Enhanced CBN Blade Tip Systems for Improving Engine Efficiency

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Energy efficiency of gas turbines is paramount because of fuel costs: the highest operating cost for airlines and a significant cost to the power generation industry. For nearly 30 years, efficiency gains drove most technical innovation within gas turbine engines. Today's newest generation of turbine engines are helping both the airlines and power generation operators more effectively control fuel costs associated with power system operation and, additional new developments are underway to continue driving up efficiencies of new turbines.

One key technology that can contribute to greater overall fuel efficiency in gas turbines is the use of sophisticated protective barrier coatings on engine components, particularly the clearance-control coatings used on high-pressure turbine blades. Gas bypass between the rotating turbine blade tip and the engine casing affects both the efficiency and power output of an engine. An increase in this clearance of just 125 µm can result in an increase of 0.5% in specific fuel consumption.

Abradable coatings were designed to allow the turbine blade abrasive tip to cut a path into the shroud abradable coating to improve the seal between blade tip and casing. A holistic approach to improving the abradable system (abradable coating and blade tip) is necessary.

Most blade tip systems currently in use were developed in 1990s and are still widely used. Current blade tips are limited, as the matrix oxidizes at high temperature losing its ability to hold, as well as protect, CBN (cubic boron nitride) particles. CBN particles also oxidize at elevated temperatures and have limited service life. Improvement in blade tips, both in cutting particles and the matrix that holds them, will therefore improve abradable system performance and allow the use of denser, more erosion-resistant abradable materials.

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Turbine engine blade tip.

Blade tip coating system

The blade tip currently in use has four essential components (Fig.1) and typically a microstructure such as that shown in Fig. 2. The components are metallic undercoat, metallic matrix, CBN particles, and diffusion coatings.

The metallic undercoat is essentially a bond coat that provides oxidation resistance. As the matrix and CBN particles can rapidly degrade under frictional heat generated during abradable seal cutting, the metallic undercoat provides oxidation protection to the underlying base metal during engine life. CBN particles are held in a matrix material (usually an electroplated MCrAlYHf alloy), and a diffusion aluminide is applied to provide further matrix protection.

Chromalloy has been applying CBN-based electroplated blade tips for more than 15 years, and currently is developing ways to improve existing technology to make these coatings cut better and last longer in gas turbine engines.

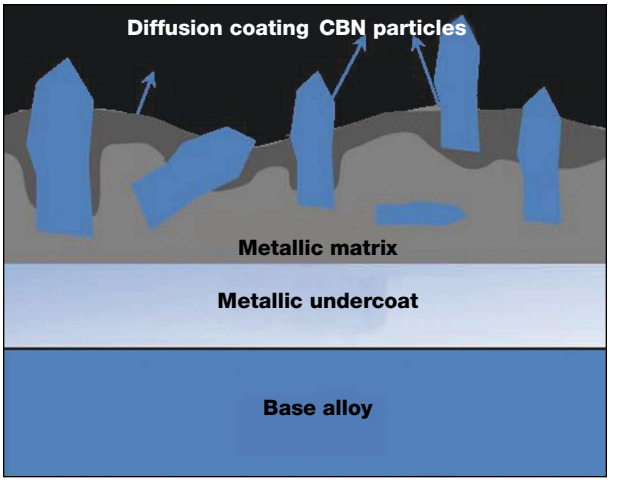

Fig. 1 — *Schematic of various components of a typical CBN tip system.*

The overall system is complex and, therefore, separate development projects are focusing on improvements to each aspect of the blade tip. These include undercoat and matrix compositions, new diffusion coating compositions, and new generation CBN particles for enhanced abrasion and longer life.

Enhancements under consideration

Metallic undercoat: The current metallic undercoat is CoNiCrAlY, which will be replaced by a hafnium- and silicon-bearing, or a rhenium-bearing NiCoCrAlY system. The newer coatings have better oxidation and creep resistance, and help minimize base alloy cracking and damage after CBN particles wear off.

Metallic matrix: The current NiCoCrAlHf matrix will be enhanced by adding hafnium, silicon, or rhenium, or some combinations thereof to improve the oxidation of the matrix. Improving oxidation of the matrix is key, as an improved matrix will better protect CBN particles.

CBN particles: A progressive series of CBN particles were tested, including monocrystalline CBN to provide better angular cutting, and other enhanced CBN particles for improved thermal performance. CBN thermal performance is key to improving the blade tip, because a longer lasting CBN provides better incursion of the abradable coating and allows use of denser, more erosion-resistant abradable coatings that maintain their clearance over the engine's operating life.

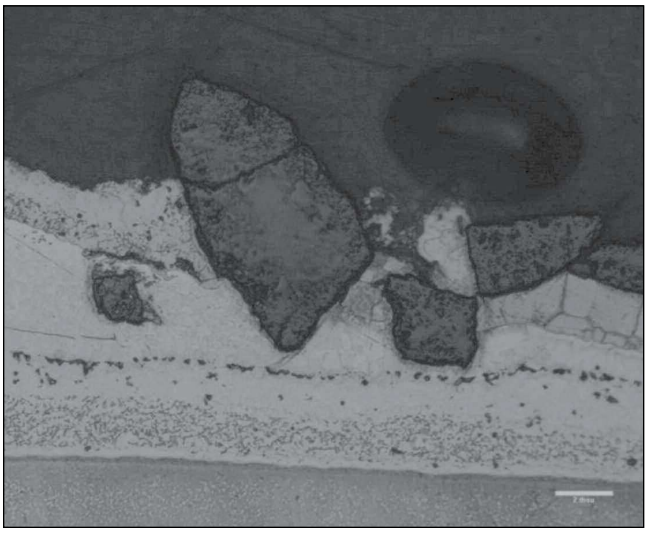

Fig. 2 — *Typical CBN coating tip consisting of a low-pressure plasma spray metallic undercoat, CBN particles embedded in a metallic matrix, and diffusion aluminide overcoat. Magnification: 200×.*

TABLE 1 — SUMMARY OF THE ENHANCEMENTS BEING CONSIDERED

	Undercoat	Matrix	CBN	Diffusion coating
Current technology	LPPS CoNiCrAlY	Electroplated NiCoCrAl	Polycrystalline	Aluminide
Enhanced CBN	LPPS NiCoCrAlY with Hf, Si, or Re additions	Electroplated NiCoCrAlY with Hf, Si, or Re additions	Monocrystalline angular	Double aluminide or platinum aluminide

Some novel systems containing stable oxide ceramics are also being developed, which will provide blade tip cutting ability well beyond the initial stage.

Diffusion coating enhancements: Due to the inherent nature of the CBN electroplating process, the aluminum content of the matrix is low. MCrAlY coatings depend on an adherent alumina scale to provide good oxidation protection. Therefore, a diffusion aluminide coating is applied to the matrix to provide an aluminum reservoir for extended oxidation protection. Further enhancements to the diffusion coating include applying platinum aluminide or double aluminide coatings, which provide even better protection than traditional aluminide coatings.

Table 1 gives a summary of system enhancements under consideration. All blade tip enhancements underway are available, and Chromalloy offers these coatings to airline customers and gas turbine manufacturers for engine installation. As the basic technology remains the same, and is already in used by several turbine operators in both aerospace and power generation, the enhancements being offered can be easily incorporated into existing customer coating blueprints and specification requirements. This will make introduction of the technologies into turbines faster, and will make greater fuel efficiencies more quickly accessible to airlines and other turbine operators. **iTSSe**

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