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HIGH STRAIN RATE LOADING OF ZIRCALOY

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Résumé - Des essais de traction à grande vitesse de déformation menés à température ambiante et à 300°C sur du Zircaloy ayant subi différents traitements sont analysés et comparés à ceux obtenus sous sollicitations statiques. Il est observé que l'allure des courbes contrainte - déformation dépend du traitement subi par l'échantillon et que les valeurs les plus fortes du pic de contrainte et les réductions les plus marquées de striction sont obtenues lors des essais à grande vitesse de déformation.

Abstract - High strain rate tensile loading behaviours of Zircaloys subjected to various treatments were investigated at room temperature and at 300°C, and compared with those of static cases. It was observed that the dynamic stress-strain profiles were different depending upon the specimen treatment and that the higher peak stress and the lower sectional area reduction were always recognized in the high strain rate cases.

I - INTRODUCTION

Zircaloy is employed in the power reactor application. Therefore, understanding of this material behaviour under various environmental conditions such as high strain rate loading is necessary to prevent disasters. In the present report, Zircaloy materials subjected to four different treatments, i.e., stress-free annealed, as rolled, hydrogen embrittled, and fully annealed, are tested at room temperature and also at 300°C under both static and dynamic (=high strain rate) loadings to investigate the material characterization especially under high strain rate tensile loading in comparison with the static cases.

II - EXPERIMENTAL TECHNIQUES

As shown in Fig.1, the impact block is struck by a hammer fitted on a rotating disc type tester at room temperature, and also by a hammer of a pendulum type tester at high temperature of 300°C. /1/

A split ring heater was used to heat up to 300°C. Note that the impact block is struck on the surface A from right to left to give impact tension on the specimen.

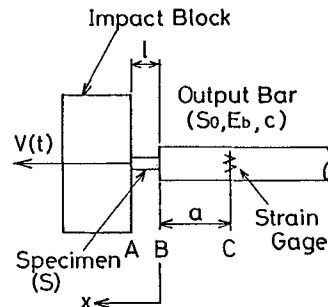


Fig.1 - Dynamic tensile loading concept

Now the produced dynamic tensile stress $\sigma(t)$ and strain $\epsilon(t)$ can be calculated from the measured strain $\epsilon_g(t)$ by four semiconductor gages located circumferentially to eliminate the bending effect. That is, by using the one-dimensional stress wave propagation theory, the stress and the strain can be written as

$$\sigma(t) = (S_0/S) E_b \epsilon_g(t + \frac{a}{c})$$

$$\epsilon(t) = \frac{1}{l} \int_0^t [V(\tau) - c \epsilon_g(\tau + \frac{a}{c})] d\tau$$

where l and S are the length and the cross sectional area of a specimen, S_0, E_b and c are the cross sectional area, Young's modulus and the longitudinal elastic wave velocity of the output bar, respectively, and V is the impact block velocity.

The measuring block diagram is shown in Fig.2./1/ In Fig.2, the impact block velocity can be measured by an electro-optical extensometer.

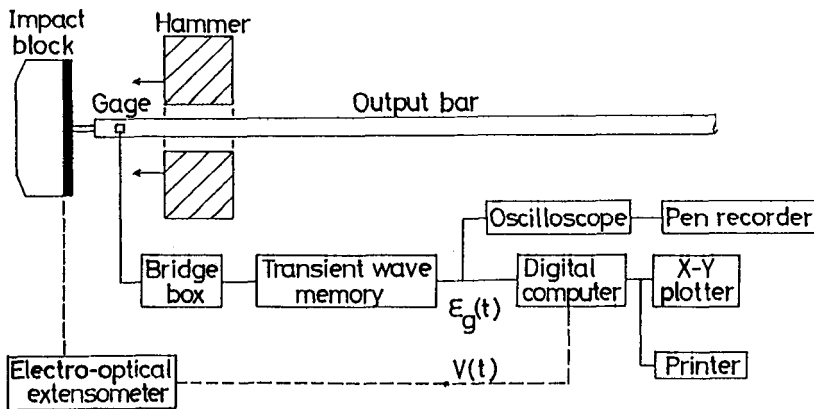


Fig.2 - Measuring block diagram.

Zirconium alloy specimen, Zircaloy-4, of which composition is as follows;

Sn	1.2 to 1.7 %
Fe	0.18 to 0.24%
Cr	0.07 to 0.13%
Zr	the rest

Its density is 6.5 g/cm^3 . The specimens are grouped in four treatments as described before, i.e., stress-free annealed, as rolled, hydro-

gen embrittled (containing 200 ppm hydrogen) and fully annealed. The specimen sizes are shown in Figs.3 and 4. Fig.3 shows Type A circular tube specimen and Fig.4 does Type B solid round bar one.

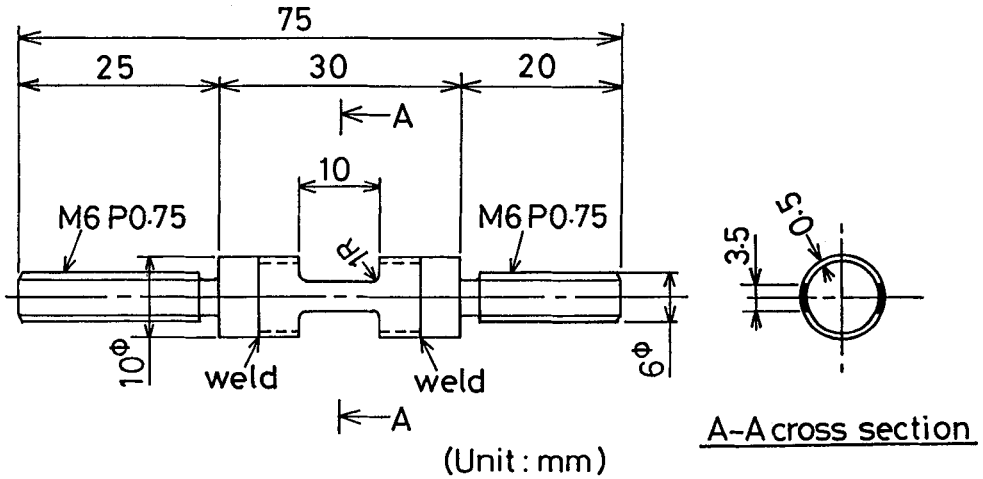


Fig.3 - Type A circular tube specimen.

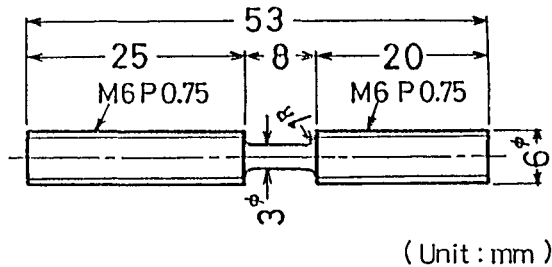


Fig.4 - Type B solid round bar specimen.

III - EXPERIMENTAL RESULTS AND DISCUSSIONS

As previously described, high strain rates of 1.5×10^3 /sec. (room temperature) and 0.45×10^3 /sec. (300°C) were applied by using the impact block so-called the one-bar method named by Kozo Kawata, Professor Emeritus of University of Tokyo /1/, and static strain rate of 1.0×10^{-3} /sec. by an Instron type tensile tester.

Figs.5 and 6 are for Type B specimens, recognizing higher peak stress

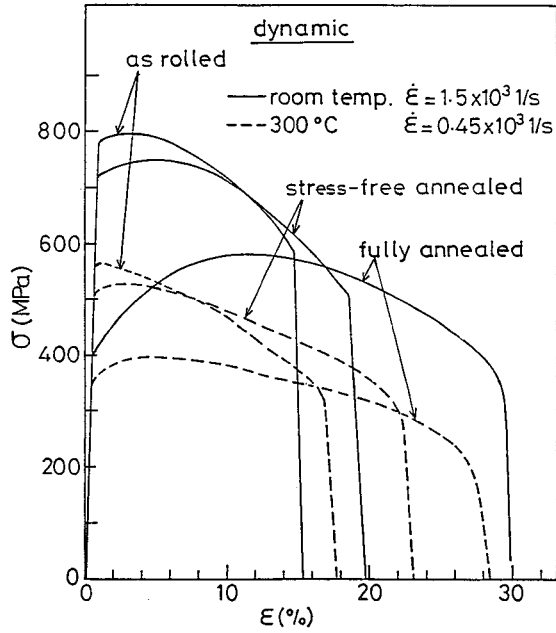


Fig.5 - Dynamic stress vs. strain (Type B specimen)

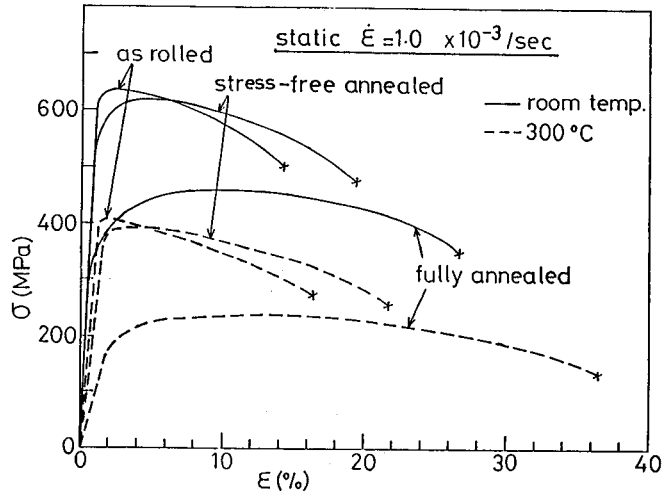


Fig.6 - Static stress vs. strain (Type B specimen)

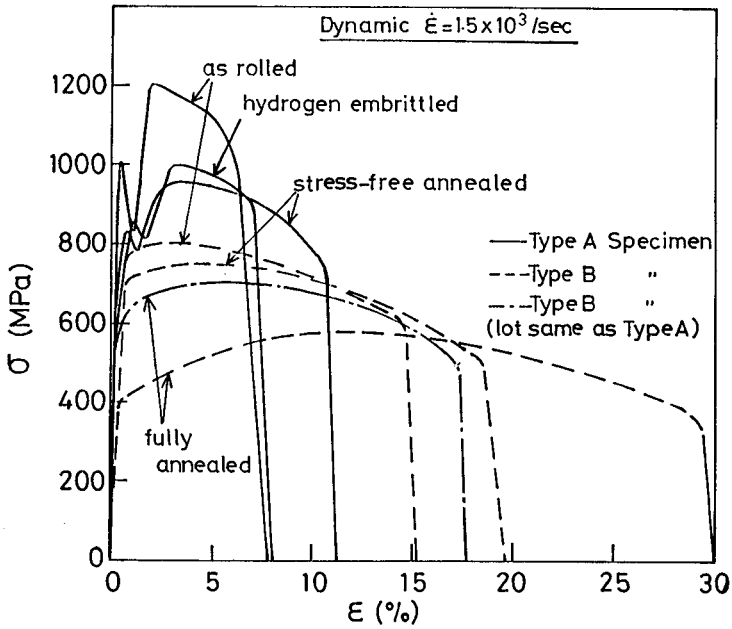


Fig. 7 - Dynamic stress vs. strain (room temperature)

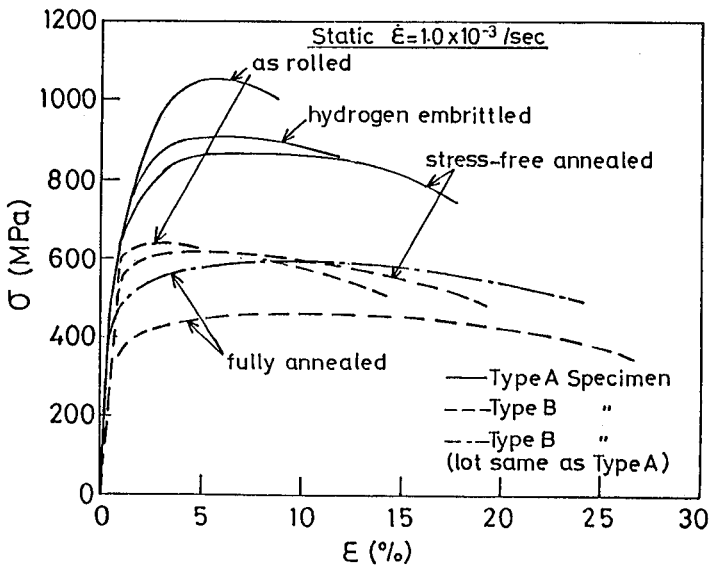


Fig. 8 - Static stress vs. strain (room temperature)

and shorter breaking strain (with the only exception for dynamic fully annealed case as shown in Fig.5) both at room temperature for both dynamic and static cases.

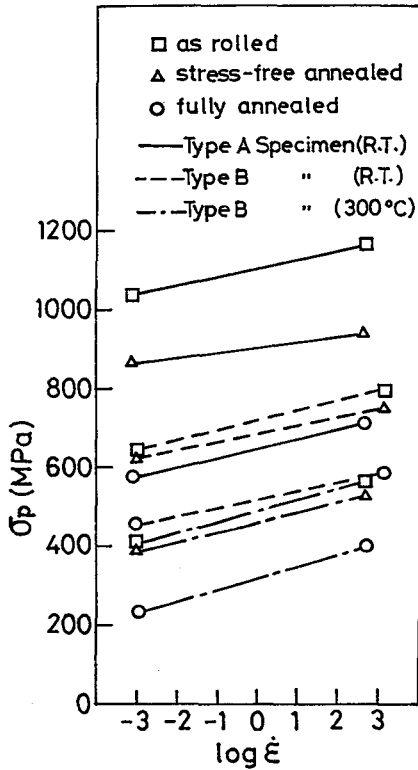


Fig.9 - Peak stress vs. strain rate correlation

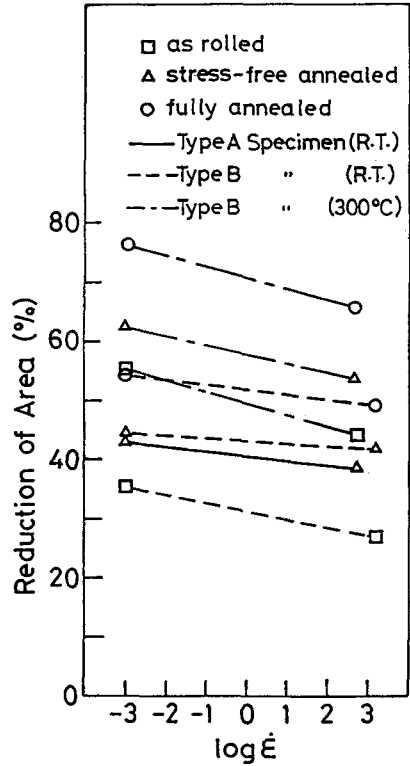


Fig.10 - Reduction of sectional area vs. strain rate correlation

In Figs.7 and 8 both dynamic 1.5×10^3 /sec. and static 1.0×10^{-3} /sec. stress-strain profiles are shown for both Type A and Type B specimens. Usually lot numbers are different with Type A and Type B. In view of these profiles higher peak stress and shorter breaking strain are observed for both dynamic and static cases of Type A compared with Type B. It may be noteworthy to observe serrations in Fig.7, probably due to stress wave behaviour at notched circular tube section of Type A specimen.

Fig.9 shows the peak stress vs. applied strain rate correlation. It is understood that the observed peak stress is always higher at dynamic high strain rate irrespective of specimen treatment, specimen type and testing temperature.

The reduction of sectional area measured after fracture is presented in Fig.10 as a function of applied strain rate. The area reduction is decreasing with the increase in strain rate irrespective of treatment, type and testing temperature.

REFERENCE: /1/ Kawata, k., Hondo, A., Hashimoto, S., Takeda, N. & Chung, H.L., Proc. 1st Japan-U.S. Conf. Composite Mater. Tokyo, JSCM, (1981) 2.