# Effect of grit blasting and intermediate layer of $MoSi_2$ on Life time of thermal barrier coating

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**Abstract-***A set of specimens prepared with Thermal barrier coatings (TBC) by air plasma sprayed containing substrate Haynes 230 and bond coat NiCrAlY with top coat as 7 wt% Y2O3 stabilized ZrO2.Conventional thermal barrier coating containing top coating and bond coating. The present developed system introduces a protective intermediate layer on bond coat of MoSi2 for preventing oxidation along with substrate treated with grit blasting. The samples treated with thermal cycling to cause failure. The present work reveals the effect of surface roughness along with intermediate layer on thermal fatigue life of TBC. High interface roughness wasfound to promote longer fatigue lives along with intermediate layer oxidizes to prevent bond coat oxidation.*

***Key words:*** TBC, Mosi2, ASP, YSZ, NiCrAlY

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**1. Introduction** —Gas turbines performance mainly depends on the temperature [4], an increase in efficiency can achieved by increasing combustion temperature [5 –9]. A higher turbine entry temperature (TET) results in higher efficiency. Consequently, development of gas turbines has driven the service temperature to higher and higher level.

Thermal barrier coating (TBC) containing ceramic top coat(TC)which acts as resistant to heat, and bond coat(BC) to improve adhesion of top coat along with metallic substrate[10]. During operation thermal loads arise from the difference coefficient of thermal expansion (CTE) of the ceramic top coat (TC) and the metallic bond coat (BC). Failure occurs at interface of BC/TC because of thermally grown oxides (TGO).There are different ways that a TBC can fail, but growth of the TGO layer at the TC and BC interface plays a significant role in failure[11].

Bond coat oxidation can be reduced by following methods

(1) Lowering interface temperature-A simple way to decrease interface temperature is to apply a thicker top coat[12]. However, the thermal stresses in the top coat are then higher and in some cases the top coat delaminates even during the spraying process [13,14].

(2) Including an oxygen diffusion barrier between the top coat and the bond coat- A layer which is introduced to prevent the oxidation of BC.

Current research tries to find the fatigue life of TBC with grit blasting along with the intermediate layer. Literature survey revealed that the surface roughness increases the fatigue strength, and suggests how these are used to create interface models. Grit blasting of substrate material increases the surface roughness[14-18]. An intermediate layer of like MoSi2 between the top ceramic layer and bond coating in the conventional TBC system enhances the thermal cyclic performance. MoSi2 forms SiO2 within the cracks. Intermediate layer prevent oxidation of bond coat, meanwhile increases the thermal cyclic performance of TBC[19-22].

## 2. Experiment

### 2.1 Materials

Four TBC coated specimens one with conventional two layer coating and other one having 3 layer along with intermediate layer substrate treated with grit blasting put through thermal cycling until failure. The sample substrates cut from 5 mm thick Haynes 230 sheet material in 30x50 mm rectangles. The substrates coated by 150μm of NiCrAlY deposited, and 250μm of 7%-yattria partially-stabilized zirconia deposited by atmospheric plasma spraying (APS).

### 2.2 Coating preparation

The roughness on substrate accomplished by grit blasting.Samples were grit-blasted by corundum with a grain size of 60-mesh to roughen and clean the substrate surface to achieve the required roughness for coating adhesion. The bond coat NiCrAlY deposited on the grit blasted roughened surface using APS with 150μm, then MoSi2 intermediate layer was deposited on the bond coating surface, and then the top YSZ coating sprayed on the MoSi2 surface. A blended composite powder of MoSi2and YSZ used at weight ratio of 3:7 for sample A 7:3 for sample B. All the coatingswere deposited using APS.Table 1 shows the details of specimens prepared

| Process involved | Sample A | Sample B | Sample C | Sample D |
|---|---|---|---|---|
| Grit blasting | Yes | Yes | Yes | --- |
| Bond coat | NiCrAlY | NiCrAlY | NiCrAlY | NiCrAlY |
| Intermediate layer | MoSi2+YSZ(3:7) APS | MoSi2+YSZ(7:3) APS | MoSi2+NiCrAlY | |
| Top coat | YSZ | YSZ | YSZ | YSZ |

Table 1 shows the details of specimens prepared

MoSi2shows the self-repair characteristic through formation of SiO2 during oxidation of MoSi2. The self-repair characteristic tested. NiCrAlY sprayed as the bond coating on the substrates APS. A composite coating of MoSi2 and NiCrAlY was then applied by APS using a different powder mixture of MoSi2 and NiCrAlY.Typical microphotographs of coatings A, B, C, and D shown in Fig.1.

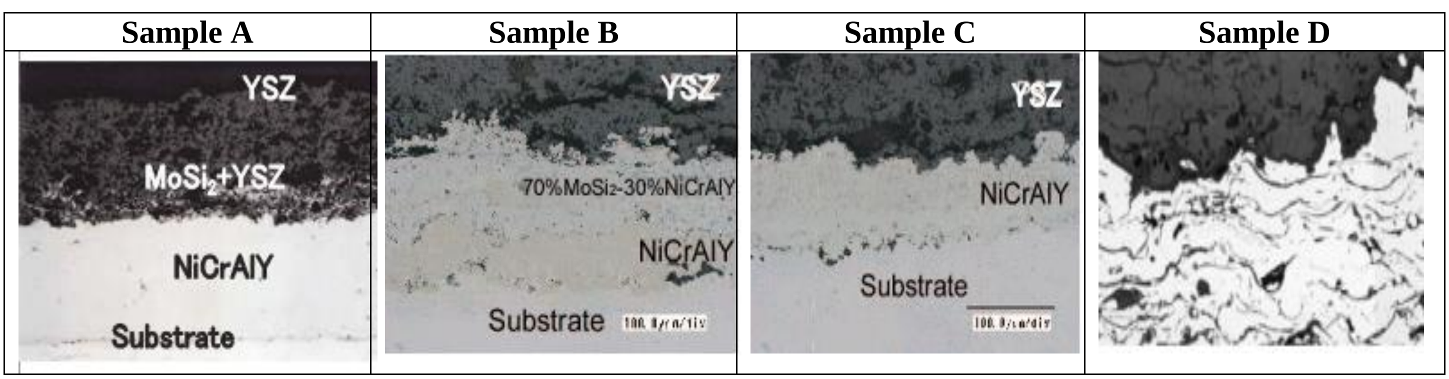


Fig. 1 Cross-sectional SEM images of used coatings

### 2.3 Thermal cyclic test

The samples were thermally cycled in a furnace until failure. One thermal cycle includes heating to 1100 °C for 1 hour and cooling by forced airflow to reach up to 1000 C which reached in about 10 min of cooling. After failure, this considered to occur when more than 25 % of the top coat had spalled.

### 2.4 Roughness generated on BC by grit blasting

Roughness of BC plays a vital role in fatigue life of TBC system because the roughness increases adhesion strength. The roughness generated by grit blasting measured by using cross sectioned specimen. The roughnesses measured by image analysis and compared with the profilometer. The test conducted to a sample length 800μm and the compared results shown in Figure 2

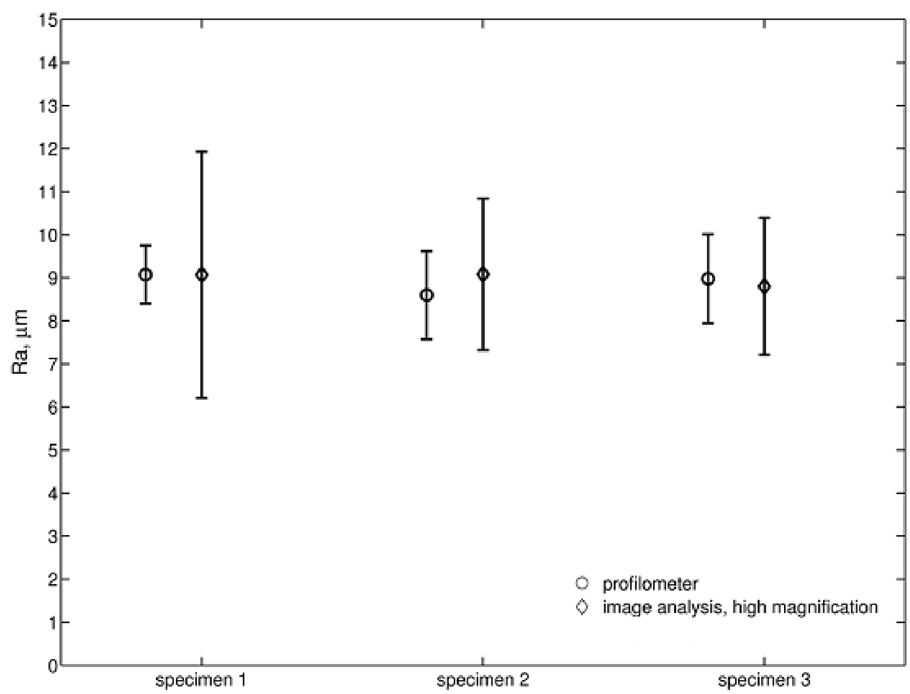


Figure 2. Comparison between the results from a profilometer and results obtained by image analysis.

3. Results

### 3.1 Influence of roughness generated by grit blasting

Four specimens with different combination prepared and test for their fatigue life. It noticed that with increase in roughness of BC gives longer fatigue lives. Figure.3 shows the number of cycles that specimens withstood until failure.

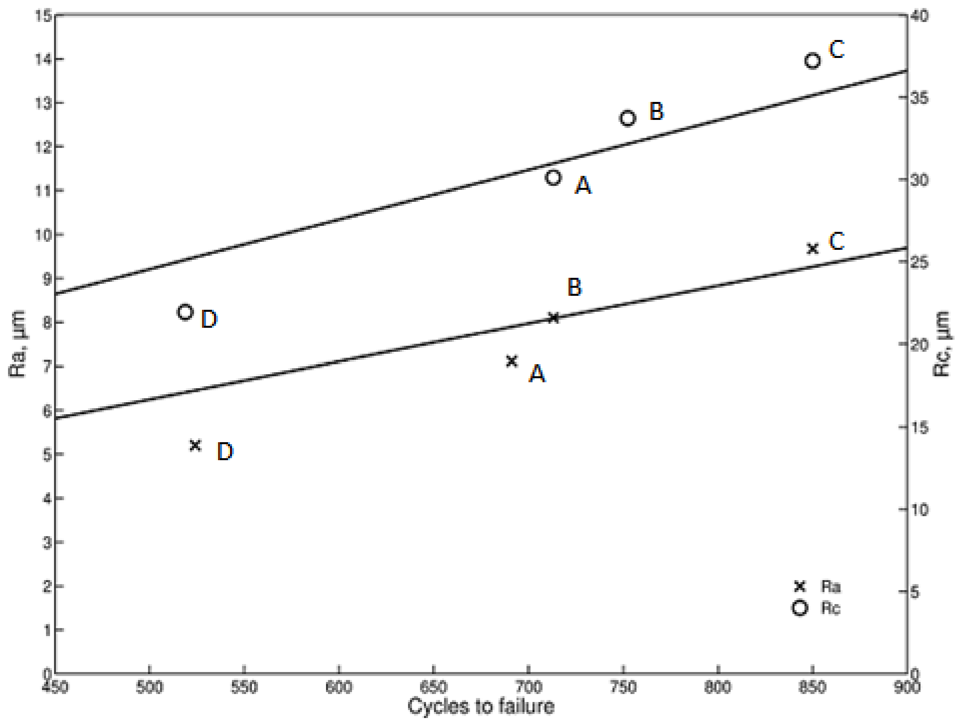


Figure.3 The influence of Ra and Rc on the thermal fatigue life

From the figure it observed that the Specimens A B and C with grit blasting observed to give much longer fatigue life because of the roughness produced in comparison with the specimen D without grit blasted specimen.

### 3.2 FE crack modeling

The FE analysis done on least representative cell of TBC. Figure 4 shows the models generated using FE code abacus. It assumed to have least representative cell on left boundary, and right kinetic boundary conditions applied. The crack growth developed for both in TGO/TC and BC/TGO interface.

Figure 5 shows the corresponding energy release rates G and fraction of interface damage. It was observed that the energy released G was higher for higher roughness values, specimen C shows better combination of roughness.

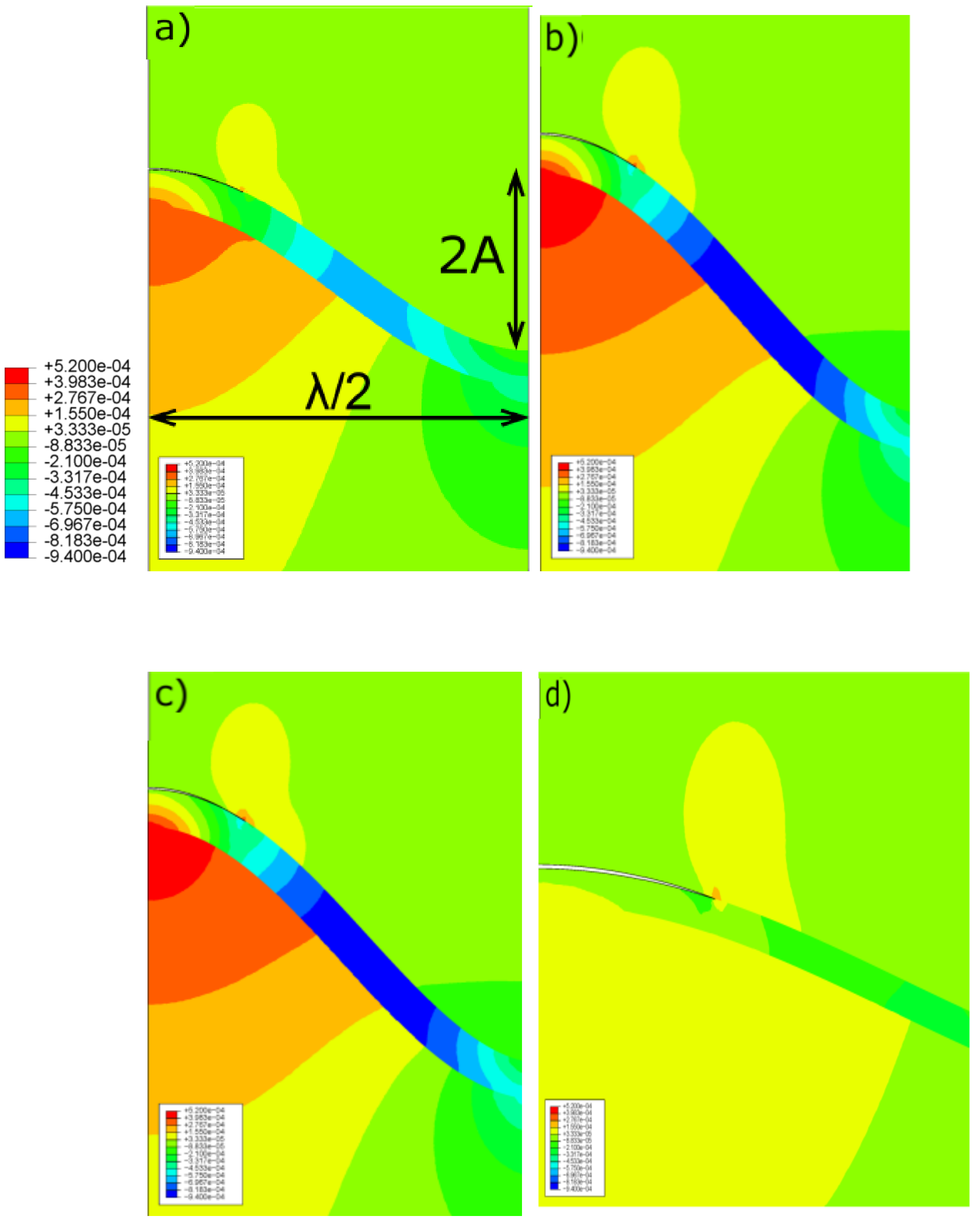


Figure 4. Vertical stress in the interface for a) Specimen A, b) specimen B, c) Specimen C d) Specimen D

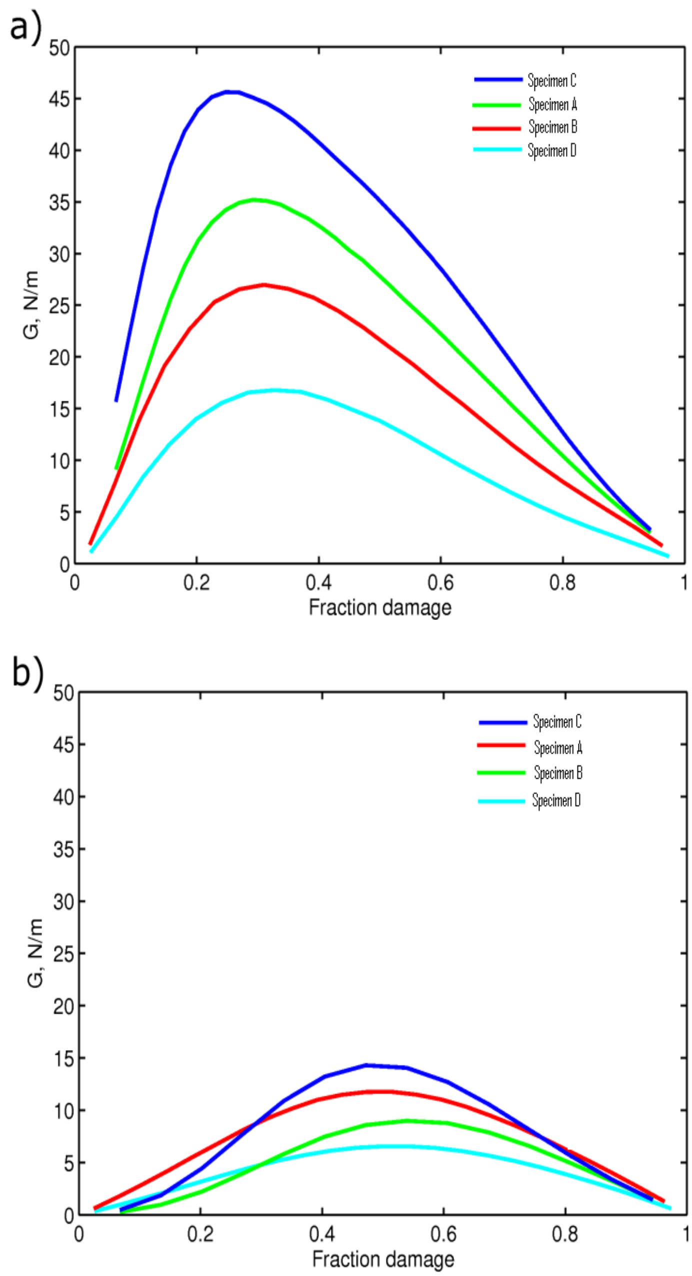


Figure 5. The calculated energy release rate G for a) BC/TGO crack, and b) TGO/TC crack.

### 3.3 Role of Intermediate layer

MoSi2 exhibits the characteristic of self-repair through formation of SiO2 during oxidation of MoSi2. Preparation methods of the intermediate layer significantly influence durability of the triple layered TBCs. Specimens prepared with APS forms Mo5Si3 through oxidation of MoSi2 during spraying according to following reaction.

$$5MoSi_2 + 7O_2 \rightarrow Mo_5Si_3 + 7SiO_2$$

The cracks and pores formed in the intermediate layer during the thermal cyclic test sealed by a protective SiO2 coating and oxidation of the NiCrAlY bond coating prevented. The self-repair mechanism of intermediate layer is schematically shown in Fig.6. Case I presents the morphology of the cracks initiated at the parallel direction to the interface between the bond coating and the intermediate layer[9]. Case II presents propagation of existing longitudinal cracks to the intermediate layer under the tensile stress which induced by the thermal cycle.

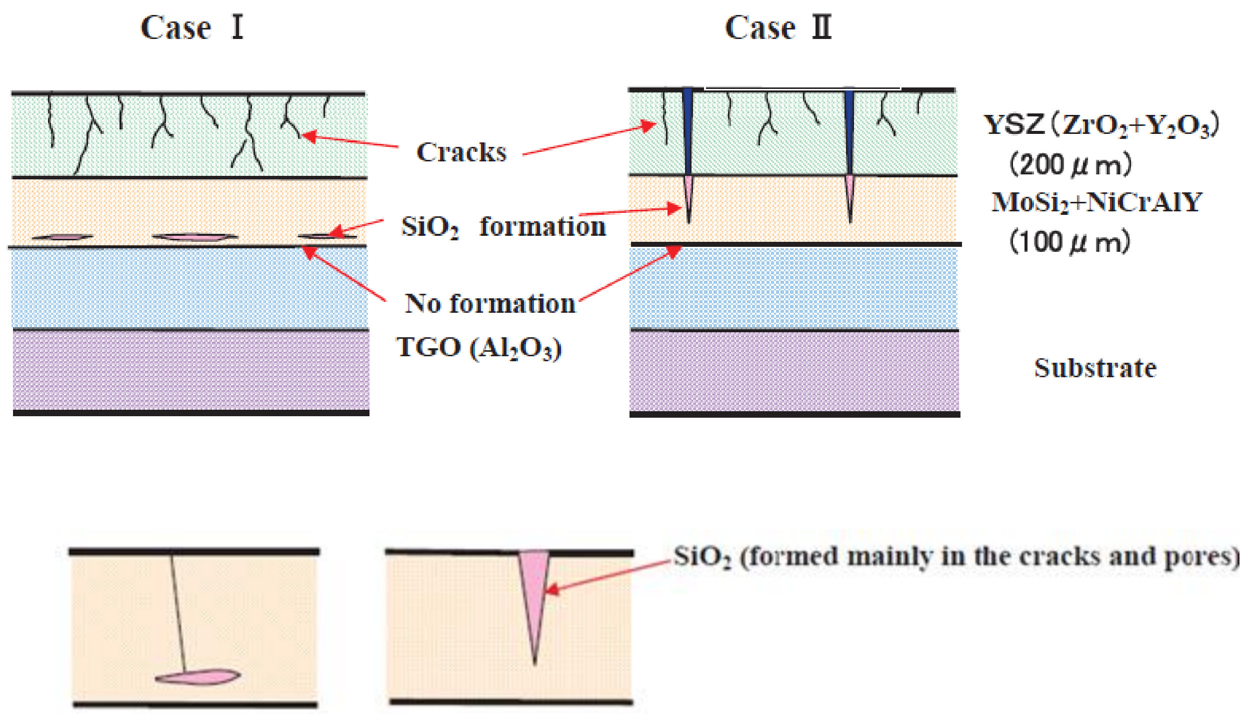


Fig. 6 Schematic diagrams of proposed self-repair mechanism of sprayed coatings for the cases I and II.

## 4. Discussions

It has observed that large variation in fatigue life caused by interface roughness generated by grit blasting and FE models shows the crack growth in TBCs. The performed modeling with FE may serve as a tool for evaluation of the relative behavior of crack growth in the suggested interface models.

In conventional double layer TBC oxygen atoms from the atmosphere penetrate TC mainly through cracks and pores to the bond coating and oxidize the BC that is NiCrAlY at high temperatures. as a result TGO formed at interface of TC/BC. The intermediate layer of MoSi2 used to form triple layer of TBC causes reduction in growth of TGO by filling the pores and cracks.

## 5. Conclusion

Grit blasting has increased the surface roughness of the substrate which has significantly increased the thermal fatigue life of TBC. Sample with grit blasting A, B and C gives better fatigue life in comparison with specimen D without roughened surface. Profilimeter and image analysis used to find the various roughness parameters like Ra and Rc. It was found to have correlation with thermal fatigue life where higher values of roughness Ra and Rc gives longer life. These roughness parameters are applied to FE modeling of crack growth in specimens for shortest and longer life.

MoSi2 composite has introduced as an intermediate layer to the conventional duplex TBC systems to create a triple layered TBCs to prevent the oxidation of MCrAlY bond coating and improve the thermal cyclic performance. Specimen C with MoSi2 and NiCrAlY as intermediate layer was found to give longer thermal fatigue life of TBC. MoSi2 composite of intermediate layer of C forms SiO2 after oxidation. The formed SiO2 seals the pores and cracks and prevents oxidation of bond coat which reduces the formation TGO thereby increasing the thermal fatigue life of TBC.

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