A NEW TRANSIENT PHOTOTHERMAL REFLECTANCE TECHNIQUE

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Introduction

Photothermal methods have proved suitable for the testing of fiber composites, coatings on composites (Moksin and Almond, 1995), ceramics (Seibeneck et al. 1977), anisotropic materials (Enguhard et al. 1990) and optical coatings (Zimmermann et al. 1994), In these methods, a thermal wave is generated by sample absorption of modulated or pulsed laser and sensed by using an appropriate detection scheme. Opaque materials as used in protective coating may be broadly classified into highly light absorbing and reflecting materials. These materials are normally chosen because of their excellent resistance to corrosion, oxidation, erosion and wear, and they can withstand reasonably high temperature beside their aesthetic value. The ability to remotely characterise nondestructively the surface and subsurface layer of such materials is important in the study of near surface properties and changes in those properties during and/or following exposure to corrosive and aggressive environment.

Materials and Methods

In this study, a thermal wave was generated by pulse laser heating of a small volume of the sample, which caused rapid localised temperature rise up to about 10°C. Hence expansion of the surface layer before the temperature decays to ambient and subsequently the surface returns to its original form. The resulting changes in thermal infrared radiation from the sample surface were remotely detected by a wide-band infrared detector. In the case of highly reflecting sample, the focus of the present work, the thermal infrared signals were too weak to be directly detected by using the infrared detector. A laser probe was used instead to monitor appreciable deformation/ displacement on the surface profile as it underwent temperature change.

Results and Discussion

The normalised time - dependent photothermal displacement signals were fitted reasonably well to numerically calculated results for steel, brass and aluminium samples. The signals sharply rose to a peak value before slowly decayed back to its original value at zero level. From visual inspection of the data, the three characteristics of the curves were decay time, rise time and amplitude. The curve for copper had the fastest decay, which was followed for aluminium, brass and stainless steel. The curve decay for the rate was inversely related to thermal diffusivity as predicted. The rise time consistently followed the thermal conductivity trend i.e. the rate at which the surface deforms is dependent on the speed at which the heat is conducted in the materials. Thus, steel which had the lowest thermal conductivity among the samples displayed slowest rise time followed closely by aluminium, brass and copper. On the other hand, assuming the samples absorbed more or less the same amount of energy delivered by the pump laser, the signal amplitude changed with the slope of the deformation. This in turn increased largely with thermal expansion of the materials and decreased to much smaller extent with thermal diffusivity.

Conclusions

The results presented above significantly compliment previous work on dynamics of heat transfer in materials. However, the detection scheme, though proved sensitive in this work, is much more difficult to operate in comparison to direct detection.

References

Enguhard, E., Boscher, D., Deom, A. and Balageas, D. 1990. Measurement of thermal diffusivity of anisotropic materials by converging thermal wave technique, *Mat. Sci. Eng.* B(5): 172-176.

Moksin, M.M. and Almond, D.P. 1995. Nondestructive evaluation of paint coatings using the thermal wave interferometry technique, *J Mat. Sci.* 30: 2251-2253.

Moksin, M.M., Grozescu, I.V., Wahab, Z.A. Yunus, W.M.M. and Azmi, B.Z. 1997. Effect of boron carbide composition in Si/B_4C composite on surface temperature decay as revealed by thermal wave method, Nondestr. *Testing. Eva.* 13: 239-245.

Seibeneck, H.J., Hasselman, P.H., Cleveland, J.J. and Bradt, R.C. 1977. Effects of grain size and micrcracking on the thermal diffusivity of $MgTi_2O_5$. *J Am. Cer. Soc.* 60: 336-338.

Zimmermann, P., Ristau, D. and Welsch, E. 1994. Potentiality of the photothermal surface-displacement technique for precisely performed absorption measurement of optical coatings, *App. Phys.* A(5): 377-383.

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