Effect of Gun Nozzle Geometry, Increase in the Entrance Convergent Section Length and Powder Injection Position on Cold Sprayed Titanium Coatings

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Abstract

Nozzle geometry influences gas dynamics making sprayed particle behavior one of the most important parameters in cold spray process. Gas flows at the entrance convergent section of the nozzle takes place at relatively high temperature and are subsonic. Thus, this region is a very suitable environment for heating spray particle. In this study, numerical simulation and experiments were conducted to investigate the effect of nozzle contour, entrance geometry of nozzle and powder injection position at nozzle on the cold spray process. The process changes were observed through numerical simulation studies and the results were used to find a correlation with coating properties.

Keywords: cold spray, nozzle geometry, titanium

1. Introduction

Cold spray [1] is a new coating method for deposition of metal, alloy, polymer, or composite powder material onto various substrates. In the cold spray method, a coating is formed by exposing a substrate to high velocity (300 to 1200 m/s) solid-phase particles accelerated by supersonic gas flow at a temperature (ambient temperature to 700K) much lower than the melting or softening temperature of the feedstock.

Previously, we have studied the effect of nozzle geometry on the HVOF and cold spray process [2, 3].

According to the paper [4], the critical impact velocity decreases with increasing particle impact temperature. It should be noted that the particle impact temperature depends mainly on the gas temperature, nozzle geometry, particle injection position, size and specific heat of particle.

The present study focuses on the effect of the nozzle geometry, entrance geometry of convergent–divergent nozzle and the particle injection position on the titanium particle temperature and coating properties. The gas flow in the entrance convergent section of the nozzle exhibits a relative high temperature and is subsonic. This kind of

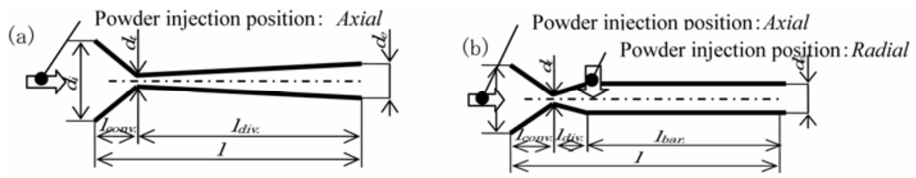

Fig. 1. Schematic cross-section diagram of the cold spray nozzles used:(a) Convergent-divergent nozzle (Type A) and (b) Convergent-divergent -barrel nozzle (Type B)

Table 1 Nozzle geometry and size-Comment

Nozzle No.	Nozzle geometry	Powder injection position	di [mm]	dt [mm]	de [mm]	l [mm]	lconv. [mm]	l div	lbar. [mm]
A50	Convergent-divergent (De Laval)nozzle	Axial	40	2	7	300	50	25	0
A100						300	100	20	0
A150						400	150	25	0
B50-a-200	Convergent-divergent (De Laval)-barrel nozzle	Axial	40	2	8	267	50	17	200
B50-a-300						367			300
B50-r-200		Radial				267			200
B50-r-300						367			300

Table 2 Spray conditions

Working gas at nozzle intake	Gas type	Nitrogen
	pressure P_i [MPa [gage]]	3.0
	temperature Tgi [K]	600～660 (623)
Gun traverse	Speed[mm/s]	20
	Pitch[mm]	2
Spray distance [mm]		15

environment is suitable for heating spray particles [2].

2. Experimental equipment and methods

Cold spray equipment improved was used for the present study [3]. Schematic cross-section diagram of the cold spray nozzles which was used this time is shown in Fig.1. The size of these nozzles is presented in Table 1. Spray condition is shown to Table 2. Pure titanium powder (TILOP -45, Sumitomo Titanium Co, Tokyo) was used for feedstock powder.

In the present paper, the internal nozzle flow was treated as quasi-one-dimensional isentropic flow. This one-dimensional approximation is simple and sufficiently correct for the present purpose internal nozzle flow [2, 3]. It uses a value indicated by the underline in Table 2 for the numerical simulation.

3. Experimental results and discussions

Fig. 2 shows the effects of nozzle geometry on the deposition efficiency and the measured and calculated particle velocity. Due to the higher actual particle velocity with type B nozzle, the deposition efficiency is high.

Fig. 3 shows the entrance convergent section length of the De Laval nozzle on the deposition efficiency and the actual and calculated particle velocity. Deposition efficiency can be seen to reach its peak of 75% when A100 nozzle was used.

Fig. 4 shows the effect of particle injection position and gas pressure at the nozzle intake on the calculated results of cold spray process. The influence of powder injection position and nozzle intake gas pressure on the cross-sectional SEM structures and porosity of cold sprayed titanium coatings was not show. Accoging to these results, the actual particle velocity, deposition efficiency and porosity of the coatings increase with increasing gas pressure. Due to the high particle temperature, the deposition efficiency and porosity of the coatings with axial powder injection were superior to that with radial injection.

4. Summary

The actual particle velocity, deposition efficiency and porosity of the coatings were dependent on geometry and entrance convergent section length of the nozzle and powder injection position in cold sprayed titanium coatings.

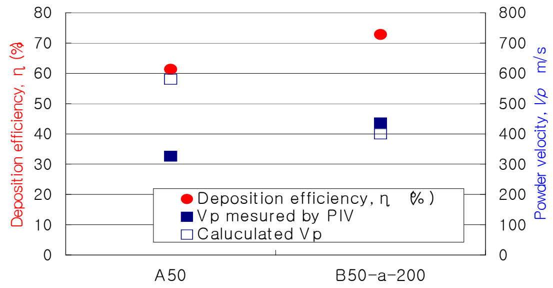

Fig. 2. Effect of nozzle geometry (Type A, B) on the deposition efficiency and the measured and calculated particle velocity with titanium powder.

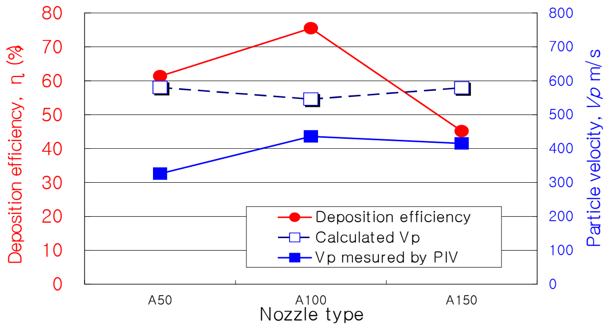

Fig. 3. Effects of entrance convergent section length of the De Laval nozzle (Type A) on the deposition efficiency and the measured and calculated particle velocity with titanium powder.

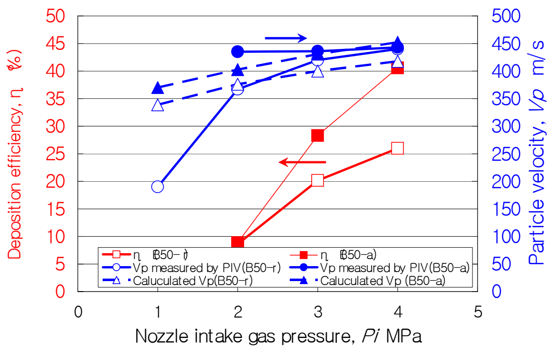

Fig. 4. Effects of powder injection position and nozzle intake gas pressure on the deposition efficiency and the measured and calculated particle velocity with the Type B nozzle.

5. References

1. A.P.Alkimov et. al. , US.Patent no.5,302,414, (1994)
2. K.Sakaki and Y.Shimizu, J .Thermal Spray Technol. 10[3], pp. 487(2001).
3. K.Sakaki, et. al., Proc. of International Thermal Spray Conference, p.385(2002).
4. T.Schmidt, et. al. CD-R of Proc. of International Thermal Spray Conference, p.232 (2005)