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PASSIVE NEUTRON PULSE WIDTH TECHNIQUE

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PASSIVE NEUTRON PULSE WIDTH TECHNIQUE*

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ABSTRACT

The passive pulse measuring method described exploits the fact that the induced maximum stress in a bar or strip of fissile material rapidly heated by a neutron radiation pulse is in part dependent on the ratio of the heating time to the mechanical response of the bar. The mechanical response of a bar is proportional to the length of the bar. Permanent deformation induced in an array of carefully measured bars of varying lengths may be determined after radiation exposure. Since the temperature rise the bars experienced is known (using radiochemistry), postshot calibration and calculations will determine "characteristic" heating times and radiation pulse widths.

INTRODUCTION

Because of severe environmental limitations and the costs associated with making an active measurement of the rise time of a neutron pulse, an alternate simple passive technique was devised. The method takes advantage of the permanent deformation introduced by the rapid heating of various lengths of fissile material exposed to a neutron pulse.

THEORETICAL DESCRIPTION

The technique employed exploits the fact that a stress is induced in a bar or strip that has been heated faster than it can mechanically respond. Austin and Parker¹ derived an expression for the stress displacement.

It was found that the stress in the bar is a function of Young's modulus of the material, the coefficient of thermal expansion, the temperature rise, and the ratio of t_1/τ , where t_1 is the characteristic heating time and τ the fundamental period of natural vibration. The mechanical response, in turn, is equal to $2L/a$, where L is the length of a bar with both ends free and a is the sonic velocity in the bar. If the maximum stress exceeds the yield stress of the material, a permanent deformation that will be a function of the preceding parameters will occur in the material.

If we plot stress amplitude versus the ratio of the heating time divided by the mechanical response time, a curve as shown in Fig. 1 will be obtained. As previously noted, the parameter τ is proportional to the length. Hence, by arranging bars of varying length in the neutron flux and constructing the strips out of a fissile material such that the product of $E\alpha\Delta T$ will exceed the maximum yield stress, we will introduce a permanent deformation in some of the longer bars and upon recovery relate this deformation to the neutron characteristic heating time. The percentage of deformation will be larger in the longer bars. Thus, we may compare the preshot and postshot measurements of the length of the bars.

EXPERIMENTAL DESIGN

The experimental configuration selected for our experiment is shown in Fig. 2. The strips or bars of Orallo were carefully machined and precisely measured. Their location and measurement were noted. Several samples of each strip were to act as controls and were also measured and

Fig. 1. Stress amplitude dependence on heating time.

Fig. 2. Location of various lengths of Oralloy strips.

to provide rapid temperature pulses on control samples. One may vary the pulse width electrically and compare the deformation of specimens pulsed in the laboratory with those obtained in the field.

To eliminate temperature as a variable, radiochemistry may be used to measure the ΔT experienced by the test samples. This value of ΔT can then be obtained with the capacitor bank by varying the applied voltages or stored energy in the bank.

GENERAL CONCLUSIONS

The convenience of the method outlined is that a small, rugged, passive package may be used to measure neutron pulse widths. However, accuracy and versatility are somewhat limited.

set aside. The assembly was packaged in a small box with the dimensions shown. It should be noted that the package is small and compact. Crushable carbon foam was used between the strips to prevent impacting of one bar on another or on the case. The box was designed so that it could easily be mounted with bolts. The entire assembly was sealed with RTV silastic to ensure a hermetic seal. The bars were designed so that the $t_{1/7}$ ratio varied from 0.2 to 0.8 for some assumed characteristic heating time. This wide a range covers any large uncertainty in the predicted pulse width and provides a redundant series of samples.

DESIGN CONSIDERATIONS AND ERRORS

This technique is limited when the characteristic heating is short. Typically, sonic velocity varies from 0.1 to 0.2 in./ μ sec for most metals. In the case of 2-in.-long Oralloy bar the mechanical response time will be approximately 40 μ sec. If we want a large $t_{1/7}$, we have to make the bars smaller. However, we are limited in that the machinery used to measure the length of the bars has some finite accuracy (for example, ± 0.0001 inch). As the bar becomes shorter, permanent deformation becomes smaller, and the measurement error becomes larger.

Other considerations such as poor design data for yield strength at the required dynamic stress and elevated temperatures introduce some error. However, many material property uncertainties may be eliminated by a postshot calibration technique utilizing a capacitor bank.

FOOTNOTES

*This work was performed under the auspices of the U. S. Atomic Energy Commission.

¹A. L. Austin and R. Parker, "Determining the Dynamic Elastic Modulus at Elevated Temperatures by Using Rapid Heating Techniques," J. Basic Eng., (ASME), March 1967.