TECHNICAL NOTE

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Influence of X-Radiation on Behavior of Strain Gages

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ABSTRACT: In this paper the performance of resistance strain gages in a radiation environment is examined. Values of apparent strain are measured by strain gages mounted on two kinds of backing materials (polyester and polyimide) as a function of X-ray flux. A comparison of the behavior of both types of strain gages is presented and discussed.

KEYWORDS: apparent strain, irradiation, X-ray, strain gages

Electrical resistance strain gages are the main technique for many problems in the field of experimental stress analysis. However, in using this technique, one has to take into account each parameter that may affect the resistance of the strain gage. When in-pile strain measurements have to be performed, temperature and radiation damage are, among others, the most important sources of parasitic effects [*1–3*].

The rate of change of resistivity with irradiation dose is dependent upon several strain gage initial conditions. The exact rates cannot be predicted for all kinds of strain gages, so experimental data must be obtained for each combination of gage and bonding technique of interest [*3–5*]. The present work concentrates on the influence of X-ray flux on bonded resistance strain gage installation with two different encapsulating layers (backing materials).

Experimental Procedure

Two sets of identical constantan strain gages, mounted on two different plastic backing materials (polyimide and polyester), were tested. The polyester strain gage was made by Tokyo Sokky Kenkyujo Co. Ltd., Model PL-5 (gage resistance: 120 ± 0.3 Ω). The polyimide strain gage was made by Tokyo Sokky Kenkyujo Co. Ltd., Model NSLA-6 (gage resistance: 120 ± 0.3 Ω). The backing materials were made with the same dimensions (15 by 6 by 1 mm). The strain gages were used as full bridges. Temperature was also measured by using a chromel-alumel thermocouple and a strain gage (Model TFL-10, made by Tokyo Sokky Kenkyujo Co. Ltd.) mounted on polyimide throughout the test.

Rectangular plates of stainless steel AISI 321 (50 by 30 by 3.2 mm) were instrumented with a polyimide-backing strain gage, a polyester-backing strain gage, a temperature gage, and a thermocouple, as shown schematically in Fig. 1. The strain gages were bonded with M-bond 610 epoxy, and they were overcoated with a polyester-based resin. The measurement system for the strain gages was composed of a Wheatstone bridge, an amplifier and filters, and of a thermocouple as described in Ref *3*.

One instrumented plate, identified as Plate 1, was installed in an X-ray irradiation chamber. This plate was initially submitted to an irradiation rate of 14 000 R/s and an energy of 400 W during 90 h. Then, it was exposed to an irradiation rate of 28 000 R/s and energy of 800 W during 400 h. An X-ray source with Mo target, voltage of 40 kV, and current of 20 mA was used. Another instrumented plate, identified as Plate 2, was installed without radiation exposure. This plate was used as a reference.

Experimental Results

The temperature was approximately 37°C in Plate 1 and approximately 28°C in Plate 2. Variation of temperature was not observed during the experiment, meaning that temperature remained constant. The temperature difference between the thermocouple and the temperature strain gage was ±2°C in each plate throughout the tests.

In Fig. 2 are shown the results obtained in Plate 1 during the first experiment (400 W, 14 000 R/s, 90 h). Both strain gages showed a similar behavior, and the observed difference in the apparent strain after 90 h is small.

After 400 h under an irradiation rate of 28 000 R/s and energy of 800 W (Fig. 3), one can observe a quite different behavior of the strain gages. While the apparent strain measured by the polyimide strain gage remained approximately constant, the apparent strain obtained by the polyester strain gage showed a sharp increase with the increase of the irradiation dose.

Discussion

During the first experiment of irradiation exposure, both types of strain gages behaved in a similar manner. The difference of the measured apparent strain is likely to be due to a drift of the electronic measuring equipment (lack of initial equilibrium of the bridge circuit). The measurements were obtained from a system without initial balance (initial zero). In this way the initial values obtained for each strain gage were out of phase. This becomes evident on analyzing Fig. 4 which shows the influence of time on the apparent strain, measured by both strain gages mounted on Plate 2 (without irradiation exposure).

During the second experiment, it was observed that the polyester strain gage showed a sharp increase in apparent strain on increasing the irradiation dose, while the polyimide strain gage exhibited no

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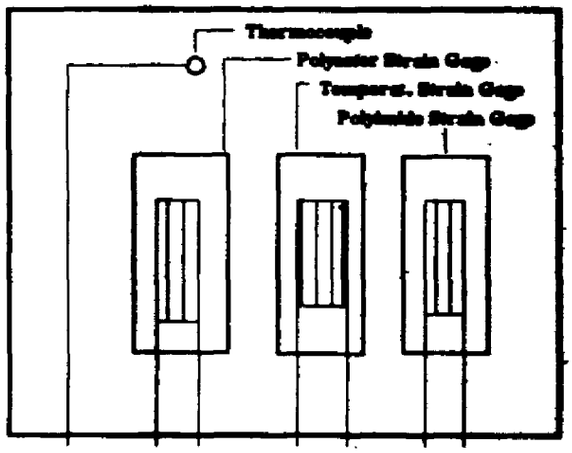

FIG. 1—*Instrumented plate of stainless steel.*

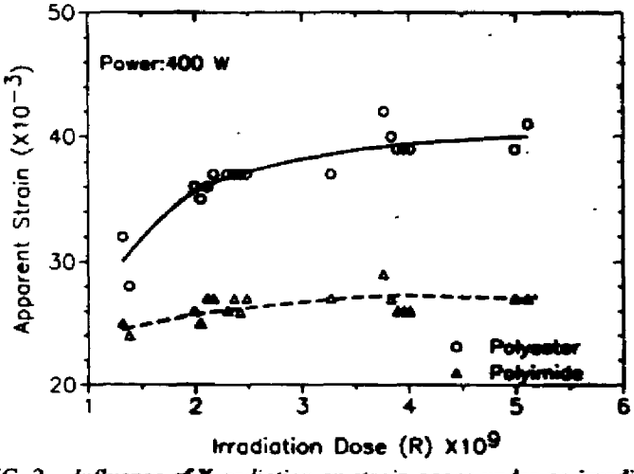

FIG 2—*Influence of X-radiation on strain gages under an irradiation rate of 14 000 R/s during 90 h.*

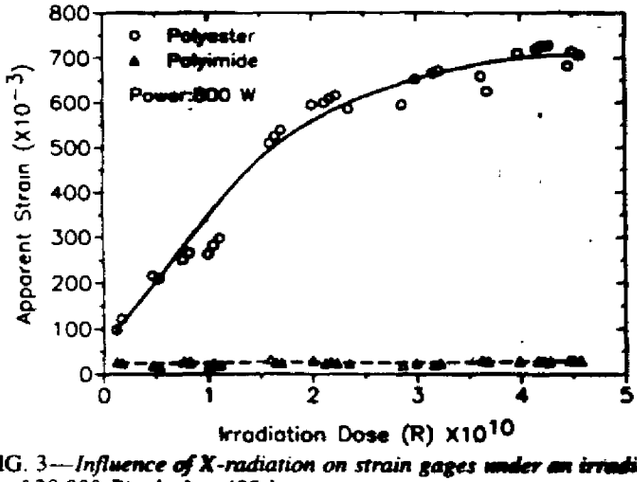

FIG. 3—*Influence of X-radiation on strain gages under an irradiation rate of 28 000 R/s during 400 h.*

influence of irradiation dose on apparent strain. Both strain gages were mounted in an identical manner, and the signal conditioning was also identical. The only difference between the two strain gages was the encapsulating layer (backing material). Thus, this difference is due primarily to the disorder created by the X-radiation on the polyester backing material. In this material, the X-ray produces a nucleation of defects in the lattice, which could cause

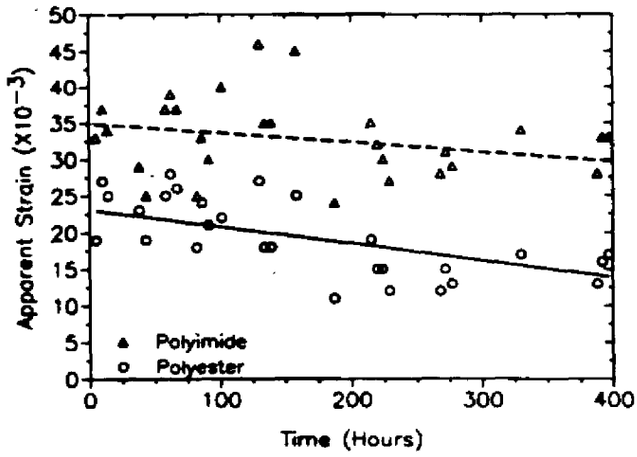

FIG. 4—*Influence of time on apparent strain of strain gages mounted on plate without irradiation.*

the resitivity to increase as the irradiation dose (and number of defects) increases.

Conclusions

In this work the behavior of strain gages under irradiation exposure was determined by comparing two kinds of encapsulating layers (backing materials): polyester and polyimide. From the measurements it can be concluded that strain gages with polyester backing materials undergo significant apparent strain increases during X-ray irradiation, the magnitude of which depends on the intensity of the flux and on time. On the other hand, strain gages with polyimide backing materials have shown no influence of irradiation on the values of apparent strain.

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References

[1] Wnuk, S. P., "Progress in High Temperature and Radiation Resistant Strain Gage Development," *Experimental Mechanics*, Vol. 5, 1965, p. 456.

[2] Mansur, T. R., Lourenço, O. R., Gomes, P. T. V., and Maia, N. S., "High Temperature Measurements," *Proceedings*, International Conference on Experimental Mechanics: Advances and Applications, Singapore, 1996, p. 109–112.

[3] Figliola, R. S. and Beasley, D. E., "Theory and Design for Mechanical Measurements," John Wiley & Sons, New York, 1991.

[4] Fehrenbach, P. J., Morel, P. A., and Sage, R. D., "Effect of Neutron Irradiation on the Electrical Resistance of Ni-Cr Weldable Strain Gages," *Transactions of the American Nuclear Society*, Vol. 45, 1983, p. 236.

[5] Morandi, G., "Le Tecniche Estensimetriche nel Campo Nucleare: Possibilità e Limiti de Applicazione," *Energia Nucleare*, Vol. 18, 1971, p. 55.

[6] Andreae, G., "Zum Messen mit Dehnungsmeßstreifen unter dem Einfluß von Kernstrahlung," *Materialprüfung*, Vol. 18, No. 7, 1976, p. 236.

[7] Tallman, C. R., "Effects of Nuclear Radiation Effects on Ceramic Cemented Strain Gages and Polyimide-Encapsulated Epoxy Bonded Gages," International Conference of the Instrument Society of America, Los Alamos, 4–7 Oct. 1971, Paper No. 71, p. 622.