Computational Investigation of MCrAlY Coatings Under Different Gas Mixtures in Vacuum Plasma Spray

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Abstract: In this study, we report computational results of arc plasma and particles for a better understanding of Vacuum Plasma Spray(VPS) for metallic coatings. The model has been applied to MCrAlY bond coats by using VPS with Ar and H_2. In particular, H_2 influences the oxidation of coatings by increasing the temperature and decreasing the velocity of particles. The findings indicate that the properties of gas mixtures are significant for coatings.

1. Introduction

Due to its high energy density, the plasma spray process has the advantage of the deposition of metallic and ceramic coatings. One of the best methods for applying metallic coatings, such as bond coats in thermal barrier coatings (TBC), is vacuum plasma spraying (VPS) [1]. This is because it lowers oxidation during the deposition process. However, the VPS process is complex and involves many parameters, so it is difficult to understand the correlation between process parameters and metallic coating characteristics. To enhance the understanding of plasma spray for metallic coatings, a computational model that simulates the behavior of arc plasma and particles is required.

In this work, we used computational models that combine discrete particle modeling (DPM) and thermal plasma to demonstrate the effect of Ar and H_2 on the plasma arc and MCrAlY coating. This method allowed for the calculation of the temperature and velocity profiles of the plasma jet and particles under various Ar and H_2 mixing conditions. Under the same conditions, the simulation results were compared with MCrAlY coatings.

2. Computational method

To predict the VPS process, a three-dimensional computational model was developed. To capture the behavior of the arc plasma and its interaction with injected particles, the computational domain includes the plasma torch, powder feeder, and vacuum area. Thermal plasma simulations were used to represent the arc plasma inside the torch under the assumption of local thermodynamic equilibrium (LTE), and an Eulerian-Lagrangian method was used to calculate the interaction between arc plasma and powder particles [2,3]. Various Ar and H_2 flow rates were used as process gases to examine the impact of gas mixes. The analysis was conducted by changing the Ar flow rates to 30, 40, and 50 L/min, along with H_2 flow rates of 9, 12, and 14 L/min.

3. Results and Discussion

Figure 1 shows the simulation results for inflight particles under varying Ar flow rates. When the Ar flow rate increases while keeping the H_2 flow rate constant, particle velocity rises, but their temperature decreases. Also, the porosity and the amount of oxide in the coatings decrease. This is presumably because Ar increases the velocity of the particles due to a larger drag force, which slows down the oxidation rate. On the other hand, particle temperature increases and particle velocity drops as the H_2 flow rate increases with a fixed Ar flow rate. Also, the energy-dispersive spectroscopy (EDS) test shows that when the flow rate of H_2 is 14 L/min, there is more oxide at the interface. This is because of the higher heat transfer by H_2 with a higher enthalpy and a higher thermal conductivity.

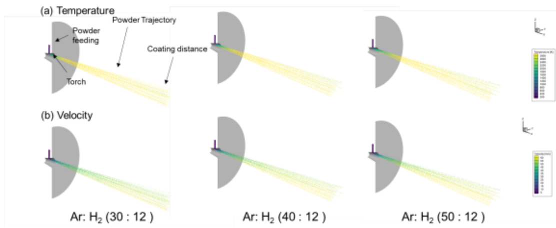

Fig. 1. Comparison between velocity and temperature distribution of particles with the Ar flow rates of 30, 40, and 50 L/min

4. Conclusion

We conducted the simulation analyses using thermal plasma modeling and DPM to investigate the effects of Ar and H_2, which are process gases in VPS. Changing the flow rates of Ar and H_2 allows for control over the temperature and velocity of the injected particles through interactions with the arc plasma. In particular, oxidation prevention is significant when forming metallic coatings. Since H_2 tends to increase the temperature of particles while reducing their velocity to raise oxidation, precise control of its flow rate is essential. Also, further research is needed to explore the conditions required to minimize oxidation.

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References

[1] S.H. Liu et al., Mater. Today Phys., **27**, 100832 (2022)
[2] H. Kwon et al., Met. Mater. Int., **29**, 1825-1840 (2023)
[3] H. Park et al, J. Phys. D. Appl. Phys., **51** 395202 (2018)