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INFLUENCE OF ROUGHNESS ON QUALITY MOLYBDENUM DEPOSIT LAYER BY THERMAL SPRAYING

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Abstract

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In this paper we deal with the impact of roughness on the quality of molybdenum layer. Insufficient cleaning may result in a poor quality of the sprayed layer. Our aim is to analyze the influence of surface roughness on the quality of molybdenum layer thickness applied by thermal spraying. Thermal spraying influence several physical and chemical properties of the coating surface. The most important ones include: hardness, density, porosity, corrosion resistance and adhesion. This technology of surface treatment of material is often used for its high degree of hardness. Hardness and erosion resistance are the parameters that need to be achieved particularly in working conditions where there is excessive depreciation of a component.

Keywords: thermal spraying, coating properties, microscopy, quality, roughness

INTRODUCTION

Thermal spraying can provide thick coatings (approx. thickness range is 20 micrometers to several mm, depending on the process and feedstock), over a large area at high deposition rate as compared to other coating processes such as electroplating, physical and chemical vapour deposition. Coating materials available for thermal spraying include metals, alloys, ceramics, plastics and composites. They are fed in powder or wire form, heated to a molten or semi molten state and accelerated towards substrates in the form of micrometer-size particles. Combustion or electrical arc discharge is usually used as the source of energy for thermal spraying. Resulting coatings are made by the accumulation of numerous sprayed particles. The surface may not heat up significantly, allowing the coating of flammable substances. Coating quality is usually assessed by measuring its porosity, oxide content, macro and micro-hardness, bond strength and surface roughness.

Thermal spray is a versatile, adaptable, potentially cost-effective technology in which a wide range of metals, ceramics, polymers, and composites can be applied to almost any metal to protect against wear, corrosion, abrasion, high temperature, chemicals, and erosion. It can also rebuild worn parts of almost any metal, and can be applied by hand or by robots, in the field or in the factory. Because of these capabilities, the technology has increased part life, improved efficiency, and reduced repair costs in the aircraft, automotive, mining, and power generation industries, as well as other industries and many consumer products. The thermal spray process requires a material in wire or powder form that is transferred to the surface by heat and/or kinetic energy, forming a protective layer. Thermal spray equipment basically consists of a spray gun, materials that are sprayed, a carrier gas, and simple to highly sophisticated controls. Equipment, materials, processes, and controls may be designed for specific applications. This versatility enables engineers in almost every industry throughout the world to improve the function of their equipment and structures.

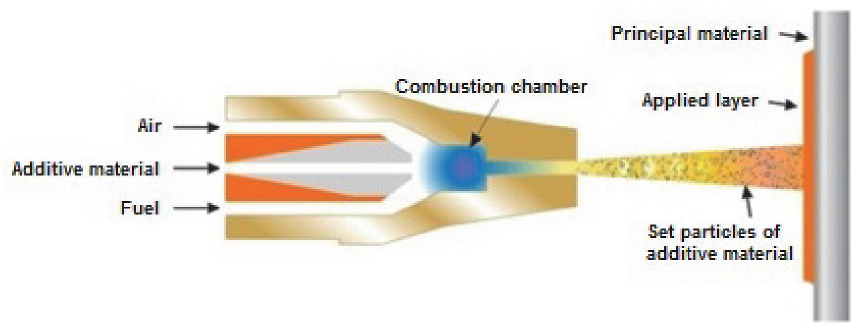
Applying coatings has its foundation in a manufacturing sector. The aim is to increase the quality by applying layer on material and thus to prolong the service life, increase depreciation resistance in operation and ultimately cost savings (Kotus *et al.*, 2011). Whether it is a molybdenum, boron (Kováč *et al.*, 2010; Mikuš *et al.*, 2012), vanadium or zinc applying (Votava *et al.*, 2012), there is a significant influence of macro and microstructure (Čičo *et al.*, 2012).

In general, the process of coatings creation by the technology of thermal spraying can be characterized as fusing additive material in form of powder, wire or rod, which particles are accelerated and applied on a prepared surface of the base material by degreasing or dry sanding (Čičo, 2009). After the impact on the base material, a partial or full deformation of individual incident particles occurs, that gradually solidify quickly, they are cooled and form a heterogeneous structure. On the cross-section of coating, shaped boundaries between the deformed particles and individual coating layers applied including any accompanying properties, especially porosity can be seen. In most industrial coatings applications created by thermal spraying technology there is an effort to limit the size and number of pores to the smallest possible number. Violating technological procedure increases the risk of defects such as micro-cracks, crevices, isolation of individual particles in the coating or applied layers separation, therefore it is absolutely necessary to execute the optimization of technological process. Executing optimization of technological parameters for a particular additive material, the technology method and a panel work conditions are essential for a successful achievement of desired coating properties ant its service life. To keep the cutting process in smooth functioning, it is necessary to follow certain principles in conjunction with temperatures during the cutting process. It mainly affects the roughness of the machined surface, geometric accuracy of the product and the service life of cutting tools such as machine tools (Kročko *et al.*, 2010). To improve the quality of the surface and geometric dimensions, new materials such as cemented carbide, cubic boron nitride and cut ceramic which all are characterized by several times higher resistance (Žitňanský *et al.*, 2012). In the manufacture of complex components we use unconventional or progressive machining methods that can efficiently and with great precision achieve desired results (Žitňanský *et al.*, 2011). The research deals with components corrosion stability, adapted by galvanization. After the research we can conclude that the surface roughness does not affect the corrosion resistance. The evaluation process of technological adaptation is to select an appropriate method of surface finish and control of thickness of the material applied on the selected components. By Zn-Ni method we can apply the coating thickness from 11 up to 13.4 microns. It is required that the coating thickness would ranged from 8 to 15 microns. In case of wrong selection of technological parameters, defects negatively affecting the coating properties may occur and thus reducing their service life and reliability. The applied coating is not completely homogeneous nor compact and the nature of coating creation itself generates conditions for pores formation, resp. of associated phenomena's such as oxides that arise during thermal spraying of some metal materials based on iron in normal atmosphere.

MATERIALS AND METHODS

Procedure of Sample Preparation

1. Evaluating the optimum implementation of sample (with molybdenum deposit layer by thermal spraying) cut from a prepared part coated with molybdenum.
2. Clamping the sample in the chuck of vertical cutter with water cooling. The cutting speed may not be too slow, but also cannot exceed the limit when it could damage the surface of the part or break the cutting disc.
3. Placing the whittled sample into a prepared glass container with ethanol. The container is then put in ultrasound and covered.
4. Sample drying. Preparing the SimpliMet1000 machine (an automatic electrohydraulic press for samples hot crimping). Inserting the sample



1: *The principle of thermal spraying*

into the machine system and pouring two measuring cups of black epovit or the amount that evenly and completely encloses the entire sample. Putting a sample ID on a surface and gentle pouring of white epovit. Pushing back and covering the system.

5. Checking the settings of the Sipmplemet3 device. For watering these types of samples, the following values are supposed to be set:
   - Pressure 290 MPa;
   - Temperature 150 °C;
   - Heating time 2 min.;
   - Cooling time 5 min.
6. Preparing the moulding press. Making sure that during moulding, spring pressure affects the centre of each sample.
7. Inserting the preparation into the Ecomet3 grinder. When grinding, we use grinding papers, grinding wheels and polishing discs, 3 µm monocrystal to support the polishing of the surface, demiwater.
8. Mambo disc polishing. Taking out the samples from the preparation. Rinsing. Cleansing with cotton wool. Ethanol spraying and desiccator drying.
9. Preparing the etchant in a glass container. The etchant is a chemical compound of NH_3 and ethanol. The surface of the prepared sample is dipped in ethanol for 2–3 seconds. The eroded surface must be immediately rinsed in clear water and sprayed with ethanol. The sample identification data is written into the database (Furka, 2012).

Measurement Procedure of Prepared Samples

In case of steel parts the surface of which is covered with molybdenum, it is not required to measure the core hardness and part surface hardness. According to the technical documentation, an emphasis is on the thickness of molybdenum layer on the surface of the part. This thickness is clearly shown on the technical drawing in Fig. 2.

Using a moulding press, the sample is prepared in a way that would enable an objective observation of part surface under the microscope.

We set the microscope at 100× magnification and then choose a section on the surface that would help us to perform an analysis. Using the Leica software, we take a picture of the studied surface with an emphasis on the sample to be well lit and the picture sharp and clear. We divide the surface of a sample into 100 µm sections according to Fig. 3. Afterwards, we perform the measurement of layer thickness for every 100 µm.

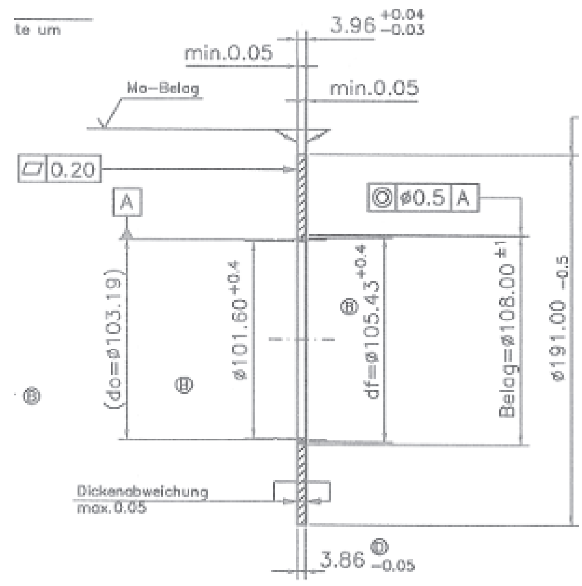
RESULTS AND DISCUSSION

Influence of Roughness on Quality Molybdenum Deposit Layer

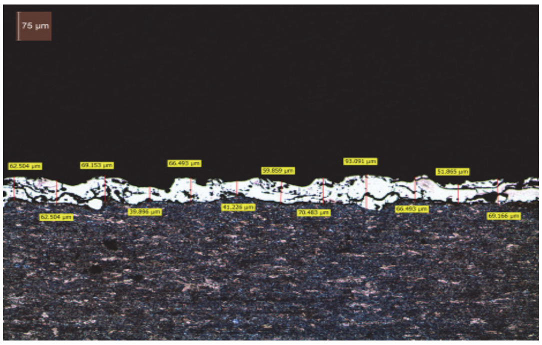
The roughness of the base material has a significant impact on achieving quality of molybdenum layer and a sufficient thickness. The minimum roughness value is defined in technical documentation for each specific unit, however, it may be enshrined in customer standard and its allowable range applies to all parts. To increase the roughness we use two types of machining. Sandblasting is the first option and it ensures increase in surface roughness of the base material to a desired value of Rz = 25. This value is required in a technical drawing.

The second option is a belt grinding of units, when the unit is grinded to roughness of Rz = 5–10 according to customer standards.

The layer spreaded values of sandblasting unit are shown in Tab. I.



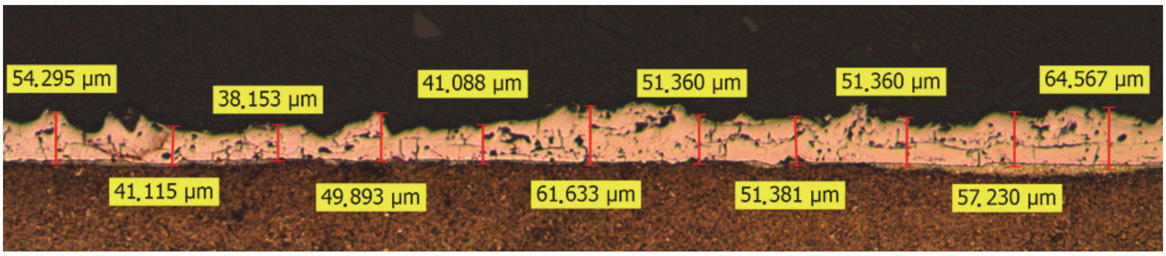
2: *The tolerance of thickness specified in the technical documentation*



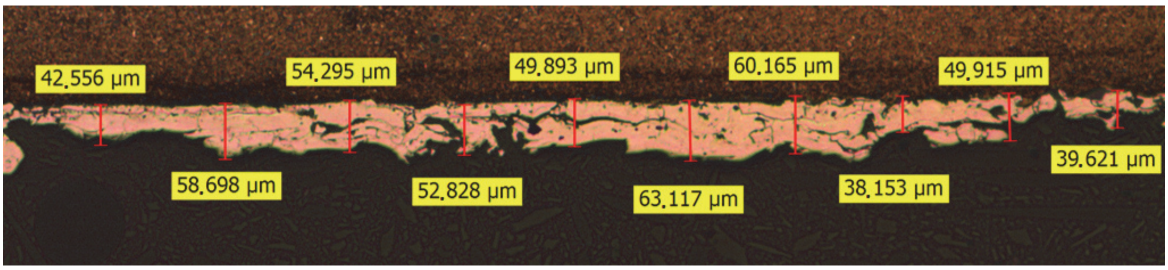
3: *The surface of sample studied devided into sections*

I: *Measuring of Mo thickness after sandblasting*

Number of measurement	Sample 3/Part 1 [µm]	Sample 3/Part 2 [µm]
1.	54.295	42.556
2.	41.088	58.698
3.	38.153	54.295
4.	49.893	52.828
5.	41.088	49.893
6.	61.633	
7.	51.36	60.165
8.	51.36	38.153
9.	51.36	49.893
10.	57.23	39.621
11.	64.567	
Min./Max.	38.153/64.567	38.153/63.1
Average value	**51.094**	**50.92**



4: *Molybdenum sample No. 3/part No. 1 – Magnification: 10×10, average value: 51.094 µm*



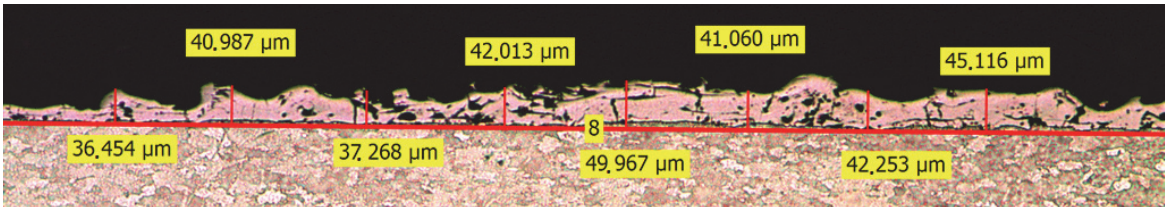
5: *Molybdenum sample No. 3/part No. 2 – Magnification: 10×10, average value: 50.92 µm*

The requirement for a thickness of Mo layer: min. 50 µm.

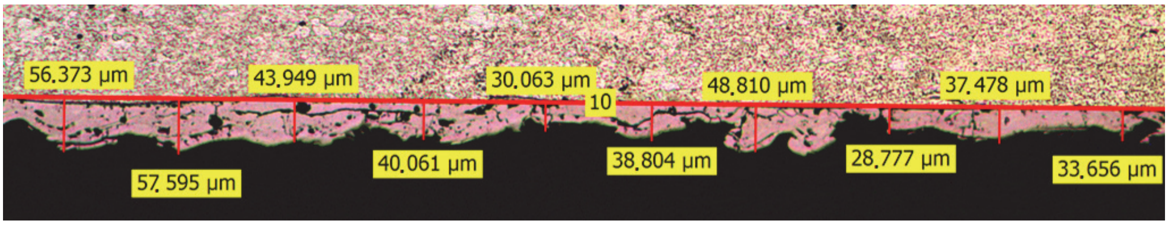
Sandblasting corrodes the unit's surface, and thus achieves a high surface roughness. High roughness achieved causes the applied additive material is not reflected from the base material. A average values in both samples (Figs. 4 and 5) meet the minimum required thickness min. 50 µm. The maximum measured thickness of the molybdenum sample #3/ Part 1 (Fig. 4) is 64.567 µm. Looking at the sample

II: *Measuring of Mo thickness after beld grinding*

Number of measurement	Sample 4/Part 1 [µm]	Sample 4/Part 2 [µm]
1.	36.454	56.373
2.	40.987	57.595
3.	37.268	43.949
4.	42.013	40.061
5.	49.967	30.063
6.	41.06	38.804
7.	42.253	48.81
8.	45.116	28.777
9.		37.478
10.		33.656
Min./Max.	36.454/49.967	28.777/57.595
Average value	**41.89**	**41.557**



6: *Molybdenum sample No. 4/part No. 1 – Magnification: 10×10, average value: 41.89 µm*



7: *Molybdenum sample No. 4/part No. 2 – Magnification: 10×10, average value: 41.557 µm*

surface in the vicinity of the place where the highest value was measured there is a clearly visible hollow. Its origin can be attributed to the process of sanding when the particles hit the surface of the base deforming it at an increased rate.

The layer spreaded values of belt grinding unit are shown in Tab. II.

The requirement for a thickness of Mo layer: min. 50 µm.

The lower surface roughness was achieved by belt grinding, therefore a filler material tends to reflect to the surroundings when applied. Consequence of reflectivity results in shrinkage of material at the expense of the layer, thereby reducing its thickness that was confirmed by measurement of the sample No. 6, which did not meet the required specified thickness of min. 50 µm after data evaluation.

CONCLUSION

Belt grinded and sandblasted surface disrupt the surface of the base material, it is therefore necessary (after their completion) to ensure that the next operation – application of additive material would be carried out in the shortest possible time. The surface is active after its treatment and due to the action of oxygen there could be corrosion created within the next 12 hours. Corrosion can be removed only by further surface grinding, but this could ultimately result in falling below the total thickness of a unit and thus corrupt it in terms of its applicability within the device that the unit was rated for.

Thanks to the precision and perfection of an application process it is possible to significantly improve the quality of the process by saving the amount of additive material as well as the time needed to perform this operation. The objectives and a long-term strategy of companies is to constantly increase quality while reducing the costs associated with the production process.

However, it is important to pay attention to the generated waste containing molybdenum or chromium, or other substances (Mikloš *et al.*, 2002; Šolc *et al.*, 2011). Insufficient cleaning is the result of human mistakes and human failures (Mikloš, 2010). It is therefore necessary to improve the reliability of the human factor in order to improve the quality of deposited layers (Mikloš, 2011).

Applying coatings using thermal spray is an established industrial method for resurfacing metal parts. The process is characterized by simultaneously melting and transporting sprayed materials, usually metal or ceramics, onto parts. The spray material is propelled as fine molten droplets, which, upon striking the part, solidify and adhere by primarily mechanical and, in some cases, metallurgical interaction. Each layer bonds tenaciously to the previous layer. The process continues until the desired coating thickness is achieved. Thermal spraying can be used to apply coatings to machine or structural parts to satisfy a number of requirements:

- repair worn areas on parts damaged in service,
- restore dimension to mismachined parts,
- increase a part's service life by optimizing the physical surface properties.

The primary advantages of thermal spraying include the range of chemically different materials that can be sprayed, a high coating deposition rate, which allows thick coatings to be applied economically, and spray equipment portability.

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