ALTERNATIVE LOW-COBALT POWDER FOR PTA HARDFACING

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Abstract

Continuous improvement of quality and cost saving in manufacturing of machine parts result in the search for an alternative materials for high temperature applications. In the present study a comparaison of cobalt-matrix material and iron based material for PTA hardfacing is presented. These materials are used for plasma hardfacing of sealing surfaces of industrial valves operating at elevated temperatures. The feed stock powders were compared in terms of particle geometry and quality. The deposits were made by continuous current and by pulse current of 3 and 100 Hz. The samples were subjected to thermal stress at 600 ˚C for 3 hours. The geometry and the structure of deposits were compared. Microhardness were meassured on cross section of the deposits. It was found that the iron based materials becomes harder after heat treatment. Even that they present lower hardnes than cobalt based ones.

Keywords: Pulsed-PTA, hardfacing, cobalt-based alloys, iron-based alloys, microhardness

1. INTRODUCTION

Cobalt based alloys are used in wide range of applications where the highest wear and corrosion resistance is required. They are suitable for high temperature applications and have better creep resistance compared to iron-based superalloys. They are used for sealing surfaces of valves and their seats, parts of pressure gauges and stressed parts of industrial valves. In comparison to high-nickel-content alloys, they are also better weldable. [1] [2] [3]. Cobalt alloys of this type were put into practice by Elwood Haynes, the American metallurgist. These alloys are composed of cobalt matrix, carbon, molybdenum, chromium, nickel and tungsten. The total number of these alloys is about 60 and are named by trade names such as Celsit, Stellite. Cobalt prices in world markets have grown significantly over the last two years after a period of stagnation (**Figure 1**). Since 2013, the price has more than doubled. At the end of March 2018, the price of one ton of cobalt was 76,410 € [4]. The consequence of the described situation is continuously growing effort to find materials with reduced cobalt content and with properties that meet the requirements for critical and supercritical conditions (i.e. thermal power plant).

Figure 1 Cobalt price development, last 5 years

The aim of this project is to compare and characterize properties of cobalt- and iron-based powders for plasma hardfacing. The Deutsche Edelstahlwerke powder portfolio [3] contains three types of ferrous alloys (Fesit VP, Fesit SN-P, Fesit NP), which should correspond to Celsit cobalt alloys (Celsit VP, Celsit SN-P, Celsit NP) The aim of this experiment is to examine the similarity of these powders. In this experimental work FESIT V-P and CELSIT V-P are tested in the form of powders for plasma welding [5] [6]

Table 1 corresponding alloys, assumption [2]

Celsit V-P (Alloy 6)	**Fesit V-P (TS-1)**
Celsit SN-P (Alloy 12)	**Fesit SN-P (TS-1)**
Celsit N-P (Alloy 1)	**Fesit N-P (TS-1)**

2. EXPERIMENTAL

Welding of the coatings on the mild steel substrates was carried out on a PPC 250 R6 hardfacing automate (KSK, s.r.o., Czech Republic). The machine allows the use of pulse welding at frequencies of 0-200 Hz and a welding current of 50 to 250 A. The plasma trajectory can be controlled in 6 axes - 2 axis by positioner and 4 axis by plasma torch. Hardfacing can be controlled manually or using program management. [7]

Two types of additive materials in powder form were used in the experiment; their chemical composition is shown in **Table 2** (Fesit V-P, melt 253942) and in **Table 3** (Celsit V-P, 256568 and 256569). The chemical composition differs, in particular, in the cobalt content, where CELSIT V-P powder is represented by higher percentage. In the FESIT V-P powder the cobalt content is 13 wt% only. Cobalt is replaced by an iron matrix that is more cost-effective than cobalt.

Table 2 Chemical composition of powder FESIT V-P wt %, Ch.no 253942 [8]

C	Si	Mn	P	S	Cr	Mo
1.17	4.94	0.15	0.018	0.007	29.2	0.07
Ni	W	Co	B	Fe		
10.3	0.05	13	0.003	rest		

Table 3 Chemical composition of powder CELSIT V-P wt %, Ch.no 256568 a 256569

C	Si	Mn	P	S	Cr	Mo
1.024	1.36	0.16	0.01	0.005	27.7	0.05
Ni	W	Co	B	Fe		
1.00	4.23	Rest	0.005	1.11		

A 25 mm mild steel base material was cut into 30x87 mm samples. Temperature of substrate was measured by two thermocouples. The first thermocouple was placed at the beginning of the welding, the other on the opposite side of the sample. The temperature was recorded by the ALMEMO 5690-2M [8]. The temperature pattern for the thermocouple 2 is shown in **Figure 2**: The temperature of the substrate during the welding of the pulse welding current was higher than that of the continuous current. [10]

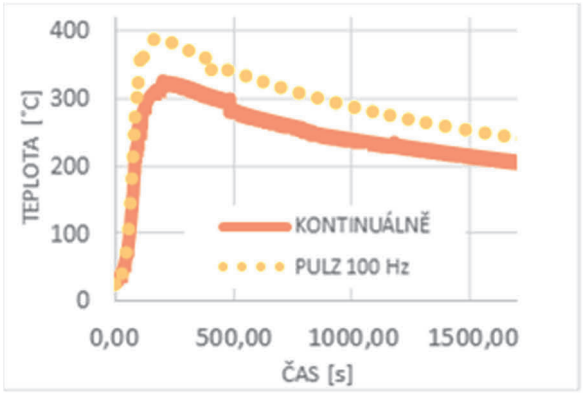

Figure 2 temperature of substrate

In the experiment, six one-layer welds were deposited onto the base material. The wide of welding pattern was 13 mm and wave speed 8 mm · s^{-1}, a torch speed was 2 mm · s^{-1}. The feed rate was set to 13. After deposition, the sample was cooled down in flux backfill.

After welding and cooling, the samples were cut into two by metallographic saw. One part was characterized after welding. The second part of each sample was subjected to a thermal treatment at 600 ° C for 8 hours.

The Vickers hardness of the samples was measured on Indenta Met 1104 (Buehler) microhardness apparatus. The tip load was set to 1K (corresponds to one kilogram load), imprinting time of 11 s. Imprints were taken through the centre of the samples at a distance of 1 mm apart. For subsurface hardness and hardness nearby melting line was made 5 impressions. Three or four imprints were then made in the area of the deposited layer.

Table 4 sample identification

Sample	Powder type	Current Cont/pulse	Current [A]	Thermal treatment
F1	FESIT V-P	pulz 3 Hz	210/90	no
F2		pulz 100 Hz	212/82	
F3		Cont.	114	
F4		pulz 3 Hz	210/90	yes
F5		pulz 100 Hz	212/82	
F6		Cont.	114	
C1	CELSIT V-P	pulz 3 Hz	210/90	no
C2		pulz 100 Hz	212/82	
C3		Cont.	114	
C4		pulz 3 Hz	210/90	yes
C5		pulz 100 Hz	212/82	
C6		Cont.	114	

3. RESULTS AND DISCUSSION

The grain size of the additive materials was observed with respect to porosity and particle size. Production of powder for welding is carried out by injecting a melt stream into an inert atmosphere. The produced particles are then sifted through sieves and sorted by size. For plasma welding, the optimum particle size is approximately 140 μm.

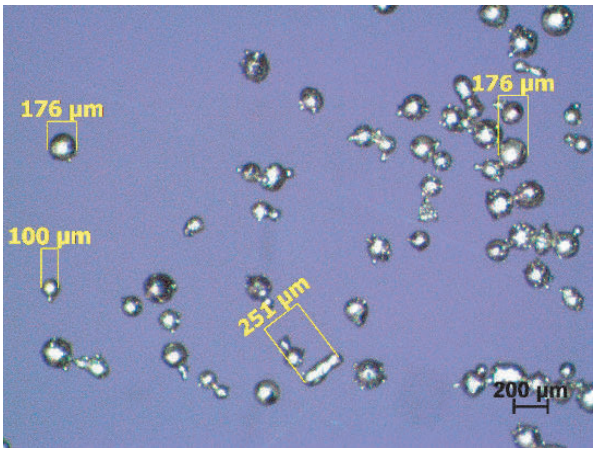

Figure 3 Powder particles of Celsit V-P

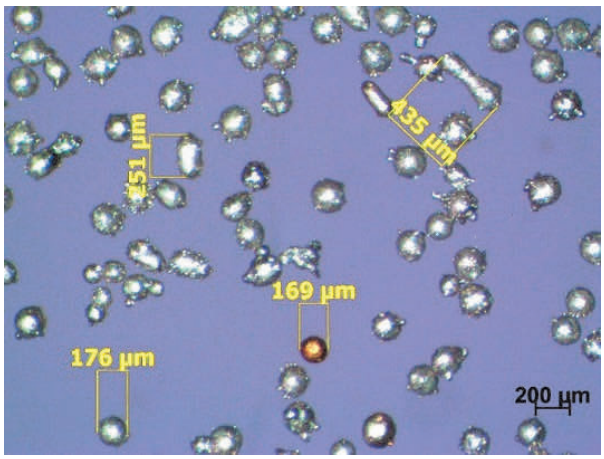

Figure 4 Powder particles of Fesit V-P

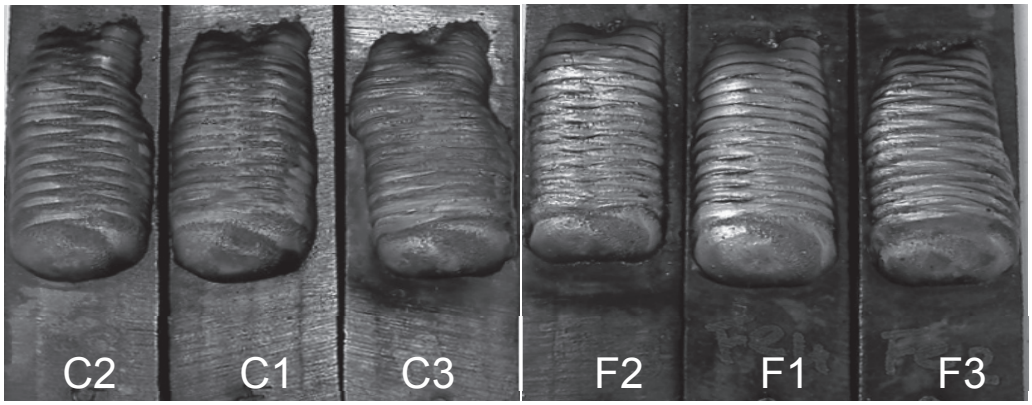

Figure 5 Deposits of Celsit V-P (C1, C2, C3), Fesit V-P (F1, F2, F3)

The individual particles are rounded in both powders; however powders show a non-uniformity of shapes from spherical to elongated particles of different diameters. In the FESIT V-P powder (**Figure 4**) there are also particles with a length twice the maximum value of the particle size. In contrast, the CELSIT V-P powder (**Figure 3**) is characterized by an increased amount of adhering small particles on larger particles. The declared particle size of the additive materials used is 63-200 μm. Despite these aspects, powders meet the requirements for these materials and no differences in properties have been found during powder feeding to the melting pool.

The weld surface of all samples is regular and homogeneous (**Figure 5**). Differences in the technological properties of welding powders were not observed between two tested powders. Occasional swings in the direction of welding were caused by the alignment of the torch trajectory during the welding process.

The microstructure was observed on cross sections made approximately in two-thirds of weld length from the beginning of the weld. It turns out that welds made by the pulse current show less wettability and better holding of the "wall" of the weld (**Figure 6**). Beads performed at 3Hz pulsed current have an irregularity corresponding to individual plasma pulses. In general, this mode with minimal wettability can be recommended for applications where it is necessary to create a narrower and taller wall. For flat applications, a frequency of approximately 100Hz can be recommended

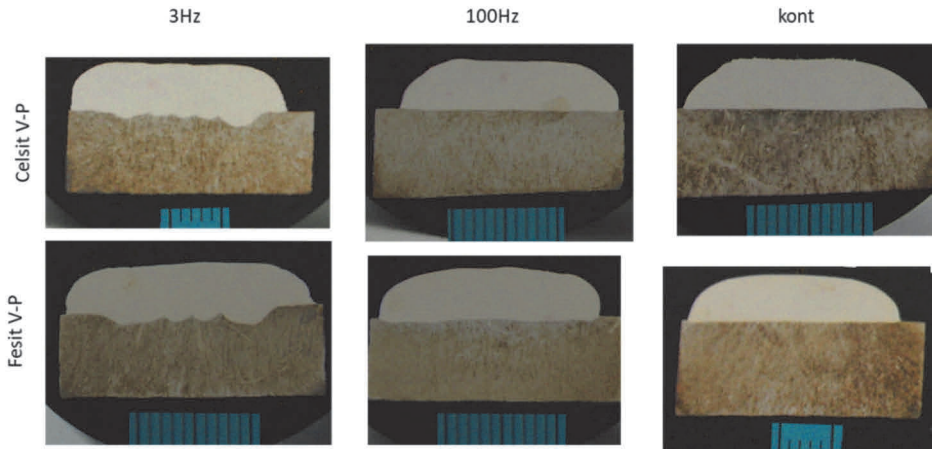

Figure 6 Cross sections of deposits

The microstructures of the individual samples show a dendritic structure. (**Figure 7** - **Figure 10**) Dendrites are probably rich in cobalt. [9]

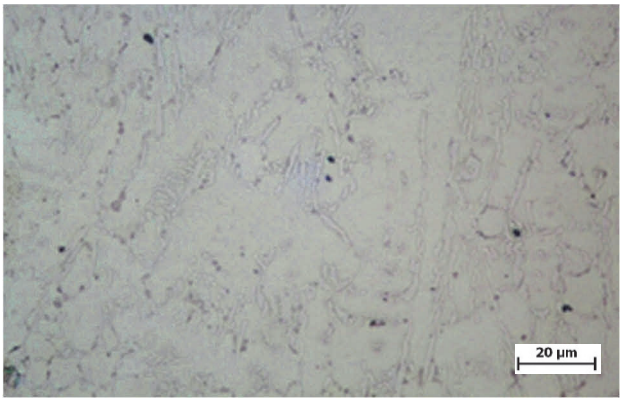

Figure 7 Microstructure of sample F3, 500x

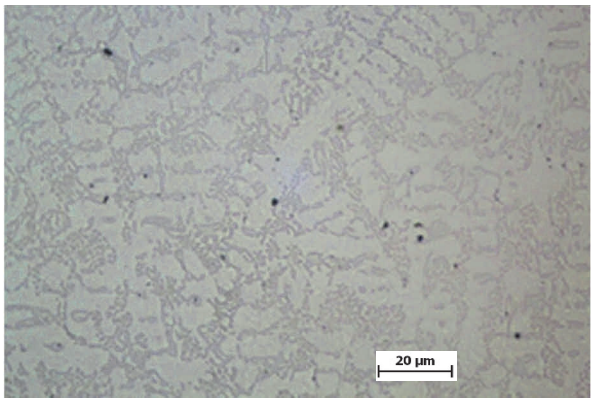

Figure 8 Microstructure of sample F6, 500x

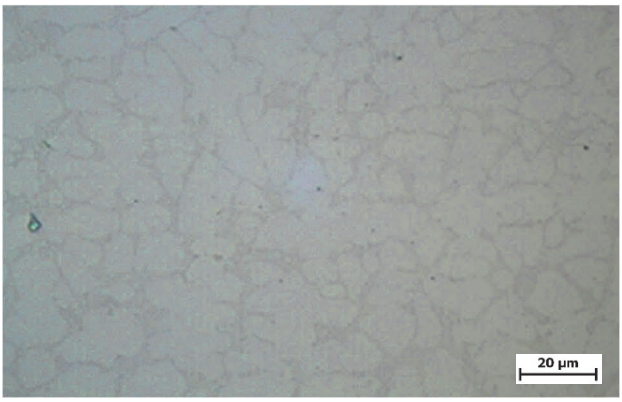

Figure 9 Microstructure of sample C3, 500x

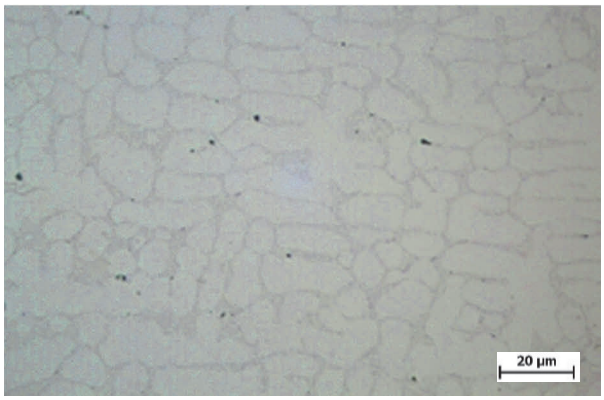

Figure 10 Microstructure of sample C6, 500x

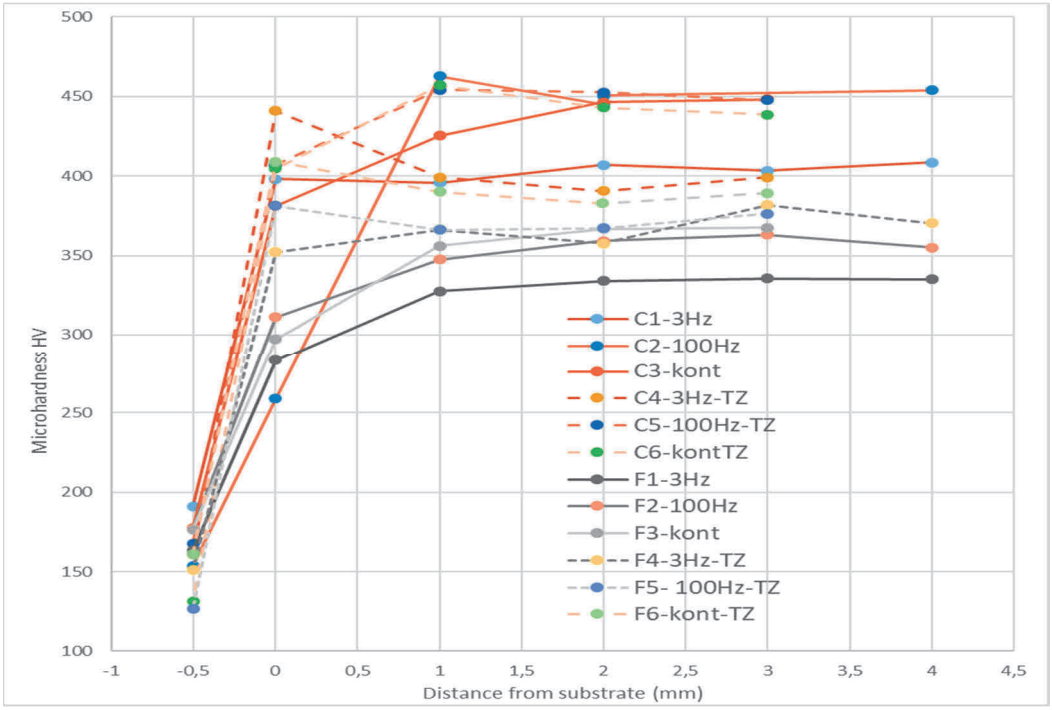

Figure 11 Microhardness of all samples on cross sections, in the middle of the layer

Structures after heat treatment are not much different from those of untreated samples. According to [10] [11], there are cobalt particles in the etched area - shiny areas, dark areas are areas of eutectic structure.

The course of hardness for all samples is characterized by a stable values with a decrease in hardness in the area of the base material (**Figure 11**). The x-axis corresponds to the depth of the impression so that the value 0 lies on the transition of the weld - base material (marked with a dashed line in the graph). The hardness of the weld is approximately twice the hardness of the base material.

For the CELSIT V-P additive material (sample group C), a higher hardness for all six samples is clearly visible. The highest hardness of 454 HV was achieved for C2 - pulsed current at 100 Hz.

Heat treatment caused curing of all samples in the transition area of the welding-base material. In addition, for FESIT V-P samples (Group F), the hardness increase is approximately 50 HV. CELSIT V-P coatings did not present any hardening effect after the thermal treatment. In contrast, there was a slight decrease in hardness (**Figure 12**).

Figure 12 Microhardness after hardfacing and after heat treatment on 600 C/8h

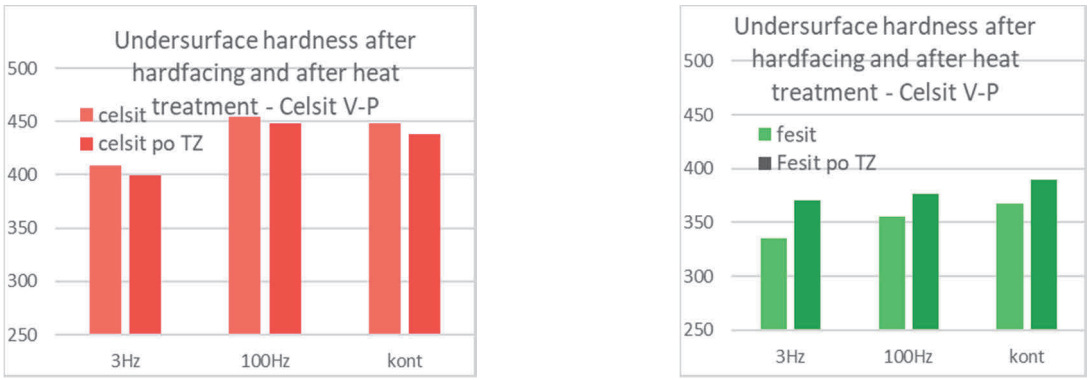

Figure 13 Microhardness of layers Celsit V-p and Fesit V-P after welding and heat treatment on 600 C/8h

CONCLUSIONS

In this experimental work, six samples of cobalt and low-cobalt alloy were welded and heat treated. Two types of additive materials were used: FESIT P-V and CELSIT P-V. All deposits were well bonded to the base material.

The additive powder material exhibited a non-uniformity of shape and particle size. Based on practical findings in welding and particle analysis, the material was judged to be suitable for the plasma transferred arc deposition.

Structures of deposited materials were evaluated micro and macroscopically.

The highest hardness was achieved with the CELSIT V-P material using a 100 Hz pulse welding current. The CELSIT V-P powder exhibits a higher hardness of welded coating for both untreated and processed samples than FESIT P-V powder. The heat treatment hardens the welded layers especially on the transition of the welding-base material.

The microstructure of the samples is dendritic, after the thermal exposure for the cobalt weld is identical, with the low-cobalt weld slightly different.

The prerequisites of this work were similar to those of FESIT V-P and CELSIT V-P powders. These experiment results do not fully correspond to the DEW powder distribution [2]

ACKNOWLEDGEMENTS

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REFERENCES

[1] POPE, J. Edward. Rules of thumb for mechanical engineers: a manual of quick, accurate solutions to everyday mechanical engineering problems. Houston: Gulf Pub. Co., 1997. ISBN 978-0884157908

[2] ALMSTRÖM, Linda a Camilla SÖDERSTRÖM. ALternative materials for high-temperature and high-pressure valves. Karlstad, 2010. Degree Project. Karlstads universitet. Vedoucí práce Pavel Krakhmalev.

[3] Stellite. Chemistry learner [online]. b.r. [cit. 2018-03-28]. Dostupné z: http://www.chemistrylearner.com/stellite.html

[4] 5 Year Cobalt Prices and Price Charts. In: InvestmentMine [online]. b.r. [cit. 2018-03-26]. Dostupné z: http://www.infomine.com/investment/metal-prices/cobalt/5-year/

[5] Werkzeugniss nach 10204-2.2: DEW FESIT V-P. Deutsche Edelstahlwerke, 2010

[6] Werkzeugniss nach EN 10204-2.2: DEW CELSIT V-P. Deutsche Edelstahlwekre, 2016

[7] Plazmové automaty. KSK Česká Třebová [online]. b.r. [cit. 2016-10-04]. Dostupné z: http://www.kskct.cz/plazmove-automaty/

[8] Měřící ústředny Almemo. ALHBORN: Přesná německá měřící technika [online]. b.r. [cit. 2016-12-15]. Dostupné z: http://www.ahlborn.cz/pristroje/merici-ustredny-almemo/almemo-5690-2m-merici-ustredna-az-se-100-univerzalnimi-mericimi-vstupy.html

[9] VITE, M., M CASTILLO, L.H. HERNÁNDES, G. VILLA, I.H. CRUZ a D. STÉPHANE. Dry and wet abrasive resistance of Inconel 600 and stellite. 2004, , 6

[10] PAESI, R. M. G. a A. SCHEID. ARTIGOS TÉCNICOS/TECHNICAL PAPERS Effect of deposition current on microstructure and properties of CoCrWC alloy PTA coatings. b.r

[11] SAWANT, Mayur S. a N.K. JAIN. Investigations on wear characteristics of Stellite coating by micro-plasma transferred arc powder deposition process. Wear. 2004, , 10