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Characterization of D-Gun Coated YSZ+Mullite Mixture

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Abstract: ***This work involves study about thermal barrier coatings and the need for thermal barrier coatings in IC engines. Study was made on different materials which are in use for thermal barrier coating along with its effect on improving the performance of the engine. Based on the study about the coating materials, suitable materials were selected which can be used for thermal barrier coating in IC engines. Mullite+YSZin the ratio of 80/20 was coated using D-Gun with different set of operating parameters. The process parameters were first optimized for the coating of the chosen materials. Material characterization of the coated specimen involve the morphological analysis and hardness***

Keywords: D-Gun Coating, Mullite+YSZ, Characterization, Process Parameter, Thermal Barried Coating, hardness, morphology

1. Introduction

Thermal barrier coatings (TBC) are extensively used in areas of higher temperature like those of gas turbines and IC engines. A TBC system consists of a top coat and a bondcoat. The top coat provides thermal insulation to substrate and withstands large temperature gradients while the bond coat provides oxidation resistance along with an adhesion of the top coat to the substrate. Thermal spraying methods are used for the coating of the top coat and bond coat [1]. Plasma spraying and electron beam physical vapor deposition may be used. Even though plasma spraying can lead to a low thermal conductivity owing to the porosity and lamellar structure it does have the drawbacks of unmelted particles and defective microstructures within the coatings which may result in TBC delamination and spallation [3].

D-gun spraying is characterized by spraying of particles which are accelerated by detonation wave and impact on the substrate to be coated with high velocity of 800-1200m/s [4]. The high particle velocity produces a uniform and dense coating with a high hardness and good adhesion to substrate which gives a good coating performance.

Mullite (3Al2O3.2SiO2) is an important ceramic material which can be used for TBC applications. It do posses the advantages of low density, high thermal stability, low thermal conductivity and favorable strength and creep behavior. It has been seen that compared with YSZ, mullite do have a much lower thermal expansion coefficient and higher thermal conductivity and better oxygen resistance than YSZ. In application like in diesel engines where surface temperatures are lower than that encountered in gas turbines and where temperature variations across coatings are large, mullite is an excellent alternative to YSZ. However but at a temperature of above 1273K the thermal cycling life of mullite is found to be inferior to that of YSZ. Cystrallization too happens in mullite at 1023-1273K which is accompanied by volume contraction causing in cracking and de-bonding [2].

YSZ is found to have a higher thermal coefficient of expansion and a lower thermal conductivity than that of mullite [5]. A composite thermal barrier coating made of mullite and YSZ is found to have a better creep resistance along with the improvement in the thermal cycling life.

The objective of this work is to coat a composite mixture of mullite and YSZ in the ratio of 80:20 using D-gun and to study about the changes in the microstructure, hardness and find the optimum process parameter based on the results obtained.

2. Procedure

The Detonation gun basically consists of a long water cooled barrel with inlet valves for gases and powder. Oxygen and fuel (acetylene most common) is fed into the barrel along with a charge of powder. A spark is used to ignite the gas mixture and the resulting detonation heats and accelerates the powder to supersonic velocity down the barrel. A pulse of nitrogen is used to purge the barrel after each detonation. This process is repeated many times a second. The high kinetic energy of the hot powder particles on impact with the substrate results in a buildup of very dense and strong coatings.

The mixture of mullite and YSZ in the ratio of 80/20 is prepared by mixing the powders in ball milling machine continuously for two hours containing zirconia balls.

Before coating of the powders, the specimens are first grid blasted using sand blasting. The specimens to be coated for optimization of parameters are then fixed onto a holder and the coating is carried out.

Depending upon the powder to be coated the parameters chosen for coating varies. Oxygen is the one which controls the combustion process taking place and acetylene controls the flame velocity. Nitrogen acts as a carrier gas. The flame is that of neutralizing with oxygen to acetylene ratio remaining constant in all the parameters considered for the optimization of the parameters for coating.

The sample generated for thermal cycling test is coated on superalloyinconel. The coating consists of a bond coat of NiCrAlY which act as a adherent to the top coat. The bond coat thickness was in the range of 75±100µm and the top coat thickness was in the range of 100µm. The coated sample is then made to undergo thermal cycling to test for its thermal shock resistance.

3. Characterization

The coated specimens are characterized for different characteristics such as morphology, hardness and porosity [1].Based on the characterization studies being carried out on the coated specimens the optimization process parameters is made for the coating of the powders on the piston and cylinder head. The specimens to be coated are first grid blasted using sand blasting. The sand blasted specimens are then fixed on the holder. The specimens are then coated using three different set of parameter keeping the ratio of oxygen to acetylene as constant.

The coated specimens are then cut using ISOMET 1000 which is a precision sectioning saw designed for cutting various types of materials of materials with minimal deformation. The cut specimen is then hot mounted using ISOMET hot mounting press apparatus. The specimen is kept for mounting for time duration of 20minutes.

The mounted specimen is then polished using sand papers of different sizes ranging from 800 to 4000 in a systematic and sequential manner till the specimen gets mirror polish. The final polishing of the coated specimen is done using diamond polish with sizes of 3µm, 1µmm and 1/2µm. The finely polished specimens are then analyzed for morphology, hardness and porosity. Microstructural analysis of such finely polished specimens was carried out using scanning electron microscope. The hardness was tested using Viker Hardness Testing and the thermal cycling was carried out to study about the thermal resistance of the coated specimen.

4. Results and Discussion

The specimen of Mullite+YSZ was coated using the parameters shown in table 1

Table 1: List of Operating Parameters

Parameter	O2(lph)	C2H2(lph)	N2(lph)	Spraying Distance (mm)
1	4800	1720	720	200
2	5040	1920	720	200
3	5040	2240	720	200

Figure 1 shows the microstructure obtained using first set of operating parameter.

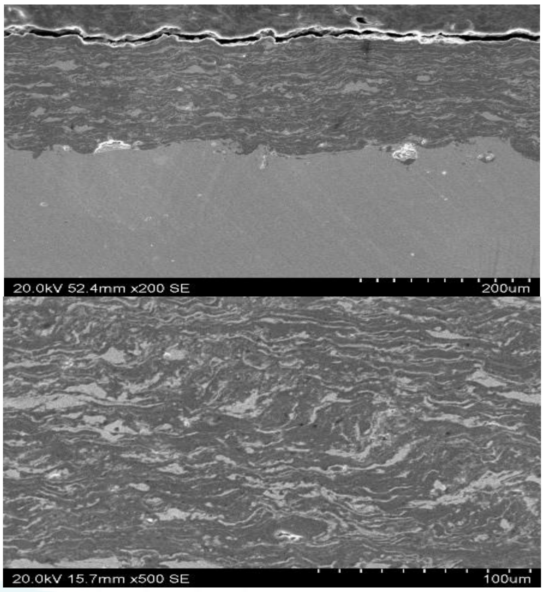

Figure 1: SEM Image of Parameter 1

The SEM analysis shows the coating using 1st parameter was uniform with proper flow if mixture of mullite and YSZ.

Figure 2 shows the EDS analysis of the specimen coated using 1st parameter of mullite + YSZ.

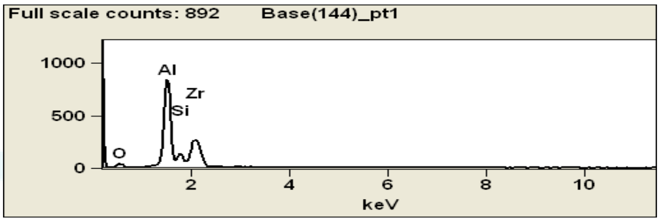

Figure 2: EDS Analysis for Parameter 1

EDS analysis shows that the percentage of mullite and YSZ was in accordance with the percentage of the materials being mixed.

Figure 3 shows the image analysis of specimen coated using 2nd parameter of mixture of mullite + YSZ

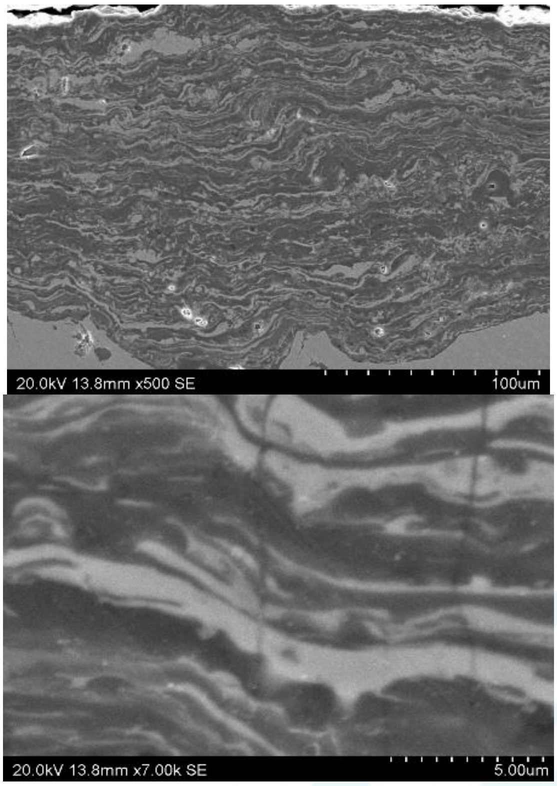

Figure 3: SEM Image for Parameter 2

The SEM image shows that the coating was uniform. But vertical cracks were found to develop in the coating which is not favored.

Figure 4.13 shows the EDS analysis of coating of specimen using 3rd parameter of mullite + YSZ

The EDS analysis shows the percentage of mullite and zirconia was found in accordance with the mixing proportion. While white flows correspond to the YSZ, the black one corresponds to that of mullite.

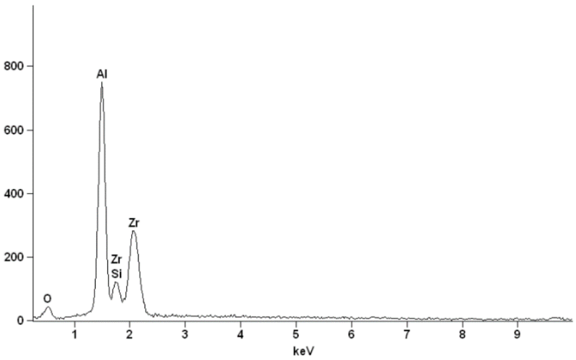

Figure 4: EDS Analysis for Parameter 2

Figure 5 shows the image analysis of specimen coating using 3rd parameter of mullite + YSZ

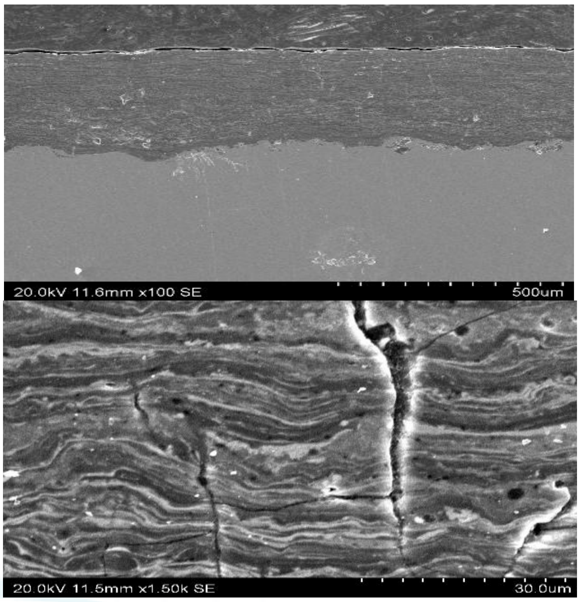

Figure 5: SEM Image for Parameter 3

The SEM analysis shows that, the coatings have developed vertical cracks as well as horizontal cracks.

Figure 6 shows the EDS analysis of the coated specimen using 3rd parameter of mullite + YSZ

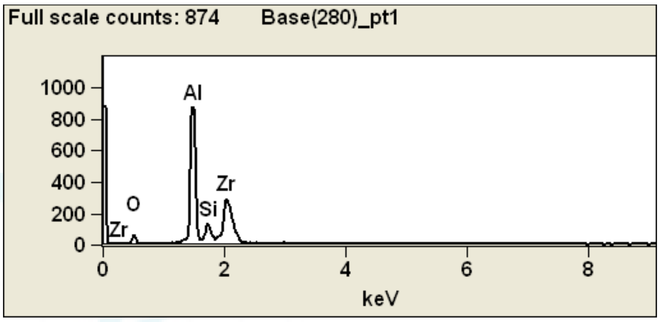

Figure 6: EDS Analysis for Parameter 3

Table 2: Hardness Value for Different Parameters

Parameter	Average	Maximum	Minimum	Std. Deviation	No. of Indentations
1	656HV 0.2	710HV 0.2	608HV 0.2	40.2	10
2	701HV 0.2	799HV 0.2	608HV 0.2	62.43	10
3	1114HV 0.2	1268HV 0.2	956HV 0.2	95.86	10

The hardness values shows that the hardness was maximum for coating using 3rd parameters but with greater deviation in the values. The hardness of coating using 1st parameter was found to be least but with lesser deviation in the hardness values.

5. Conclusion

Based on the study carried out the following observations were made.

1. Mullite+YSZ was coated in the proportion of 20:80 using D-Gun coating using three different set of process parameters.
2. The characterization study was carried out so as to find the optimum set of process parameters for coating.
3. Microstructural analysis and hardness measurement was carried out.
4. Based on the results obtained, if was observed that first parameter for coating would result in optimum coating.

References

[1] T.M. Yonushonis, Overview of Thermal Barrier Coatings in Diesel Engines, Journal of Thermal Spray Technology, March 1997:50-56

[2] X. Q. Cao, R. Vassen, D. Stoever, Ceramic materials for thermal barrier coatings, Journal of the European Ceramic Society, June 2002:1-10

[3] Barbezat Gérard, Application of thermal spraying in Automobile Industry, Journal of Surface and Coatings Technology, June 2006:2028-2031

[4] Douglas H. Harris and Joe Lutz, Thermal Barrier Coatings-Technology For Diesel Engines, SAE Technical Paper Series, March 1988

[5] R. Soltani, H. Samadi, E. Garcia and T. W. Coyle, Development of Alternative Thermal Barrier Coatings for Diesel Engines, SAE Technical Paper Series, April 2005

[6] T. Hejwowski and A. Weronski, The Effect Of thermal barrier coatings on diesel engine performance, Jouranlof Surface Engineering, Surface Instrumentation and Vacuum Technology, 2002:427-432

[7] I. Taymaz, K.Cakir and A. Mimargolur, Experimental Study of Effective Efficiency in a ceramic coated diesel engine, March 2005:1182-1185

[8] A. Tricoire, B.Kjelman, J. Wigren, M. Vanvolsem and L. Aixala, Insulated Piston Heads for Diesel Engines, January 2009:217-222

[9] C. Cano, E. Garcia, A.L. Fernandes, M.I. Osendi, and P. Miranzo, Mullite/ZrO2 coatings Produces by Flame Spraying, Journal Of the European Ceramic Society, February 2008:2191-2197

[10] P.L. Ke, Y.N. Wu, Q.M. Wang, J. Gong, C. Sun, L.S. Wen, Study on Thermal Barrier Coatings produced by Thermal Spraying, Journal of Surface and Coatings Technology, September 2004:2271-2276

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