# Advanced protective coatings to improve machining of critical superalloys can help aerospace, energy & petrochemical sectors

Posted On: 04 NOV 2026 5:21PM by PIB Delhi

An advanced surface-engineering approach developed by scientists can help improve the durability of cutting tools used for machining super alloys.

This could help aerospace, energy and petrochemical sectors, where nickel-based superalloys are indispensable for components operating under extreme conditions.

Machining of super alloys for use in aircraft engines, power plants and petrochemical systems is a major manufacturing challenge. Nickel-based superalloys such as Inconel 718 (IN718), IN625 and IN617 possess exceptional strength and hardness which make them difficult to cut or shape. Rapid work hardening, poor thermal conductivity and strong chemical interaction with cutting tools accelerate tool wear, reduce productivity and increase manufacturing costs.

Scientists from the International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad, an autonomous R&D Centre of the Department of Science and Technology (DST) have developed and evaluated two nanocomposite protective coatings—Titanium Aluminium Silicon Nitride (TiAlSiN) and Chromium Aluminium Silicon Nitride (CrAlSiN)—on widely used tungsten carbide cutting tools.

The coatings were deposited in-house using cathodic-arc physical vapour deposition and this helped evaluate the performance of tools for milling of IN718, IN625 and IN617. The study examined both tool life and the mechanisms governing coating performance.

The research revealed an important finding: there is no single coating that performs best for every superalloy. The effectiveness of a protective coating depends significantly on the chemistry of the material being machined and its interaction with the coating.

For IN718, the TiAlSiN-coated tool improved tool life by about 80% compared with an uncoated tool, while for IN625, the improvement was about 60%. For IN617, however, CrAlSiN proved remarkably superior, increasing tool life by more than 200%. The results demonstrate that one coating may be better suited to IN718 and IN625, while another can perform substantially better for IN617. The findings provide a scientific basis for selecting coatings according to the specific alloy being machined.

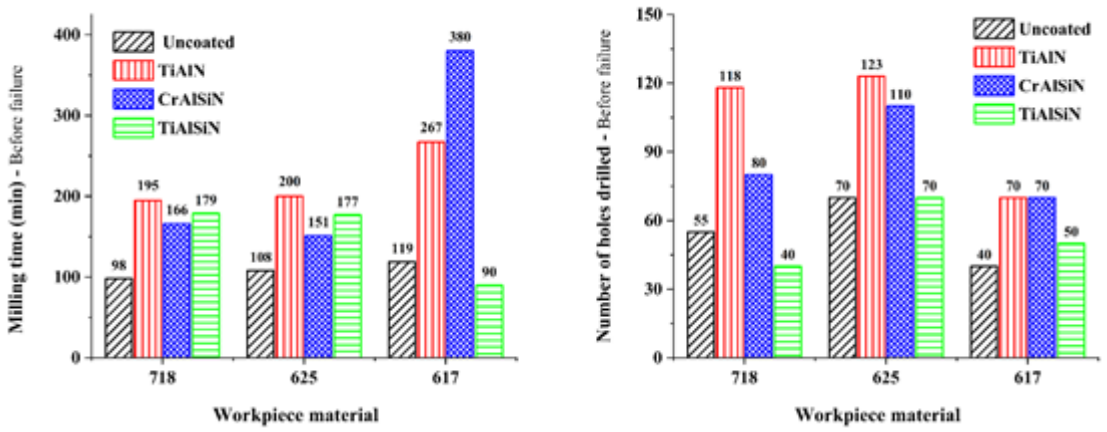



***Fig 1:*** *Advanced nanocomposite coatings significantly improve the life of tungsten carbide cutting tools. The results show that the optimum coating depends on the specific nickel-based superalloy being machined.*

The researchers also investigated how cutting tools failed. A major cause of damage was repeated adhesion of workpiece material to the tool surface. During machining, a layer of the superalloy can stick to the cutting edge and, when it subsequently breaks away, it pulls tiny fragments from the tool, progressively causing chipping. The coatings helped delay this damage and extend tool life. Chipping and progressive wear were identified as the major failure modes, with abrasion, adhesion and attrition contributing to the overall wear process.

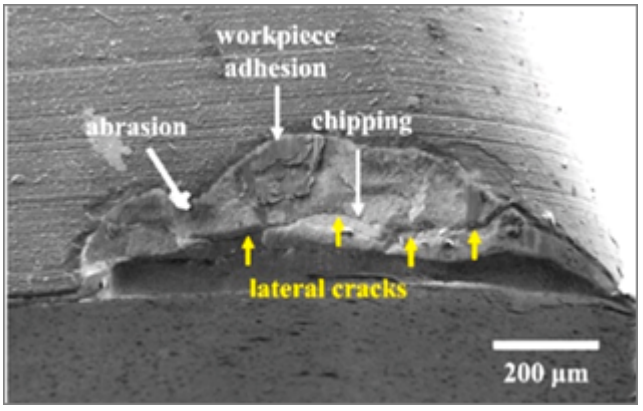



***Fig2:*** *A Scanning Electron Microscope image of a cutting-tool edge showing workpiece adhesion, abrasion, chipping and lateral cracks—key mechanisms responsible for tool failure during machining of nickel-based superalloys.*

The researchers also examined the metal chips generated during machining. The chips exhibited characteristic shear bands and serrated or saw-tooth patterns, reflecting the intense thermo-mechanical conditions during cutting. The degree of chip segmentation was related to tool performance, providing further insight into the complex machining behaviour of these advanced alloys.

Longer-lasting cutting tools can reduce downtime, improve productivity and lower the cost of machining high-value engineering components.

More significantly, the study points towards a science-based, application-specific approach to protective coatings. Rather than seeking a universally superior coating, manufacturers can select or design coatings based on the composition and behaviour of the particular

alloy being machined. This can contribute to more efficient, reliable and cost-effective manufacturing of components made from advanced materials.

The research carried out at ARCI's Centre for Engineered Coatings, has been published in the journal *Materials Today Communications.*

The study demonstrates that the key to improving the machining of some of industry's most demanding materials lies not merely in developing a better coating, but in matching the right coating to the right material.

Link to Publication:

https://doi.org/10.1016/j.mtcomm.2024.109101

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