-375	90-115
	.100-.200	2.55-5.1	.015-.030	0.4-0.075	250-300	75-90
	.300-.700	7.6-17.8	.03-.09	0.75-2.3	75-175	25-55

TABLE 3. MECHANIZING PROTOCOL OF TEST TUBES

Machining		1		2	
Type of machining		Milling	Turning	Milling	Turning
			X		X
Surface to be machined		Transversal	Longitudinal	Transversal	Longitudinal
		X		X	
Data of the piece	Material	Stainless steel 304		Stainless steel 304	
	Diameter (mm)	25,4		25,4	
	Length (mm)	100		100	
Insert		V-sharpening tungsten carbide		V-sharpening tungsten carbide	
Clamping system		P40 burin		P40 burin	
Cutting speed (rpm)		92		140	
Advance (mm/rev)		0,978		0,978	
Cutting depth (mm)		0,2		0,4	
Texture	Ra(μm)	17		17	

Having defined the variables, it was important to carry out an experimental design taking into account the mechanizing conditions. Therefore, a factorial design was developed by varying the cutting speeds between 140 RPM and 92 RPM with the two different P40 and P20 burins with tungsten carbide insert with a V-sharpening with 3 repetitions as shown in Table 4.

TABLE 4. NUMBER OF EXPERIMENTS

EXPERIMENT	1	2	3	4	5	6	7	8
Tool	P20	P20	P20	P20	P40	P40	P40	P40
Cutting speed (RPM)	92	92	140	140	92	92	140	140
Cutting depth (mm)	0,2	0,4	0,2	0,4	0,2	0,4	0,2	0,4

A pair of cutting speeds of 7.34 and 11.17 m/min was used, which are given at 92 and 140 rpm respectively, with an advance of 0.978 mm/revolution and a cutting depth of 0.05 mm, using stainless steel AISI 304. The reason for the selection of these parameters was due to limitations in the tool in the selection of RPM as shown in Figure 1, it handles standard speeds that when performing calibration tests did not work in the best conditions RPM higher than 220 rpm that is, because the cutting depth along with the mechanizing angle make the burin fail instantaneously if the above parameters are increased, and therefore the burin tends to generate more replicable textures to these conditions.

The Spanish Pinacho lathe was selected for its good history and availability at the Pascual Bravo University, see Figure 1.

a. b.

FIGURE 1. PINACHO LATHE a. U PASCUAL BRAVO MACHINE AND TOOLS LABORATORY. b. RPM SELECTION MODE.

After the mechanizing process, the test tubes obtained were stored in a hermetic package with silica gel to remove moisture from the test tubes and keep them dry until the coating. The roughness measurement was carried out on a Mitutoyo roughness tester from the National University of Colombia. Finally, the data obtained was collected and added to the mechanizing protocol.

3. Results

Surfaces with textures of type c orientation were obtained with the lathe and burins with insert of tungsten carbide with a V-sharpening, as evidenced in figure 3 does not notice a visual change in the orientations in the textures with burins P40 and P20 and when measured, it is not a definitive variable to generate the textures.

Figure 3. Lathe texture

After obtaining the textures, they were evaluated and submitted to 5 minutes of sandblasting to be also evaluated as seen in Figure 4.

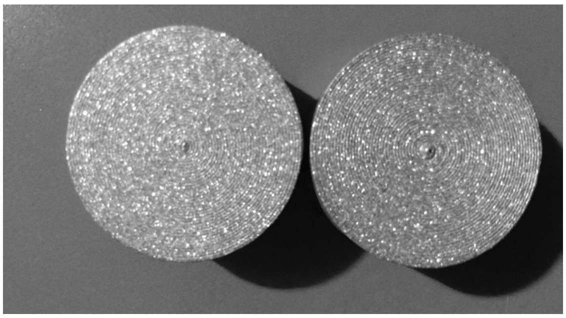


Figure 4. Lathe texture plus sandblasting

In Table 5, the most influential parameters of roughness were collected when making the measurements. With these results it is clearly noted that the variables Ra, Rz, Rp, Rv are much larger in lathe and lathe combined with sandblasting than just using the sandblasting, which suggests that the surface activation changes in a very significant way since these variables are the ones that have the most correlation with the dispersive and polar component of free energy.

TABLE 5. ROUGHNESS RESULTS

Parameters	Sandblasting (um)	Lathe (um)	Lathe + sandblasting (um)
Ra	7.591	19.865	14.539
Rz	52.951	100.186	81.520
Rp	24.086	68.187	40.217
Rku	3.179	2.523	2.461
Rv	37.068	50.771	43.965

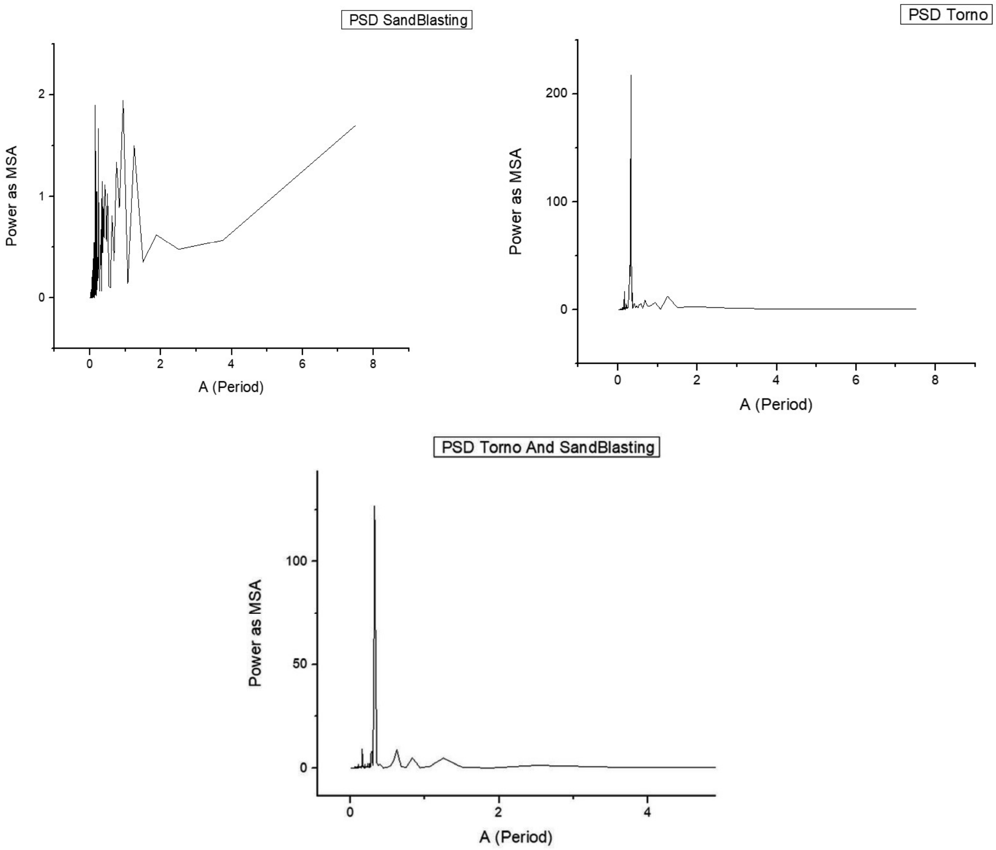


FIGURE 5. POWER SPECTRAL DENSITY (PSD) FOR THE SURFACE ACTIVATION PROCESSES.

It was done by the data collection with a Power Spectral Density (PSD) to verify the recurring signals in each of the textures and it was found that the signal that was obtained when evaluating the profile of the lathe was not erased when it was combined with the sandblasting, which suggests that sandblasting after machining does not affect the profile of the lathe.

4. Conclusions and discussion

When evaluating the results of the texture variables it is implied that these in lathe give very high results, which increases the dispersive component of free energy and decreases the polar component giving a lower result of free energy and therefore a surface activation in the substrates evaluated and with the tools used in this experimentation.

Al evaluar los resultados de las variables de textura se da a entender que estas en torno dan resultados demasiado altos lo que aumenta la componente dispersiva de energía libre y disminuye la componente polar dando un resultado inferior de energía libre y por ende una activación superficial en los sustratos evaluados y con las herramientas usadas en esta experimentación.

Also when evaluating the sandblasting PSD, too many repetitive signals are denoted in a very short period, but these signals are potentiated with a previous mechanizing.

In order to reach higher roughnesses than 5 um in sandblasting in materials of significant hardness, the exposure time must be carefully studied by studying the material, although with the mechanizing process higher roughnesses are reached in their average (Ra).

When a combination of the two techniques is presented, all the parameters are improved and the benefits of these techniques are combined.

The P20 burin did not show statistically significant changes compared to the P40 in its results, so it is suggested to use P40 for its great commercial use.

This paper work suggests to continue evaluating with other techniques and as a result the effect on adhesion in coatings using the ASTM C633 standard to analyze the actual adhesion of the coatings.

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