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Research Article

Analysis and optimization of thermal barrier coating on gas turbine rotor blade using YSZ with variable bond coat

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Abstract:

Thermal barrier coatings on gas turbine blades is one of the most research area in heat resisted applications. The study focuses on enhancing the performance and durability of gas turbine rotor blades by analyzing the thermal barrier coating (TBC) system. The primary objective of this work is to improve the overall efficiency of turbines and enhance their heat resistance by utilizing yttrium-stabilized zirconia (YSZ) with a variable bond coat. We achieved ideal coatings with minimal defects by employing optimized spraying parameters. However, even with advanced spraying techniques, issues such as porosity remain unresolved. This article examines atmospheric plasma spraying of zirconium oxide, in combination with titanium oxide and carbide, as a method for assessing porosity in plasma-spraying coatings. To analyzed an L16 orthogonal array, treating the bond coat as a variable. The selected and optimized parameters include spray distance, bond coat, torch input power, and temperature, using Taguchi prediction with Mini-Tab. A bond coat thickness of 100 µm, with an input power of 35 kW, at a spray distance of 75 mm and a temperature of 12000 °C, yielded the best results.

1. Introduction

Thermal barrier coatings (TBCs) are advanced materials systems designed to protect components from the detrimental effects of high temperatures. They are typically applied to surfaces exposed to extreme heat, such as those found in gas turbine engines, aircraft components, and industrial furnaces [1]. TBCs act as thermal insulators, significantly reducing the amount of heat that can transfer from the hot environment to the underlying substrate [2]. In gas turbines, higher operating temperatures translate to improved fuel efficiency and reduced emissions. In aircraft engines, higher temperatures can increase thrust and power output [3]. By reducing thermal stresses and oxidation, TBCs can significantly extend the lifespan of critical components [4]. A metallic layer (often a NiCrAlY alloy) that adheres to the substrate and provides a strong foundation for the ceramic topcoat. A thin layer of oxide (Alumina oxide) that forms naturally at the interface between the bond coat and the ceramic topcoat [5]. The primary heat-insulating layer, typically composed of yttria-stabilized zirconia (YSZ). YSZ retains its structural integrity and insulating properties at high temperatures [6].

1.1 Significance of work

Exploring new ceramic materials with even lower thermal conductivity and improved durability. Developing more efficient and cost-effective methods for applying TBCs. Developing accurate models to predict the lifespan of TBCs under different operating conditions. An attempt made to verify the bond coat effect on adhesion of topcoat to improve the thermal restiveness of coatings with optimization method for finalizing best process parameters. Thermal resistivity with top layer adhesion thickness are the output parameters of optimization and micro-structures analyzed for best, medium, low coated samples. Plasma-sprayed coatings typically exhibit some porosity, which can affect thermal conductivity and mechanical properties. The bond strength between the coating and the substrate is crucial for the coating's performance. YSZ has low thermal conductivity, making it an excellent thermal barrier material.YSZ coatings exhibit good wear resistance, which is important for many applications.

2. Related works

Recent studies have demonstrated that 8YSZ thermal barrier coatings on stainless steel substrates significantly improve thermal shock resistance and durability. This enhanced performance is attributed to the unique microstructural properties of 8YSZ, which provide superior insulation and fracture resistance under high-temperature conditions. Additionally, advancements in coating techniques, such as atmospheric plasma spraying, have further optimized these coatings for industrial applications.
Advanced gas turbines often utilize thermal barrier coatings (TBCs) to protect metallic substrates from the effects of high-temperature gases and oxidation. These coatings can significantly improve the pumping capacity and efficiency of turbochargers. A study conducted by Sohn et al. [1] investigated the microstructural development of TBCs in high-pressure turbine blades both before and after service. The findings revealed noticeable sintering and phase transitions, and the tip of the serviced blade exhibited spallation of yttria partially stabilized zirconia (YSZ). Gurrappa and Rao [2] Hot corrosion tests were conducted on cylindrical specimens with varying thicknesses of thermal barrier coatings (TBCs). The results indicated that the optimal thickness of TBCs can extend the life of the underlying superalloy by approximately 600 times. Yang et al. [3] examined failure behavior under cyclic thermal stress by developing a finite element (FE) model for the turbine blade with TBCs. Additionally, Zhu et al. [4] studied how the shape of the thermally grown oxide (TGO) influenced stress distribution while subjecting a turbine blade with TBCs to cyclic thermal loading. Brown et al. [**5**] To maximize the performance of gas turbines, it is advisable to remove air during the compressor's middle stage. This optimization helps improve the mass flow rate of the cooling air. A method for lowering coolant temperature and enhancing gas turbine performance was proposed by Moon et al. [6] through a process called coolant intercooling. When evaluating gas turbine performance, it is essential to consider cooling, as highlighted in various studies. For instance, Sahu et al. [7] investigated both simple and complex cooled gas turbine cycles, finding that intercooled recuperated gas turbine cycles demonstrated higher efficiency. Additionally, Salpingidou et al. [8] showed that the thermal efficiency and specific fuel consumption of recuperative gas turbine cycles are influenced when the cooling of turbine blades is taken into account. The heat transfer process is further enhanced by the use of thermal barrier coatings (TBCs). These coatings, made from low thermal conductivity ceramics, are applied to metal surfaces and represent advanced materials. When TBCs are integrated with the blade substrate, they modify the overall heat conductivity of the wall. The development and validation of thermal barrier coatings (TBCs) using a power plant controlled by Mitsubishi Heavy Industries were detailed in the study by Okajima et al. [9]. Ogiriki et al. [10] explored the effects of TBC deterioration on the creep life of gas turbine engines, focusing on high-pressure turbine blades, which are considered the life-limiting components of gas turbines. Sahith et al. [11] conducted research on gas turbine TBCs, including a survey of the available substrate, bond coat, and top coat materials, as well as the application procedures used for these coatings. The TBCs were evaluated based on various criteria and operational conditions. Wu et al. [12] discussed the advantages and disadvantages of the primary technologies utilized for TBCs in gas turbines and analyzed the characteristics of new ceramic materials, providing a detailed explanation of how these technologies function. In recent years, researchers have studied the impact of different TBC thicknesses. To determine the optimal TBC thickness, Gurrappa et al. [13] conducted tests at a range of temperatures and corrosive pressures. Ziaei-Asl et al. [14] investigated how varying TBC thicknesses affected stress and temperature distribution across the blade body. Based on their optimization of TBC thickness for gas turbine blades, Sankar et al. [15] concluded that partially stabilized zirconia is the ideal material for TBCs, taking into account temperature, stress, and cost. In a novel approach to enhance thermal insulation and the lifespan of combustor tiles, Nagabandi et al. [16] proposed locally increasing the TBC thickness in hotspot zones. The combined effects of the internal element layout, TBC thickness, and coolant amount on the metal and TBC surface temperature were investigated in conjugate heat experiments carried out by Huang et al. [17]. The temperature inside distribution of turbine blades covered with varying thicknesses of TBCs was measured by Frackowiak et al. [18]. Based on combustor liner thicknesses treated with varying amounts of TBC, Radhakrishnan et al. [19] conducted a thermal analysis and predicted the creep lifespan. Research on gas turbine cooling air systems that use TBCs has recently been reviewed by Yunus et al. [20]. Previous research has primarily concentrated on TBCs' effects on turbine blades, as well as their materials and mechanisms.

3. Methodology and materials

The study utilized atmospheric plasma spraying to apply thermal barrier coatings onto ss304 substrates. This method involved injecting powdered coating material into a high-temperature plasma jet, where it melted and was propelled onto the substrate, forming a protective layer. The atmospheric plasma spraying technique was employed to apply thermal barrier coatings on the SS304 substrate. This method involves using a plasma torch to melt and accelerate the coating material, allowing it to adhere and form a protective layer on the substrate surface.

3.1 Plasma Coating Methodology for YSZ Coating on SS304

Substrate Preparation: Surface Cleaning: The SS304 substrate must be thoroughly cleaned to ensure proper adhesion of the YSZ coating. This typically involves: Removing oils and contaminants using solvents like acetone or isopropanol. Creating a rough surface profile using abrasive media like alumina or glass beads. This enhances mechanical bonding.

Plasma Spraying Process; Plasma Generation: A high-temperature plasma jet is generated by passing a high-current electric arc through a gas (typically argon or a mixture of argon and helium), **Powder Injection:** YSZ powder (yttria-stabilized zirconia) is injected into the plasma jet. Particle Melting and Acceleration: The plasma jet melts the YSZ particles and accelerates them towards the substrate. **Deposition:** The molten particles impact the substrate, flattening and solidifying to form a coating. **Coating Build-up:** The process is repeated layer by layer to achieve the desired coating thickness.

Considerations

- Plasma Gas: Type and flow rate of the plasma gas significantly influence the plasma temperature and jet velocity.
- **Powder Feed Rate:** Controls the deposition rate and coating microstructure.
- **Spray Distance:** The distance between the plasma gun and the substrate affects the particle velocity and temperature upon impact.
- **Current and Voltage:** Determine the plasma jet temperature and energy.
- **Substrate Temperature:** Can influence coating micro structure and adhesion.

3.4 Process Parameters

The Taguchi method plays a crucial role in the development of the design of experiments, as it helps to optimize processes by systematically assessing the influence of various parameters. By using this method, researchers can improve product quality and performance while minimizing costs and resource usage. The parameters and levels given-in the table1. Taguchi design of experiments is a statistical method developed to improve the quality of manufactured goods by optimizing the process parameters. It aims to identify the most influential factors in a process and determine their optimal levels to minimize variability and enhance performance. By systematically examining the interactions between variables, Taguchi design helps in achieving robust and efficient production processes. The variable matrix experiments given in the table 2.

Table1: *Parameters for design of experiments*

Parameter	Level-1	Level-2	Level-3	Level -4
Bond coat (μm)	60	80	100	120
Spray distance(mm)	50	75	100	125
Temperature (℃)	900	1000	1100	1200
Torch power (KW)	25	30	35	40

Table2: *Parameters for Taguchi design of experiments*

Experiment S.No	Parameter 1	Parameter2	Parameter3	Parameter4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	2	4	3

11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

Table 3. *Experiment results for selected Design of experiments*

Experiment S.No	P1(µm)	P2(mm)	P3(℃)	P4(Kw)	Top Coat thickness (µm)	Thermal conductivity(W/m.k)
1	60	50	900	25	180	1.20
2	60	75	1000	30	210	1.14
3	60	100	1100	35	200	1.16
4	60	125	1200	40	190	1.17
5	80	50	1000	35	220	0.91
6	80	75	900	40	215	0.92
7	80	100	1200	25	205	1.08
8	80	125	1100	30	198	1.15
9	100	50	1100	40	240	0.84
10	100	75	1200	35	260	0.79
11	100	100	900	30	225	0.87
12	100	125	1000	25	235	0.86
13	120	50	1200	30	218	0.88
14	120	75	1100	25	230	0.86
15	120	100	1000	40	212	1.06
16	120	125	900	35	204	1.15

Table 4. *Taguchi prediction for the Design of experiments*

Experiment S.No	**Top Coat thickness (µm)**	**Thermal conductivity(W/m.k)**	S/N Ratio	Mean	StDev	Ln(StDev)	Rank
1	180	1.20	-2.90103	91.8887	128.320	4.85765	16
2	210	1.14	-2.91959	105.732	147.987	4.99528	10
3	200	1.16	-2.90420	99.6662	139.242	4.93456	13
4	190	1.17	-2.89852	95.0475	132.692	4.88749	15
5	220	0.91	-2.93364	109.917	154.089	5.03613	6
6	215	0.92	-2.93062	107.046	150.018	5.00841	8
7	205	1.08	-2.92238	103.202	144.494	4.97135	11
8	198	1.15	-2.91595	100.864	141.084	4.95383	14
9	240	0.84	-2.95310	120.583	169.412	5.13075	2
10	260	0.79	-2.96406	131.684	185.179	5.22902	1
11	225	0.87	-2.93833	112.397	157.653	5.05887	5
12	235	0.86	-2.94138	117.016	164.203	5.09798	3

13	218	0.88	-2.93483	108.526	152.168	5.02251	7
14	230	0.86	-2.94054	114.893	161.196	5.08098	4
15	212	1.06	-2.92999	107.819	151.047	5.02296	9
16	204	1.15	-2.91597	102.738	143.737	4.96608	12

Table 5. *Estimated Model Coefficients for Means*

Term	Coef	SE Coef	T	P
Constant	108.064	0.4840	223.270	0.000
A 1	-9.980	0.8383	-11.905	0.001
A 2	-2.806	0.8383	-3.347	0.044
A 3	12.356	0.8383	14.739	0.001
B 1	-0.335	0.8383	-0.400	0.716
B 2	6.775	0.8383	8.082	0.004
B 3	-2.292	0.8383	-2.735	0.072
C 1	-4.546	0.8383	-5.423	0.012
C 2	2.058	0.8383	2.454	0.091
C 3	0.938	0.8383	1.118	0.345
D 1	-1.314	0.8383	-1.567	0.215
D 2	-1.184	0.8383	-1.412	0.253
D 3	2.938	0.8383	3.504	0.039

Table 6. *Analysis of Variance for Means*

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	1041.35	1041.35	347.116	92.61	0.002
B	3	273.88	273.88	91.294	24.36	0.013
C	3	112.75	112.75	37.583	10.03	0.045
D	3	47.80	47.80	15.933	4.25	0.133
Residual Error	3	11.24	11.24	3.748		
Total	15	1487.02				

Table 7. *Response ranking table for mean and S/N*

	S/N ratio	Means

Level	A	B	C	D	A	B	C	D
1	-2.906	-2.931	-2.921	-2.926	98.08	107.73	103.52	106.75
2	-2.926	-2.939	-2.931	-2.927	105.26	114.84	110.12	106.88
3	-2.949	-2.924	-2.928	-2.929	120.42	105.77	109.00	111.00
4	-2.930	-2.918	-2.930	-2.928	108.49	103.92	109.61	107.62
Delta	0.043	0.021	0.010	0.003	22.34	10.92	6.60	4.25
Rank	1	2	3	4	1	2	3	4

Table 8. *Response table for Standard deviation*

Level	A	B	C	D
1	137.1	151.0	144.9	149.6
2	147.4	161.1	154.3	149.7
3	169.1	148.1	152.7	155.6
4	152.0	145.4	153.6	150.8
Delta	32.1	15.7	9.4	6.0
Rank	1	2	3	4

3.5 Experimentation procedure

The YSZ coatings are prepared using zirconyl nitrate as a liquid precursor. The synthesis process involves the following steps: First, combine 20 grams of zirconia oxide (ZrO2) with 80 grams of potassium bisulfate (KHSO4) in a crucible. Heat the mixture in a muffle furnace at 600 °C for 15 minutes, then allow it to cool. Once cooled, the powder mixture is placed on a hot plate and heated for three hours with 600 mL of double-distilled water and a small amount of sulfuric acid (H2SO4). After these three hours, a 25% ammonia (NH3) solution is added. The resulting liquid will then condense. Once the precipitate has been heated for 20 minutes on the hot plate, it is combined with double-distilled water and filtered ten times to remove any remaining zirconium oxide. To prepare a one-liter solution of synthesized ZrO2, mix 400 mL of double-purified water with 100 mL of nitric acid (HNO3). Heat this mixture on a hot plate for 20 minutes to produce ZrO2. Finally, add 500 mL of double-purified water to complete the process.

After adding the 25% ammonia solution to 10 ml of zirconyl nitrate, the mixture is allowed to precipitate. It is then heated over a hot plate for 10 minutes. After being filtered 10 times to remove any impurities, the solution is heated to 800^0C, deposited in a small crucible, and allowed to dry for some time. As a proportion of ZrO2 following heating, the mole wt is calculated. In order to create YSZ, zirconyl nitrate and nitric acid are combined with Y2O3 and heated on heating plates for 30 minutes. This is an additional solution to the Zirconyl nitrate solution. Y2O3 solution at a concentration of 8 mol% was lastly added. zirconium oxide (ZrO3)2

SPPS coatings:
The research group from the State of Connecticut conducted multiple experiments to investigate the mechanism of SPPS (Solution Precursor Plasma Spray) coating deposition. It has recently been recognized that the concentration of precursors in the solution significantly affects splat formation and coating design during the SPPS process. This, in turn, influences how ceramic powder melts and solidifies. In low-concentration precursor solutions, clumps and solvent evaporation lead to the formation of a shell. The group has studied semi-pyrolyzed particles and porous materials. Their investigations also cover processes such as solvent vaporization, droplet rupture, solvent precipitation, and the pyrolysis of solutions at high concentrations.

Coating processes:

A YSZ coating was applied using a solution and a Sulzer Metco 9MB plasma spray cannon. An ABB six-axis robotic arm was integrated with the cannon. Argon served as both the primary and secondary gas, similar to hydrogen. The robot allowed for adjustments to the raster speed and spray distance. The substrates, which were 50 mm x 50 mm square pieces of 304-grade stainless steel with a thickness of 5 mm, were first coated with alumina powder as a bonding layer before the deposition of the YSZ coating. The parameters for the plasma coating were fixed: the argon-hydrogen gas ratio was set at 80:20, with a current of 400 amps, a voltage of 50 volts, and a robot rastering speed of 700 mm/s.

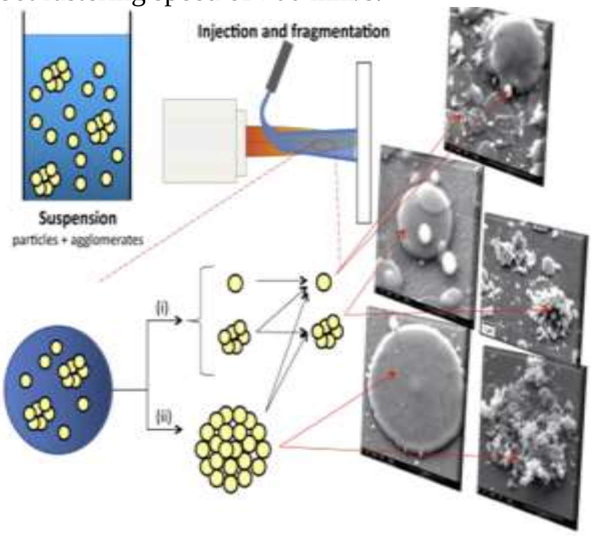

Figure 1. *SPS coatings deposition mechanism*

Experimentation samples for plasma coating can be used to enhance surface properties, providing a more durable and precise by reducing the thermal conductivity of the material. The experimental setup shown in the figure2. The coated samples are shown in the figure 3.

Figure 2 *Experimental setup for present work*

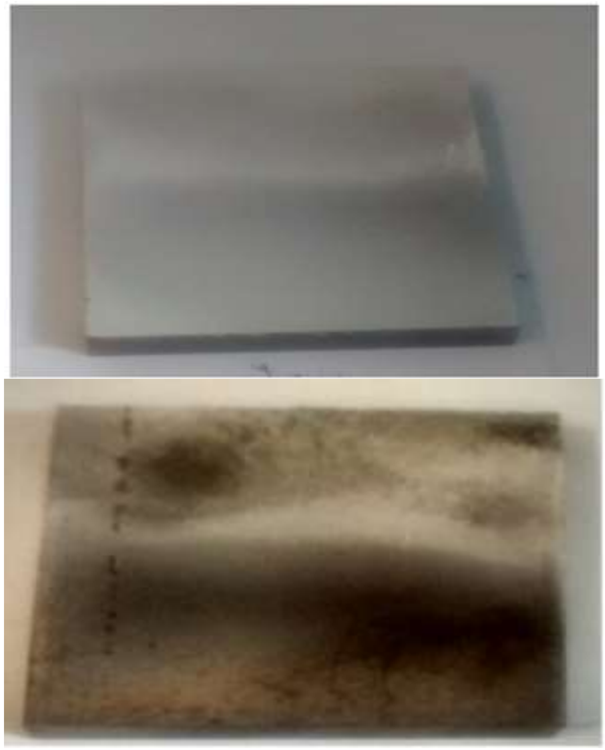

Figure 3. *Samples with high layer deposition coat and low layer deposition coat*

4. Results and Discussions

The Taguchi method was employed to optimize the parameters for the top YSZ coat application. This involved selecting an orthogonal array to systematically vary the critical coating parameters, such as spray distance, Bond coat, torch power and temperature. By analyzing the signal-to-noise ratio, the optimal settings for achieving a high-quality YSZ coat were determined, minimizing variability and enhancing performance.

The goal of this experiment is to determine how P1, P2, P3, and P4 affect top coat thickness and thermal conductivity, statistical analysis (e.g., ANOVA - Analysis of Variance) would be performed on the collected data.This table represents a designed experiment aimed at understanding the influence of four factors on top coat thickness and thermal conductivity. The data collected will be statistically analyzed to identify significant relationships and optimize the desired responses. As the regular data checks with the coating thickness experiment 10 given top bond coat analyzed in micro structure, Thermal conductivity reduced with more coating at a bond coat thickness of 100 µm with 70mm distance. For better permutations of parameters on sixteen experiments statistical analysis done using Mini-Tab software.

Experiments with higher S/N ratios are considered better because they indicate less sensitivity to noise factors that is 2.964 with experiment 10.A smaller standard deviation indicates less variability and more consistent results from the table4 it indicates not much variation in consistency of the result. Taguchi often aims to reduce variation while achieving the target. Based on the ANOVA results, the effects of different factors on the responses (both the mean and the S/N ratio) are analyzed. This helps determine the optimal levels of each factor to achieve the desired performance and robustness. Taguchi analysis where the primary focus is on optimizing the top coat thickness and thermal conductivity while minimizing the impact of noise factors.

All levels of factor A are statistically significant, as their p-values are less than 0.05. This means that changing the level of factor A has a significant impact on the response. The coefficients tell us the direction and magnitude of the effect. For example, A1 has a negative coefficient, meaning that changing to level 1 of factor A *decreases* the response by 9.980 units compared to the reference level.Level 2 of factor B is statistically significant (p = 0.004). Changing to level 2 of factor B is associated with an increase in the response by 6.775 units. Level 1 of factor C is statistically significant (p = 0.012). Changing to level 1 of factor C is associated with a decrease in the response by 4.546 units.Level 3 of factor D is statistically significant (p = 0.039). Changing to level 3 of factor D increases the response by 2.938 units as shown in the table 5.

The mean variations from table6 the p value for first 3 factors are less than 0.05, the fourth variable of torch power have a p value of 0.133 which is not consistent level effected in coating for top coat deposition.

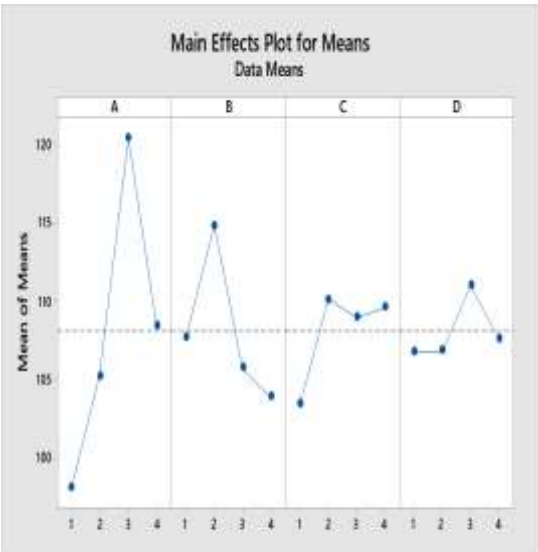

Figure 4. *Response graph for means*

A larger Delta value for a factor means that changing the levels of that factor leads to a larger change in the response. This indicates that the factor has a strong influence on the response. The observations in table7 and table8 showing that bond coat have highest preference followed by distance of spraying with delta values 0.043,22.34 and 32.1 for S/N, mean and standard deviation

The observations from figure 4 Factor A shows a dramatic increase in the mean response from level 1 to level 2, followed by a decrease at level 3 and a further increase at level 4. This suggests a strong, non-linear effect of Factor A on the response. Factor B shows a peak at level 2, suggesting that this level yields the highest mean response for this factor. Factor C shows relatively small changes in the mean response across all levels, indicating a weaker effect compared to Factors A and B. Factor D Shows a slight increase from level 1 to 2, followed by a decrease at level 3 and an increase at level 4. The changes are relatively small, suggesting a possible weak effect of Factor D. The average mean signifies factor A level3, Factor B level2, Factor C level2 and factor D level 3 is the appropriate combination for further work.

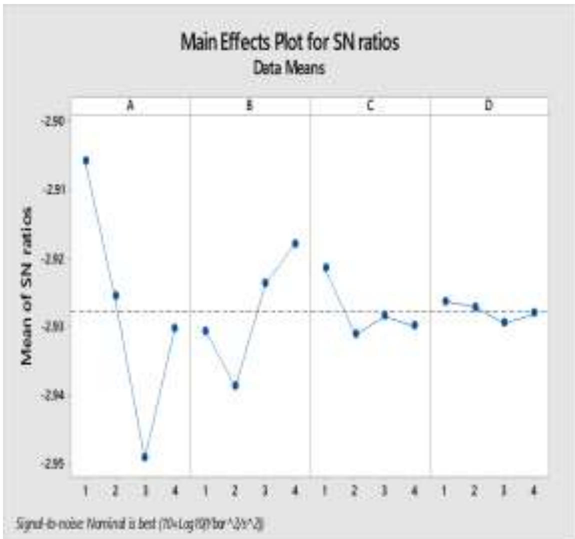

Figure 5. *Response graph for Signal to noise ratio*

The figure 4 demonstrates Factor A Shows a significant drop in the S/N ratio from level 1 to 2, followed by a slight increase at level 3 and a further drop at level 4. Level 1 appears to be the best for maximizing the S/N ratio for Factor A.Factor B: Shows a peak in the S/N ratio at level 4, suggesting this level provides the most robust performance for Factor B.Factor C: Shows a relatively flat line with a slight increase at level 2. This indicates that Factor C has a minimal impact on the S/N ratio.Factor D: Shows a relatively flat line with a slight increase at level 2 and 3. Similar to Factor C, Factor D has a small effect on the S/N ratio.To achieve the most robust performance, you would choose the factor levels that correspond to the highest S/N ratios:

A1,B4, C2 (or any level, as the effect is small), D2 or D3 (or any level, as the effect is small).

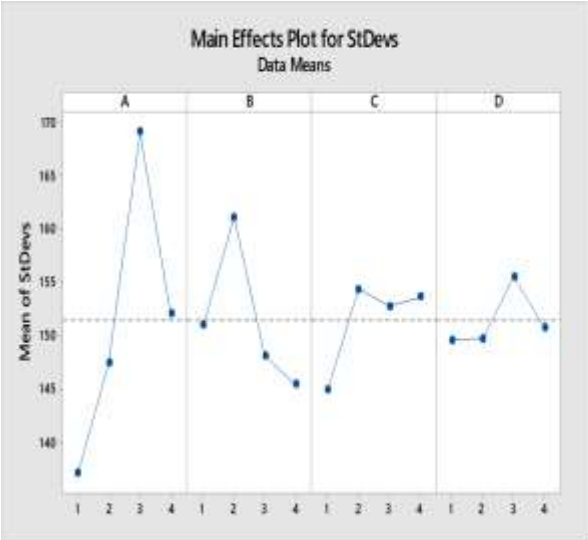

Figure 6. *Response graph for Standard deviation*

Analyzing Figure6 graphs for the Factor A: Shows a dramatic increase in standard deviation from level 1 to 2, followed by a decrease at level 3 and a further increase at level 4. This indicates that Factor A strongly influences the variability of the response. Level 1 appears to provide the most consistent results for Factor A. **Factor B s**hows a peak in standard deviation at level 2. This suggests that level 2 leads to the *least* consistent results for Factor B. **Factor C s**hows relatively small changes in standard deviation across all levels, indicating a weaker effect on variability compared to Factors A and B. **Factor D** shows a slight increase from level 1 to 2, followed by a decrease at level 3 and an increase at level 4. The changes are relatively small, suggesting a possible weak effect of Factor D on variability. To achieve the most consistent results, you would choose the factor levels that correspond to the *lowest* points on the plot:A1,B1 (or B3 or B4), C1 (or any level, as the effect is small),D1 (or D3).

4.1 Micro structural analysis of gas turbine rotor blade

Micro-structural analysis is essential for understanding the performance and durability of YSZ TBCs on gas turbine rotor blades to characterizing the micro-structure of the YSZ top coat, the Al_2O_3 bond coat, and the substrate shown. Each of 2 samples from variable bond coat analyzed for coating inter-phase. TGO, or thermally grown oxide, acts as an intermediary layer that enhances bonding between the substrate and the top coat. It provides a stable interface that can

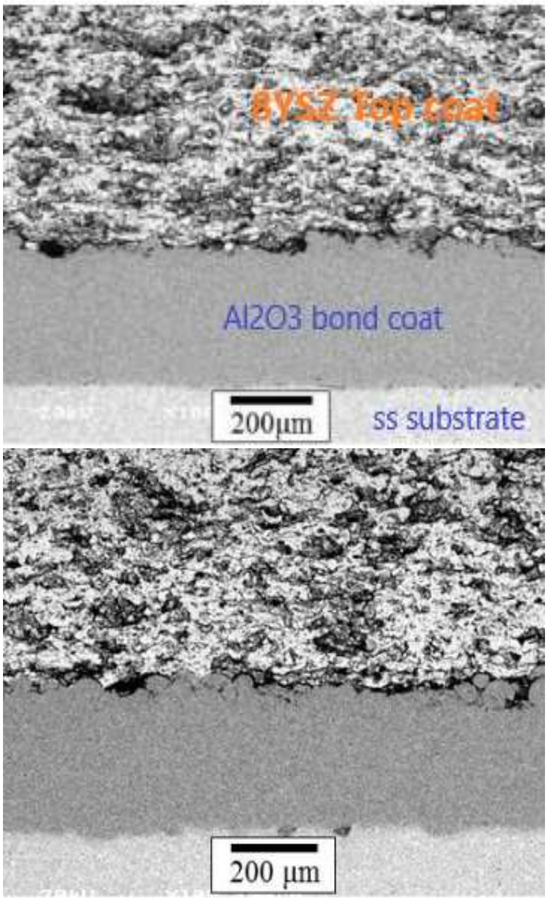

Figure 7 *a): Sample-10 b) Sample-9 for 100µm bond coat*

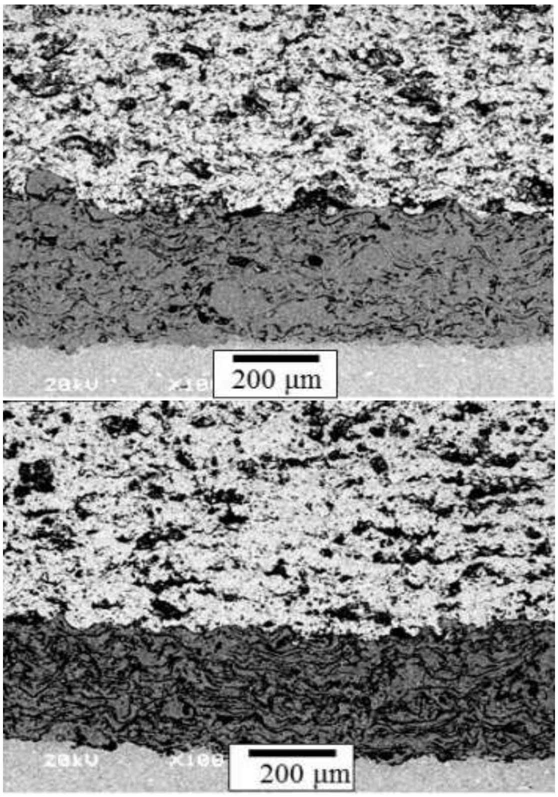

Figure 8. *Sample-6, Sample-7 at 80µm bond coat*

accommodate thermal expansion differences and improve the adhesion of the coating. Additionally, the micro-structure of TGO can influence the durability and performance of the bond under thermal cycling conditions. The even deposition of Top coat shown in the figure7.

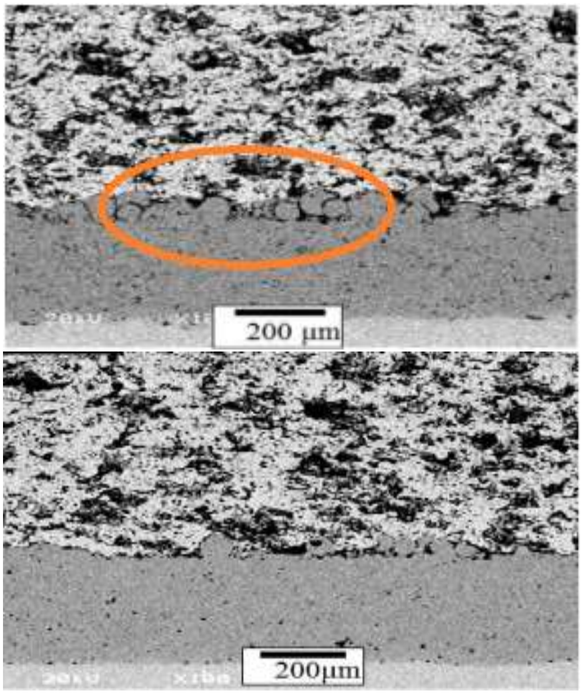

Figure 9. *Sample-13 and sample 14 at 120µm bond coat*

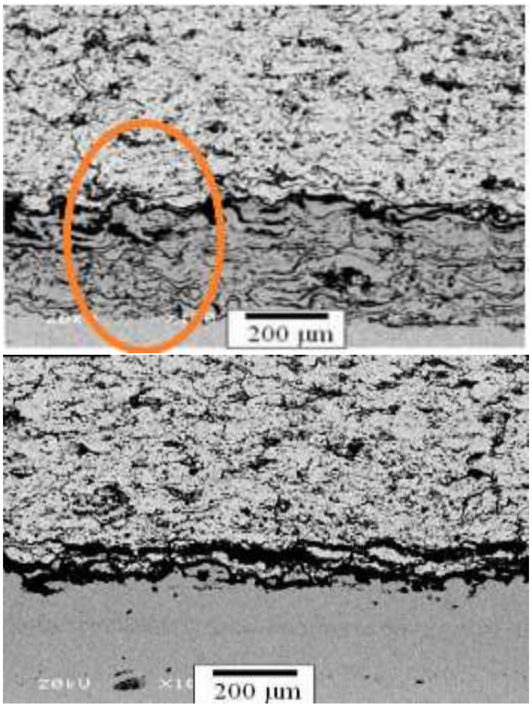

Figure 10. *Sample-1 amd sample 4 at 60µm bond coat*

Analyzing the structure in figure 8 with 80µm bond coat there is some pits and flaws between bond coat and top coat. The observations in both the samples 6 and 7 as same, in 7th sample it looks a bit better compare to 6.

Even though the bond coat is higher the TGO rate is high which can leads to low sticking of top coat as shown in figure9.

The figure 10 shows the abnormalities of bond coat and top coat with TGO variation for sample 1 and 4. Compare to sample 1 at higher-temperatures TGO added for lower bond coats.

4. Conclusions

The Yttria-Stabilized Zirconia (8YSZ) coating performance can be significantly enhanced by optimizing the bond coat composition using the TAGUCHI L16 method. Analyzing the micro-structures of the TGO layer and its interaction with an Al_2O_3 bond coat will provide insights into the ideal parameters for improved adhesion and longevity. By fine-tuning these parameters, the overall thermal barrier coating system can achieve higher thermal resistance and durability. Present work elaborately discussed the significance of parameters selected and the statistical analysis concluded that at 100µm bond coat TGO given better result at a spray distance of 75mm and at higher temperatures of coating.

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- **Ethical approval:** The conducted research is not related to either human or animal use.
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