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Surface Treatment of Thermal Sprayed Ceramic Coatings by Laser Beam

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ABSTRACT

Composite structure of magnesia partially stabilized Zirconia (MgO-PSZ) with a Ni-Al bond coat have been investigated.This composite was sprayed on to a stainless steel grid of stainless steel-304 substrate to produce coating layer. The measurements of microstructure surface roughness, porosity and microhardness for sprayed layers wereperformed. PulsedNd: glass laser with pulse duration of 300 µs. and an energy ranging between (1-7.6)jouleswas used to investigate the effect of heat treatment on the sprayed layer.The laser treatment causeda reduction in surface roughness and porosity.An improvement in the mechanical properties of the composites wasobserved.

Keywords: Thermal Coating; Advanced Material Engineering; Laser Treatment ; Composite Materials.

المعاملة السطحية لطلاء السيراميك المحضر بالرش الحراري باستخدام الليزر

الخلاصة

في هذا البحث تم مناقشة تركيب المادة التراكبة من الزركونيا المستقرة بالمغنيسيا المضاف اليها المادة الرابطة المتكونة من الالمنيوموالنيكل. تم رش المادة التراكبة المحضرة حراريا على قواعد فولاذية مقاومة للصدأ لتكوين طبقة الطلاء. تم تقييس وتقويم التركيب المجهري والصلادة الدقيقة وخشونة السطح المسامية باستخدام ليزر النيديميوم النبضي بنبضات 1ات امد زمني 300 مايكروثانية وضمن حدود طاقات (1-7.6) جول. سببت المعاملة بالليزر اخفاضا في قيمة البخشونة السطحية والمسامية. لوحظ ايضا تحسنا في الخواص الميكانيكية لطبقة الطلاء.

INTRODUCTION

Thermal sprayed ceramic coating are widely used as athermal barrier coating (TBC) for gas turbine and other heat engine components. These coatings reduce the surface temperature of the metal components and act as barriers to the hot corrosion degradation of the substrate. Potential advances from the use of

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such (TBC) are quite large and include extension of service lifetime, operation with lower quality fuels and reduction or elimination of the cooling requirement [1]. The most successful ceramic coatingwas obtained with Zirconia powders [2]. Pure Zirconia exists in three crystalline structures; these are monoclinic, tetragonal,and cubic structure. One of the alloying elements (MgO,Cao and Y_2O_3) was added to the zirconia to decrease cubic, and tetragonal -monoclinic transformation structure[3,4].When the alloying elements add with a certain limit, physical and mechanical properties are most useful to study the effect of adding partial stabilization [4]. Most popular composite material used in thermal barrier coating (TBC) is cermet, which is a mixture of metal bonding and ceramic oxide such as (Z_rO_2, Al2, O3, Cao, Y2O3 or MgO[5]. The advantage of a adding metal to ceramics is to enhance mechanical strength, thermal shock, and creep resisting [6]. Also good solubility is obtained with ceramic oxide and binding materials, by decreasing the melting point of ceramic. This phenomenon is very useful in thermal spraying process. Mostly, all thermal coating are suffering from some problems of porosity and surface defects existing in the coating layer. These may degrade the physical and mechanical properties [7]. Laser treatment can be performed to introduce alloying mixtures and also high adhesion strength between coating and base[8]. In order to improve, the surface properties of coating. Laser treatment can be performed to improve the mechanical properties of the coating layers as a result of providing high power per unit area [9].The purpose of this study is to evaluate the surface roughness and porosity modifications of flame sprayed cermet coating of (Z_rO_2 25 Mgo) +Ni-Al) deposited on (304)St.St. substrates by using a pulsed laser beam at different power densities.

MATERIALS AND EXPERIMENTAL PROCEDURES

The substrate was stainless steel (304) in a cylindrical shape of (l0 mm) diameter and (20mm) height. Before being sprayed, substrates were grit blasted with crashed silicon carbide to increase the surface roughness, because the bonding between coating layer and substrate is mechanical. The 50 (Ni-Al) alloys were used as a self-bond, which gives good adherence properties and reduces the thermal properties mismatch between the cermet layer and substrate. The cermet layer was flame sprayed as shown in Figure (1): The cermet coating was prepared from commercial Zirconia (Metco201) stabilized with 25% magnesia, where powders are mixed at (50%wt ZrO_2+ 25Mgo and (50%wt Ni –Al) then dried by oven at 70 c° for one hour. The laser system used in this work is laboratory made Nd: Glass laser. It gives 300µsec laser pulses at 1.06µmwavelength. A 3cm positive lens was used to focus the laser beam on substrates. Surface roughness of the required area was measured by perthometer type 6sp.This instrument could measure the roughness of the required area by automatic Scanning with fine needle and take the average of all Scanned area. Porosity measurements were made according to the (ASTM-c830) [9]. The structure of the coating layer was investigated by X-ray diffraction with (Cuk) radiation. The Microstructure of the coating was determined by optical and atomic force microscopy (AFM).

RESULTS AND DISCUSSION

The spraying is done with flame spray coating. Operating parameters during coating process are listed in Table (1). Figure (2) shows the XRD Patterns of cermet coating before and after laser treatment. It is clear that one of the strong peaks of the

Al_3Ni_2 which belongs to the binder material. The pattern shows also for ZrO_2 higher peak intensity increasing with the increase the energy of laser. The peak of Z_rO_2 has been transformed form tetragonal of monoclinic phase to cubic phase according to (JCPDS) No 34-1084. Table (2) shows the effect of energies on the surface roughness and the porosity of coating layer for different energies. This Table indicates that there is a significant change in roughness and porosity values, which corresponds to the heating effect in the irradiated zone surface of the coating layer. The behavior of roughness and porosity results are approximately similar. At low laser energy, there is no significant change in porosity and roughness values because there is little heating effect which has no significant effect on the porosity or roughness values. Increasing energy of the laser pulses has increased melting, so that porosity, particle size, and roughness have reduced due to sealing. The reduction in porosity percentage, particle size and roughness are shown in Table (2) and Figure (3). The increase in energy over (6J) caused some damage in the coating layer as shown in Figure (4). This led to an increase in porosity value expected. Cracks spacing increased also with increasing laser energy over (6J) due to the porosity escaping upwards through the molten composite layer which produced deformations in the surface. [10, 11].

CONCLUSIONS

Good adhesion between ceramic coating and substrate was achieved when using (Ni-Al) binder in thermal spray by flame. The microstructures of the coating layer showed better distribution of the particles on the substrate when using pulsed laser energies below (6J).Melting of coating surface and some cracks spacing were observed after raising the pulsed energy above (6J). X-ray analysis showed an increasing peak intensity of the cubic Zirconia with the increase of laser energy.

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Table (1) Operating parameters during composite Coating process of (NiAl+ZrO_2+Mgo).

Properties	Values
OXY-Acetylene	0.7, 4
Spraying Distances	8, 12, 16, 20 cm
Thickness Coting	1.35+0.3mm
Flame spray temp	3000-3025°C
Particle size of powder	μm) 75-100(
Coating Time	(1-2)min
Time between tow spray process	5 sec

Table (2) The results from (AFM) show the effect of laser energies on the coating surface.

Laser Energy (J)	Roughness (Average) (nm)	Practical Size (nm)	Root Mean Square(nm)	Max Length Surface(nm)	Porosity %
Without Treatment	1.47	98.11	1.79	8.20	20
1	1.49	94.79	1.76	7.6	18.74
4	0.558	70.43	0.718	4.69	9.31
6	0.213	68.85	0.265	3.71	3.39
7.6	1.50	113.16	1.53	9.21	15.07

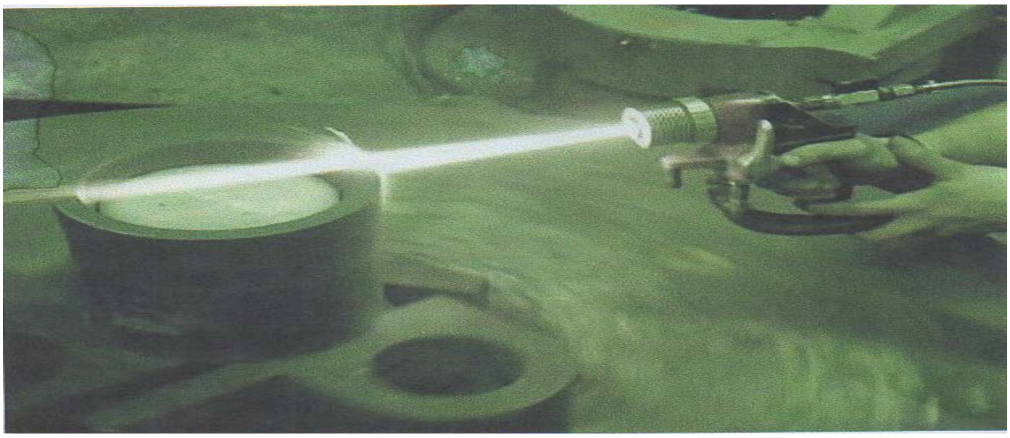


Figure (1) Flame-thermal spraying of the composite material.

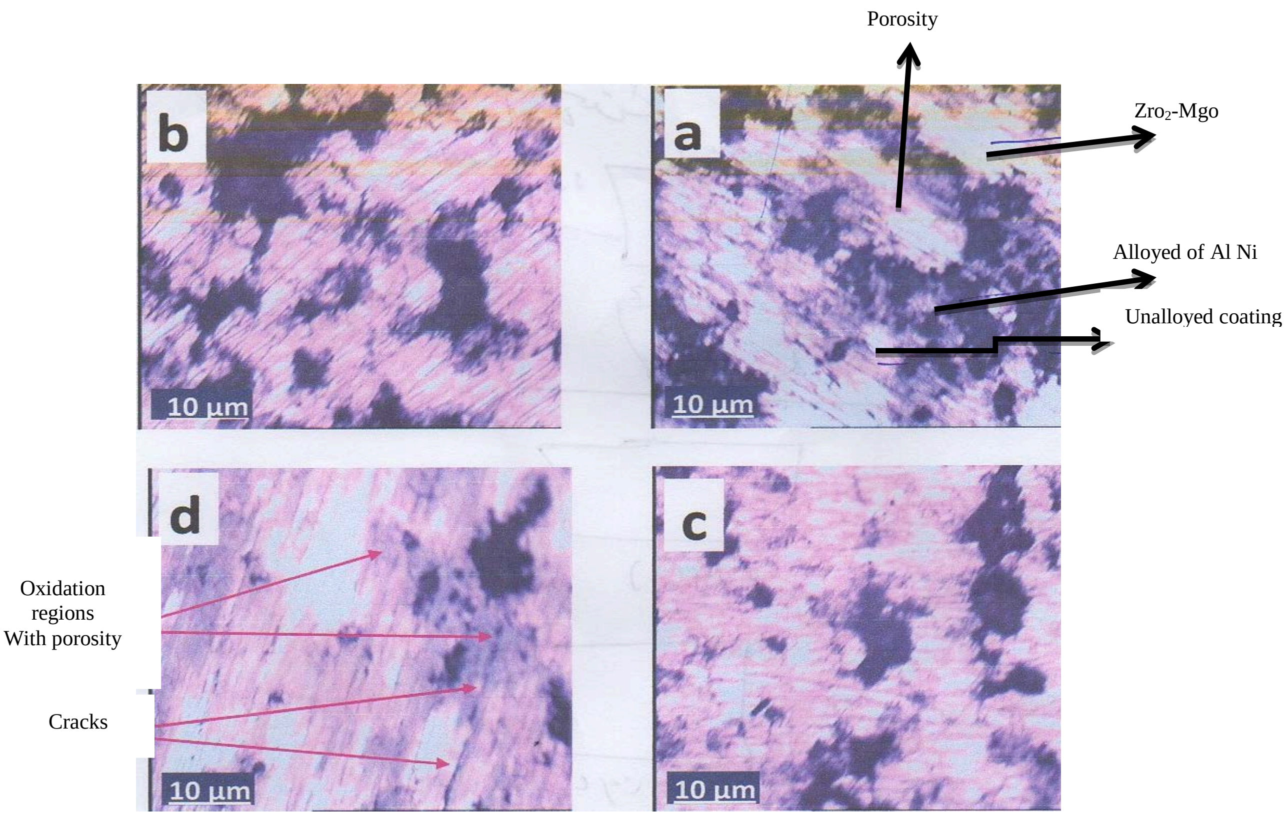


Figure (4) The effect of laser energies on the composite coated surface microstructure:-As sprayed, (b)- 4J, (c)- 6J, (d)- 7.6J)

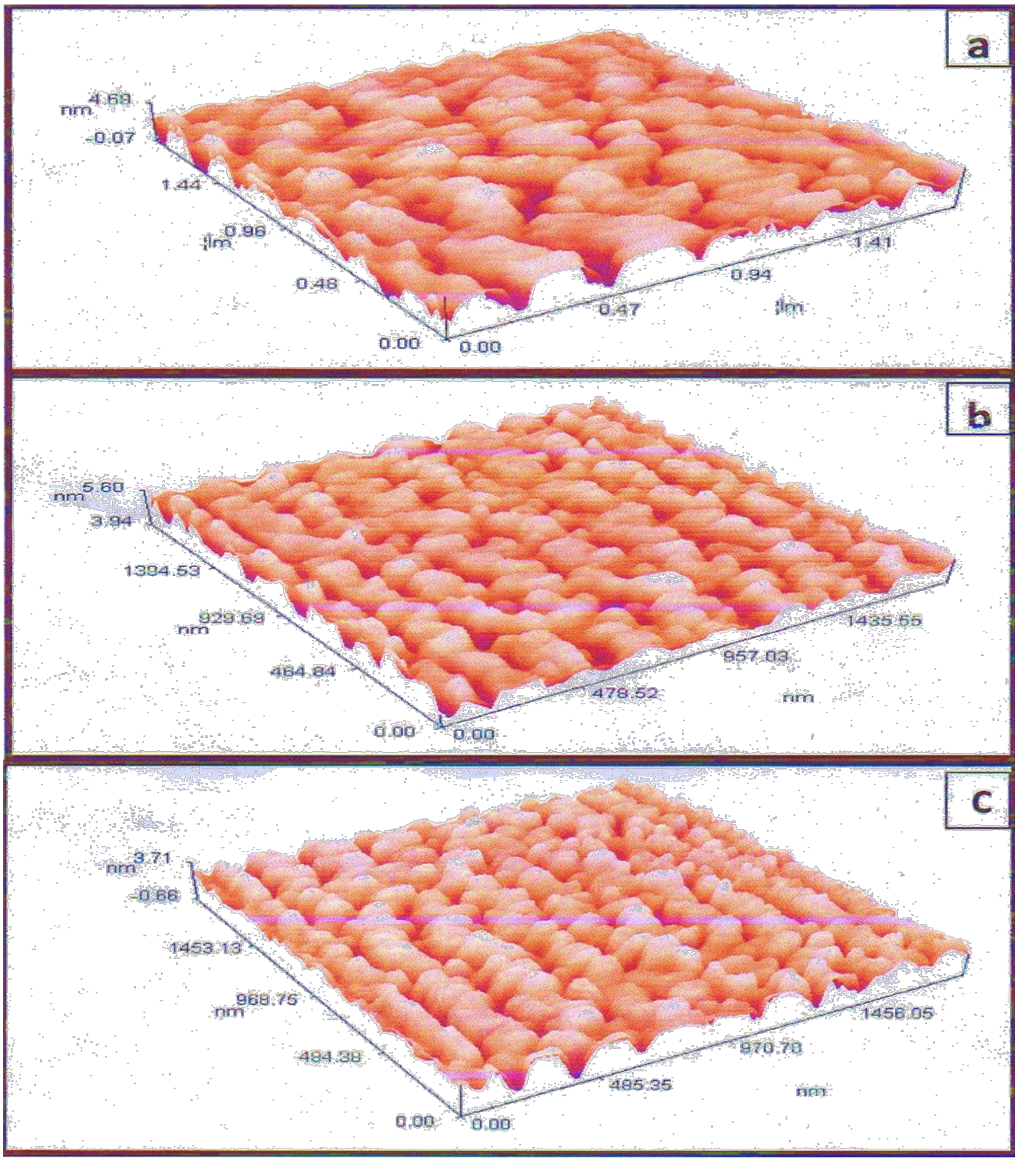
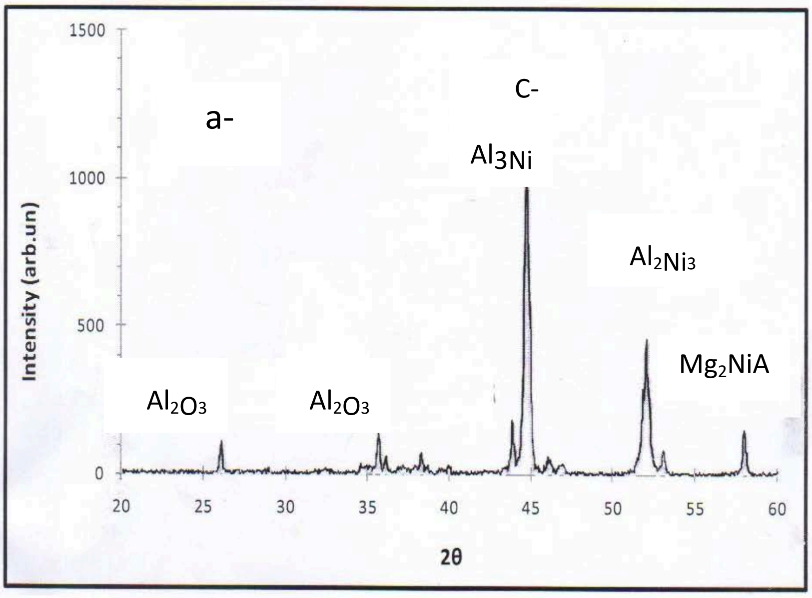


Figure (3) 3-D atomic force microscope (AFM) results on the Composite coating surface at different treated energies: (a) - without treatment (as sprayed), (b) - 4J, (c)- 6J.



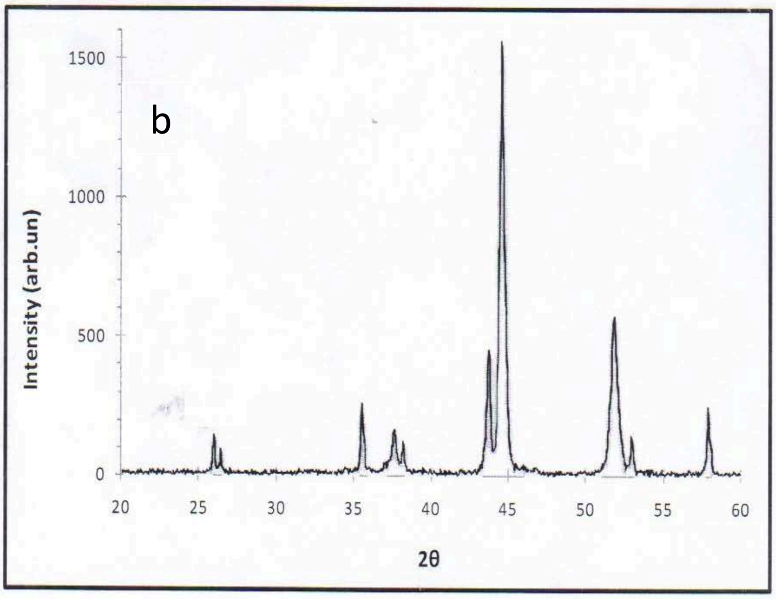


Figure (2) XRD Pattern of the cermet coating: (a)-As sprayed, (b) - Laser treatment (6j)