

Evaluation Of Coating Methods on Turbine Blades and Its Analysis

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Abstract

This article presents issues concerning the relationship between the degradation of the coating of gas turbine blades and changes in the color of its surface. Conclusions were preceded by the determination of parameters characterizing changes in the technical condition of protective coatings made based on a metallographic examination that defined the morphological modifications of the microstructure of the coating, chemical composition of oxides, and roughness parameters. Most of gas turbine performances evolving coatings on combustion chambers because of its high temperature withstand ability improves combustion process. As a part of this some works which is considerable for improving performances stage wise compressor blades also coming in to consideration. Deterioration of blades also affects total performance of turbine, this leads to engine performances depended on gas turbine efficiency. In order to stream line minimum gaps occurred in long life cycles of gas turbine linked engines thermal stresses on blades also becoming a needful factor of research. Coatings are frequently applied on gas turbine components in order to restrict surface degradation such as corrosion and oxidation of the structural material or to thermally insulate the structural material against the hot environment, thereby increasing the efficiency of the turbine. However, in order to obtain accurate lifetime expectancies and performance of the coatings system it is necessary to have a reliable understanding of the mechanical properties and failure mechanisms of the coatings.

Keywords: Gas Turbine, coating on blades, corrosion and oxidation.

Introduction

Gas turbines used in jet engines are exposed to great thermal and mechanical loads. They are distinguished by their efficiency, which depends on the temperature of exhaust gases at the turbine inlet. It should be noted that over time, excessive temperature concerning operating temperature can lead to the degradation of the blade's structure and thus to turbine failure. One external symptom of blade degradation is a change of its surface color, which is a diagnostic signal indicating alteration of its technical condition. The most common method of monitoring blades uses visual optoelectronic observation where the color of the blade's surface is recorded. This technique allows for

non-invasive monitoring of the technical condition (degradation) of blades through the use of a video scope with the initial reliability assessment (improvement of technical condition) being performed by comparing obtained images of the blade's surface with a picture of the surface of a standard blade. However, this type of non-invasive monitoring requires personnel who possess advanced skills, its results are more difficult to interpret, and, in comparison to invasive methods, it provides limited credibility. For these reasons, it becomes necessary to subject blades to a metallographic examination that provides a lot more information regarding changes within their structure but excludes them from further use.

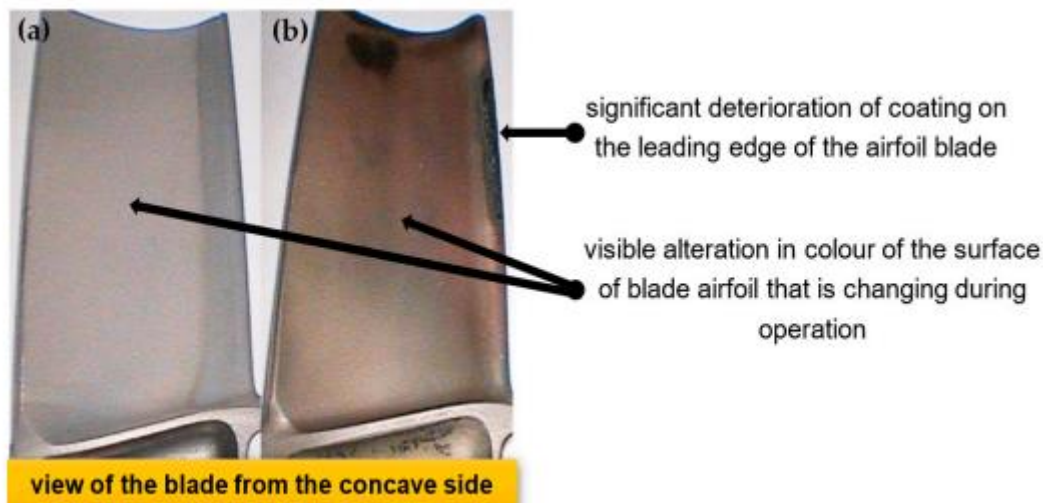


Figure 1: Exemplary blade images: (a) benchmark blade; (b) turbine blade leading edge damaged due to overheating

Different types of gas turbine coatings

To protect the underlying metallic substrate against a corrosive environment a coating that forms a thermally grown oxide should be applied. If the requirement is to protect against a high temperature, a coating type that acts as a thermal barrier can be applied. Coating used in

gas turbines can be divided into three major types: diffusion coatings, overlay coatings and thermal barrier coatings. They are briefly described below. In Fig. 2 it is demonstrated how the applied coating can be selected on basis of the corrosion and oxidation performance.

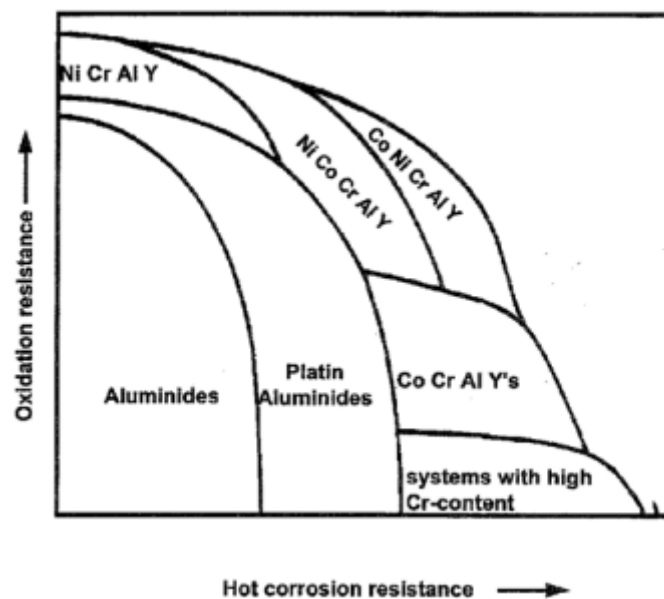


Figure 2: Oxidation and corrosion resistance of different types of coatings

Diffusion coatings: Produce a corrosion/oxidation resistant thermally grown oxide by enriching the surface with either Al, Cr or Si through diffusion. Diffusion coatings are the most widely used types in gas turbine engines and are applied for example on rotating parts like turbine blades. They have a

homogeneous microstructure with good thermo mechanical fatigue properties. A critical limitation is the high ductile-to-brittle transition temperature and the very brittle nature below the transition temperature.

Overlay coatings: Produce a corrosion/oxidation resistant thermally grown

oxide by depositing a pre-alloyed material with desired composition on the surface. Typical compositions are based on the MCrAlX alloy system, where M is Ni, Co, Fe or a combination of these and X is Y, Si, Ta, Hf, etc. The main advantage in comparison to diffusion coatings, which have properties that strongly depend on the substrate composition, is that their properties can be better controlled and balanced for a specific application. In general, overlay coatings have better oxidation and corrosion resistance than diffusion coatings and can be used at higher temperatures, see Fig. 2. They can also be deposited in thicker layers, which may extend the lifetime of the coating. The limitations of overlay coatings are the relatively poor reproducibility of the properties as they are highly dependent on the process.

Thermal barrier coatings: Bi-material coatings consisting of a thermally insulating ceramic topcoat, usually yttria or magnesia stabilised zirconia, which are deposited on top of a MCrAlX bondcoat. The bondcoat produces the protective oxide scale between the topcoat and the bondcoat. Due to the inherent brittleness of ceramics, thermal barrier coatings mostly are used in non-rotating parts such as combustion chambers, transition ducts, vanes, exhaust nozzles and afterburners. Two major benefits can be obtained with thermal barrier coatings: either a prolonged lifetime of parts by reducing the substrate temperature or, alternatively, an increased engine efficiency by reducing the air cooling flow or increasing the combustion temperature.

NiAl COATINGS

Diffusion coatings protect the turbine components against the environment by promoting an oxide scale. This can be produced by enriching the component surface through diffusion by an oxide-forming element, usually Al, Cr or Si. The most common diffusion coating is aluminide because alumina has low oxygen diffusivity and superior adherence. NiAl and CoAl intermetallic coatings are produced in this way. The aluminium in the coating reacts with oxygen in the environment, which results in a protective alumina scale. The protective ability decreases with time as the aluminium reservoir in the coating is consumed. Diffusion coatings

can be applied by using techniques such as pack cementation, slurry-fusion and chemical vapor deposition (CVD). Pack cementation and slurry fusion were the first methods introduced and later came the CVD method, which is advantageous when cooling passages are to be coated. The pack cementation is the traditionally way to apply diffusion coatings and has been used since the late 1950s for protecting turbine blades under aero, industrial and marine service.

Mechanical properties of thermal barrier coatings

Variation in coating properties

There are a large number of mechanical properties that must be considered when studying durability of thermal barrier coatings, for example elastic-plastic properties, creep properties, fracture properties, bond and adhesive strength properties, thermo mechanical fatigue strength and erosion properties. However, the literature gives a wide range of mechanical properties of thermal barrier coatings. This does not mean that the deposition process lacks reproducibility, but instead that different powders, different torch designs and different operating parameters are used. Most research in the field of TBCs has also been directed towards the process microstructure relationships. However, there are still many parameters that are relatively unknown, for example, interaction effects between topcoat, bondcoat and substrate at high temperatures. Thermodynamic modelling of the elements diffusion and oxidation reactions will in future give important insights in the long-term properties of gas turbine coating systems.

METHODOLOGY

The fully used blade, with a proposed life of 24 k EOH, of the 80 MW-class gas turbine is shown in Fig. 1. Delamination of the top coat, including damage to the basic material, can be observed on the leading edge, and partial delamination of the top coat is also seen on the trailing edge. These types of blade damage are similar to those previously reported. However, to account for differences in the substrate material used in the blade, chemical composition of the bond coat and top coat, crystallinity and manufacturing

process, this study performs a comprehensive analysis of the blade's microstructure to evaluate the lifespan of thermal barrier coating from a micro structural perspective.

RESULTS AND DISCUSSION

The thermal barrier coating on the first stage blade consists of 500 μm top coat and 400 μm NiCrAlY bond coat. The microstructure of the middle edge of the blade, including the thermal barrier coating. The blade edge is the area first reached by high-temperature flames of 1,100 $^{\circ}\text{C}$, and thus most susceptible to damage caused by high-temperature corrosion and oxidation. Observations of the leading edge found delamination on the top coat, which also featured many fine cracks leading to the insides

of the bond coat. For a TIT of 1100 $^{\circ}\text{C}$, when the top coat serving as a 150 $^{\circ}\text{C}$ thermal barrier is delaminated, high-temperature corrosion and oxidation are accelerated as the substrate material is directly exposed to high-temperature flames. Blade life is further reduced when cracks form at the interface of the top coat and bond coat. Many cracks were found at the interface of the top coat and bond coat in high-temperature parts, with some cracks growing through the bond coat and into the substrate material. Most cracks entered the bond coat after growing in a single direction, while others were briefly restrained at the interface of the substrate material and bond coat followed by regrowth into the substrate material.

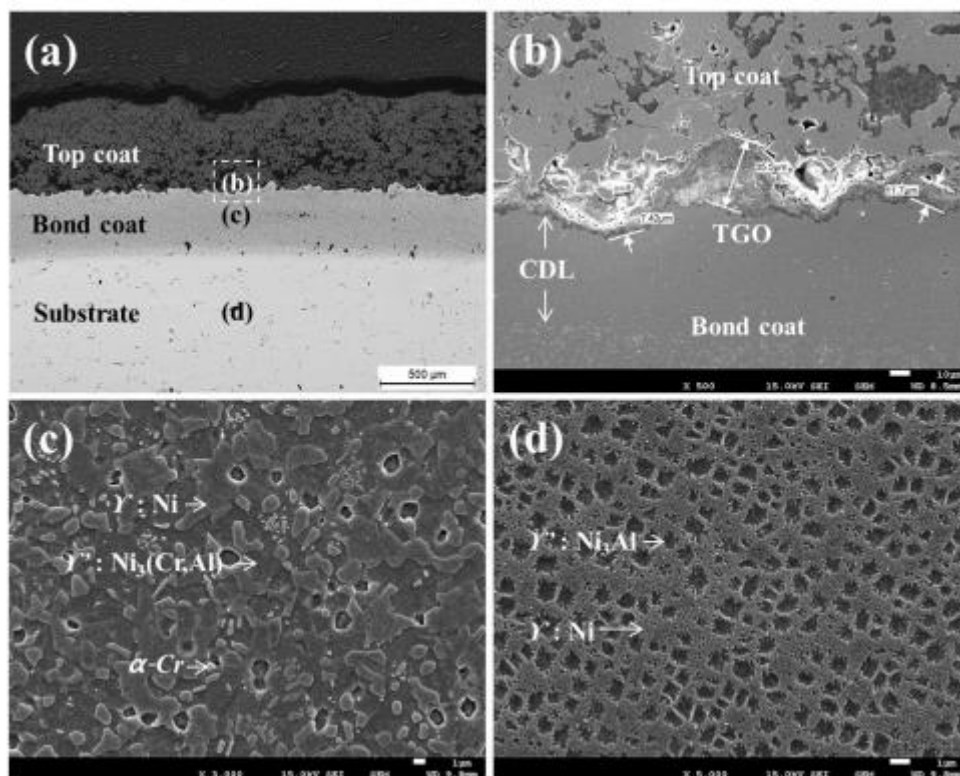


Figure: Microstructure of TBC coating (a) blade surface, (b) interface between top coat and bond coat, (c) phases in bond coat, (d) phases in substrate.

Surface densification of modified coatings

Optical micrographs of all as-sprinkled, phosphate settled and laser-covered covering be appeared in Figs. as-showered reference coatings show standard powerless microstructure of plasma sprinkled TBCs. In phosphate settled coatings approximately 300-400 μm thick surface layer was densified. Autonomously in laser covering a 50-150 μm

thick layer be densified in view of softening of covering surface.

Phosphate settling reduced aggregate porosity of coating via 30-39 %. Demonstrate porosity estimations of as-showered and phosphate settled coatings were likely affected by draw outs that were appeared display availability. This outcome be customary for plasma showered oxide coatings. In any case, it could be

recognized that extent of draw outs be bring down in phosphate settled coatings in which association of lamellae be reached out because of settling.

So deliberate aggregate porosity decrease in phosphate settled coating is decently an aftereffect of diminished porosity, yet what's more an immediate consequence of diminished

extent of intensity outs. Porosity decrease in phosphate settled coating is found within like way in open porosity estimation where decay continued running from 24-48 %. It ought to in like way be seen that mercury porosimetry result tends to mean open porosity of whole covering.

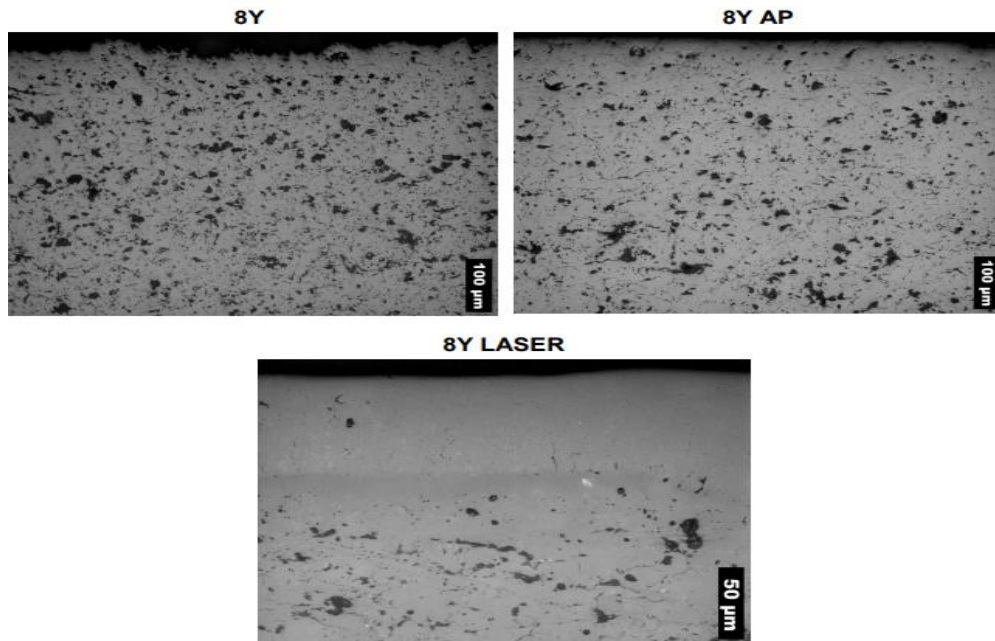


Figure: Optical micrographs of showered and adjusted 8Y based TTBCs

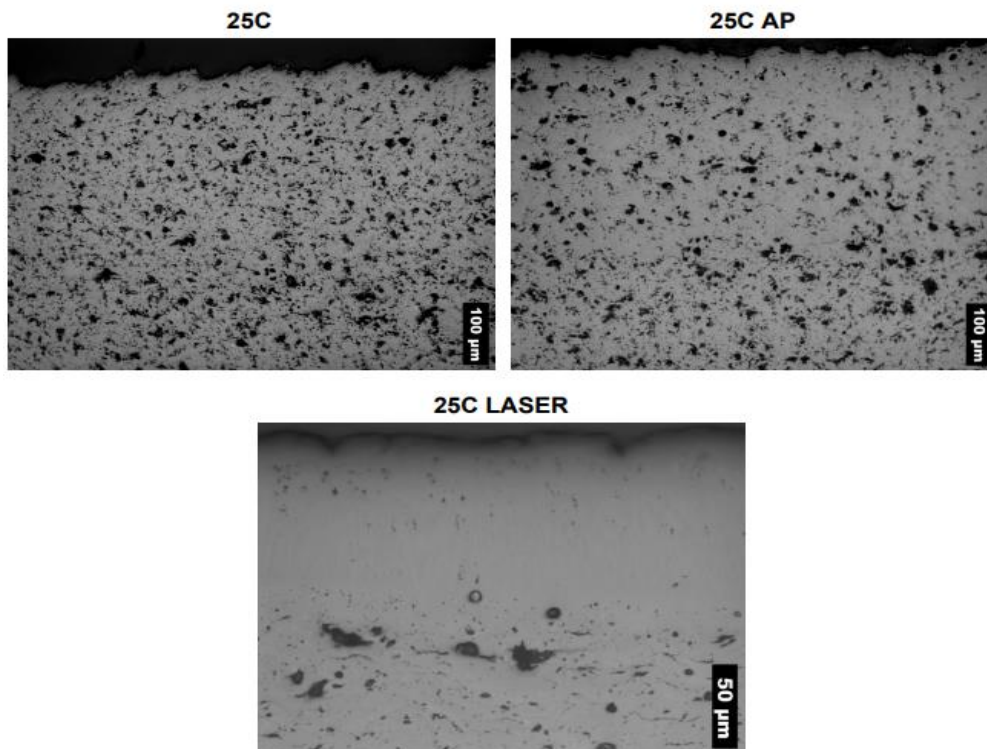


Figure: Optical micrographs of as-sprayed and modified 25C based TBCs

Trademark microstructure of laser-covered coatings

Top-see SEM microstructures of laser-campaigned TTBCs are showed up in Fig. 16. 8Y LASER coatings have to some degree smooth and even surface. Shade of yttria balance zirconia covering changed from light decreases to clear yellowish/white in context of laser covering framework. Optically it could be outlined as prompt and smooth. Surface geography of 25C LASER covering was furthermore rar smooth, regardless a couple of pits, 200-500 μm in breadth, were opened to surface. Gap be likely passed on while gotten gas, from covering porosity, made tracks in an opposite bearing from condense pool in center

of covering system. Light greenish/yellow shade of covering changed to dull in laser covering.

On or hand, surface of 22M LASER covering was to great degree coarse with stacks of pits, yet white shade of 22M did not change in laser treatment. Covering shading shade groupings in laser covering more likely worked out as expected because of adjustments in stoichiometry in middle of fast warming and cooling shapes. Reversibility of shading change was showed up in an immediate warmth treatment in air at 1250o C for 5 hours, after which shade of 8Y LASER and 25C LASER coating almost composed key shade of feedstock powder.

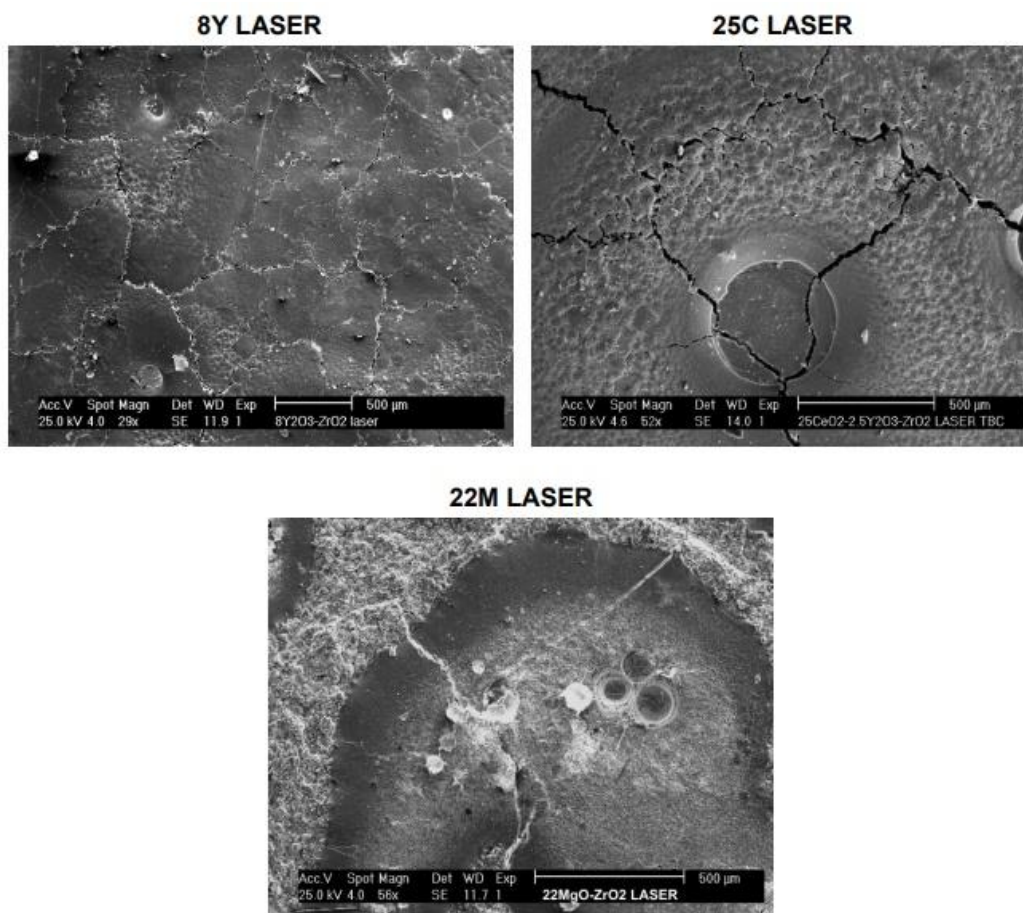


Figure: Top-see SEM micrographs of laser covered coatings

Cross sectional optical increasingly small scale follows, exhibited that dissolving had happened effortlessly in 8Y LASER and 25C LASER coatings, at any rate in 22M LASER covering thickness of combined layer moved fundamental. high extent of free MgO in 22M covering structure perhaps underlined erratic softening of surface, since gathering point and

vapor heap of MgO and ZrO₂ separate somewhat. Some little scale breaks with length shorter than layer thickness happened inside deteriorated layer. Some logically widened full scale parts, 200-500 μm since long time back, associated past secured layer.

In 8Y LASER covering full scale breaks took somewhat straight lined vertical introduction

while fragment of immense scale parts in 25C LASER covering spread out underneath split up layer and decided upward. In 22M LASER covering vertical parts be basically progressively unpredictable, and from time to time blended underneath softened layer and

caused halfway denying of secured zone. run of the mill number of vertical far reaching scale parts in laser anchored coatings, when checked from covering cross section, be 1.5/mm for 8Y LASER, 1.4/mm for 25C LASER and 1.9/mm for 22M LASER.

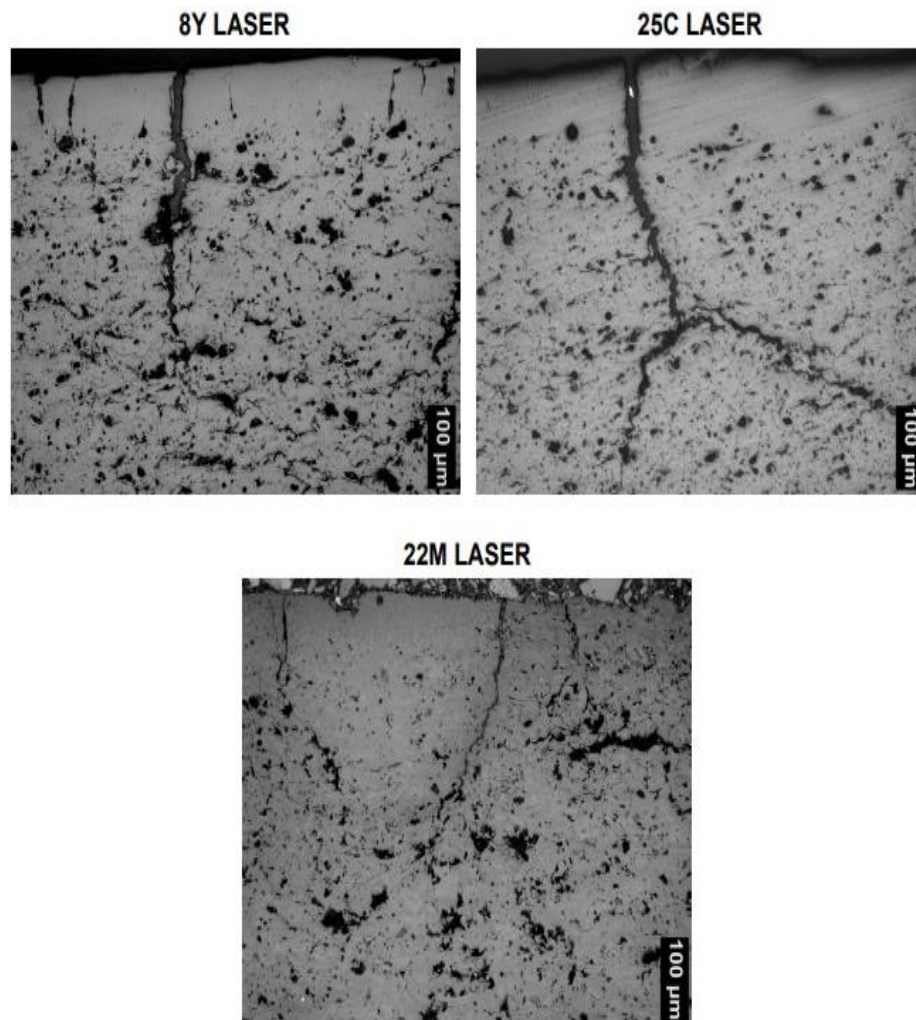


Figure: Cross sectional optical micrographs of laser-covered coatings

CONCLUSION

Impact of high temperature presentation on covering execution as far as warm properties was illustrated. Sintering was seen inside microstructure of thermally uncovered examples; prompting significantly expanded warm conductivity. Be that as it may, microstructural changes couldn't be specifically measured with microstructure methods utilized up to this point. While sintering of microstructure affected all coatings; how much warm execution corrupted was dependant on micro structural highlights. Again coatings created with a pore previous showed a littler

corruption in execution. Regarding strategies utilized for surveying effect of microstructure (change in structure) and science of coatings; laser streak strategy is most suitable for TBCs at all temperatures. While procedure gives aberrant information on micro structural transforms, it can give quantifiable information. By and by, re is no technique promptly accessible to straightforwardly evaluate micro structural includes in adequate detail that would n be able to be connected to warm property changes it is evident that best in class warm hindrance frameworks working at higher temperatures or potentially for long terms

(business flying machine applications for instance) require further improvements. Use ought to include materials, mechanical and displaying perspectives. Instances of conceivable enhancement field be low warm conductivity along with high strength clay top coat, ecological assurance, bond coat through advanced TGO development along with forbidden bury dispersion, and additionally better comprehension of disappointment components and forecast of lifetime.

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