Improved Thermal Spray Consistency Via Plume Sensors -An Aerospace Perspective

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Abstract

Plume Sensor Technology can assist the conventional thermal spray shop to improve process consistency and output for many different process categories. In spraying of abradables, analysis of the powder injector site with the SprayView System can help determine the best injection site and combination of powder and carrier gas. For Cold Spray, with the critical nature of terminal velocity for many materials and dependence upon particle size/distribution, the DPV/CPS 2000 system can assess the seed and size distribution in the plume via laser technology. With HVOF and any other conventional thermal spray process, the balance of thermal energy (temperature), intensity (powder feed and thermal mass), and speed (velocity) are critical to process success and can be measured by the Accuraspray System with the additional input of monitoring maximum substrate temperature on the same screen. The Plume Sensor data can be relied upon in conjunction and correlation with microstructural, tensile, and hardness data to meet and exceed stringent aerospace specifications. In the present paper, the use of the Accuraspray system in real production situations will be discussed and highlighted.

Introduction

When assessing use of the plume sensor, the initial task is sometimes educating the potential user on the information which the system provides. The bottom line of a plume sensor is providing <u>*real time*</u> data on what is coming out of the plasma gun for the purpose of making <u>*instantaneous process decisions*</u> in lieu of waiting for the metallurgical specimens to tell the operator if the spray meets established acceptance criteria.

The Accuraspray can be used as a comparison tool (easiest implementation-requires little if no baseline data) for:

- Comparing new powder lots with the existing powder lot (with passing results) to insure the new lot will have similar results
- Comparing booth set-ups from day to day to shift to shift
- Comparing booth to booth set-ups on same coatings

Plume sensors such as the Accuraspray can serve as a baseline troubleshooting tool when a <u>*failing result*</u> is received from the laboratory. The system can then be used to baseline the *failing* plume characteristics and allow the operator to *improve* the plume to achieve passing results. For instance, if porosity and unmelts are the issue, an increase in temperature is in order. The operator/engineer can then work within the operation sheet to make positive changes for *passing results*. Furthermore, the existing baseline of a *passing* coating can be used to:

- Increase deposition efficiency
- Use a cheaper powder
- Develop parameters for a new part using current data from the Accuraspray

Comparison and baseline troubleshooting will improve both turnaround and delivery with reduction in failed samples and stripping of coatings.

For longer term, the Accuraspray can be used as a tool to establish baselines and spray windows (requires time and commitment of both lab and production in long term project) allowing the spray location to gather information for:

- Day to day usage
- Correlation of lab data/microstructures to Accuraspray data
- Training sprayers to understand trends

In any situation, the Accuraspray or any plume sensor tool can significantly enhance process consitency and reproducability.

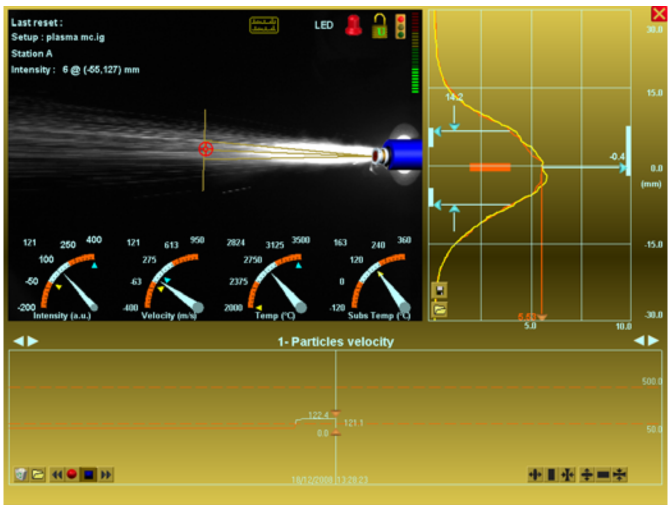
Accuraspray Usage Examples

Accuraspray usage at varied locations has been documented to improve and characterize various thermal spray processes. Experiments carried out at two different facilities where the system has been used will be summarized and discussed.

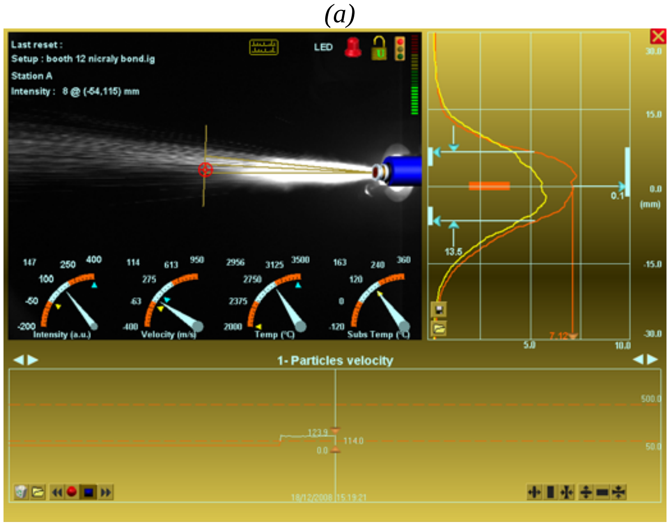
Location 1

Booth A

In the spraying of a NiCrAlY bond coat, the lab indicated that the oxide content was trending to the marginal level. Review indicated the gun hardware was at the 13 hr mark on a 20 hr rebuild cycle. Figure 1 shows the profile of the plume at 13 hrs. A decision was made to rebuild the gun (Fig. 2) and a new lab sample submitted. The results of the lab sample showed significant reduction in oxides and an increase in the acceptable process window. Continued and future use of the Accuraspray in the booth should result in a pro-active change of hardware when the characteristics of a Fig. 1a plume are achieved.



(a)



(b)

Figure 1. Comparison of used gun hardware (yellow baseline)(a) with new gun hardware (orange baseline)(b)

Booth B

In the spraying of a Metco 81 VFNS, the lab indicated that the porosity and unmelt content was unacceptable and resulted in a failing sample. The Accuraspray was set-up to establish the *failing* baseline and characterize the plume. By changing the powder feed rate, gas flows and power in a combined effect in lieu of changing single parameters and submitting multiple lab samples, improved and passing lab results were achieved in submittal of only two (2) lab samples. Continued and future use of the Accuraspray in the booth should result in a pro-active characterization of the 81 VFNS process understanding hardware hours and using optimum parameter settings.

Booth C and D

In discussions with engineering and production personnel, the T-800 was chosen as a first trial balloon for establishing a baseline and beginning to develop long term (LT) data. There have been problems with porosity, unmelts, and oxides with this coating and problems with trying to spray with nearly the same parameters in two different booths. There were also four (4) suppliers of T-800 which further complicated the production situation of two (2) different booths. As the powders and booths were analyzed, temperatures, velocities, and stand-offs were optimized to achieve an optimum microstructure (Figs. 2-5). Cluster oxides were still an issue and traced to cooling air issues that were partially solved with new air placement.

Table 1 T-800 Evaluation.

Run	Intensity	Velocity	Temperature	Booth	Powder	Comments
1	39	187	2967	C	Target	Baseline
2	76	202	3601	C	New	Temperature and Intensity Change
3	38	228	3455	D	Target	Velocity and Temeporature Change
4	81	236	3937	D	New	Change in All Parameters

Location 2

At Location 2, a traditional analysis of varied plasma parameters was performed. In traditional control of thermal spray processes, there is a plus/minus $\pm$ tolerance around parameters such as gas flow, amperage, voltage, etc. Varied parameters were selected and "box" or process map drawn around the tolerances. This was performed on both used and new gun hardware to analyze how the outputs varied when different combinations were used. Figures 6 and 7 show the comparison of the new and used electrodes.

In Figures 8 and 9, a comparison of new and used hardware can be observed for Metco 450 powder. Primary gas pressure and flow (PGP and PGF), secondary gas pressure and flow (SGP and SGF), powder feed gas pressure and flow (PFGP and PFGF), powder feed rate (PFR), and amperage (AMP) were varied. The zero mark on the graphs is the midpoint of the setting range or what normally an operator would dial into

Figure 2 Plume Profile of Target Powder with Acceptable Results (yellow line)-Booth C

Figure 3 Plume Profile of Another Powder (orange line) with Target Powder (yellow line)-Booth C. Note 600°C difference in temperature

Figure 4 Plume Profile of Target Powder(orange line) in Booth D compared with same Target Powder (yellow line) in Booth C. Note 400°C difference in temperature and increased velocity

Figure 5 Plume Profile of New Powder(orange line) in Booth D compared with original Target Powder (yellow line)-Booth C. Note 1000°C difference in temperature and increased velocity.

Figure 6 Comparison of New vs. Used Electrode

Figure 7. Comparison of New vs. Used Nozzle

the control console. The temperature, velocity and intensity of plume were plotted for review and analysis.

As can be seen from the comparsion, the temperature shows the major effect of a change in gun hardware for Metco 450.

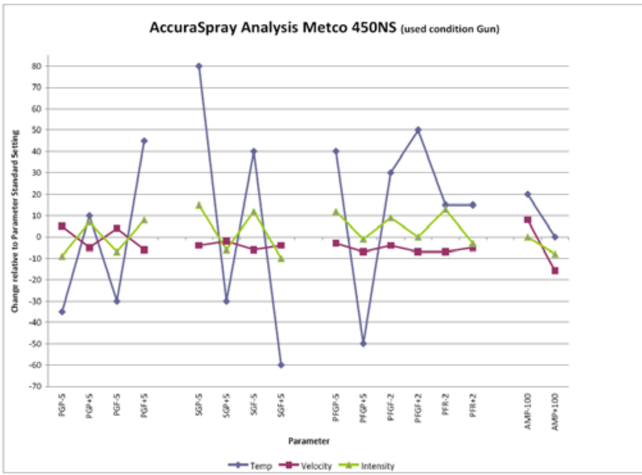


Figure 8 Metco 450 with Used Hardware

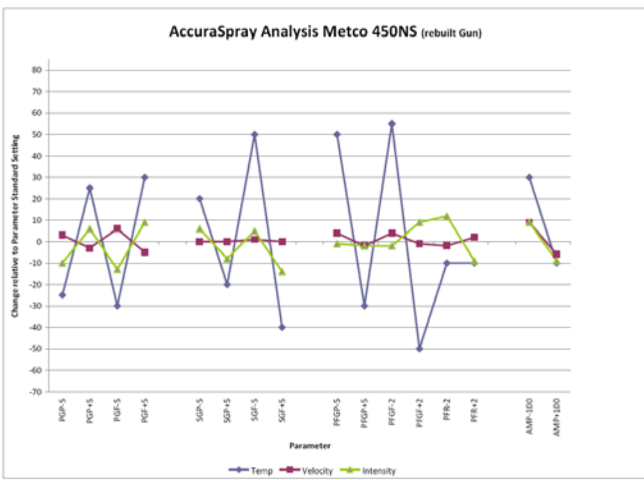


Figure 9 Metco 450 with New Hardware

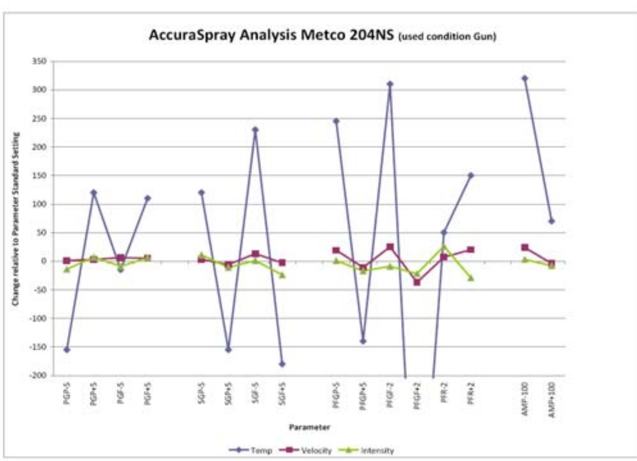


Figure 10 Metco 204 NS with Old Hardware

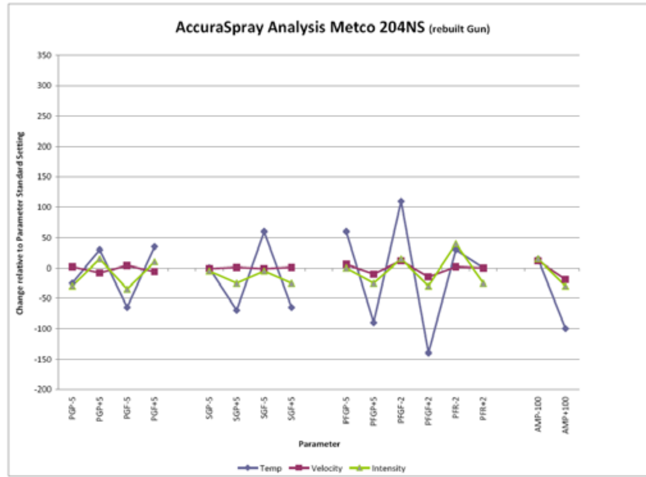


Figure 11 Metco 204 NS with New Hardware

As can be seen from the comparison with Metco 204NS, the temperature variation was significant enough to cause a a microstructural failure in quality control. In reviewing Figs. 6 and 7, one might ask the question: does an operator need a plume sensor to observe the obvious degradation of the electrode and nozzle? However, the more important question is: can we predict the temperature with the Accuraspray (and the gun hardware degradation) at which the onset microstructure failure occurs? Does the operator posess enough experience to visually determine the exaxct moment at which the worn gun parts wil cause a failing test? With the obvioue answer that they cannot predict with palin observations, the Accuraspray plume sensor information would allow us to be proactive and prevent delivery issues and eliminate probable stripping of sprayed hardware. Plume sensors can be valuable and useful tools in daily production.

Summary

Evidence has shown that use of plume sensors in production can result in improved consistency and reliability. With HVOF and any other conventional thermal spray process, the balance of thermal energy (temperature), intensity (powder feed and thermal mass), and speed (velocity) are critical to process success and can be measured by the Accuraspray System. The Plume Sensor data can be relied upon to provide comparisons of powder lots, baselines for introduction of new powders, and transfer of parameters from booth to booth. When failed samples from the laboratory are obtained, the Accuraspray plume sensor allows for baseline of the failed gun condition and insight into changes which can result in passing lab results. Long term usage can result in process mapping and acceptance ranges for plume values such as temperature, velocity, and intensity. This data in conjunction with microstructural, tensile, and hardness data will allow thermal spray facilities to meet and exceed stringent aerospace specifications on a consistent basis now and in the future .

Reference

1. J. Blain, L. Pouliot, F. Nadeau,M. Lamontagne, C. Moreau,, Optimization of Sensor Optics for Industrial Thermal Spray Sensors, in Global Coating Solutions Proceedings of the 2007 International Thermal Spray Conference, Ed. Beijing, China, May 14–16, 2007, p832
2. L. Pouliot, J. Blain, F. Nadeau,J. F. Bisson, M. Lamontagne,C. Moreau, Significant Increase in the Sensitivity of in-Flight Particle Detector through Improvements and Innovation, in Thermal spray 2001-New Surfaces for a New Millenium, Ed. C. C. Berndt, K. A. Khor, E. F. Luscheider, 28-30 May, 2001, p723
3. J. Blain, L. Pouliot, F. Nadeau, J. -F. Bisson, G. Vaudreuil, C. Moreau, Integration of a Feedback Controller into a Standard in-Flight Particle Sensor in Thermal Spray 2003; Advancing the Science and Applying the Technology, Ed. B. R. Marple, C. Moreau, 2003, p1131
4. B. R. Marple, R. S. Lima, C. Moreau, S. E. Kruger, L. Xie, M. Dorfman, Processing and Properties of Yttria-Stabilized Zirconia Tbcs Produced Using Nitrogen as Primary Plasma Gas, in Global Coating Solutions Proceedings of the 2007 International Thermal Spray Conference, Ed. Beijing, China, May 14–16, 2007, p405

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