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SELECTED PARAMETERS OF MICRO-JET COOLING GASES IN HYBRID SPRAYING PROCESS

The innovative technology, like thermal spraying with a micro-jet cooling is one of the important modification of classical ultrasonic spraying methods. Using of micro-stream with gases like argon or nitrogen allows to cool the coating immediately after spraying, and thereby reduce the time of transition during the injection of each layer. As a result of the process, the fine dispersive structure of coatings is obtained during the shorter time in comparable to the classical high velocity oxygen fuel process (HVOF). The parameter of process and the type of stream equipment determine the quality of the obtained structure and thermal stress in the coating. The article presents the relationship between selected parameters of hybrid process and properties of the coatings. The presented technology should be adapted to the actual production of protective coating for machines and construction working in wear conditions.

Keywords: hybrid system, thermal spraying, type of cooling stream

1. Introduction

The service life of coating depends directly on the type and quality of the coat and its resistance to specific environmental factors. It is determined by the structure and properties of the obtained coating material, and these can be formed by appropriate choice of chemical and phase composition of coating and manufacturing technology (Fig. 1) [1-5].

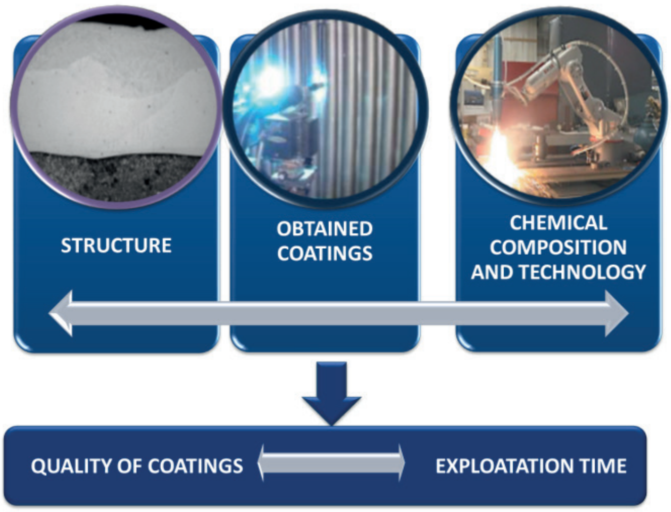

Fig. 1. Functional relationship between: structure, properties and manufacturing technology of coating

The most important factors determining the choice of spraying technology include (Fig. 2) [7]:

- application capabilities of the type of material with established and often complex chemical and phase composition
- produce the desired structure by the chosen technology (thickness of approx. 400-500 mm), a low porosity (~ 1-3%) and a strong bond with the substrate.)
- the availability and cost of ownership of equipment and additional materials.
- the element type and the area to protect, for example: shape of structure partly determines the type of device because it must be kept distance of the recommended thermal sprayed surfaces
- environment - the possibility of using the technology on an object, the method of surface preparation, environmental conditions affecting the operating personnel and equipment
- a high efficiency of the process, because the coatings are produced during the downtime of equipment,
- qualifications and experience persons performing the protection

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Fig. 2. Main factors influencing the choice of coatings technology

Trends in development of technologies and materials for thermal spray coatings for energy applications seeking to develop a coating of possibly high resistance properties in the complex conditions of wear. Selected parameters of thermal spraying technologies are presented in Fig 3 and Table 1.

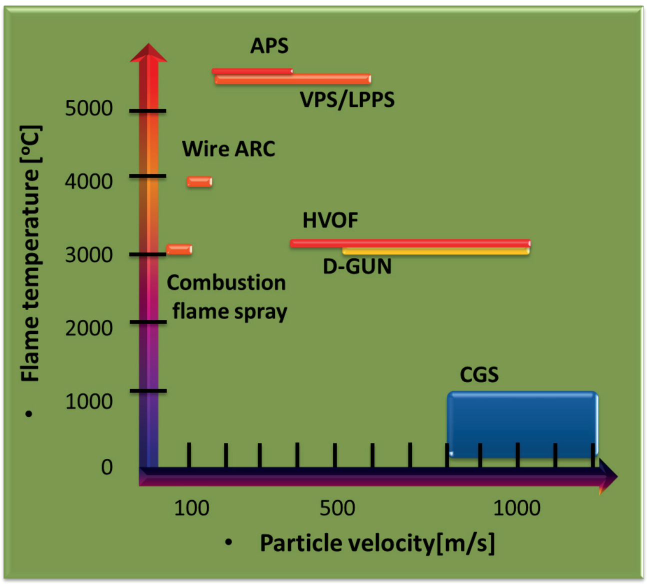

Fig. 3. Diagram of particle velocity with flame temperature of selected spray systems [2]

TABLE 1

Selected parameters of thermal spraying technologies [2-4]

Method:	Flame temperature [°C]	Speed of the particles [m/s]
APS	12000	150 - 400
VPS/LPPS	12000	150 - 600
ARC	4000	100 - 130
Flame	3000	40 - 100
HVOF	3000	400 - 1000
D-Gun	3000	500 - 1000
CGS	300 - 1000	800 - 1200

Among the methods presented in Figure 3, the most promising for the production of coatings for applications in complex corrosive and erosive conditions are: supersonic HVOF (high velocity oxy fuel) , ARC and plasma spraying methods (APS, LPPS, VPS), although the plasma spraying technique does not provide a good seal and compactness of the structure [2]. Now increasingly are used modifications of these technologies. The most important developments in this field include technology [1-7]:

tasked to accelerate the movement of particles ,eg.: modifications to reduce the diameter of guns;

obtaining layers of lower porosity, eg.: spraying at high speed in air, like HVAF- High Velocity Air Fuel method

An important phenomenon occurring with the spraying of classical and modern methods is a tendency to the formation of thermal stresses in the coating. The thermokinetic energy is required to melt the powder and acceleration of the material in the gas (Fig. 4). This leads to significant heat input to the target surface. During the spray process it is recommended to use:

- a low level of heat, which in practice is very difficult to carry out
- or a suitable heat removal of the deposited coating during the process.

This can be achieved by the multi-layer coating technique with cooling by oxygen or air [1, 3-8]. The resolved is not always favorable. This causes oxidation of the particles deposited in the stream of gases and the process requires an interval of time between spraying of successive layers.

Therefore, the third a very important direction of methods development of thermal spray coatings is finding solution to change the way surface cooling to reduce thermal stresses in the coating and shortening time to pass during the injection of each layer.

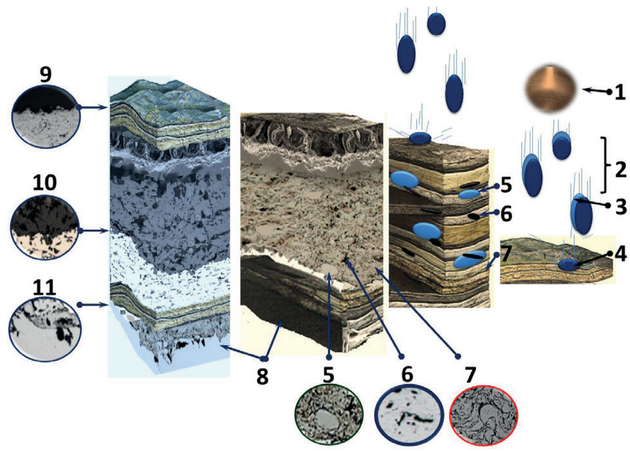

Fig. 4. Diagram of spraying process and coating materials :

1 - heat source (arc, flame); 2 - giving the speed of the particle; 3 - oxide coating; 4 - blow particles into the ground; 5 - not molten particles; 6 – pores; 7 - the oxide layers; 8 - the base material; 9 - surface roughness; 10 - transition zone in the coating layered; 11 - transition zone between the coating

The results presented in publications and the structure observations of construction materials cooling by micro-jet system showed good relationship between the innovative construction of micro-stream and quality of obtained structure [9-19]. The results are the base to the continuation of investigation to the adaptation the presented micro-jet welding technology to thermal spraying processes of coatings. The authors developed a hybrid method using micro-jet cooling system. The innovative method of spraying is the modification of HVOF system by micro-jet streams. It is assumed, that the hybrid technology allowed for preparation of fine-dispersive, and high density coatings.

This article presents the relationship between structure properties of obtained coatings and selected technological parameters of their production. The gases parameters change in stream flow by controlling the amount and diameters of nozzles and their impact on the resulting quality of the coatings. The results show the complexity of the problem and the difficulties in the correct execution of the spraying process.

2. Materials and research methods

The material to research consisted the obtained coating by the process of the hybrid thermal spraying. The process parameters are chosen so, that in a single pass to obtain the coating with a thickness of 1 μm. The distance between Jet Cote II gun and the surface of metal was 0.25 ± 0.03 [m], the distance of gun with cooling micro-injector was 0.30 ± 0.03 [m], velocity of HVOF gases is above of 2000 [m/s]. For the cooling process were used nozzles: type A 40, type A 50, type B 40 and type B 50. For all types of nozzle was used gas: nitrogen. The speed of the gun with micro-jet nozzle regard to the sample was about of 0.5. Other parameters and kind of thermally sprayed process were: voltage in the range of 25÷30 [V] and the intensity of 150÷250 [A].

3. Results and discussion

The results indicate that the technology allows to obtain the correct macro- and micro-structures using injector with one nozzle in the cooling process. Presented structure is finely dispersed, sealed and it characterized low porosity (Fig.5). The thickness of coating is above 450 μm.

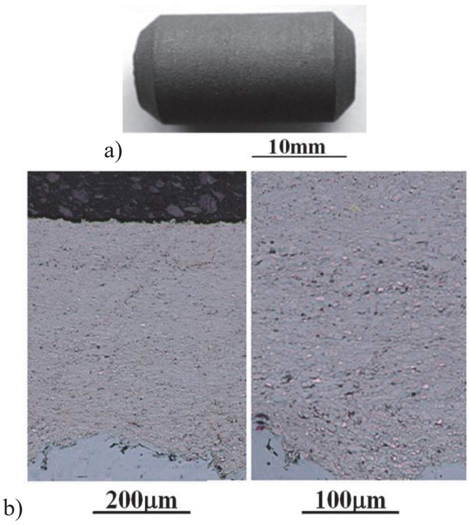

Fig. 5. a) View on the surface and b) microstructure of coatings sprayed by hybrid system with injector type A40

Nozzle type B40 and B50 causes too rapid cooling of the surface of the test material. In the material you will see changes such as: cracks or delamination (Fig. 6-7). It evidences of incorrect choosing the parameters of the process. The results clearly confirmed that to rapid cooling of the surface of the coating causes unfavorable structural changes. The area without cracs of coating sprayed by HVOF system with cooling by injector type B 40 characterized porous microstructure comparable to the microstructure of conventional sprayed coatings by HVOF system (Fig 6 -8).

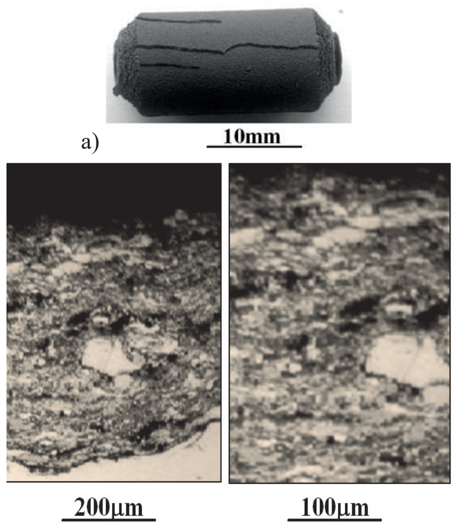

Fig. 6. a) View on the surface and b) microstructure of coating sprayed by hybrid system with injector type B 50

But the registered changes (cracks or delamination, exfoliatin) , suggested that applied layers

are subject to degradation during the exploitation time (Fig 7.a).

In the case of the use of the nozzle A40 is the correct result as to obtain fine-grained , good density and a compact structure with low porosity. In this case the micro-jet is suitably designed injector for spraying the coating process.

It can be concluded that only the injector stocked with an adequate system of nozzles walking, with given diameters enable very accurate to regulate the temperature decrease and obtain high quality structure of the material. Thus, the number of nozzles and their diameters (measured in mm) are chosen depending upon the spraying process and base material.

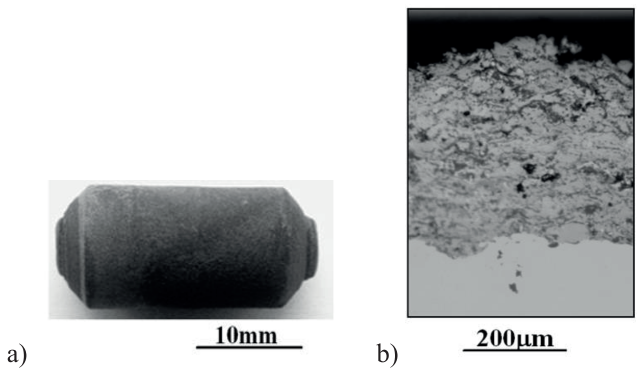

Fig. 7. a) View on the surface with exfoliation area and b) microstructure of coating sprayed by hybrid system with injector type B 40

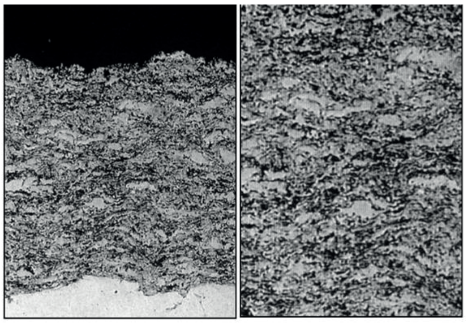

Fig. 8. Microstructure of coating sprayed by classical high velocity oxy fuel system [7].

4. Summary

Hybrid method, combining thermal spraying and micro-jets cooling represents the modern coating technology, characterized by exceptional precision. The presented and analyzed result shows that the coating structure obtained by hybrid spraying method depends on the use a different construction of injector micro-jet (type with one or two-nozzles). The results indicate that the selection of the cooling parameters needs to be adjusted to the type and the thickness of the final sprayed material.

The use of a cooling nozzle type A40 and A50 allowed to obtain high-quality structure. The structure characterized by low porosity, fine grain and uniformity of layer application. The process ensures the precision and reproducibility of the results. The investigation results confirmed the possibility of using hybrid method as a modification of the classical ultrasonic method. The developed hybrid method with micro-jet cooling system can be successfully used for parameter adjustment of coating structure. It allows for rapid and precise reduction of surface temperature and it has got a positive influence on the grain structure .

As the result of using a faster cooling of surface coating, it is observed: the cracking process and exfoliation of coating. It can be assumed that, the thermally stress are increased in the structure during the spraying and direct cooling by injector type B50. In this case, the maintenance of a very low level of heat during the process does not provide sufficiently high quality of coatings. It should be noted, that the use the cooling nozzle type B50 and nitrogen gas is inappropriate to achieve the correct structure with a thickness of about 450 mm in set time.

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