EXPERIMENTAL RESEARCH ON STRUCTURAL HARDENING OF THE MAXIMUM STRESSED CRANKSHAFTS SURFACES OBTAINED BY THERMAL SPRAYING

Alina Elena BUȘARU[1], Mariana GORAN[2] , Roxana Alexandra GHEȚA[3], Gabriel Marius DUMITRU[4], Gabriel IACOBESCU [5]

This paper presents the analysis of the layers deposed by thermal spraying in order to identify the optimum material and thermal process used for crankshafts reconditioning. In the context of evaluating the layers' properties, the aim of the experiment is to obtain a good wear resistance. One sample was made by S235 steel coated with 100 C6 (Rul1) powder and intermediate layer of Mo, for the second sample being used a non-alloyed quality steel DC01 covered with Stellite and subjected to a re-melting treatment in plasma jet. The results show that the stellite coat presents a significant wear resistance compared to Rul1through high hardness and decreased porosity resulting by plasma jet re-melting treatment.

Keywords: metallographic examination, hardness test, electric arc metal spraying, plasma thermal spraying.

1. Introduction

Reconditioning technologies are a branch that keeps their economic interest under very low investment risk. From a reliability point of view, they aim to achieve a technical performance at least equivalent to the original performance of the original part and thus extending the life of the engine. In the case of crankshaft metallization, wear is transferred on a part already considered "consumable" - the roller bearing, which makes subsequent repairs easier.

The properties of metal sprayed layers deposed by plasma spraying [7] [11] process are remarkable. The reconditioning of the parts by metal spraying process is a very frequently used method. The purpose of using this method is to obtain improved properties of the deposited layers thanks to the special materials which can be sprayed.[5][6]

In order to establish the optimal process of engines reconditioning it was chosen as analysis element one of the most complex piece of the engine, the crankshaft. Therefore, there were proposed two alternatives for increasing wear

[1]PhD Student, University POLITEHNICA of Bucharest, e-mail: alina_614@yahoo.com
[2]PhD Student, University POLITEHNICA of Bucharest , e-mail: gorancmariana@yahoo.com
[3]PhD Student, University POLITEHNICA of Bucharest , e-mail: Roxana_gheta@yahoo.com
[4]Prof., University POLITEHNICA of Bucharest, e-mail: gmdumitru@yahoo.com
[5]Prof., University POLITEHNICA of Bucharest , e-mail: gabiiacobescu@yahoo.com

resistance of the areas maximum stressed of crankshafts, as following: deposition by electric arc metal spraying of 100 C6 (Rul 1) [4] layer (material for bearings) and deposition by thermal spraying [a] in plasma jet of a Stellite layer. Stellite alloy is a range of cobalt-chromium alloys designed for wear resistance. It may also contain tungsten or molybdenum and a small but important amount of carbon.

Metallographic [8] examination was chosen to analyses materials microstructure in order to identify both defects and degree of influence, which microstructure may have on the physical and mechanical characteristics of the piece [1].

2. Experimental data

For the study of deposited layers by thermal spraying there were used two specimens, as presented in Fig. 1 and Fig. 2.

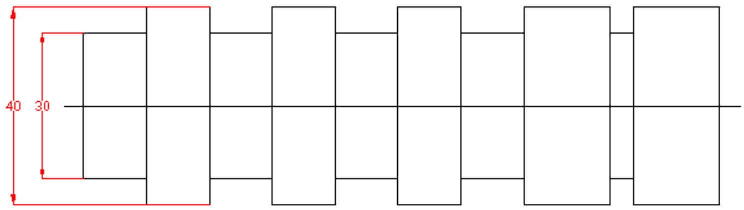


Fig. 1. Specimen No.1 - base material S235 (structural steel)

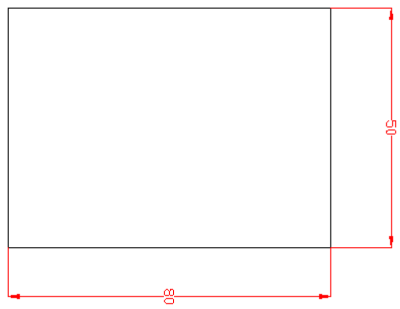


Fig. 2. Specimen No. 2 – base material DC01 (double pickled metal sheet)

Coating of Specimen No.1, as presented in Fig. 3, was made by using electric arc metal spraying, in two steps:

In the first step it was deposited an intermediate layer of Mo powder with intensity of the current I=360 A, wire electrode diameter Ø 1.8, electric arc voltage U_a=60V, spraying distance L = 80mm, spraying gas pressure 0,55 MPa. In the second step it was sprayed a layer of 100 C6 (Rul 1) [4] with an intensity of the current I=280 A, wire electrode diameter Ø1.8mm, electric arc voltage U = 60V, spraying distance L=140-150 mm, spraying gas pressure de 0,45 MPa ;

Fig. 3. Specimen No. 1 after deposition of 100 C6 (Rul 1) [4] layer, using electric arc metal spraying

Coating of Specimen No.2 was made by using plasma jet metal spraying (this method is used for reconditioning of parts with significant functional role - the case of crankshaft), presented in figure 4. In the first step it was sprayed a layer of Stellite in plasma jet (cold plasma) [1][5][9], plasma jet temperature 8800° K, plasma gas formed by Alcohol and H2O, power 40 kW, I= 385 A. In the second step, was made a re-melting treatment post-metallization, in order to close the pores and cracks, which leads to increased hardness of deposited layer and increased chemical corrosion resistance (plasma jet speed was lower, time was increased, facts that converged to melt the base material from 10 up to 20 µm);

Fig. 4. Specimen No. 2 after deposition of Stellite layer, using metallization process by spray in plasma jet

3. Experimental part

In order to make metallographic analysis of deposited layers on both specimens, it is necessary to obtain metallographic [8] samples with a good surface for analysis.

The samples were obtained with a die cutting machine for metallographic samples in LAMET Laboratory (IMST, UPB), presented in Figure 5.

Fig. 5. Die cutting machine for metallographic sample - LAMET-UPB laboratory

In order to obtain plane surfaces, they were grossly polished and fitted in the embedding resin. Finally, a gross polishing and finishing was applied using automatic polishing machine Alpha-Vector Buehler (LAMET Laboratory) – see Fig. 6.

Fig. 6. Automatic polishing machine Alpha-Vector Buehler

After obtaining metallographic samples, presented in Figure 7 (a, b), there were made microstructural analyses, using optical microscope type Euromex (LAMET Laboratory), presented in Fig. 8.

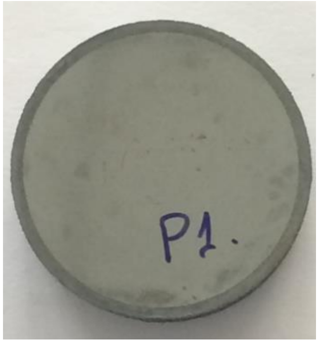


Fig. 7

a. Metallographic sample 1 obtained from Specimen 1

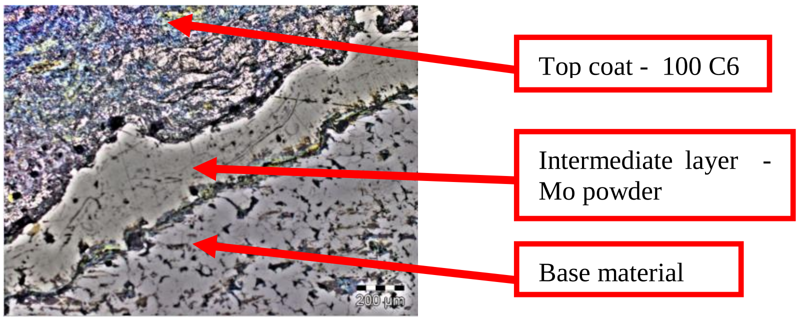
b. Metallographic sample 2 obtained from Specimen 2

Fig. 8. Optical microscope type Euromex

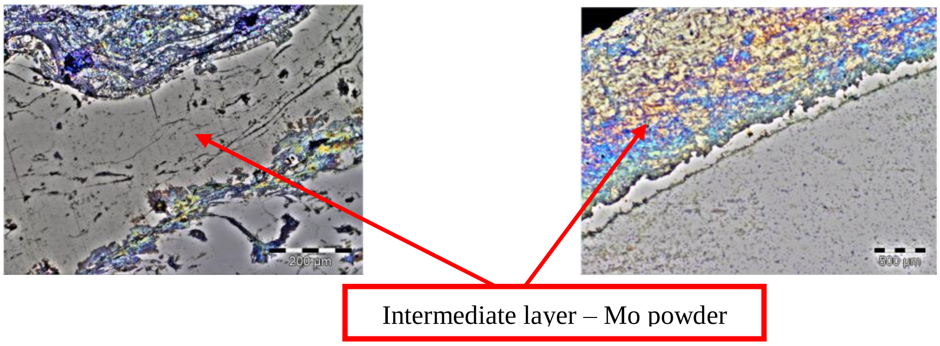
4. Experimental results

4.1 Micrograph of deposited layers

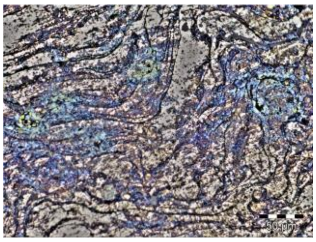
Micrograph of Specimen No. 1 is presented in Figure 9 (a, b, c, d).



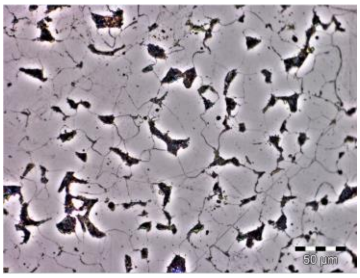
a. Micrograph of deposited layers on Specimen1



b. Micrograph of intermediate layer (Mo powder)



c. Micrograph of deposited layer 100 C6(Rul 1)[4]



d. Micrograph of base material (S235 – structural steel)

e.

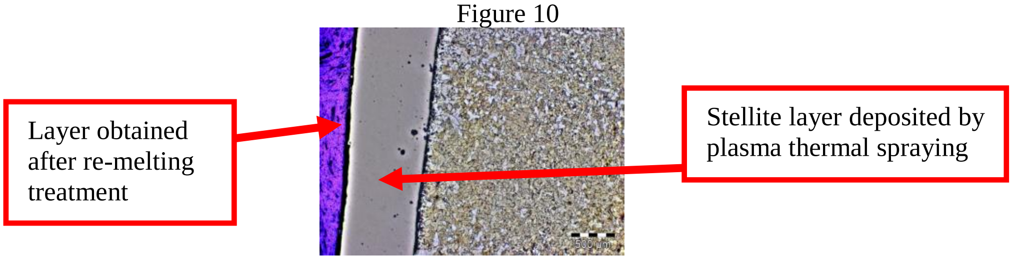
Fig. 9 Micrograph of Specimen No. 1

Due to various advantages, metallization by thermal spray with electric arc is worldwide spread, as following: hardening the deposited layer, very high productivity, low costs, in comparison with other metallization processes; Deposited layer may be composed of alloys that can have very good characteristics regarding wear resistance and good mechanical characteristics;

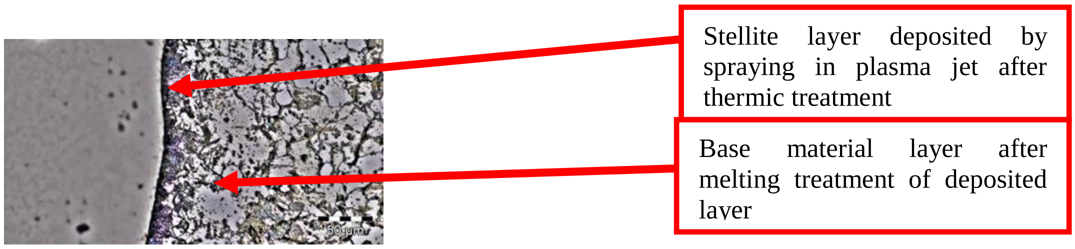
The disadvantages with high impact on the entire process are related to necessity of correlation between spraying electrical current intensity and wire feed rate because the incomplete wire melting phenomena may occur, which leads to low properties of deposited layer.

Micrograph of Specimen No 2 is presented in figure 10 (a,b,c).

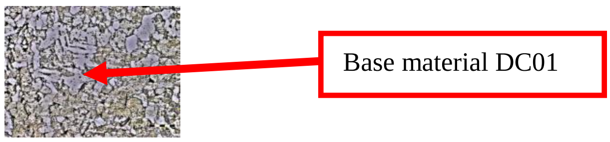
Figure 10



a. Micrograph of deposited layers on Specimen No 2



b. Micrograph of Stellite layer



c. Micrograph of base material

Metallization [10] by spraying with plasma jet was used to obtain a very good quality of deposited layer and adhesion to base material (mechanic adhesion and micro welding bridges). Highly resistance to adhesion surface is another very important characteristic of deposited layer.

For determining micro hardness of deposited layers on both Specimens, it was used Vickers method. This method consists in pressing with a force F, of a penetrating diamond on the sample surface, followed by measuring the length of the remaining fingerprint after the removal of the test force. [1][2]

For determining the lowest and the highest hardness level [1][2][3] of deposited layers by thermal spraying of base material and intermediate layer, there were made 10 determinations of each Specimen, with 0,2 N force (HV 0,2) and 10 seconds pressing time. The results are results obtained with micro hardness tester Shimadzu HMV 2T (Fig. 13), in LAMET Laboratory and shown in table 3, Fig. 11 and Fig. 12.

Table 3.

Micro hardness values HV 0,2 for Specimen 1and Specimen 2

Determination no.	Test 1-Specimen 1			Test 2-Specimen 2		
	Top coat of 100 C6 by plasma thermal spraying	Intermediate Mo layer by electric arc thermal spraying (increased parameters of spraying and smaller spraying distance)	Base material S235	Post metallization layer obtain by re-melting treatment	Stellite layer deposited by plasma thermal spraying	Base material DC01
1.	186	152	132	357	95	88
2.	166	158	121	378	94	90
3.	183	128	132	320	94	89
4.	150	158	138	346	96	96
5.	169	151	143	327	93	102
6.	162	137	118	350	96	92
7.	139	132	130	384	87	96
8.	153	141	128	406	93	98
9.	168	134	131	381	96	102
10.	173	148	129	356	95	97
	Average 164,9	Average 143,9	Average 130,2	Average 360,5	Average 93,9	Average 95

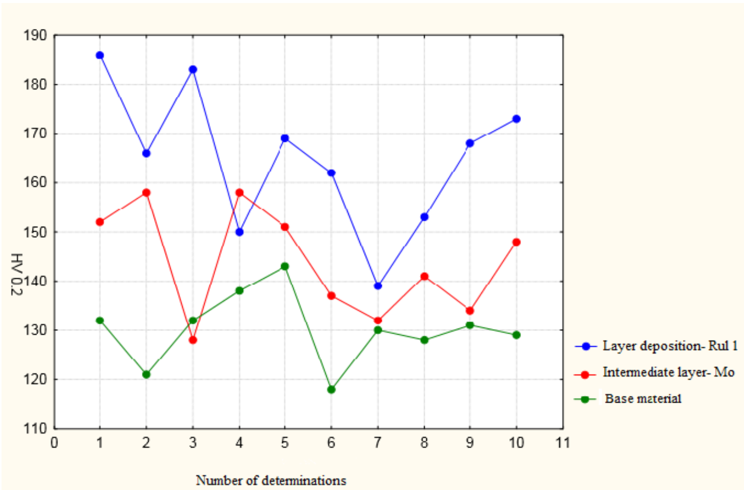


Fig. 11. Micro hardness of deposited layers by electric arc thermal spraying - Specimen no. 1

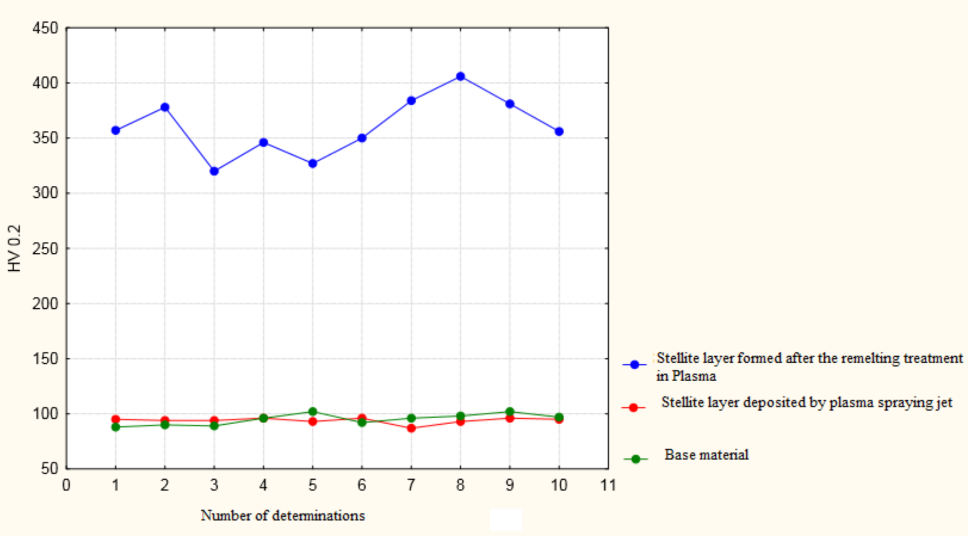


Fig. 12. Micro hardness layers deposited by plasma thermal spraying – Specimen no. 2

Based on results obtained, comparative analysis was made, in order to establish the optimal reconditioning method of crankshafts.

Micro hardness comparison of base material is presented in Fig.e 13:

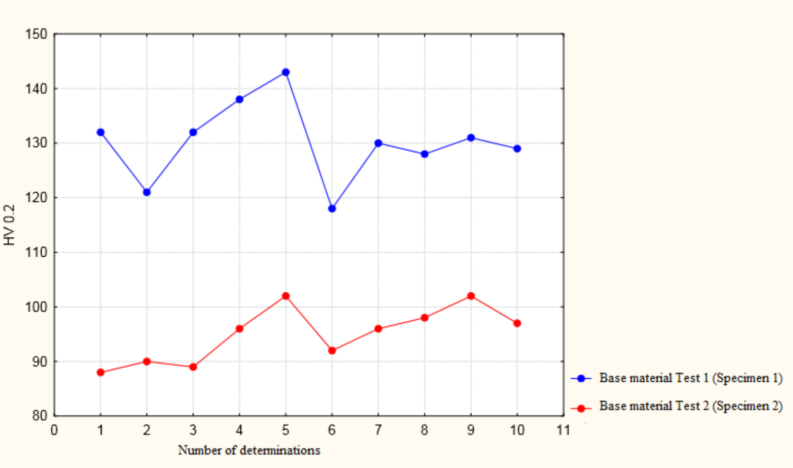


Fig. 13. Comparison of base material micro hardness

Base material of Specimen no.1 is much harder than base material of Specimen no. 2.

Comparison of micro hardness of intermediate Mo layer of Specimen no.1 with Stellite layer before re-melting treatment of Specimen No. 2 is presented in Fig. 14.

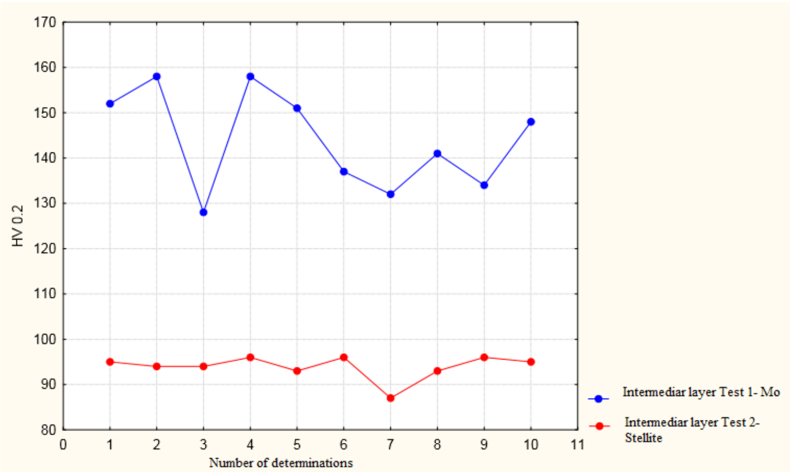


Fig. 14. Comparison between Mo intermediate layer and Stellite

Intermediate Mo layer is much harder than the Stellite layer.

Comparison of micro hardness of the top coat of Specimen no.1 (100 C6(Rul 1)[4]) and Stellite layer obtained after re-melting treatment of Specimen no. 2 is presented in Figure 15.

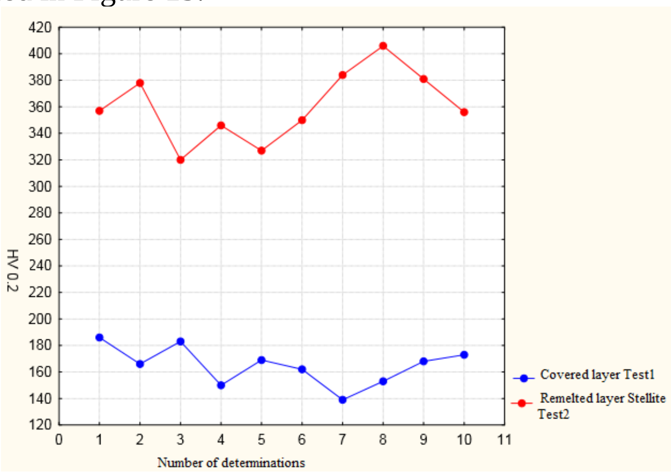


Fig. 15. Comparison between 100 C6 top coat and stellite layer obtained after re-melting treatment

Hardness of re-melted Stellite layer is higher than hardness of deposited layer on Specimen no.2 (100 C6) (Rul 1) [4].

5. Conclusions

After comparative analysis it is proved that Stellite layer obtained after re-melting treatment offers higher hardness and bigger wear resistance than 100 C6(Rul 1) [4] layer deposited on Specimen no.1.

Corrosion resistance of Stellite layer is superior as it is observed in Figure 4 in comparison with 100 C6 (Rul 1) [4] layer (Fig. 3.), the specimens being preserved in same conditions.

In terms of economic aspects, the costs of plasma spraying [12] process are higher than electric arc thermal spraying. In this case, the choice of the optimal method to be used is based on the operating conditions of the engine.

Even though the costs of plasma thermal spraying are higher, the advantage is that are excluded transport costs, because the device is portable and allows method to be used on site conditions, with all economic advantages deriving from it.

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R E F E R E N C E S

[1] *Ionela Voiculescu, Ion Mihai Vasile, Elena Manuela Stanciu, Alexandru Pascu* , Indrumar de laborator Stiinta si ingineria Materialelor (Laboratory Guide for Science and Materials Engineering) , Editura Lux Libris, Brasov 2015 acreditată CNCSIS, cod 201

[2] SR EN 1043-1:1997. Încercări distructive ale îmbinărilor sudate din materiale metalice. Încercarea de duritate. Partea 1: Încercarea de duritate a îmbinărilor sudate cu arc electric (Destructive testing of welded joints in metallic materials. Hardness testing. Part 1: Hardness testing of electric arc welded joints).

[3] EN 1043-2:1996 .Încercări distructive ale îmbinărilor sudate din materiale metalice. Încercarea de duritate. Partea 2: Încercarea de microduritate a îmbinărilor sudate *(* Destructive testing of welded joints in metallic materials. Hardness testing. Part 2 The micro-hardness testing of welded joints)

[4] Rul 1STAS 1456/1 - 89 : Oţeluri pentru rulmenţi; Mărci şi condiţii tehnice de calitate (Bearing steels; Brands and technical quality standards)

[5]*G.M. Dumitru, C. Radu, B. Dumitru,* "Recondiționarea și repararea produselor", (Reconditioning and repairing products), *Editura Printech, București 2010*

[6] *Roxana-Alexandra Gheța, Laurenția Bichir, Mariana Goran, Alina-Elena Bușaru, Gabriel Marius Dumitru,* "Characterization of Cr2O3 Adhesion Properties by Destructive Testing

in Accordance with the APS Metal Spraying Process Parameters", *Key Engineering Materials, Materials Research and Application II, p. 9, May 2017*

[7] *Brandt,R.,Neuer,G.,Worner,B.,*Thermophysical properties of plasma sprayed materials, Revue Internationale des hautes Temperatures et Refractaires,1979,vol.16

[8] *George F. Vander Voort*, Metallography Principles and practice, ASM International,1999

[9] *D. Apelian, M. Paliwal, R. W. Smith & W. F. Schilling*, Melting and solidification in plasma spray deposition — phenomenological review, International Metals Reviews,1983,vol.28, pages 271-294

[10] *D.Botez, Sorin Constantin, Gabriel Marius Dumitru, Bogdan Dumitru, Dina Viorel-Cristian,* "Ultrasound Examination-Mean of Analysis of the Layers Properties Deposited Throught Different Thermal Spraying Methods", Applied Mechanics and Materials, vol.186,pp.169-175, 2012

[11] *Mariana Goran, Alina-Elena Busaru, Roxana Alexandra Gheta, Laurentia Bichir, Gabriel Marius Dumitru, Gabriel Iacobescu*, "The interface characterization for ceramic layers coated by thermal spraying", U.P.B. Sci. Bull., Series D, Vol.79, Iss. 2, 2017

[12] *Mrdak, M., Venci, A., Nedeljkovic, B.,& Stankovic, M.* "Influence of plasma spraying parameters on properties of thermal barrier coatings", Materials Science and Technology, vol.29, 2013-Issue 5.