# Particle Deposition, PD Process
# – New Potential in Material Processing –

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**Abstract**

*Oridinal thermal spray process has developed into two ways, namely, temperature dominated represented by plasma spraying, and velocity dominated represented by HVOF. It is common for both that the particle materials sprayed are basically in melted or half melted condition. New process has developed recently, that is, Cold Spray and Aerosol Deposition. Particle's heating is limited in CS lower than half of the material's melting point. Moreover, exactly no heating is loaded in AD process. Through the investigation on common feature for these three spraying processes, potential of new material process - Particle Deposition, PD – is considered and proposed.*

**Keywords : thermal spray, cold spray, aerosol deposition, domination factor, surface modification**

## 1. Introduction

As a core process for thick coating formation, thermal spraying has remarkably grown up in the last two decades and been applied so widely into many industrial fields. Here, it can be said that the ordinal thermal spraying, TS has developed into two ways until today, that is, one is temperature dominated, typically shown as plasma spraying. In this case, particles are usually fully melted by enough heating from surroundings such as plasma, laser beam, combustion flame and so on. Another is velocity dominated, on the other hand, represented by HVOF. In this case, particles are not always melted completely and instead, enough kinetic energy plays a role for the deformation and deposition. However, it is common for both that the particle materials sprayed have relatively wide range in size distribution, usually from 5 to 50 micron meters.

Recently, new processes have developed in this field, that is, cold spray, CS and aerosol deposition, AD, respectively. Particle's heating is usually limited in CS, namely, lower than half of the melting temperature of the material. Moreover, exactly no heating is loaded in AD process, particles are completely kept at room temperature. Usually, these new processes are relatively more sensitive in a particle preparation, that is, narrow distribution range in partile size is preferred for both to obtain high quality coatings.

In the present study, through the investigation on common feature for these three ordinal and new spraying processes, a potential of new material process - particle deposition, PD process- is considered and proposed. As a main subject in a material process research lies in an establishment of the controllability, main concern is how we can make PD process so highly controllable and reliable one.

## 2. Experimental and Results

Three kinds of spraying process were observed in the present study. In the ordinal thermal spraying, several kinds of metallic powder materials were sprayed onto the mirror polished substrates with the size of 25mm x 25mm x 5mm. The substrate material used was AISI304 stainless steel. Changing tendency in a splat pattern both with increasing the substrate temperature and decreasing the ambient pressure was mainly investigated. To perform this, both atmospheric plasma spraying and low pressure plasma spraying were conducted. To investigate the splat pattern of the particles, powder materials were sprayed and collected onto the substrate through a shutter plate with 10 mm diameter hole installed at just before the substrate. Flattening pattern of the splat on the substrate surface was observed by both optical microscope and SEM.

Experimental results have revealed that a splat shape of most powder material onto the flat substrate surface has a transitional changing tendency from a distorted with splash to a lenticular without splash at a narrow temperature range with an increase of the substrate temperature. The transition temperature ***Tt*** was defined and introduced by the authors[1]. Moreover, it was verified experimentally that the adhesion strength of the coating changed transitionally with the substrate temperature increasing, and its dependence on the substrate temperature corresponded quite well to that of the splat shape as shown in Fig. 1. Thus, the investigation of the flattening mechanism of the sprayed particle on the substrate surface is significantly meaningful for the practical usage of the thermal spray process.

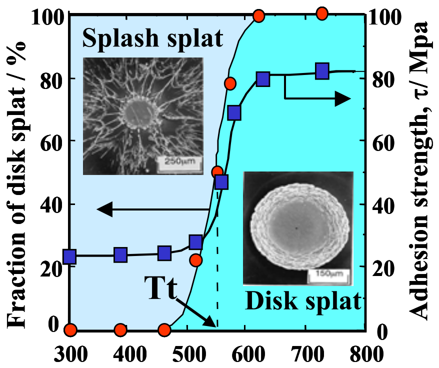


**Fig. 1. Dependence of fraction of disk splat and adhesion strength on substrate temperature.**

The effect of ambient pressure on the flattening behavior, on the other hand, was systematically investigated in the low pressure plasma spraying by reducing the pressure while the substrate temperature was kept exactly at room temperature. From the result, it was found that the disk splat appeared easily by reducing the ambient pressure. Experiments have also revealed that the transition behavior from the splash splat to the disk one can be recognized in most of the metallic materials by reducing the ambient pressure. The transition pressure ***Pt*** at which the particle's splat pattern change to the disk splat from the splash splat was also defined and introduced by the author.

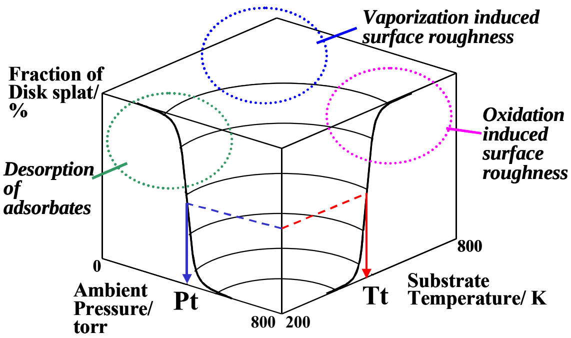


**Fig. 2. 3-Dimensional transition map of flattening behavior in thermal spray process.**

Bottom surface microstructure change both by changing the substrate temperature and the ambient pressure was observed. The similar tendency in microstructure change from porous to dense was observed in both cases. The fact indicates that the eqiuvalent effect can be given for the flattening of the particle both by substrate temperature increasing and ambient pressure decreasing. The dependence of fraction of disk splat both on the substrate temperature and ambient pressure was illustrated schematically in Fig. 2. By selecting the optimum operating conditions for both factors in the ordinal thermal spraying, the coating microstructure and any other properties of the coating can be controlled. Thus, the control of thermal spray process can be attained by introducing both ***Tt*** and ***Pt*** as critical conditions[2].

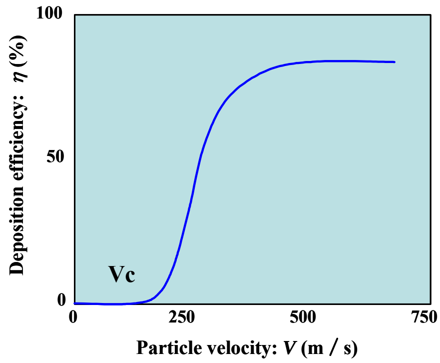


**Fig. 3. Critical velocity in cold spray process.**

As it has been almost revealed recently, a critical particle velocity, Vc exists in cold spray process[3], over which particle begin to adhere onto the substrate surface as schematically shown in Fig. 3. It also has been pointed out that Vc value depends on the combination between particle and substrate matetials and on the particle size as well. From an academic viewpoint, physical meaning of the critical velocity itself has to be clarified and mechanism for an increasing tendency of deposition efficiency in a velocity range over Vc has to be verified as well. Anyway, the process can be effectively controlled by this critical value.

Simillar tendency has been recognized in AD process[4], that is, many kinds of ceramic particles are successfully deposited and formed high quality thick coatings under some moderate or critical conditions both in particle velocity and size distribution ranges.

### 3. Summary

Particle deposition, PD including thermal spray, cold spray and aerosol deposition, is expected to be as a highly potential material process which realizes not only surface modification but also spray forming in the near future.

### 4. References


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