REALIZATION OF MELTED LAYERS WITH CO₂ LASER ON SINTERED CERAMICS

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Abstract - The high sensitivity of ceramic materials to surface defects requires a surface treatment for minimizing this disadvantage or to reject their effects. The laser is a convenient and sometimes unique tool for investigating some of the methods of treatment or processing ceramics that may significantly improve their properties. The surface layers of materials were melted in air using a CO₂ laser radiation. As with most ceramic oxides, this radiation is efficiently absorbed and dissipated as thermal energy. The material used in this study was a sintered zirconia substrate (Mg - PSZ). The surface analysis by scanning electron microscopy indicated that fine and complex microstructures were developed in the surface of melted layers. The different phases in the substrates, before and after laser treatment, were detected by X-ray diffraction. Indentation technique has been applied to determine the hardness of melted layer and substrate.

1 - Introduction

Some studies have been conducted on laser interaction with ceramic materials, but the attempts to heat ceramic bodies with high intensity laser beam have usually resulted in crack formation and degradation [1].

For example, ceramics welding with laser, which is considered as not possible with any other processing methods, have been studied by M. Ikeda [2]. For preventing crack formation at the welded part, a preheating at slow cooling was effective. The samples used were of two types, i. e., alumina and forsterite which have different thermal expansion coefficients and heat conductivities. The samples were placed in a furnace. No micro-cracks were observed on the welded part and perfect jointing is carried out. But large pores are observed on the boundary of the weld part of forsterite, these pores are considered to be congregation of dispersed micro-air pores.

B. L. Mordike and R. Sivakumar [3] have used a laser beam to locally melt and densify the ceramic coatings. The authors have concluded that the laser is a powerful tool that can effectively be used to remelt and solidify plasma sprayed ceramic coatings. The above can be accomplished with a low energy input of a 250 joules/cm², preferably in the pulsed mode. By heating the sample to 850 °C in a furnace during laser treatment and also by slow cooling in the furnace, it is possible to minimize somewhat the extent of cracking.

K. Hashimoto and al. [4] have studied the laser drilling of alumina substrate. The CO₂ laser produces an annular ridge of glassy material around the laser-entrance hole, but the YAG laser produces a small amount of ceramic debris around the laser-entrance hole.

2 - Experimental procedure

A CO₂ laser beam was used having a power density of 750 W/cm² by using a cylindrical lens with a focal length of $f = 254$ mm, to modify the distribution of the beam. The laser was operating in the TEM₀₀ mode giving a Gaussian beam intensity profile, figure 1.

The samples used are sintered zirconia (Mg - PSZ) substrates. Table 1 gives a summary of the zirconia characteristics. The samples were cut in small bars with dimensions 4 x 5 x 25 mm.

T_m (°C)	ρ (g/cm ³)	σ_f (MPa)	E (GPa)	H_v (GPa)	K_{IC} (MPa√m)
2715	5,7	200 - 800	200	11	5 - 8

Table 1 : Summary of the zirconia characteristics [6]

By heating the sample to 1200 °C with an auxiliary heating apparatus during the laser treatment and also by slow cooling, it is possible to avoid the cracking of substrates. To reach the melting temperature of the material, with this weak power density, we have effected several successive passes of the beam at the same area [5].

3 - Results and discussion

Figure 2 shows the scanning electron micrograph of the surface of sintered zirconia which was melted on the surface using the a continuous wave mode. As we can see, melting is complete and fine solidified structures were

obtained. The depth of melting is about 70 μm , figure 3. In the case of thick melting, the heat loss by conduction through the substrate is higher than that by radiation from the surface. This implies that solidification starts at the interface of the melted and unmelted layers. In the cross-section micrograph, it can be seen that the melted layer has a dendritic structure with a glassy phase in the grain boundaries and interdendritic spacing.

X-ray diffraction patterns obtained at room-temperature for Mg - PSZ sample before and after laser treatment are compared in figure 4. After treatment there was a change in the intensities of the peaks. However, some peaks have disappeared. Vickers indentation, at room-temperature was used, for characterizing the material. An increase in the hardness of the molten layer obtained by laser treatment is observed, figure 5.

4 - Conclusion

The treatment of zirconia (Mg - PSZ) with CO_2 laser beam, using auxiliary heating apparatus, give the possibility to obtain fine microstructure without cracking. The melted layer is harder than the substrate.

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Fig. 1 : Distribution of laser beam energy on the sample surface

Fig. 2 : Grain refinement on the surface after laser treatment

Fig. 3 : Cross-section of Mg-PSZ (etched with HF acid)

Fig. 5 : Vickers indentation

Fig. 4 : X-ray diffraction patterns ($\text{CuK}\alpha$) for Mg-PSZ before (A) and after (B) laser treatment.