STRUCTURE OF LASER SURFACE MELTING OF PLASMA SPRAYED WITH 6.5 YTTRIA PARTIALLY STABILIZED ZIRCONIA+

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Abstract

Results are reported on the effect of laser sealing of plasma sprayed yttria partially stabilized zirconia plasma sprayed with yttria . An improvement in the topography of the plasma sprayed layers are obtained at specific energy between 1 and 2 J/mm^2 . Results have been obtained showing the possibility of using laser beam to seal the porosity of low yttria partially stabilized zirconia to produce low or free porosity and fine cell structure ceramic.

المستخلص

لقد تمت دراسة تاثير المعاملة بالليزر لغلق المسامات الخارجية لطبقات الرش بالبلازما لنظام الزركونيا المثبتة جزئيا بالياتريا وبنسبة وزنية ٦,٥. ادت المعاملة بالليزر وعند طاقة نوعية ضمن المدى ١-٢ جول/ملم٢. النتائج التى تم الحصول عليها التي اوضحت امكانية استخدام الليزر لغلق المسامية لطبقات الرش بالبلازما لنظام الزركونيا-ياتريا مع الحصول على بنية مجهرية ذات حبيبات ناعمة.

Introduction

The use of ceramic thermal barrier coatings is of growing interest due to the combination of properties required for advanced turbine engines [1]. These engines are required to work at higher and higher temperatures due to the increased thermodynamic efficiency possible with higher operating temperatures. Although high porosity coatings give significant thermal protection there are problems with adhesion, mechanical strength and corrosion through cracks and interconnected pores.

It was found that some of these problems could be reduced if the surface of these layers were to be sealed by melting with lasers [2-5]. Sealing eliminates the porosity and cracks, which enhance the hot corrosion resistance; it also improves the mechanical properties (hardness, strength and toughness) of the coating layers [6].

The paper reported for the first time the effect of laser sealing of a stabilized zirconia based coating plasma sprayed with 6.5 yttria which has the optimum proportion of stabilized phases..

Experimental Procedures

Specimens of medium carbon steel 5.6 mm thick were plasma sprayed to approximately 380 um thick layers of ZrO_2 – 6.5 wt%Y_2O_3 and 120 um Co-32Ni-21Cr-8Al-0.6Y bond layer (type AMDRY 935) from powders of average particle sizes ~ 60 and 150 um respectively. The thickness of sprayed layers was determined from polished transverse section. The mild steel samples were shot blasted just before the spraying and then fixed into the rotary jig of spraying unit by mean of screws. An

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automatic robot spraying system manufactured by Plasma Technick Ltd was used to spray bond and ceramic layers on to mild steel substarte(Table 1). A step-scanning mode with 2O of 0.01^o interval and a count time of 1 sec was employed. Automatic step scanning was carried out over the low and high angles 2O ranges of $27.5-32^o$ and submitted also to J. Materials Science Letters, U.K.

$2-75.5^o$ respectively. Surface melting of coating was achieved with a 2kW CO_2 CW laser. The beam powers (P) were in the range of 0.8-2 kW with a diameter (D) of 5 mm. The traverse speed (V) was varied over the range of 5 to 370 mm/s. These parameters gave values of the specific energy (P/DV) J/mm^2 from 0.4 to 80 J/mm^2.

Table 1: Processing plasma sheet of plasma sprayed and bond layers.

Substrate Preparation	Grit blast
Grit Type	alumina
Blast Pressure	6 bar
Blast Distance	100 mm

Spray Parameters

	Bond Layer	**6.5 wt% YPSZ**
Plasma Gas	Ar	Ar
Pressure, bar	3	3
Flow Rate, L/min	50	30
Secondary Gas	H2	H2
Pressure, bar	3	3
Current, A	600	600
Voltage, kV	60	60
Spray Distance, mm	120	120
Angle, degree	90	90
Carrier Gas	Ar	Ar
Flow Rate, L/min	4	3
Spray Rate, g/min	55	30

Results and Discussion

The plain views of as-sprayed surface without grinding and polishing and the polished transverse section of as-sprayed surface are shown in the SEM micrographs of Figs. 1 and 2 respectively. X-ray analysis of the structure showed that the as – sprayed layers are consisted completely of non-transformable tetragonal phase namely t' (Table 2) . The as – sprayed layer showed a relatively non-homogeneity in the distribution of Porosity and chemical composition. Some surface Particles are cracked. Some cracking in the plasma layer as well as at the interface is apparent. Laser surface melting produced a bottuioldal structure as in common with ceramic coating of other zirconia based (2). This is illustrated in (Fig . 3).

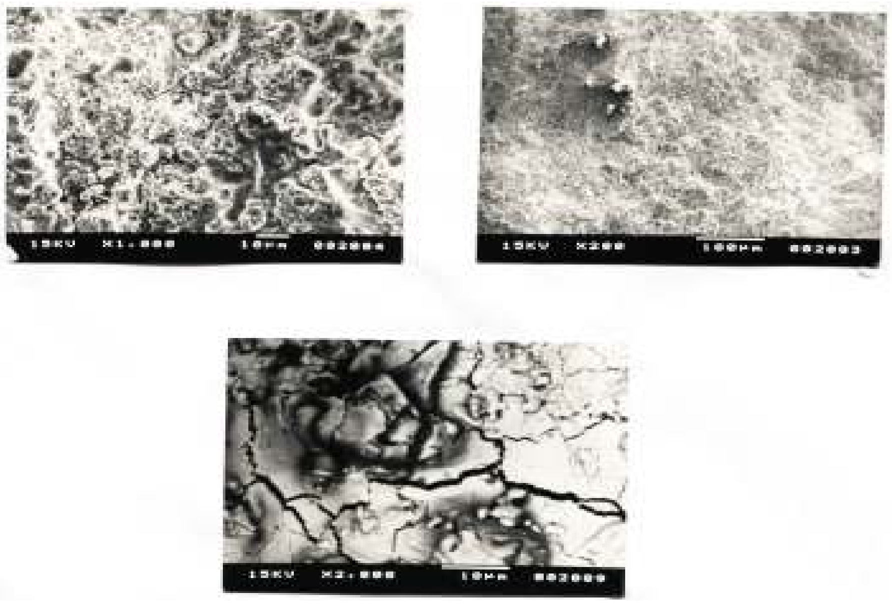

Fig.1 :SEM micrographs of plan views of as-sprayed layers.

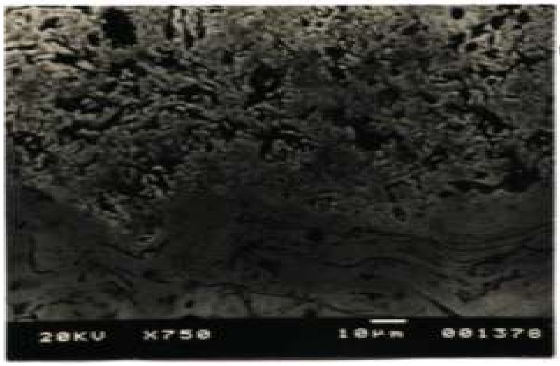

Fig. 2 SEM micrograph of transverse section showing the bonding between the layers, internal porosity and cracks.

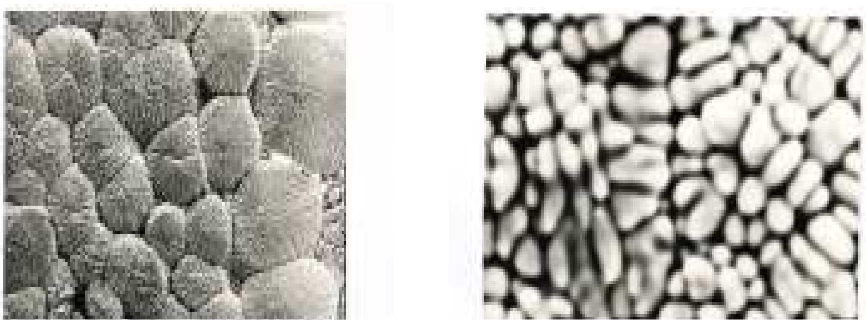

Fig. 3: Higher magnifications of the plan view of sealed layer showing the cells.

The specific energy had a marked effect on the structure of the sealed melted layer. At low specific energy (~ 0.43 J/mm2) only non-uniform complete sealing is observed (Fig.4). The melt layer does not spread across the entire treated track. This is due to lack of fluidity in the molten layer due to insufficient specific energy. There is also cracking from the inner porosity layers leading to fracture of the edge regions adjacent to the porosity (Fig.5). Higher magnification of this region showed the formation of very fine cell structure (Fig.6).

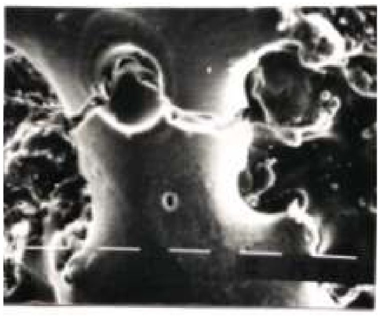

Fig. 4 SEM shows the partial sealing layer at low specific energy (800 W laser power and 370 mm/s traverse speed).

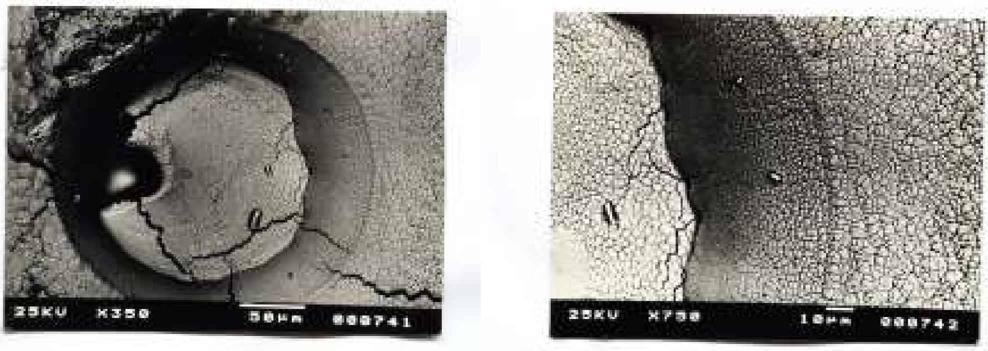

Fig. 5 SEM photographs showing the cracks for the sealed porosity.

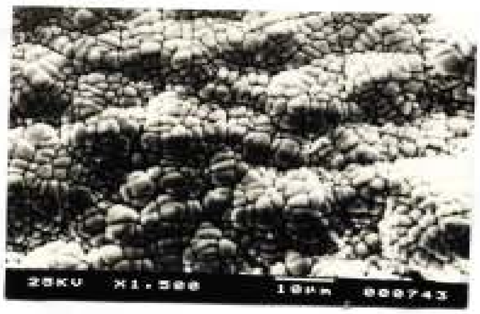

Fig. 6: Higher magnifications SEM photograph showing the cells inside the porosity.

Increasing the specific energy to 2 J/mm^2, by decreasing the traverse speed, gave a very shallow surface crack for optimum sealed layer. This coating was sealed and appeared to be adherent as the parent plasma sprayed coating (Fig.7). Further increase of the specific energy to 2.5 J/mm^2 by decreasing the traverse speed still sealed the layer but more surface and deep cracks were observed (Fig. 8).

Fig. 7 SEM micrographs of the plan view and transverse section of optimum laser sealing (1000 W laser power and 100 mm/s traverse speed).

Fig. 8 SEM micrographs at relatively high specific energy shows the cracks from plan view and transverse section (800 W laser power and 64 mm/s traverse speed).

Increasing the specific energy even further to 4.3 J/mm^2 by reducing the traverse speed caused deep melting of the half to the thickness of plasma sprayed layer down to near the bond layer (Fig.9). This layer showed significant thinning of the ceramic due to flow away from the hot region due to surface tension forces. Higher specific energy caused excessive stress in the coating and often resulted in the complete damage and removal of the coating (Fig.10). This has serious effect on the quality.

Fig. 9 SEM photographs of the transverse section showing the deep cracks and thinning of ceramic layer (1000 W laser power and 47 mm/s traverse speed).

Fig. 10 SEM photographs of the transverse section showing the deep melting of the sprayed ceramic layer (1000 W laser power and 22 mm/s traverse speed).

At high specific energy of higher than 25 J/mm^2 corresponding to high power and relatively low traverse speed operation sever cracking was observed (Fig.11) with deep melting even to the bond layer down to the substrate.

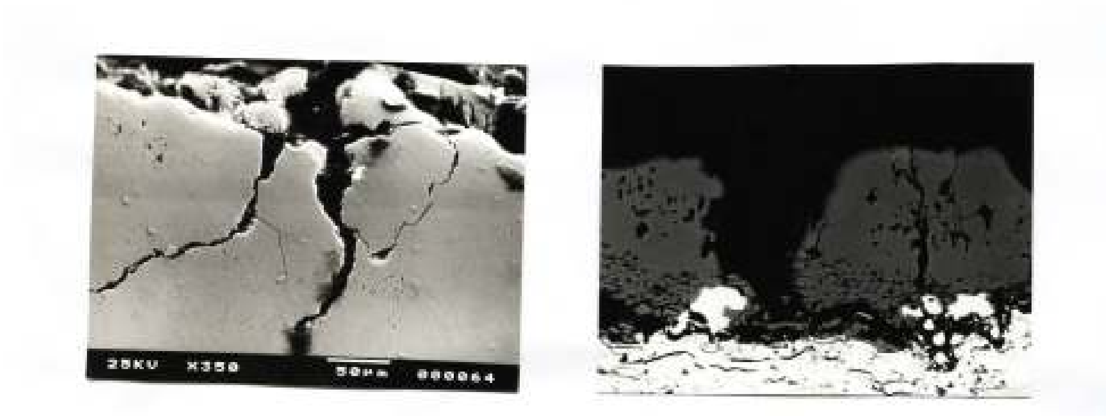

Fig. 11 SEM and optical photographs of transverse sections at very high specific energy showing the complete damage of plasma and bond layers (800 W laser power and 6.3 mm/s traverse speed).

Table 2: Step scanning X-ray data of as-sprayed and as-sealed layers.

D, nm	Phase	Plane
As-sprayed		
0.2950	t’	111
0.1287	t’	400
as-sealed		
0.2955	t’	111
0.1280	t’	400

Conclusions

1. The process of sealing plasma sprayed ceramic layers by surface sealing with CW laser is possible for the 6.5 wt% yttria stabilized zirconia.
2. Sealing surface with very low porosity and shallow cracks is obtained using specific of less than 2 J/mm^2.
3. Higher values of the specific energies still give sealed but with noticeable deep cracks.
4. Even higher values of the specific energies have led to complete melting of the coating and bond layer or even down to the substrate with severe cracking and bad quality.

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