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Solutions Flash

Real-time sensor technology improves process control while reducing time and cost

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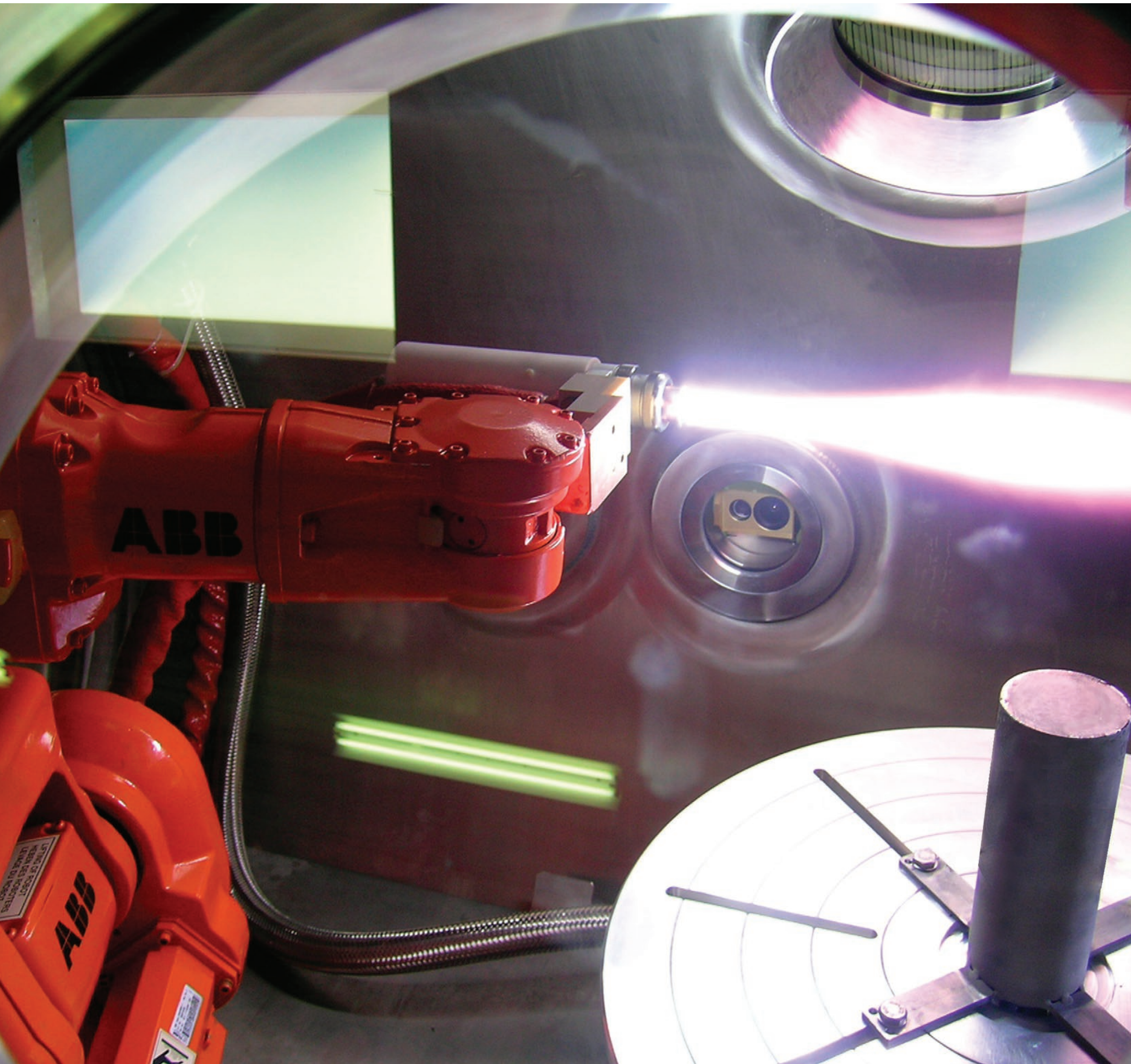


Today's situation

As is the case with many industrial processes, control of the thermal spray process continues to improve so that results are more predictable and reproducible. Materials have tight controls on chemistry and particle size. Spray equipment is increasingly more sophisticated and reliable, reducing the potential for process drift and improving efficiency. Post-coating characterization methods are better understood and more widely employed.

However, the last 'black box' of thermal spray, that of what occurs in the spray plume, could not be conveniently monitored and analyzed as part of the production process. Quality control for thermal spray coatings is often destructive in nature, requiring that test coupons or test parts be routinely sprayed during production. These test pieces, examined post production, are used to determine if that entire coating run meets the required specifications. Failure means expensive rework or scrap, not to mention loss of valuable production time and materiel.

The Oerlikon Metco solution

The thermal spray plume can now be diagnosed through the use of real-time sensor technology. By integrating spray plume monitoring and control earlier in production, greater process reliability, reduced processing time and reduced processing costs can be realized.

What is on-line sensor technology?

Real-time sensor technology uses optics combined with sophisticated computer algorithms to continuously monitor and characterize the thermal spray plume and provide feedback in real time.

Oerlikon Metco and our technology partner, Tecnar Automation Ltd., provide packages that fully characterize the spray plume through the measurement of:

- Average particle velocity and temperature
- Spray plume intensity, position and geometry
- Substrate temperature (optional)

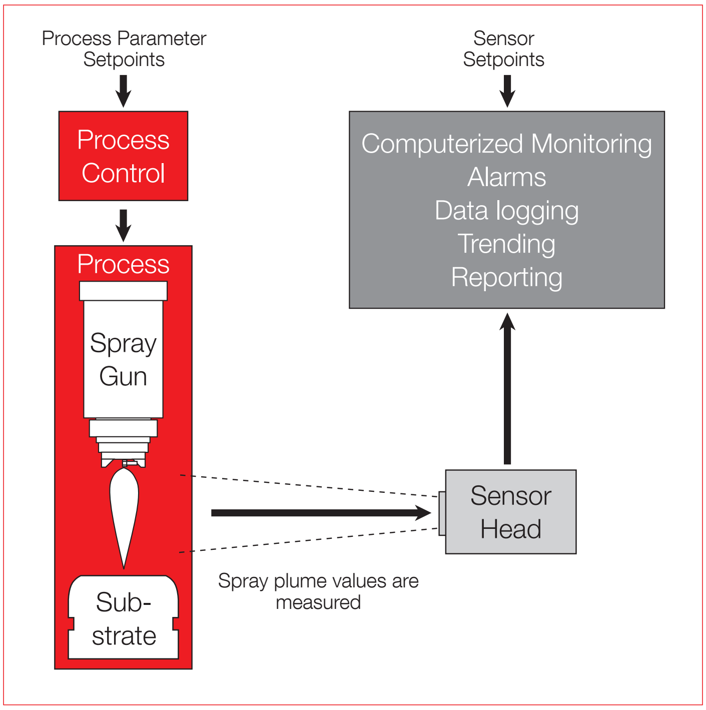
During the coating process, data is captured continuously on a real-time basis by a high sensitivity sensor and processed through a PC. The data is displayed in real-time and recorded, which is easily imported for further off-line analysis. Minimum and maximum values for all parameters are operator-adjustable, with alarms for out of limit conditions.

Tecnar Accuraspray-4.0

The Accuraspray-4.0 from Tecnar Automation Ltd., precisely monitors and characterizes the thermal spray plume in real time. The system measures:

- Particle velocity and temperature
- Spray plume geometry and position
- Substrate temperature (optional)

The Accuraspray-4.0 notifies the operator if spray conditions exceeds predetermined processing windows, and also provides spray run reports that can include data logging and trending.



Real-time sensor technology

The Tecnar Accuraspray 4.0 system shown with sensor head.

Solution description and validation

Demonstrating real-time sensor control using an abradable coating as an example

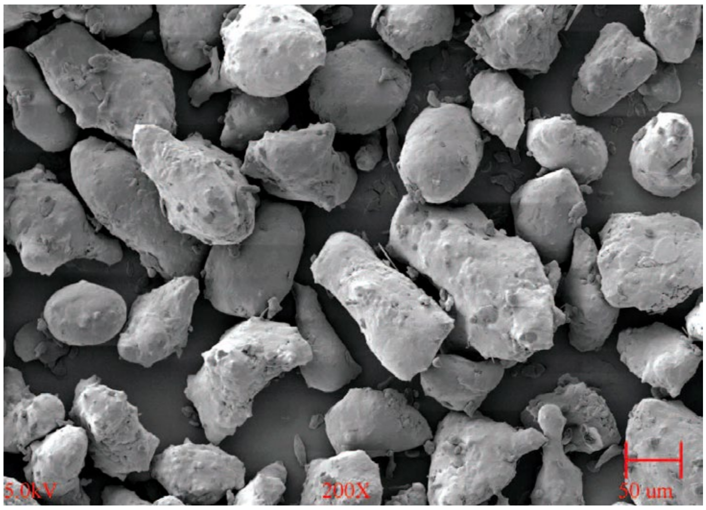
Application of a clearance control abradable coating provides an excellent case study to demonstrate the benefits of real-time sensor technology:

- Abradable coatings are often applied to large components and with a high thickness, requiring spray campaigns of an hour or more per component.
- Post-coating quality evaluation is intensive. In addition to metallographic evaluation, coating hardness, bond strength and erosion resistance tests are performed.
- Coating hardness and erosion resistance are inversely proportional to abradability. Desirable values are optimized to the specific service requirements.
- Deposit efficiency is a critical concern for abradable coatings, because of the large quantities of the coating material used and the long spray campaigns. Therefore, optimized spray parameters are highly desirable.

For this case study, Metco 301NS abradable material, applied using the Combustion Powder ThermoSpray™ process, is used to demonstrate how real-time sensor technology can be used to best advantage.

Spray Process Information (for reference)

Coating material	Metco 301NS, a NiCrFeAlBN abradable coating material for turbine engine clearance control applications
Coating process	Combustion Powder ThermoSpray, which is the standard process used to apply this abradable material
Spray gun	Metco 6P-II
Process gases	Hydrogen / Oxygen
Sensor control package	Tecnar Accuraspray-4.0

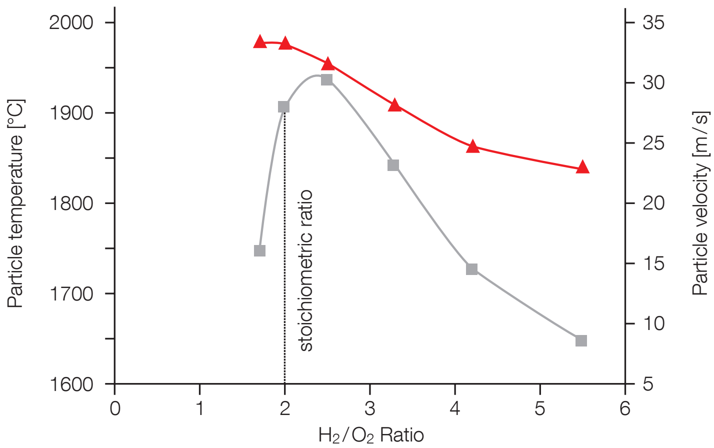


Metco 301NS composite powder for abradable applications

Dependence of particle temperature and velocity on the hydrogen / oxygen ratio

To ensure the robustness of the process, it is important that the parameter window is not in a region where relatively minor changes in the process can result in large changes in the coating.

Using real-time sensor technology, various hydrogen / oxygen ratios can be investigated. In the case of Metco 301NS, these investigations indicate that the particle temperature decreases rapidly in a lean mixture. Therefore, in this case, a rich gas mixture should be used.



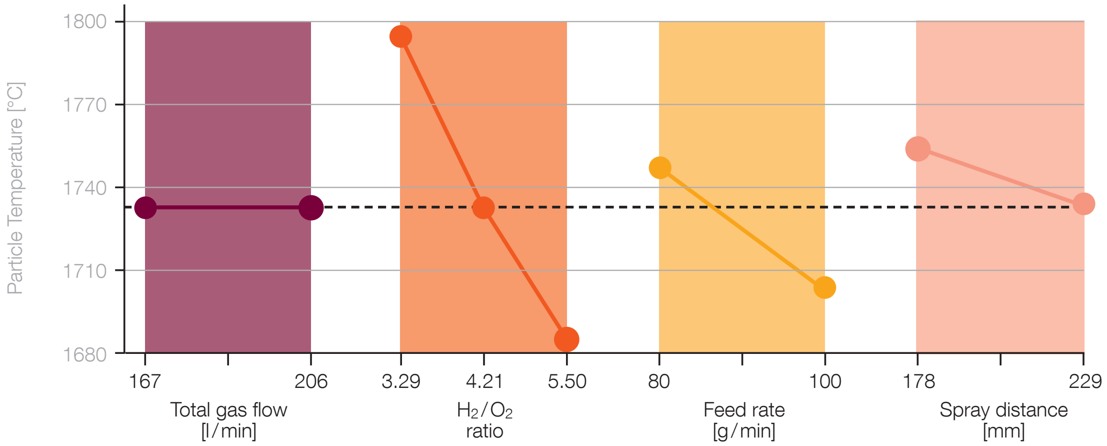
Real-time sensor technology was first used to establish the most stable area of the process window. In this case, it shows that a rich ratio of hydrogen to oxygen should be used.

Parameter effects on particle temperature and particle velocity

Using real-time sensor technology, it can be determined how changes in various spray process parameters will affect spray plume particle temperature and velocity. In a combustion powder spray process, parameters that are most often changed are:

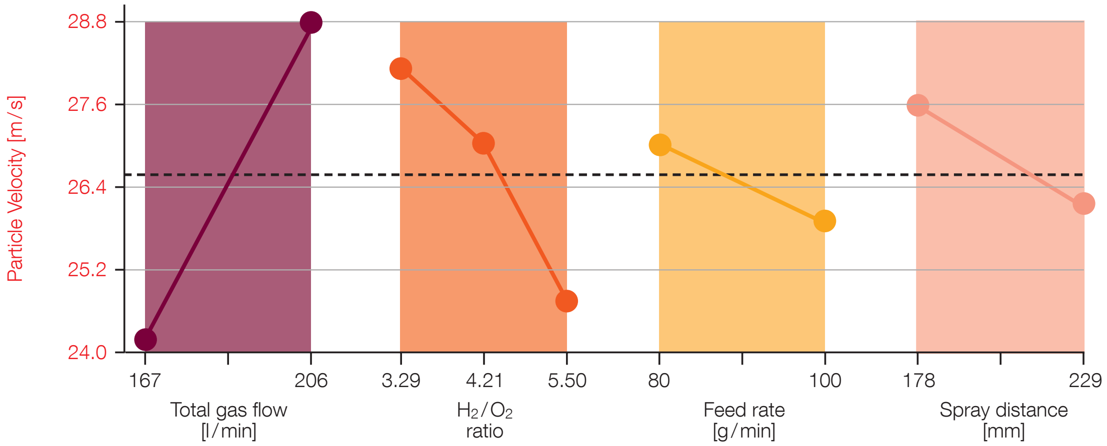
- Total gas flow
- Fuel/oxygen ratio (using rich mixtures as previously determined)
- Powder feed rate
- Spray distance

Factors that influence particle temperature



Total gas flow	No Influence.
Hydrogen/oxygen ratio	Strong influence. The highest particle temperatures are close to the stoichiometric composition.
Feed rate	Moderate influence. More particles consume more heat, so average particle temperature is cooler.
Spray distance	Moderate influence. As the gun to work distance increases, the particles are cooler when they impact the substrate.

Factors that influence particle velocity



Total gas flow	Strong influence. Flow and particle velocity are directly proportional to the total gas flow.
Hydrogen/oxygen ratio	Strong influence. Spray particles exhibit the highest velocities near the stoichiometric ratio.
Feed rate	Moderate influence.
Spray distance	Moderate influence. As the gun to work distance increases, the particles are slower when they impact the substrate.

Correlation with coating quality testing

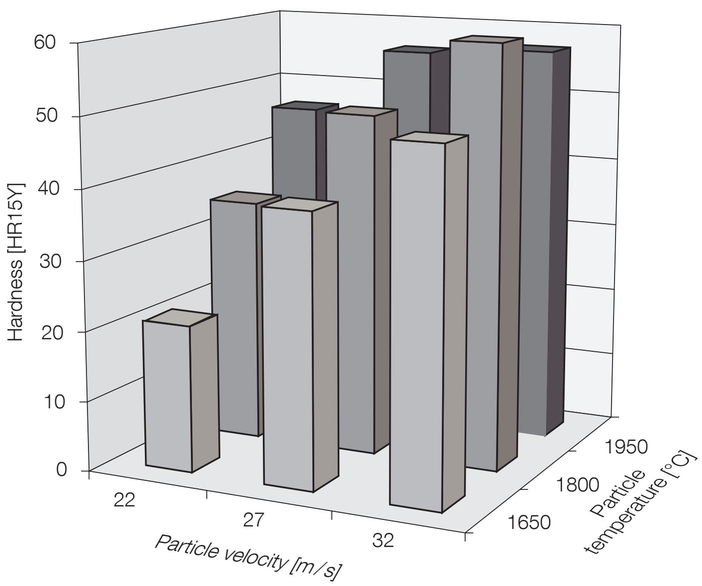
Once an understanding is established on how the coating parameters will affect the spray plume, samples are coated as spray plume data is collected. These samples are then subjected to the standard quality tests. The results of the tests are correlated with the spray plume data, establishing a spray window for coating production.

In production, the real-time sensor technology will monitor the process and alert the operator to spray plume conditions that fall outside of the established window, allowing the operator to take the appropriate action prior to completion of the spray run.

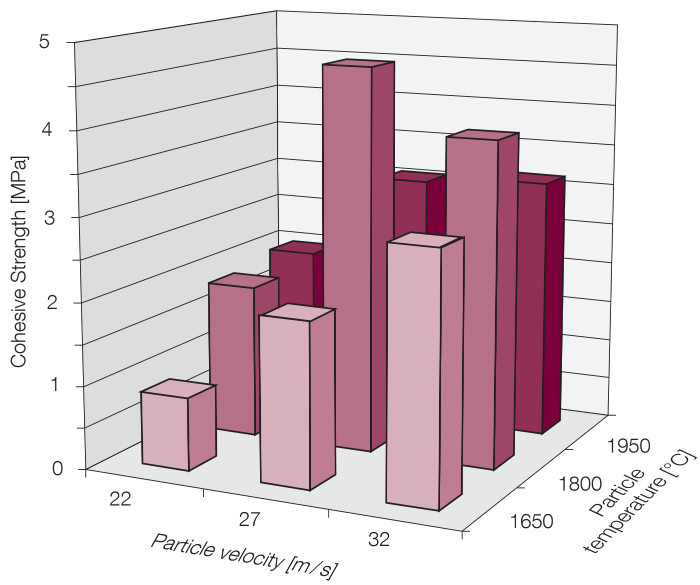
For the test case abradable coating described here, spray rate and distance, having only a moderate influence on the plume, were held constant, while gas flow rates were varied.

Optical sensor technology in combination with properly chosen tests provide data that characterize the spray process, as shown in the following four graphs:

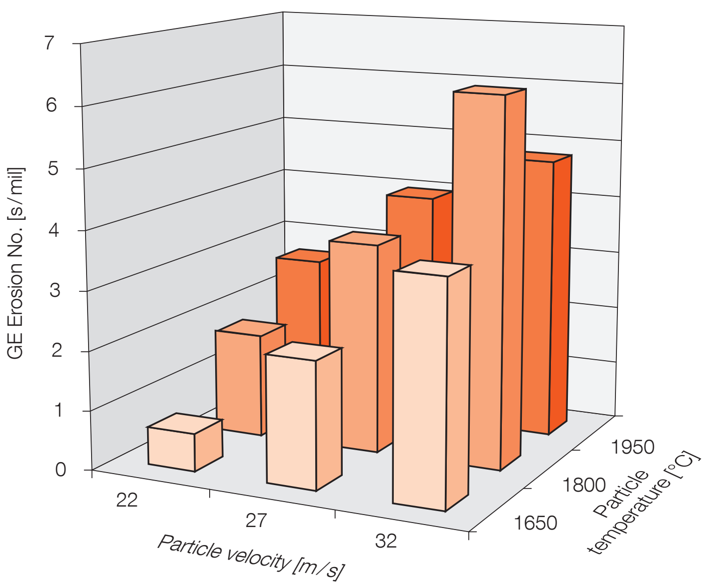
Coating hardness



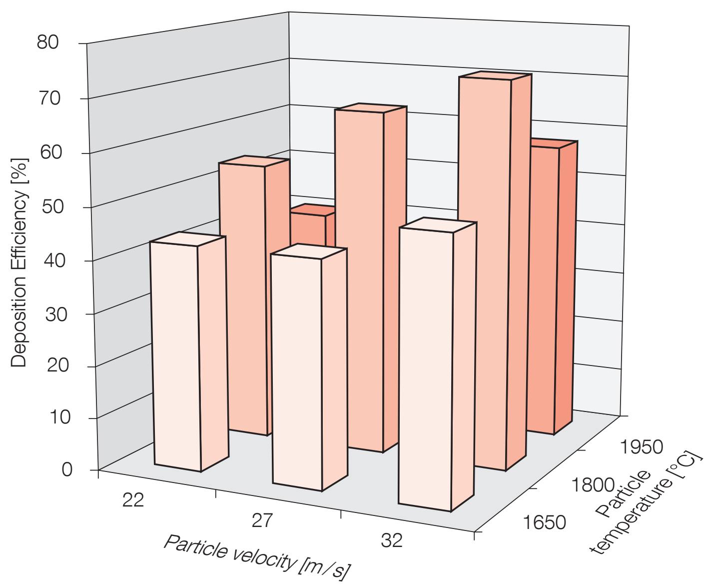
Coating choesive strength



Coating erosion resistance



Material deposition efficiency



Note**:** All data presented is for example purposes only. Customer's own sensor data and coating results will vary depending on the actual part coated, equipment set-up, powder lot and actual spray conditions.

Customer benefits

Production benefits

- Potential problems can be resolved earlier in the production process.
- Optimized spray parameters can be developed, which can reduce the cost of material, spare parts and production time.
- Improved process reproducibility through the reduction of process drift from worn gun consumables, gas variability, etc.
- Booth to booth or facility to facility spray process transfer can be efficiently managed.
- Parameter adjustment for lot-to-lot differences in spray materials is straightforward and logically executed.
- Costly rework and scrap can be greatly reduced.

Quality control benefits

- The number and frequency of quality control tests can be reduced as a result of very good correlation to other quality tests.
- Spray process traceability is improved.
- Potential for improved coating serviceability through correlation of coating service data with records of spray plume data.

Environmental benefits

- Faster development of new spray parameters.
- Parameter optimization results in higher spray rates and better deposit efficiencies.
- Qualification of new powder lots is accelerated.

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