Study on the Influences of DPV-2000 Software Parameters on the Measured Results in Cold Spray

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The velocity of particles prior to impact on the substrate is the predominant determinant of deposition characteristics and coating quality in cold spray. DPV-2000 system is an on-line diagnostic system of in-flight particles, which can measure the temperature, velocity and size of the particles simultaneously. In our previous research, DPV-2000 system was used to measure the velocity and size of in-flight particles in cold spray process, and it was investigated how the pre-setting values of some software parameters affected the measured results of velocity. In this paper, the influences of the other software parameters of DPV-2000 on the measured results are discussed. It was found that the pre-setting values of these software parameters gave significant influence on the accuracy of measured results of in-flight particle velocity.

1 Introduction

Cold spray is a relatively recent coating technology, where coating can be formed only when the velocity of in-flight particles exceeds a critical velocity [1]. Therefore, velocity is a key factor in cold spray. DPV-2000 system has been used to detect velocity, temperature and diameter of in-flight particles in thermal spray, and the measurement accuracy of Plasma Spray and HVOF is relatively high [2, 3], while a few studies have been reported on the measurement of particle velocity with DPV-2000 in cold spray, and the measurement accuracy of cold spray is not well understood [4, 5]. The work presented in this paper gives an answer to this problem. Three software parameters of DPV-2000 system, Capture Depth, No Quiet Zone (offset) and Insufficient Modulation, were tested by experiments and the effects on the measured velocity of in-flight particles in cold spray were clarified. Those parameters were explained in the manual of DPV-2000 [6].

2 DPV-2000 system

The measurement of temperature, velocity and diameter of in-flight particles with DPV-2000 is based on thermal radiation emitted from the particles at high temperature. However, the radiation intensity emitted from the particles is too weak to be detected with the optical sensor beacuse of the low temperature of particles in cold spray. Therefore, in order to detect signals from the particles, a high-power laser from CPS-2000 beams to the particles. And then the sensor in DPV-2000 can detect the light scattered by in-flight particles. **Figure 1** shows the schematic illustration how DPV-2000 system works [6].

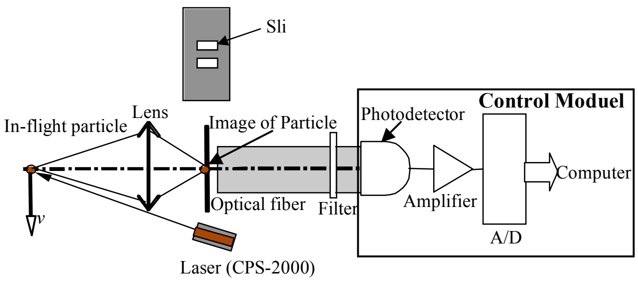

Fig. 1 Schematic of DPV-2000 system used in Cold Spray

When a particle flies in front of the lens and the particle image will pass the two-slit photomask, a two-peak signal will be generated by the scattered light and then transmitted into the control module through the optical fiber. **Figure 2** shows a illustration of typical two-peak signal detected with DPV-2000 system. The particle velocity "v" is defined as

$$v = s/TOF \times \text{Optical Magnification of the lens} \quad (1)$$

where *TOF* and "*s*" are flight time of the particle image and the distance between the two slits, respectively [6].

Capture Depth is the width of the acquisition window which is a time unit for analyzing signals as shown in **Fig. 2**. In order to find out a full signal in a acquisition window correctly, the system will identify two relatively flat regions, L and M, at each side of the signal, to ascertain the baseline of the signal as shown in **Fig. 2**. The identified regions are referred as Quiet Zones (QZ). The location of QZ is defined as

$$L = X - \text{offset}*(Y-X) \quad M = Z + \text{offset}*(Z-Y) \quad (2)$$

where offset is a cofficient as a software parameter of he DPV-2000 system to change the location of QZ. The manual referred it as No QZ (offset) [6]. The third parameter, Insufficient Modulation, is defined as 1-A/B as shown in **Fig. 2**.

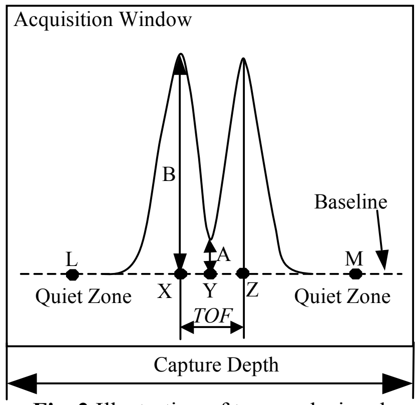

Fig. 2 Illustration of two-peak signal

3 Experimental procedures

A cold spray system developed by Plasma Giken Co. Ltd was used in the experiments. The powder was commercially available Al powder (-45 μ m) as shown in **Fig. 3**. Tecnar's DPV-2000 and CPS-2000 system was utilized to measure in-flight particle velocity, altering one of the three parameters and keeping the others constant.

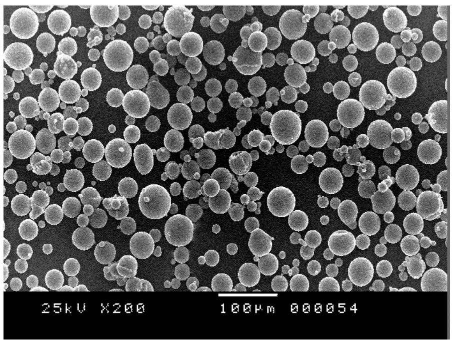

Fig. 3 SEM image of the Al powder

4 Results and discussions

A signal is recognized good only when the two-peak signal meets the criteria demanded by the software. **Figure 4 (a)** shows that the number of good signals sharply rises as Capture Depth increases until about 10 μ s, and drops when Capture Depth exceeds this value. This means that the number of signals captured in certain time decreases, as Capture Depth increases.

Figure 5 shows an example of the two-peak signals detected by the DPV-2000 system. When Capture Depth is less than 10 μ s, the width of the acquisition window is possibly narrower than the twice *TOF* of low-speed particle signals. It means that the two-peak signals generated by low-speed particles cannot be fully contained in the acquisition window and only high-speed particles be recognized as good by the criterion as shown in **Fig. 5 (a)** and **(b)**. **Figure 4 (b)** shows an evidence that particle velocity lower than about 460 m/s cannot be captured when Capture Depth is 3 μ s. **Figure 4 (b)** also shows that when the Capture Depth is larger than 10 μ s, the velocity faster than 320 m/s can be detected. Nevertheless, when an acquisition window contains more than one good signal, only the first good signal can be taken and the other good signals are rejected bu the system as shown in **Fig.5 (c)**. Therefore, the number of good signals decreases as shown in **Fig.4 (a)**.

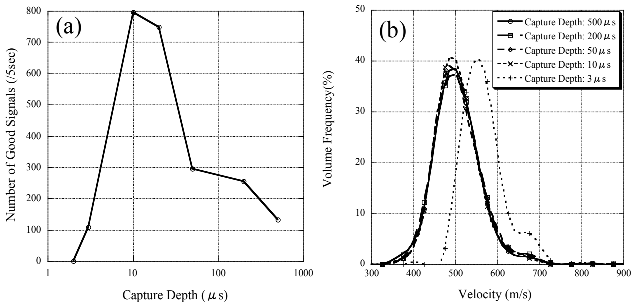

Fig. 4 Effects of Capture Depth on the number of good signals (a), and velocity distribution (b)

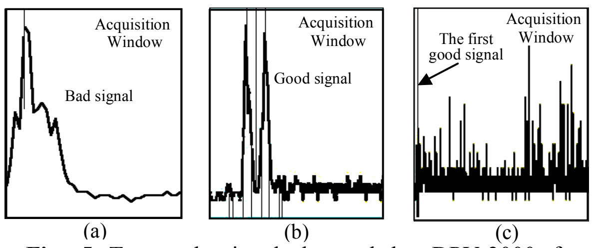

Fig. 5 Two-peak signal detected by DPV-2000 for different Capture Depth (a) 2 μ s, (b) 10 μ s, (c) 500 μ s.

Figure 6 (a) shows that the number of good signals is hardly affected until Insufficient Modulation increases to 90% and sharply decreases with its further increase. This is because the demanded signals by DPV-2000 are more near to the ideal signal but real signals are not good enough to meet the criterion. **Fig. 6 (b)** also shows that particle velocity hardly depends on Insufficient Modulation.

Figure 7 (a) shows that the number of good signals increases with the increasing of No QZ (offset) until about 100% and retains almost constant when No QZ (offset) exceeds the value. When No QZ (offset) is less than 100%, the position of QZ is located inside the two-peak signal so that it is difficult to find relatively quiet regions which can be identified as QZ as shown in **Fig. 8**. Consequentely, the signal cannot be counted as a good signal because the baseline is not able to be found. The influence of No QZ (offset) on particle velocity distribution is shown in **Fig. 7 (b)**. Measured particle velocity distribution is greatly affected by No QZ (offset) and when the value of No QZ (offset) exceeds 150%, the distributions are almost the same as shown in **Fig. 7 (b)**. Threrfore, No QZ (offset) must be set up at more than 150% to obtain accurate data.

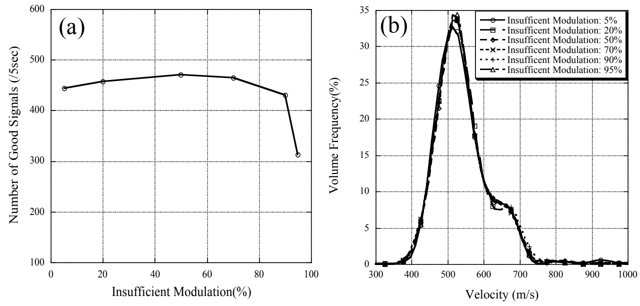

Fig. 6 Effects of Insufficient Modulation on the number of good signals (a), and velocity distribution (b)

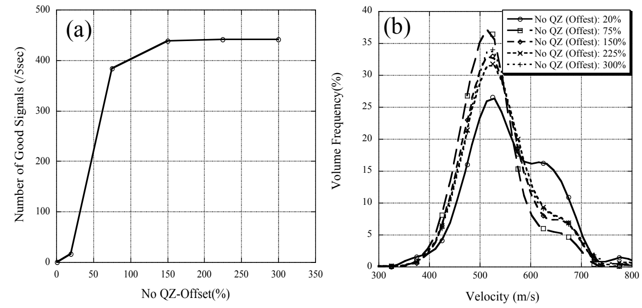

Fig. 7 Effects of No QZ (offset) on the number of good signals (a), and velocity distribution (b)

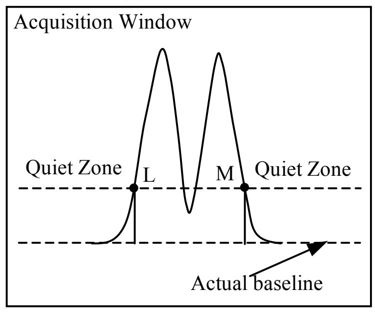

Fig. 8 A signal when No QZ (offset) is less than 100%

5 Conclusions

The three soft parameters, Capture Depth, Insufficient Modulation and No QZ (offset), have relatively significant influence on the number of good particles, respectively. Capture Depth and No QZ (offset) have also influences on the distribution of particles velocity.

6 Reference

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