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Adrian V. Petrica, Mircea Megheleş

A Proposed Method to Determine the Adherence for the Layers Made Out of Thermal Sprayed Materials on Internal Cylindrical Surfaces

The paper presents an investigation method for the adherence of the layers made out of thermal sprayed materials on the inner surface of some parts. The base material is made of steel. The deposition procedure was the electric arc thermal spraying, flame spraying asnd plasma spraying and the filler materials used were: copper, brass and aluminum bronze. The proposed method analyses the adherence force by measuring the shear unit fracture stress of the deposited layers.

1. Introduction

The most important quality factor of the layers deposited by thermal spraying is considered the adherence of the layers on the under layer. The adherence can be quantitative considered by the unit detachment stress of the sprayed layers by the under layer.

The assessment methods for the adherence in the case of cylindrical parts are related to the deposited layers by the external surfaces. In this case the adherence is calculate by the unit shearing or tension stress of the sprayed layer.

From the functionally point of view the deposited layers on the internal cylindrical surfaces are stressed to shearing. Consider as homogeneous the deposited materials at macroscopically range it can be asserted that the unit stresses are equal in any direction. In this way, to establish a measurement for the adherence in the case of deposited layers by thermal spraying on the internal cylindrical parts (bushings, bearings, rings, etc.) it's considered as sufficient to determine the unit shearing stresses of the deposited layers by the under layer.

2. Experimental specimens

As base material for obtaining the experimental specimens was used the OLT 35 steel.

The previous machining of the surface it's an important factor to provide an adequate adherence for the deposited material on the base material surface, being necessary to assure a superior roughness.

Initially the specimens were turning and nut threaded (table 1), the resulting dimensions were inserted in table 2. After that the specimens were blasted (table 3), supplementary was deposited an adherence layer by thermal spraying. Tables number 4, 5, 6 and 7 present the type of material, the used proceedings, the chemical composition and the parameters used to deposit the adherence layer. The final thickness of this layer is 0,05 – 0,1 mm.

Table 1. The parameters used to turn and nut thread the experimental specimens

Internal turning		Nut thread			Propeller pitch, [mm]	Marking of speci-mens
Rota-tions, [rot/min]	Lead, [mm/rot]	Rotations, [rot/min]	Lead, [mm/rot]	Depth of cut, [mm]		
160	0,125	200	1,5	1,621	1,5	P1 – P5
		150	0,5	0,541	0,5	P6 – P7

Table 2. The initial dimensions of the specimens

Marking of specimens	External diameter, [mm]	Internal diameter, [mm]	Length, [mm]
P1 – P5	155	140	100
P6 – P7	155	141	80

Table 3. The parameters for blasting the specimens

Grinding material	Type of sandblast machine	Granulation	Pressure, [bar]
Corundum	Compressed - air	F 13	4 – 6

Table 4. The type of the materials and the proceedings that were used to deposit the adherence layer

Marking of specimens	Form of material	Type of material	The proceeding
P1 – P5	Wire	Thermanit NiCro 82	Electrical arc
P6 – P7	Powder	Metco 447 NS	Plasma

Table 5. The chemical composition of the materials used to deposit the adherence layer

Marking of speci-mens	Type of material	The chemical composition, [%]												
		C	Fe	Mn	Cr	Ni	Mo	Si	Al	Ti	Cu	Nb	S	P
P1 – P5	Thermanit NiCro 82	0,016	0,8	3,14	20,6	72,4	-	0,05	-	0,332	0,002	2,53	0,002	0,005
P6 – P7	Metco 447 NS	-	-	-	-	89,5	5	-	5,5	-	-	-	-	-

Table 6. The parameters used to deposit the adherence layer

Marking of specimens	P1 – P5
Material	Thermanit NiCro 82
Rotations, [rot/min]	200
Arc amperage, [A]	160 – 180
Arc voltage, [V]	35 – 36
Compressed – air pressure, [bar]	3
Spraying distance, [mm]	130 – 150
Bevel of spray gun, [°]	Max. 45
Layer temperature, [°C]	80 – 100

Table 7. The parameters used to deposit the adherence layer

Marking of specimens	P6 – P7
Material	Metco 447 NS
Rotations, [rot/min]	200
Arc amperage, [A]	500
Arc voltage, [V]	64 – 70
Flowmeter settings, Ar/H_2	80/15
Carrying gas flowmeter	37
Spraying distance, [mm]	150
Bevel of spray gun, [°]	Max. 45
Layer temperature, [°C]	80 – 100

For obtaining the experimental specimens there were used the most current thermal spraying proceedings and the most frequently used addition materials in bushings, bearings and rings design (table 8). The technological parameters used to deposit these layers are inserted in tables 9 – 12.

Table 8. The proceedings and the supplement materials used to perform the experimental specimens

Marking of specimens	Type of material	Chemical composition, [%]	The proceeding
P1	Metco Copper	Cu – 99,8	Electrical arc
P2	Sprabronze AA + Laromet	Cu – 90, Al – 9, Fe – 1 + Cu – 63, Zn – 37	Electrical arc
P3	Laromet	Cu – 63, Zn – 37	Electrical arc
P4	Sprabronze AA	Cu – 90, Al – 9, Fe – 1	Electrical arc
P5	Sprababbitt A	Sn – 87,75, Sb – 7,5, Cu – 3,5, Pb – 0,25	Flame spraying with wire
P6	Metco 51 NS	Cu – 89,5, Al – 9,5, Fe – 1	Flame spraying with powder
P7	Metco 51 F – NS	Cu – 89,5, Al – 9,5, Fe – 1	Plasma

Table 9. The technological parameters for electrical arc spraying

Marking of specimens	Rotations, [rot/min]	Arc amperage, [A]	Arc voltage, [V]	Compressed – air pressure, [bar]	Spraying distance, [mm]	Bevel of spray gun, [°]	Layer temper-ature, [°C]
P1	200	200	26 – 30	2,4	110 – 130	Max. 45	80 – 100
P2	200	200	28 – 32	2,4	130 – 150	Max. 45	80 – 100
P3	200	200	35 – 36	2,4	130 – 150	Max. 45	80 – 100
P4	200	200	28 – 32	2,4	130 – 150	Max. 45	80 – 100

Table10. The technological parameters for flame spraying with wire

Marking of specimen	Rotations, [rot/min]	Spraying distance, [mm]	Oxygen and acet-ylene pressure, [bar]	Wire speed feeding, [cm/s]	Compressed – air pressure, [bar]	Bevel of spray gun, [°]	Layer temper-ature, [°C]
P5	200	100 – 120	2	2	3,65	Max. 45	80 – 100

Table 11. The technological parameters for flame spraying with powder

Marking of specimen	Rotations, [rot/min]	Spraying distance, [mm]	Oxygen pressure, [bar]	Acetylene pressure, [bar]	Bevel of spray gun, [°]	Layer tem-perature, [°C]
P6	200	130 – 180	1,86	1,03	Max. 45	80 – 100

Table 12. The technological parameters for plasma spraying

Marking of specimen	P7
Rotations, [rot/min]	200
Spraying distance, [mm]	130 – 150
Arc amperage, [A]	500
Arc voltage, [V]	60 – 70
Flowmeter Ar/H_2	150/5
Carrying gas flowmeter	37
Bevel of spray gun, [°]	Max. 45
Layer temperature, [°C]	80 – 100

The macroscopical analysis shows a good tightness of the layers, absence of irregularities and surface defects (figure 1 – 7).

Figure 1. P1 specimen: deposit material – copper.

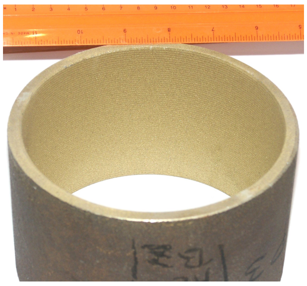

Figure 2. P2 specimen: deposit material – aluminum bronze and brass.

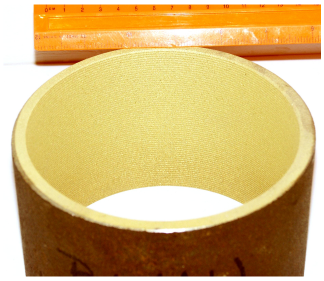

Figure 3. P3 specimen: deposit material – brass.

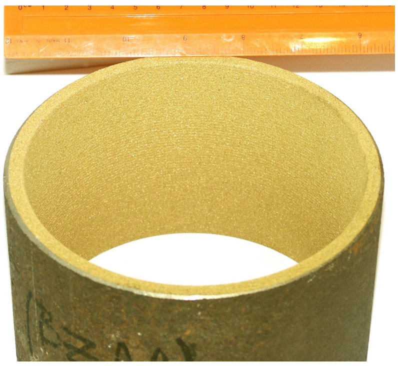

Figure 4. P4 specimen: deposit material – aluminum bronze.

Figure 5. P5 specimen: deposit material – babbitt.

Figure 6. P6 specimen: deposit material – aluminum bronze.

Figure 7. P7 specimen: deposit material – aluminum bronze.

3. Determination of the adherence by the sticking method

From the specimens were cut rings with 10 mm width. It was measured the internal diameter of these rings. For each ring it was worked off bushings with an external diameter smaller than the internal diameter of these rings.

The adhesives which were used for sticking the assembly bushing – ring were offered by the LOCTITE company. The gap recommended for the Loctite 638 adhesive its maximum 0.25 mm per radius. It looks like jell and bindings anaerobic. This adhesive is used for six specimens. The specimen P5, deposited material – babbitt, was stacked with the Loctite 3425 adhesive. At this type of adhesive the gap is bigger (maximum 3 mm per radius). It is formed from two solutions, paste shaped, which uniform mixed up in 1:1 ratio. It was chosen this adhesive for P5 specimen because the babbitt is the milder material.

After the sticking, the assemblies were testing to the shearing breakdown on a 20 tf universal pull test machine. The device used for the testing is presented in figure 8. The values for the breakdown forces is inserted in table 13.

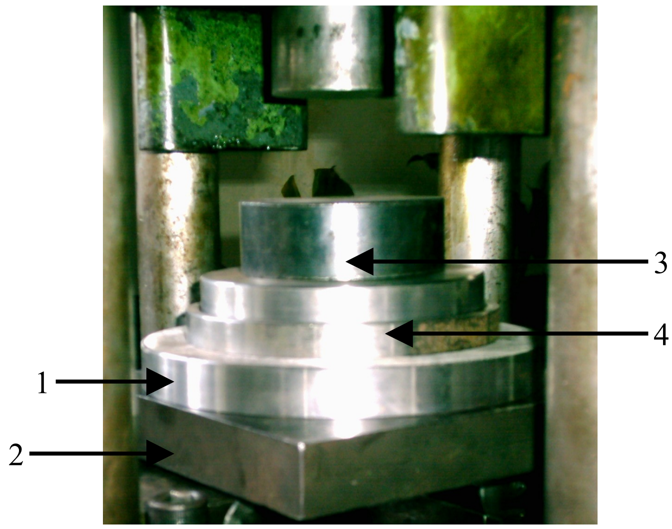

Figure 8. Device for testing the adherence of the layer to the substrate: 1 – support ring; 2 – support piece; 3 – cylinder who press down the bush; 4 – sticking couple bush – ring.

After the breaking it was discovered that the sticking surface of all the specimens isn't complete. It can be concluded that not all the surface participate to the breaking. Also, in some areas the breaking was in the adhesive, in other areas the breaking was in the layer. This aspect can be observed in figure 9. The bushes were marked so that all the circumference of these can be followed.

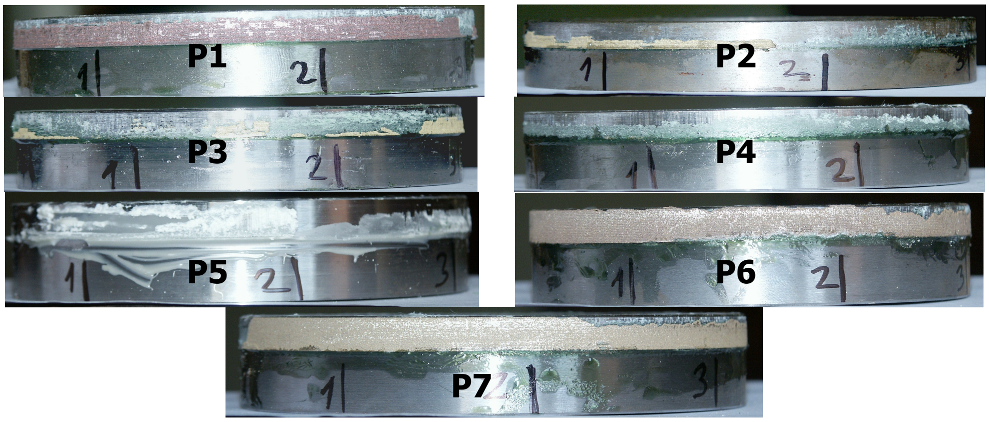

Figure 9. The appearance of the specimens after the breakdown testing

From these figures it can be remarked the sticking areas, non-sticking areas and the areas where the breaking was on the layer level.
It is necessary to determine the surface which is participating to the breaking for the unit shearing stress calculation, respectively only the surface that was stacked. In this way was created a device, showed in figure 10, which allowed the breaking surfaces scanning. In the figure 11 it is shown the aspect of the scanned surfaces.

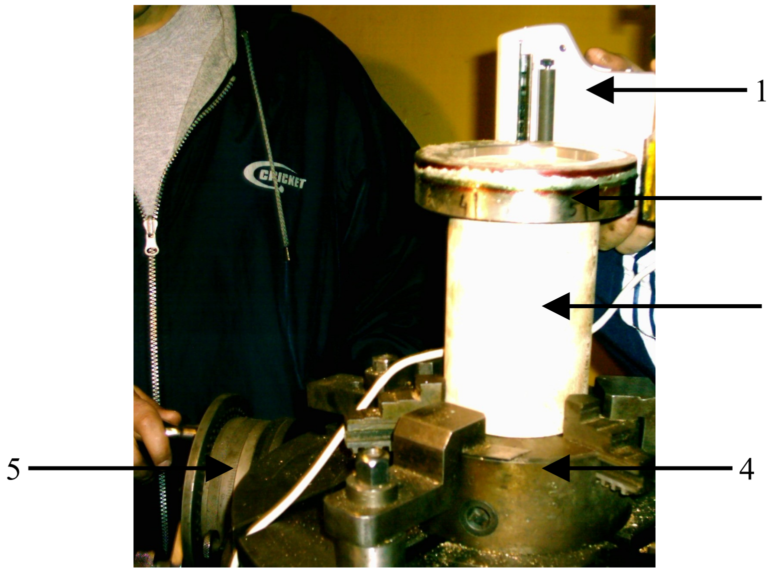

Figure 10. Device for scanning the breaking surfaces: 1 – manual scanner; 2 – bush; 3 – cylinder; 4 – miller chuck; 5 – chuck divider.

Figure 11. The aspect of the specimen scanned surface.

These images taken over with the scanner were processed with *Adobe Photoshop 7* software to quantify the breaking surfaces. A detail of one of these imagines is shown in figure 12.

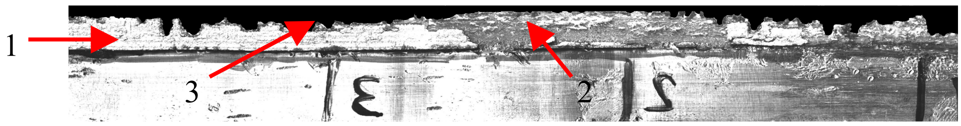

Figure 12. Detail of an image scanned and processed with Adobe Photoshop 7: 1 – layer deposited by thermal spraying; 2 – sticking area; 3 – non-sticking area.

After that, the resulting images were processed with *AutoCAD 2002* software as it follows:

- Each image it was grid equally;
- After that the grid it was split in two ways as:
  - "Full" square, respectively areas that were participating to the breaking;
  - "Empty" square, respectively areas that were not participating to the breaking.

This software has the means to quantify that squares. So, for each image it result the number of "full" and "empty" squares, number that could be used to establish the surface which participates to the breaking (figure 13).

The unit shearing stress was calculated reporting the breaking force to the sticking surface and the results are summarized in table 13.

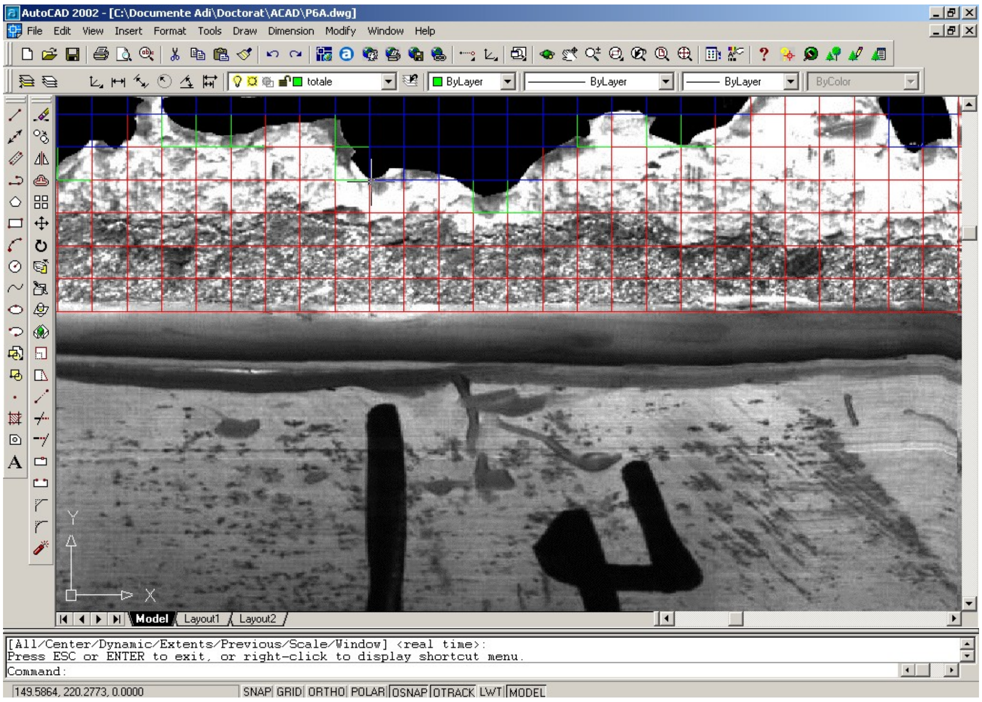

Figure 13. Aspect of processing the scanned image with AutoCAD 2002 software

Table 13. The experimental results obtained by the sticking method.

Marking of specimens	Force, [N]	Diameter, [mm]	Sticking area, [%]	Shearing stress, [N/mm^2]
P1	51777,2996	137,2	80	15,01
P2	35585,77292	137,6	38	21,66
P3	40033,99454	137,6	78	11,87
P4	31137,55131	137,6	62	11,62
P5	38699,52805	133	68	13,62
P6	34162,34201	139,4	77	10,13
P7	28824,47607	138,8	79	8,37

4. Conclusions

As a first conclusion it can be asserted that these values of the shearing stress represent the minimal values at which a part of the layer was sheared.

Firstly this method permits the appreciation of the adherence value of the deposited layer by thermal spraying on internal diameter surfaces.

Comparing the obtained values it can be issues that the adherence of these layers is good when the surfaces have a higher roughness which can eliminate the pre-heating when one of the used proceedings has a lower thermal energy. A higher thermal energy, as in the case of plasma spraying, leads to excessive heating of the deposited material, and if the under layer is "cold" the adherence has lower values.

Another element that influence the quality of the adherence is the internal diameter of the pieces where are deposited the layers. The minimal value of the internal diameter is limited by the thermal spraying distance and the accessibility of the spraying head. Also, it is possible to obtain a lower adherence for a smaller diameter.

References

[1] Petrica A.V. *Contributions regarding the increase of the availability for machine parts as bore holes*. Teză de doctorat, 10 septembrie 2004.

Addresses:

- Assoc. Prof. Dr. Adrian V. Petrica "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, pav@uem.ro
- Assist. drd. ing. Mircea Megheleş "Eftimie Murgu" University of Romania, Piaţa "Traian Vuia", nr. 1-4, Reşiţa, m.megheles@uem.ro
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