TECHNOLOGY OF MACHINING OF THERMAL SPRAYED COATINGS

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Abstract

The article focuses on the technology of machining thermal sprays and the determination of suitable machining parameters with respect to the achieved quality of the machined surface. Thermal sprays are characterized by a very good workability in terms of chip machining technology, but this production results in a defective surface quality (ripped coating). Determination of suitable parameters was performed during the Metco 52C - NS heat treatment. This spray using most commonly in the aerospace industry as a gasket for air jet compressors. The evaluation of the thermal properties of the proposed thermal processing machining parameters was carried out by measuring the force of the machine - tool - workpiece system. The KISTLER 9257B piezoelectric dynamometer was used to measure force load patterns. From the achieved results, the appropriate machining parameters were subsequently determined to reduce machine time while maintaining the required quality of the surface treated surface of the Metco 52C-NS heat treatment.

Keywords: Thermal sprayed coatings, machining, cutting inserts

1. INRODUCTION

Thermal spraying is one of the gradually evolving surface treatment technologies that create layers with specific properties. This mode of adjustment is using geared in many industries, both in the first generation and in the restoration of existing components. Depending on the type of thermal spraying selected, their components can enhance their performance, resist various stresses, and thus increase the life of the exposed parts. [1,7] The Metco 52C - NS thermal spray is one of the abradable coatings that serve as a towelling layer of air compressor blades. Even though the surface quality isn´t an important parameter for abrasion-resistant coatings, it is important to maintain the uniform appearance of the machined surface in terms of maintaining the functionality of the applied coating. In order to prevent irreversible damage to the surface of the thermal sprayed component, it is necessary to choose the appropriate technology and parameters influencing the process of retrofitting. [3,10]

2. MACHINING OF THERMAL SPRAYED COATINGS

The functionality of the thermally sprayed components is based on the selection of the correct technological procedures, additional modifications and finishes after application of the spray. In fact, it is assumed that the adhesion of the coatings to the surface of the base material is significantly affected by the mechanical anchoring component. [9] However, any interference with the deposited thermal spray layer on the surface of the component may cause it to break. Machining of smaller or larger coating thicknesses can cause tension in the coating and its alignment with the existing tension in the coating. Thermally sprayed surfaces consist of individual deformed particles of additive material and a certain amount of porosity, therefore, the cut surfaces can be counted with the intermittent cut at the cutting point with the tool and coated coating layer. Non-homogeneous porous structure and poorly selected machining parameters are the most common cause of impact, which can damage the heat spray layers and cause it to get tangled. [2,4,5]

3. CHARACTERISTICS OF THERMAL SPRAY METCO 52C - NS

For the experiment was used Metco 52C - NS Al + 12 % Silicon, which is applied by plasma spraying technology. The coated coating is powdered into a device in which it melts and accelerates in the direction of the coated surface of the part. Subsequent to the substrate, the particle will spread across the substrate in a substantial manner and will quickly become stiff. In this way, a coating is produced which has a characteristic lamellar structure and specific properties. [6, 8].

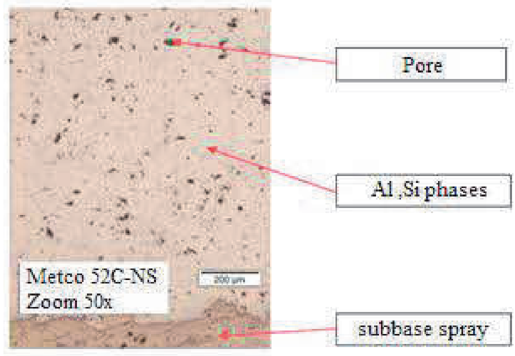


Figure 1 Structure of the Metco 52C - NS [5]

Table 1 Chemical Composition Metco 52C - NS [4]

Element	Si	Al
Mass [%]	12	88

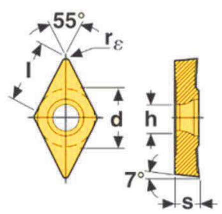
Table 2 Mechanical and PhysicalPropertiesoftheMetco52C-NS [4]

Mechanical and Physical Properties		Value	Mechanical and Physical Properties		Value
Typical Size Range	µm	106 + 45	Density *ρ*	g / cm^3	2.4
Macro Hardness	Rh	Rh90	Melting Point	°C	650
Cross Sectional Hardness	(DPH50)	120	Porosity	%	max. 5

4. PROPOSAL OF EXPERIMENTAL MACHINING OF SPRAYING

For the experimental operation was designed of thermal spraying, a cutting tool with geometry designated DCGT11T304F-AL. It is an uncoated cutting insert with positive cutting geometry. The selected geometry of the cutting insert ensures an efficient material removal and a stable process without the need for greater force loading and intense friction. Cutting insert is primarily designed for aluminium, its alloys and other non-ferrous materials. With regard to the force load on the surface of the thermal spraying and the prescribed microgeometry of the surface, a tool with a radius of r_ε = 0.4 mm was selected under predetermined cutting conditions. The aim of the experimental machining was therefore to maintain the size of the cutting force components lower than the adhesion strength of the thermal spray coating to the backing material. At the same time, the machining parameters were chosen to increase the existing heat treatment productivity and maintain the required surface quality after machining.

Table 3 Parameters of the Designed Cutting Insert

Cutting Insert	Designation	*l* (mm)	*d* (mm)	*s* (mm)	*h* (mm)	r_ε (mm)
	DCGT11T304F-AL	11.6	9.53	3.97	4.4	0.4

5. EXPERIMENTAL CUTTING PARAMETERS

The cutting parameters of the Metco 52C - NS were determined as follows - **Table 4**. In terms of increased productivity, increasing cutting speeds have been proposed for machining the spraying. The sliding value is selected so that the desired microgeometry of the surface with the radius of the tool tip is reached, namely the theoretical value of parameter R_z = 6.4 μm. The cutting depth was chosen in accordance with the tested radius of the cutting tool $r_\varepsilon \geq a_p$. The feed rate and the cutting depth were constant during experimental testing. Metco 52C - NS spraying was performed without cooling.

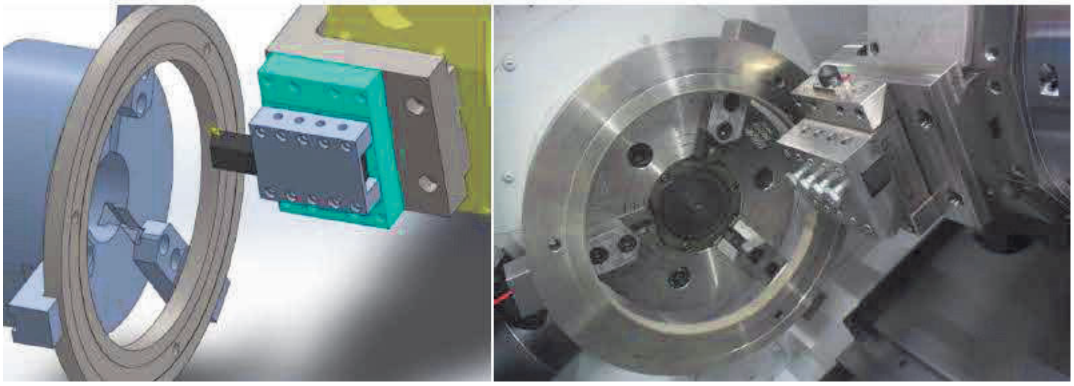


Figure 2 Scheme of the Machining System

Table 4 Experimental Cutting Parameters

Cutting parameters	1. Test	2. Test	3. Test	4. Test
Cutting Speed - v_c (m·min^{-1})	152	304	457	56.4
Depth of Cut - a_p (mm)	0.2	0.2	0.2	0.05
Feed - f (mm)	0.14	0.14	0.14	0.06

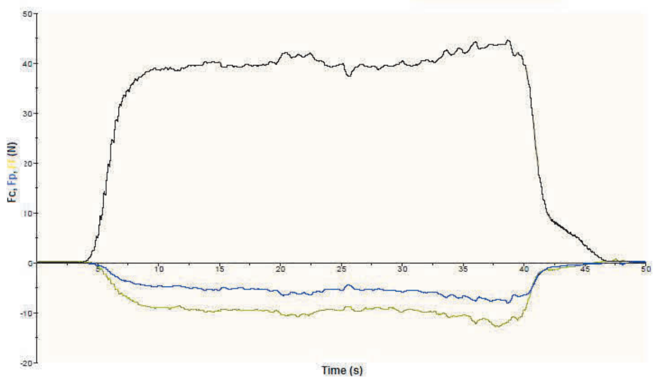
6. EXPERIMENTAL MEASUREMENT AND EVALUATION

The experimental activity deals with the determination of the size of the cutting forces applied to the Metco 52C - NS applied casting layer depending on the selected machining parameters and the radius of the rounding of the tip of the cutting tool. Measurement of the cutting force components was performed using a KISTLER 9257B dynamometer and converted using a KISTLER type 5070 amplitude amplifier. The measured load curves were filtered to remove the high oscillation frequency. Excessive oscillation of the system was due to the already mentioned porous structure of the applied Metco 52C-NS. To determine the components of the cutting force, the maximum values measured during the steady load section were selected. The individual load force components are given in absolute values due to the orientation of the measurement on the dynamometer. After machining the Metco 52C - NS coating, a visual inspection was performed to determine the occurrence of defective quality and to measure the surface roughness. Measuring the surface roughness of thermal sprays is very problematic due to the amount of pores that occur on the surface. The resulting pores are so deep that the results obtained by the touch measurement method are not always relevant and may be distorted. Surface roughness measurements were performed to compare the quality of the surface to be machined at the change in cutting speeds, provided that the pores are evenly spaced and the results are affected equally. The roughness of the surface was measured in the middle of the applied layer so that the results were not affected by the marginal parts where the defects occurred due to the application of the coating. From the measured values of the roughness parameter R_a, the highest and lowest measured values were deleted for objectivity. The arithmetic mean was determined from the remaining values.

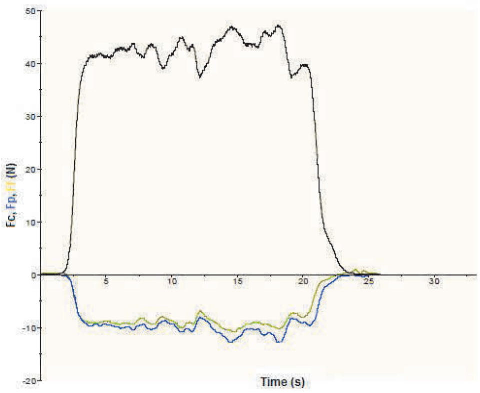
Table 5 Measured Values at Proposed Machining Parameters

Metco 52C - NS

Test 1	v_c (m·min^{-1})	f (mm)	a_p (mm)	F_c (N)	F_p (N)	F_f (N)	R_a (µm)
	152	0.14	0.2	40.47	5.69	9.83	1.94



Test 2	v_c (m·min^{-1})	f (mm)	a_p (mm)	F_c (N)	F_p (N)	F_f (N)	R_a (µm)
	304	0.14	0.2	42.69	10.19	9.06	1.82



Test 3	v_c (m·min^{-1})	f (mm)	a_p (mm)	F_c (N)	F_p (N)	F_f (N)	R_a (µm)
	457	0.14	0.2	46.81	17.04	16.83	2.09

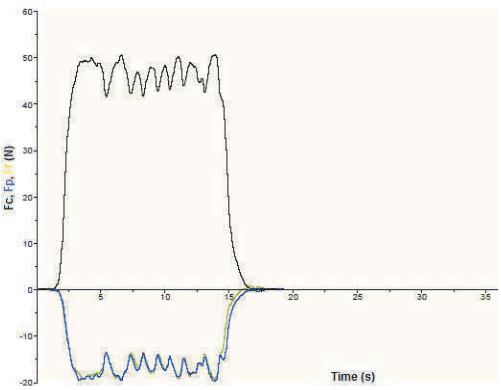
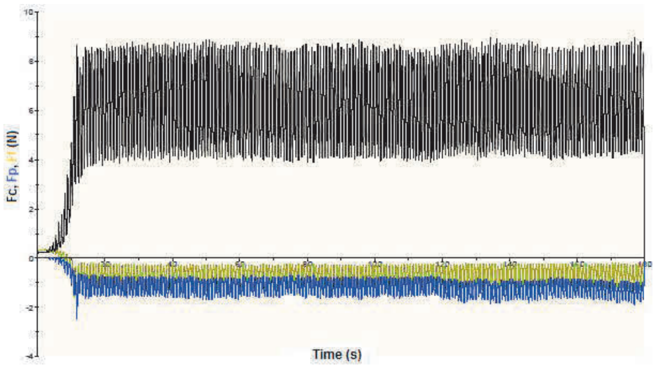


Table 6 Measured Values for Machining Parameters Recommended by the Manufacturer

Metco 52C - NS								
Test 4	**v_c (m·min^{-1})**	**f (mm)**	**a_p (mm)**	**F_c (N)**	**F_p (N)**	**F_f (N)**	**R_a (µm)**	
	56.4	0.06	0.05	6.27	1.22	0.73	1.47	
								

7. CONCLUSION

At present, thermal sprays are a modern technology that produces effective coatings, the application of which increases the resistance to stress and also the life of the machine components. The application of hot sprays is rapidly expanding and is now mainly used for aerospace applications. Depending on the type of thermal spraying used, different properties can be achieved with components. The Metco 52C - NS test spray is one of the reusable thermal sprays that serve as sealing coats for sealing the rotating parts. However, the correct functionality of thermally sprayed coatings depends on the correct choice of the additional editing technology. During the machining, it is necessary to take into account the lamellar structure of the spraying, the granularity, the considerable porosity and the occurrence of different hard and brittle phases. Incorrect choice of machining parameters could result in a reduction in the surface quality of the coating applied. When choosing them, it is also necessary to consider the adhesion of the coatings and the mechanical anchoring component. The size of the anchoring component should not be exceeded due to cutting resistance during machining in order to prevent the layers of the applied coating from being detached from the substrate and its damage.

Experimental activity was based on the comparison of the proposed parameters of the Metco 52C - NS thermal spraying with parameters recommended by the spray producer. A cutting tool, tool geometry, and cutting conditions were designed for machining the spraying. The criterion for determining more suitable parameters was the size of the force load and the quality of the machined surface. Based on the tests, measured results and visual inspection after the surface treatment of the Metco 52C - NS, it can be concluded that the range of the proposed cutting speeds was satisfactory for the surface quality achieved. At a cutting speed of 152 m·min^{-1} and selected tool tip, the trace of the cutting tool was completely minimized on the surface of the coating and the coating showed no signs of damage. Increasing cutting speed also increased the load but did not cause visible damage to the applied coating. At a speed of 304 m·min^{-1}, the lowest value of the R_a parameter was reached, but the coating began to be visibly coloured due to thermal stress. At a cutting speed of 457 m·min^{-1}, the load on the coating increased to the extent that it caused partial eruption. The coating has significantly changed colour due to thermal stress, which is totally unacceptable for quality assessment in the aviation industry. By machining the parameters recommended by the manufacturer, a much lower coating load was measured, which was mainly due to the setting of very low cutting parameters. Under these conditions, a slightly better surface roughness was measured, but much lower machining productivity was achieved compared to the proposed parameters. It follows that the parameters recommended by the manufacturer of the spraying can be several times higher without causing damage to the coating.

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