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RESEARCH OF THE THERMAL SPRAY PROCESS OF WIRE ARC SPRAYING

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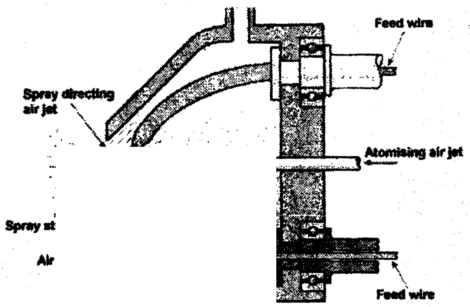
Introduction

Thermal spray has been used for about 40 years throughout all the major engineering industry sectors for component protection and reclamation. Arc spraying is the highest productivity thermal spray process. Recent equipment and process developments have improved the quality and expanded the potential application range for thermally sprayed coatings. Thermal spray is a well established technology for applying wear and corrosion resistant coatings in many key industrial sectors, including aerospace, automotive, power generation, petrochemical and offshore. In recent years, improvements to equipment and material quality have enhanced the technical credibility of the thermal spray processes, leading to a significant growth in new markets, e.g., biomedical, dielectric and electronic coatings.

A DC electric arc is struck between two continuous consumable wire electrodes which form the spray material. Compressed gas (usually air) atomises the molten material drops into fine droplets and propels them towards the substrate. The process is simple and can be operated either manually or in an automated manner. It is possible to spray a wide range of metals, alloys and metal matrix composites (MMCs). In addition, a limited range of cermet coatings (with tungsten carbide) can also be sprayed in cored wire form, where the hard ceramic phase is packed into a metal core as a fine powder.



ı of arc spray gun

The aim of this study is to try to optimise the atomizing gas velocity performing small changes on the TAFA 9000 gun nozzle geometry, using fixed thermal spray parameters. An increase in the particle velocity, providing improvements in the coating properties is expected [1].

NUMERICAL STUDY OF THE ATOMISING GAS JET

The PHOENICS commercial CFD (Computational Fluid Dynamics) code was used in a preliminary step in order to test the effect of small changes made on the original design of the TAFA 9000 gun nozzle geometry [2]. The original gun exit is composed of a converging nozzle exhibiting a 6 mm exit diameter. The meeting point of the wires (where the electric arc is formed) is situated just at the center of the exit area. The changes that were made on nozzle geometry and were tested included additional extension of the original nozzle.(Fig. 2). Different lengths and different diverging angles were tested. Simple two-dimensional computations were performed and the effect of the electric arc (150A; 30V) was taken into account by adding a volumetric heat source to the energy equation. This simplified approach was expected to lead to the first tendency (qualitative comparison) of the effect of these small changes. Finally, six different new nozzle exit designs were tested. Figure 2 presents a view of these different nozzle exit designs. In each case, the results were compared to those obtained for the original geometry (Figure 2-a). More precisely, criteria such as- the velocity magnitude and the jet divergence in the near exit region were retained. Figure 2-b incorporates a progressive change in the converging angle. Figures 2-c to 2-e show different lengths of constant area nozzle extensions whereas geometries on Figures 2-f and 2-g were built up with a slightly diverging extension.

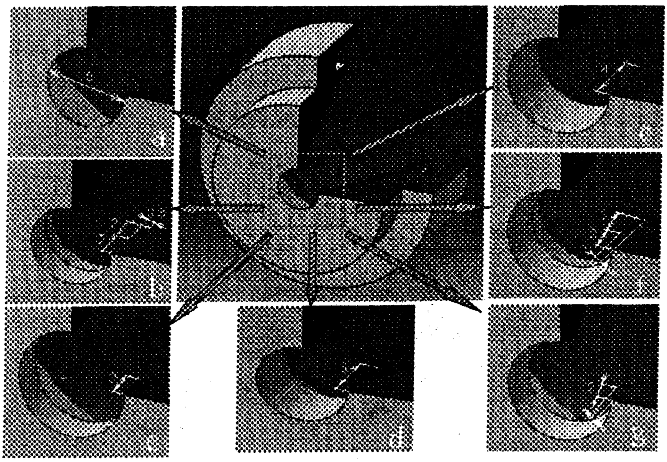
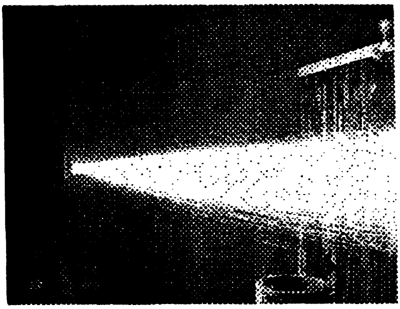


Fig.2. View of the tested diverging nozzles

Finally, one of the modified designs was selected on the basis of the numerical modeling results and the corresponding nozzle was machined in order to be tested on the experimental way. The selected design has a 3 mm constant area extension (Figure 1-d). The other designs were modeled to provide either a lower gas velocity or a larger jet divergence (if compared to the chosen one).

CHARACTERIZATION OF THE MATER JETS

Following this first preliminary modeling step, the corresponding nozzle (constant area 3 mm extended nozzle) was machined and tested. Some experiments were performed for two different type wires (TAFA 38T steel wire and TAFA 95MXC stainless steel cored wire). Figure 3 and 4 present photographs of the jet for the TAFA 95MXC wire, for the original and modified nozzles respectively. The other parameters were kept unchanged (electric arc current -150A, voltage- 30 V and a gas flow rate of 130 m^3/h). The photographs were performed using a numerical camera and visual references allowed a calibration of the photos. In spite of the problem concerning the matter jet motion, the jet divergence was found to be lower for the modified nozzle geometry (12°±1 against 16°±1). Additionally, the matter distribution at the spraying distance (150 mm) is more expanded in comparison to the original geometry.



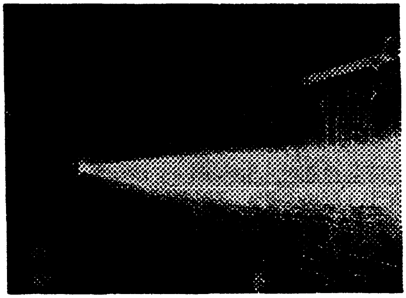


Fig.3. Jet of original nozzleFig. *4. Jet of modified nozzle*

PARTICLE SIZE DISTRIBUTION

After these experiments, it was decided to perform investigation of the particle jet. For the new experiments, the thermal spray parameters were the same for the two designs (previous ones) so that only the effect of the nozzle geometry was taken into account. In a preliminary step, particles from the spray of two different nozzle designs were collected into water container and a sieve analysis was performed using a LASER granulometer in order to allow a better calibration of the particle size distribution. Additionally, SEM micrographs of the collected particles were also made and analysed.

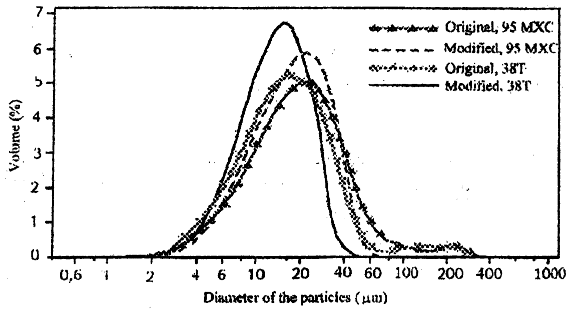


Fig.5. Diameter of the particles for the original and modified nozzles

Figure 5 presents the particle size distribution taken from the sieve analysis for the two wires and the two different nozzles. The size of particles is equally distributed on the logarithmic scale. For the steel 38T wire, the mean particle size was 26.1 ?m for the original nozzle and 22.2 ?m using the modified one. In case of the stainless steel 95MXC wire, the mean particle size was smaller. The mean particle size 18.7 ?m for the original nozzle and about 14 ?m for the nozzle of the modified geometry.

Consequently, the mean particle size of the collected particles, was about 15% lower for the 38T wire and 25% lower for the 95MXC wire using the modified nozzle. The sprayed particles of wire 35T are smaller than of cored wire 95MXC. This difference may be explained by different chemical compositions and surface tension of the liquid droplets in flight.

CONCLUSIONS

1. Computational Fluid Dynamics models can predict the influence of nozzle geometry on flows of jet and heat transfer. Also it helps to choose optimal nozzle configuration.

2. Jet flow from the modified geometry gun nozzle is converged and forms droplets of smaller size. This allowed to predict that porosity of sprayed coatings and the consuming of spray material will decrease, while the adhesion and Young's modulus will increase.

3. The investigation of arc spray with modified nozzle must be continued with sprayed coatings made from different materials and the detailed examination of mechanical and physical properties of coatings must be carried out with the aim to set the optimal relation of gun nozzle geometry and sprayed coating properties.

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