ABRADABLE THERMAL SPRAY COATINGS

Introduction and Background

Abradable thermal spray coatings, also known as clearance control / seal coatings, are successfully used today in aero-engines, industrial and steam turbines, and various other types of turbomachinery applications to reduce leakage gaps between stationary and rotating parts in order to improve efficiency (Figure 1).

Thermally sprayed abradable coatings have been applied to the compressor sections of jet engines since the late 1960's and predominantly consist of composite materials deriving their abradability from the use of low shear strength materials or from porous, friable coating structures.

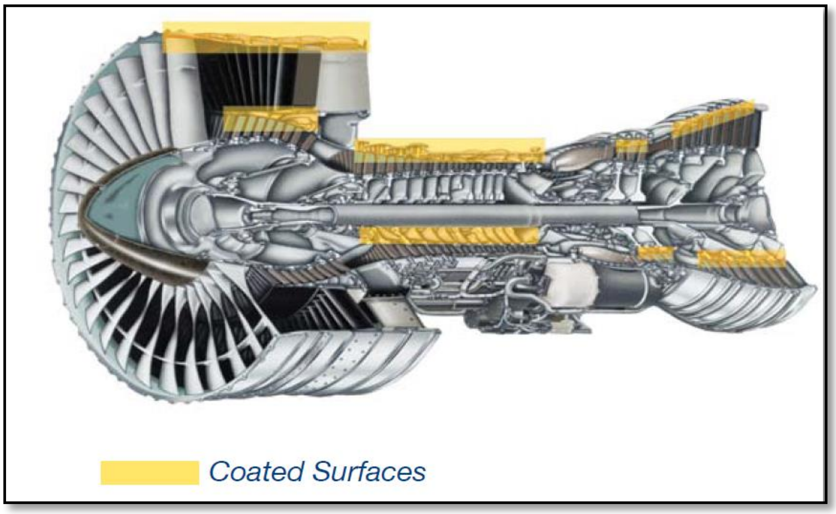

Figure 1: Areas in a gas turbine that is coated with thermally sprayed abradable materials

The key performance criteria for abradable seal coatings systems are summarised as follows:

- Rub compatibility against blades, knife fins or labyrinth seals under various conditions
- Coating cohesive strength
- Oxidation resistance at high temperatures
- Corrosion resistance in aqueous or chemical fluid or gases
- Resistance to corrosive attack at elevated temperatures

Thermaspray (PTY) Ltd

Tel: +27 11 316 6520
Fax: +27 11 316 7527
Email: info@thermaspray.co.za
Website: www.thermaspray.co.za

Physical Address:
3 Axle Drive
Cnr Axle Drive & Hammer Rd
Clayville, Extension 11
Olifantsfontein
South Africa

Postal Address:
PO Box 1152
Olifantsfontein
1665

- Sintering resistance at elevated temperatures
- Thermal shock resistance
- Resistance to solid particle erosion

The relevance of these factors is dependent on the type of application and the level of temperature and chemical exposure to which the abradable coating is exposed.

The Technology behind Abradable Coatings

The "abradability" of the abradable thermal spray coating is its capability to readily and sacrificially wear away in the event of contact by a mating rotating part, creating debris that is soft and tiny in order to find its way out without eroding other parts of the engine. The mating part will normally not experience any loss of material or, if loss of material is experienced, it is usually negligible. Some abradable alloys resist erosion by the flow of gases and are resistant to corrosion, oxidation and other degradation mechanisms.

The abradable materials and structures reduce tip clearances by allowing the blades to cut / abrade into the material without causing damage (overheating and wear) to the blade tips. The ideal abradable will be characterised by a concentration of all wear in the seal and no wear on the blade for a given rotor displacement. This allows the rotor to cut into the stator without any reduction in blade length which, in turn, would lead to increased unsealed gaps. Thus, the general rule is that abradable counterpart coating should be softer than the dynamic rubbing component material to prevent abrasive wear and/or friction-induced overheating of the dynamic component as much as possible.

The two most important properties of a good abradable coating material are hardness and lubricity. The materials must not be so hard as to cause wear of the mating part but, in the same sense, not so soft as to be easily eroded by wear particles in the gas stream. Lubricity allows the rubbing material to cut smoothly into the abradable coating and not tear away large pieces of the coating.

The following matrix materials are commonly used to embed the abradable particles (the exact composition of the materials is proprietary to the developers) and they are all also softer than the traditional steel, titanium alloy or nickel alloy blades or knife/fin seal materials used in turbomachinery:

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- Aluminium-Silicon materials for low temperature applications – include a polymer to generate porosity when burnt-out in subsequent heat treatment (sacrificial phase).
- MCrAlY (M=Cobalt, Nickel or Cobalt/Nickel, Chromium Aluminium Yttrium) for mid-range temperatures in the compressor stages.
- Yttrium-stabilised Zirconia (high temperature ceramic material) for high temperature turbine Sections.

These materials may also include solid lubricants and release agents that assist with the ease of separation of the abradable particles.

Thermal Spraying of Abradable Coatings

Abradable coatings can either be applied by the flame (combustion) spray process or the atmospheric plasma spray process. The atmospheric plasma spray process is a higher temperature process than the flame spray process, which means that materials with higher melting points can be applied with the atmospheric plasma spray process.

The abradable coatings typically applied using the flame spray process includes:

- ***Nickel – Graphite*** – hardness of coating varies according to the ratio of nickel to graphite and is suitable for rub incursions against steel and nickel alloy blades, knives or labyrinth seals. Also suited for incursion against titanium blades provided the coating has the correct sprayed hardness.
- ***NiCrAl - Bentonite*** – suitable for rub incursions against steel and nickel alloy blades, knives and labyrinth seals used in steam turbine balance piston applications. This coating is considered too abrasive for titanium blade applications with the risk of blade tip oxidation and titanium fire generation.
- ***NiCrFeAl – Boron Nitride*** – the boron nitride in this coating assists with oxidation resistance and also acts as a solid lubricant that assists cutting processes during blade incursions.

The abradable coatings typically applied using the atmospheric plasma spray process includes:

- ***Aluminium and Aluminium Bronze alloy/polymers*** – these coatings combine the desired properties of the soft shearable and heat resistant polymers with the higher strength shearable alloys and are also used for rub incursions

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1665

- ***MCrAlY-Boron Nitride/Polymers*** – coatings like CoCrAlY (Cobalt-Chromium-Aluminium-Yttrium) have improved oxidation and corrosion resistance compared to other Nickel-Chromium base abradable materials up to a maximum temperature of 650°C and in [other] some cases up to 750°C.
- ***Ceramic Zirconia base abradables*** – these coatings have excellent thermal shock resistance, toughness and sintering resistance and the coating structure and properties created during thermal spraying makes this coating resistant to thermal shock.

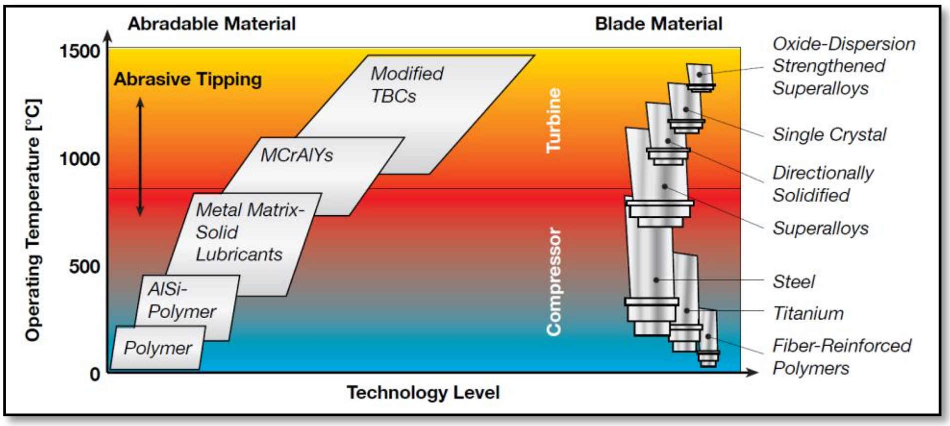

Figure 2: Schematic illustration of the type of abradable thermal spray coating used in the different areas of a turbine and compressor

Figure 2 shows different abradable coatings and blade materials used at the different operating temperatures. It is shown that as the operating temperature increases, the sophisticated abradable coating and blade material also changes in order to withstand the higher operating temperatures.

Original Equipment Manufacturing Specifications and Approvals

Several OEM's have developed material approvals and specifications specifically for the application of different types of abradable thermal spray coatings to turbines and compressor components. OEM's like Rolls-Royce, Pratt Whitney, Honeywell, General Electric, Siemens and Volvo all have their own specifications for the type of abradable to be applied to the different parts of turbines and compressors (low and high temperature, as well as the different base materials).

Thermaspray has coated several components from the turbomachinery industry with an aluminium polyester abradable thermal spray coating. The components include:

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Website: www.thermaspray.co.za

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- Labyrinth seals
- Impeller eye and boss landings
- Balance drums

Conclusion

Thermal spray abradable coatings play a major role in the operating efficiency of turbomachinery. Abradable coatings can be tailored to provide the required resistance to temperature (oxidation) and corrosion, depending on the base material as well as the location of the coated component in the turbines, while adding the clearance control for optimised efficiency.

References

1. www.gordonengland.co.uk
2. Sulzer Metco – Abradable Material Approvals and Specifications
3. ***On the potential of metal and ceramic based abradables in turbine seal applications*** – Dieter Sporer, Scott Wilson, Iacopo Giovannetti, Arno Refke and Maassimo Giannozzi – Proceedings of the thirty-sixth turbomachinery symposium – 2007
4. ASM Handbook Volume 5A – ***Thermal Spray Technology*** - 2013

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