Solutions Flash

Cause and effect of Metco 320NS spray parameters for optimization of coating hardness and service life

SF-0010.2 – June 2022

Today's situation

Metco 320NS is an aluminum silicon-boron nitride powder that conforms to Rolls-Royce specification MSRR 9507/66. It has been approved as a high temperature compressor abradable for various Rolls-Royce engines, replacing other abradable materials for service temperatures up to 450 °C (842 °F). Coatings of Metco 320NS offer improved corrosion resistance, particularly in marine environments. It employs hexagonal boron nitride as a lubricant, which is more inert than other solid lubricants, such as graphite.

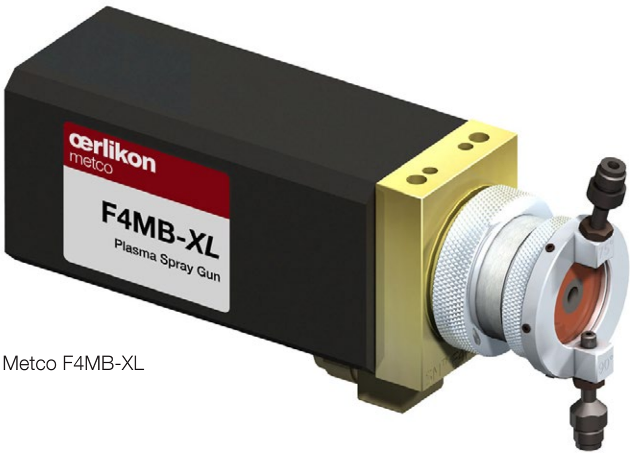
Based on extensive research, it can be clearly demonstrated that coating hardness is a critical quality control measure for understanding operational performance of Metco 320NS.

An understanding of macrohardness in this abradable coating system allows the designer to predict coating microstructure, erosion resistance, bond strength and residual binder (post-treatment). These properties can affect the overall service life of Metco 320NS coatings.

Guidelines for the control of coating hardness are identified in Rolls-Royce specifications 1; however, the best way to adjust spray parameters to achieve the recommended hardness may not be intuitive.

The Oerlikon Metco solution

The ability to adjust hardness within the Rolls-Royce specified window of HR15Y 45 to 70 is best controlled by adjusting the particle velocity. Through empirical data gathered using a series of design of experiments, this is best achieved by adjusting primary gas flows when using a Metco F4 series or 9MB series plasma spray gun.



Metco F4MB-XL

Metco 9MBM

Solution description and validation

Typical Metco 320NS coating design features

The key design features of aluminum silicon (AlSi) hexagonal boron nitride (hBN) coatings are clearly defined in Rolls-Royce specifications [a]. The AlSi matrix is used in many abradable coating systems because of its good combination of erosion resistance and abradability against various blade materials, including titanium alloys. Solid lubricants such as hBN are used to improve abradability by reducing frictional heating on contact with the blade at high translational speeds. The lubricant also helps weaken the interparticle bond strength within the aluminum silicon matrix for better friability.

To meet Rolls-Royce specifications, coatings of Metco 320NS must have a macrohardness range of HR15Y 45 to 70.

[a] CME 5033, Section 2, Standard No. E1 (new manufacture); TSD 594J OP 704 (repair and overhaul)

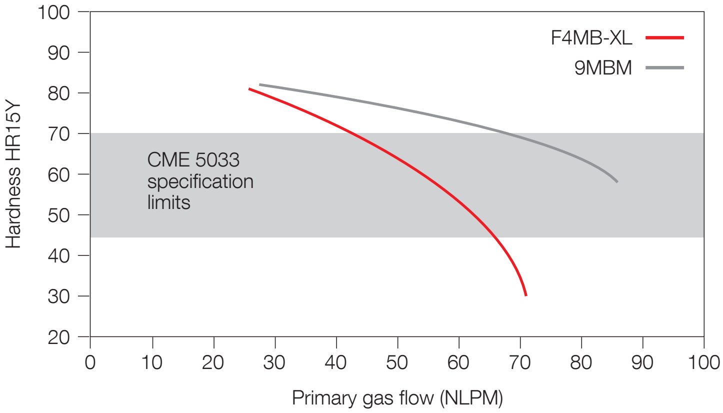
Controlling Metco 320NS coating hardness

Primary gas flow

Based on various design of experiments, it has been verified that primary gas flow is a critical parameter for operators to modify if coatings do not meet the hardness requirement specified. Slight modifications to the primary gas flow should result in coatings that meet the design criteria of the specification. Typically, reducing primary gas flows will result in increased coating hardness and a reduction in deposition rate. Conversely, an increase in primary gas flow will increase deposition rate, but reduce the coating hardness. Therefore, a subtle adjustment to the primary gas flow provides an attractive method to control coating hardness for normal lot-to-lot powder variation and equipment conditions.

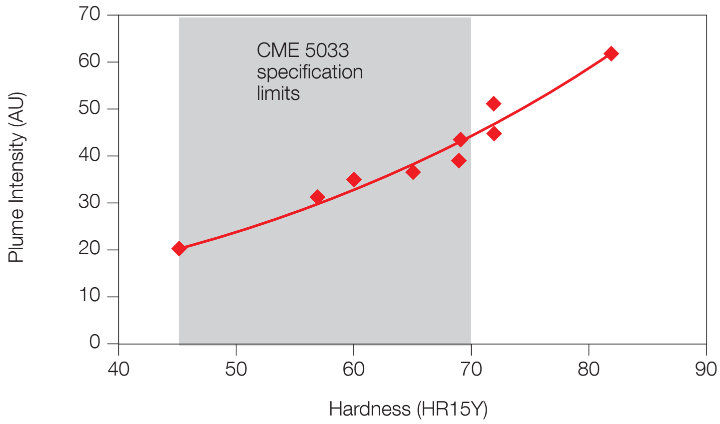
Spray parameters that use the Oerlikon Metco F4 plasma spray gun are more sensitive to gas flow variations, the result being that coating hardness can be easily adjusted throughout the design window by simply modifying the primary gas flow between 30 and 70 NLPM (68.5 and 159.8 SCFH) using a 6 mm nozzle. Using the 9MB spray gun, the GH nozzle is preferred as it readily produces coatings that have a mid-range hardness.

Once the correct coating results have been substantiated for a given lot of powder and equipment condition, the primary gas flow should be maintained.

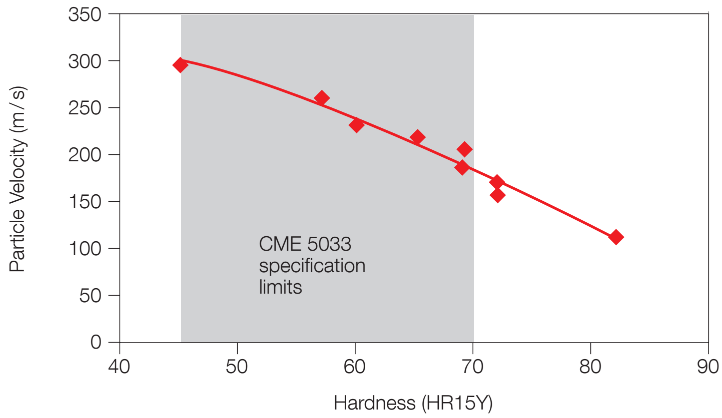


Effect of primary gas flow on coating hardness.

Using online sensor technology (Accuraspray-4.0), we can see how the change in primary gas flow affects both the intensity and velocity of the plasma flame. As expected, flame intensity is directly proportional to coating hardness and velocity is inversely proportional to coating hardness.



Correlation of plume intensity to coating hardness is directly proportional (coatings produced with the 9MB plasma spray gun).

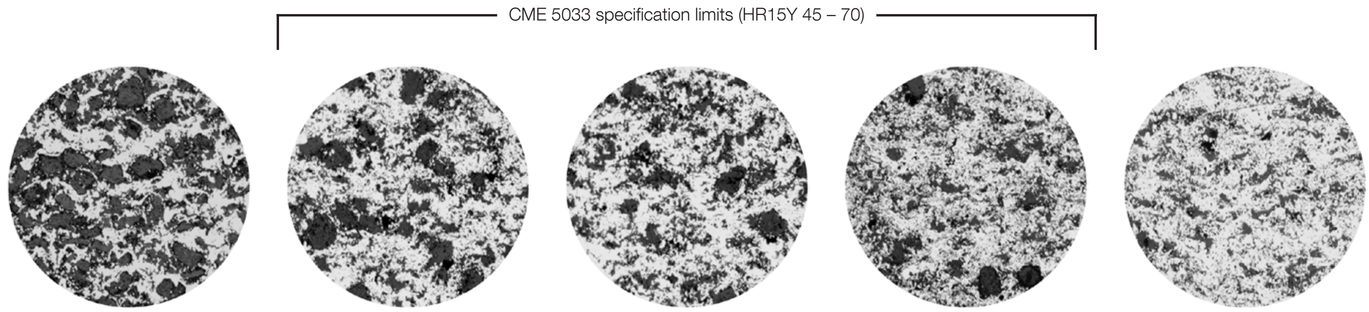


Correlation of particle velocity to coating hardness is inversely proportional (coatings produced with the 9MB plasma spray gun).

Background data

Coating microstructure and hardness

Cross-sectional photomicrographs of Metco 320NS coatings clearly show microstructural variations in phase composition vs. hardness. Coatings with low hardness show higher levels of hBN and less metal-rich phase. Coatings with high hardness show low hBN content and a high metal-rich phase. What is not apparent in this microstructure is the amount of residual binder entrapped within the coating. Binder is used in the manufacture of Metco 320NS to agglomerate the AlSi and hBN and helps minimize hBN loss during the plasma spray process. Techniques for microstructural preparation and hardness measurement require precise control in order to provide accurate and reproducible results. Preparation techniques are detailed in Rolls-Royce specification CME

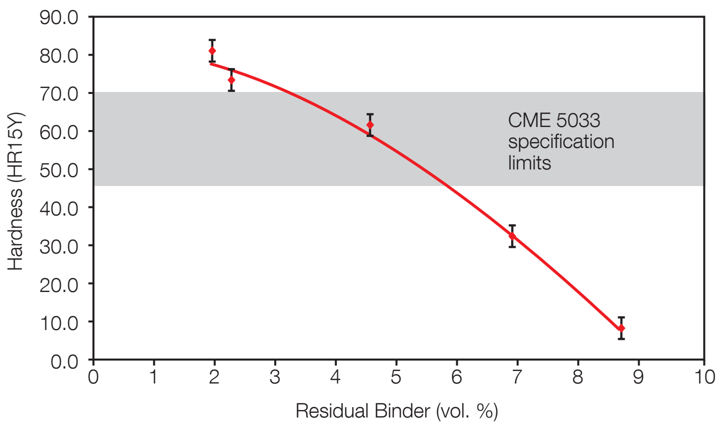


Metco 320NS coating microstructure as a function of coating hardness. The coating hardness decreases with increased hBN content. The coating hardness increases with increased metal-rich phase.

5033 Section 2, Standard No. E1 Appendix 1 (manufacture of new parts) and TSD 594J OP 704 Subtask 70-00-00-300-704-A07 (repair and overhaul). Similarly, methods for hardness testing are defined in Rolls-Royce Rationalized Process Specification 927-1 for the manufacture of new parts and in TSD 594J OP 704 Subtask 70-00-00-340-704-092 for repair and overhaul.

Effects of residual binder

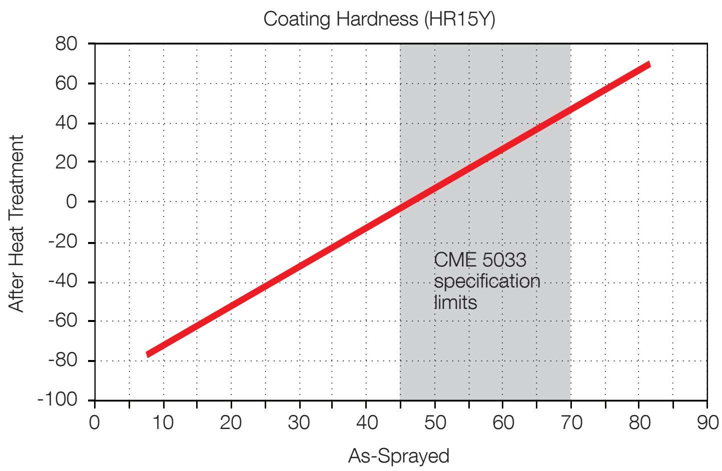
The residual organic binder that remains in the coating burns out in service. This residual has a strong relationship with the as-sprayed coating hardness as shown in the graph below. Typical levels of binder for coatings within the allowable hardness range are 3 to 6 percent by volume. Softer coatings have a higher residual and harder coatings a lower residual.



Thermal Gravimetric Analysis (TGA) of residual binder in Metco 320NS coatings vs. as-sprayed coating hardness.

Effects of ageing

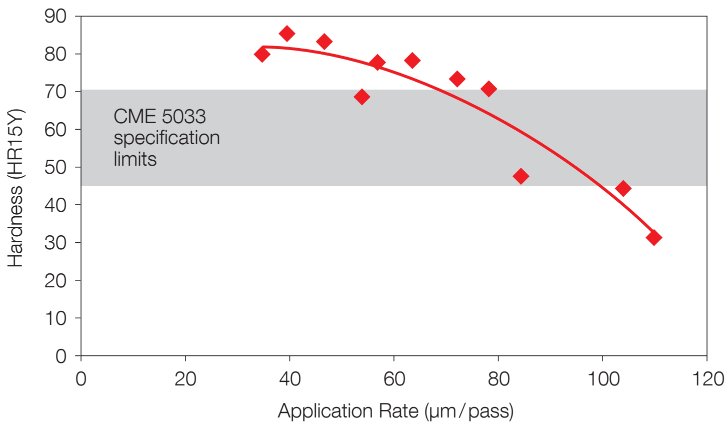
To simulate the effect on coating hardness in service, coatings were subjected to heat treatment at 425 °C for 2 hours. This heat treatment procedure is recommended for initial parameter validation for components to be coated with Metco 320NS as a means to confirm the correct coating characteristics have been achieved. After heat treatment, the microhardness of Metco 320NS coatings is significantly reduced as a result of the volume of binder in the as-sprayed coating that vaporizes on ageing. Softer as-sprayed coatings experience higher hardness reduction in service than harder as-spayed coatings. Therefore, coatings that are too soft as-sprayed may perform poorly in service. This process is used as part of the initial coating validation procedure in TSD 594J OP 704 Subtask 70-00-00-340-704-072.



Effect of as-sprayed coating hardness vs. aged coating hardness. (Ageing simulated by heat treatment at 425 °C for 2 hours)

Coating hardness as a function of application rate

The application rate and deposit efficiency of Metco 320NS coatings are typically higher when softer coatings are applied as a result of reduced residual binder loss and a lower hBN decomposition rate during the spray process. Although this is positive from an economic point of view, it may not be best from a technical view point, and is not recommended. Softer coatings typically have poorer erosion resistance and bond strength. Also note that application rates will change based on the geometry of the component sprayed.

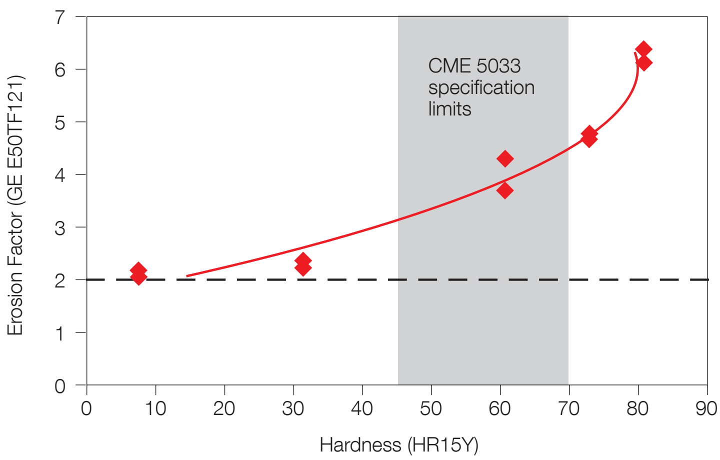


Hardness of Metco 320NS coatings as a function of application rate.

Erosion rate as a function of coating hardness

Erosion testing indicates that a higher coating hardness results in a more erosion resistant coating. This is related to an erosion factor based on the number of seconds per 0.001 in (25 µm) of coating removed. For coatings within the Rolls-Royce CME specification limits for hardness, an erosion factor between 3 and 5 is typical.

- Test method: GE E50TF121
- Impingement angle: 20°
- Control standard: Lexan
- Stand-off distance: 101.6 mm (4 in)
- Erosion media: 600 g of 240 grit
- Thickness gauge: 0.250 ball gauge

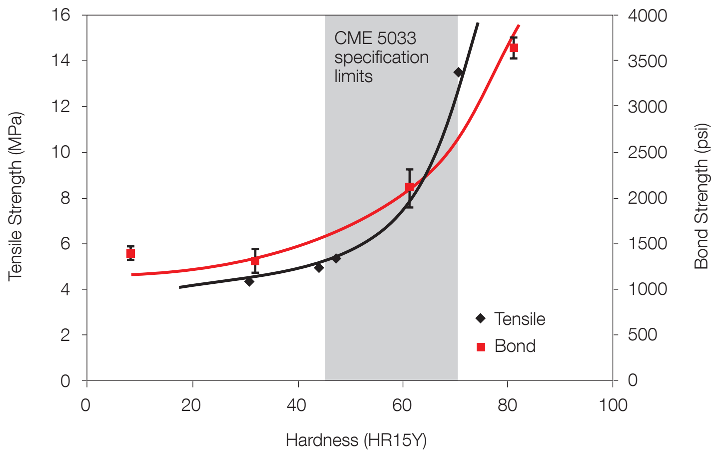


Hardness of Metco 320NS coatings as a function of erosion rate.

Coating hardness versus bond strength

Tensile bond strength testing of Metco 320NS coatings show that interparticle integrity and strength vary with coating microstructure and hardness. In the specified hardness range, the bond strength of Metco 320NS over a bond coat of Metco 450NS (95 / 5 Ni / Al) was approximately 10.34 to 17.24 MPa (1500 to 2500 psi). The variations in bond strength correlate to microstructure variations in hBN, residual binder and metal content.

- Test method: ASTM C633
- Bond bar diameter: 25.4 mm (1 in)
- Coating thickness: 0.76 mm (0.03 in)
- Adhesive: FM 1000 adhesive film
- Adhesive strength: 68.9 MPa (10,000 psi)
- Failure mode: Cohesive (Metco 320NS)



Metco 320NS Tensile bond strength as a function of coating hardness.

Benefits of Metco 320NS

- Hexagonal boron nitride is a good lubricant and more inert than graphite
- Better corrosion resistance, particularly in marine environments, than aluminum graphite abradables
- Good erosion resistance
- Good friability with little blade tip wear or material pickup in specification hardness range
- High operating temperature of up to 450 °C (842 °F) can be used throughout the compressor
- Predictable microstructure and service characteristics based on hardness range
- Predictable spray parameter window
- In General, coating specification can be met through subtle adjustment of the optimized parameters by a change in primary gas flow.

Optimized parameters are available from Oerlikon Metco for the Metco 9MB series, Metco F4 series and TriplexPro-210 plasma spray guns. Please contact your Oerlikon Metco Account Representative for more information.

Customer benefits

Benefits of blade tip clearance control using thermal spray abradable coatings in turbines and compressors

Effective

- Allows turbine to operate at lower temperatures
- Increases engine time-on-wing
- Abradable coatings are tailored to specific design parameters

Efficient

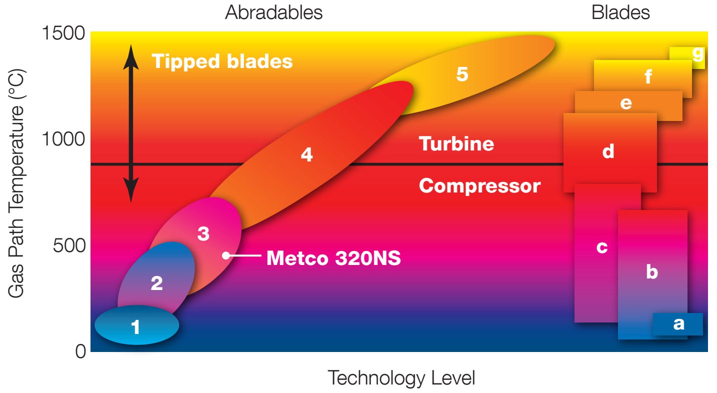
- Increases payload and mission range capabilities
- Increases high pressure compressor (HPC) stall margin

Economical

- Saves fuel
- Reduces maintenance costs
- Coatings are easily removed and reapplied

Environmental

- Reduces emissions — CO_2 and NOx



Abradable Technology
1 Polymer
2 AlSi-Polymer
3 Metal matrix with solid lubricant
4 MCrAlYs
5 Ceramics

Blade Technology
a Fiber-reinforced polymers
b Titanium
c Steel
d Superalloys
e Directionally solidified
f Single crystal
g Oxide dispersion-strengthened superalloys

Acknowledgements

Oerlikon Metco thanks and acknowledges Rolls-Royce plc for their many contributions to this document, including testing and the analysis of resulting test data.

Information is subject to change without prior notice.

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