Exhaust Systems Coatings: Thermal Barrier Coating

Thermal barrier coatings (TBC) are highly advanced material systems usually applied onto metallic surfaces including gas turbine or aero-engine parts operating at high temperatures, being a form of exhaust heat management (lessening the negative effects of internal combustion engine exhausts by preventing heat from escaping the exhaust system on automobiles). These coatings serve to insulate components, in certain degree, from large and prolonged heat fatigues by utilizing thermally insulating materials that can sustain an appreciable temperature difference between the load-bearing metallic alloys and the coating surface. In doing so, these coatings can withstand higher operating temperatures while reduce the thermal exposure of structural components, extending part life by limit oxidation and thermal fatigue.

Thermal barrier coatings commonly consist of the metal substrate, metallic bond coat, and ceramic topcoat. The ceramic topcoat is typically composed of yttria-stabilized zirconia (YSZ) for having very low thermal conductivity and remaining stable at exhaust operating temperatures. The advancements in finding an alternative for YSZ ceramic topcoat resulted many novel ceramics (rare earth zirconates) having superior performance at temperatures above 1200 °C. This ceramic layer creates the certain thermal gradient of the TBC and keeps the lower layers at a lower temperature than the surface.

TBCs have several failure modes: 1) degradation of mechanical rumpling of bond coat during thermal cyclic exposure; 2) accelerated oxidation, 3) hot corrosion, 4) molten deposit degradation,

Currently, there are .three types of ceramic coatings on the market:

1) Silica---ceramic coatings [the common solvent-based silicone paint]
2) Silica-Alumina Ceramic coatings [the oxide colloids based -ceramic coatings, the Corrocell 650M and Corrocell 850M], this type of coatings have relatively thermal insulation, abrasion resistance, and mechanically hard property, and short shelf life in comparison with the above types of coatings.
3) Water-based silicate, alumina, and silica ceramic coatings, the water-based metallic ceramic coatings, including CorroCell 1000MC and Cermakrome,
4) The CorroCell 1000C, and along with the increased thermal insulation version of the Corrocell 1000CT are the same water-based system as the above 3).

At present, the thermal barriers coatings have three type of coating technology. The first two types of coatings:

1) The coatings merely stick onto the surface with paint, depending on the adhesion strength with the metal substrates, for example, the above first two types of coatings
2) Plasma molten deposit, the ceramic material bonds with the substrates while the deposited coatings consist of a multitude of pancake-like lamellaecalled 'splats',

formed by flattening of the liquid droplets. As the feedstock powders commonly have sizes from micrometers to above 100 micrometers, the lamellae have thickness in the micrometer range and lateral dimension from several to hundreds of micrometers. Between these lamellae, there are small voids, such as pores, cracks and regions of incomplete bonding. As a result of this unique structure, the deposits can have properties significantly different from bulk materials. These are generally mechanical properties, such as lower strength and modulus, higher strain tolerance, and lower thermal and electrical conductivity due to the rapid solidification, metastable phases can be present in the deposits [cited from en.wikipedia.org/wiki/Thermal_spraying on 17th Aug. 2013]

3) Chemically interfacial bonded coatings, the coatings have formed chemical bonds with the substrates through chemical reaction with the metals substrates. The above coating types of 3 & 4 belongs this type of coatings techniques.

Automotive

Thermal barrier ceramic-coatings are becoming more common in automotive applications. They are specifically designed to reduce heat loss from engine exhaust system components including exhaust manifolds, turbocharger casings, exhaust headers, downpipes and tailpipes. This process is also known as exhaust heat management. When used under-bonnet, the specialty ceramic coatings here have the positive effect of reducing engine bay temperatures, therefore lessening the intake temperature.

Industrial

In industrial applications, where space is at a premium, thermal barrier coatings are commonly used to protect from heat loss (or gain). Especially in gas turbines and jet engines the turbine blades are covered with TBCs. Such turbine blades are made of superalloys and the TBC avoids melting, which allows to reach high gas inlet temperatures and enables high energy conversion efficiency.