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Metals, Ceramics, and Materials

MASTER

TENSILE STRAIN-RATE PROPERTIES OF THORIUM

R. E. Oakes, Jr.
R. A. Gallman

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the ATOMIC ENERGY COMMISSION under U. S. GOVERNMENT Contract W-7405 eng 26

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OAK RIDGE Y-12 PLANT
P. O. Box Y
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Oak Ridge, Tennessee

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ABSTRACT

A study was made of the effects of strain rate on the tensile properties of thorium. Over a range of strain rates from 0.01 to 200 sec^{-1}, the yield point, tensile strength, and breaking strength increased proportionally with rate, while the ductility decreased slightly.

CONTENTS

SUMMARY

An electrohydraulic tensile testing machine was used to determine the effect of strain rates between 0.01 and 200 sec^{-1} on the yield point, tensile strength, breaking strength, and ductility of thorium. Upper and lower yield stresses, tensile strength, and the breaking strength were observed to increase with increasing strain rate, even at the lower rates. Ductility was found to be only slightly decreased with increasing strain rate.

INTRODUCTION

Pure thorium is a soft, ductile, and radioactive metal. Freshly cleaned surfaces display a silvery appearance, while surfaces exposed to air slowly oxidize and become charcoal gray. At temperatures below 1,400° C, the crystal structure of thorium is face-centered cubic; above 1,400° C to the melting point (1,690 - 1,750° C) the structure becomes body-centered cubic. In the past, production of thorium and its compounds was limited primarily to quantities needed to fulfill the production requirements of the gas-mantle industry. Recently, the requirements for specialized materials have increased the demand for thorium both as an alloying agent and as a metal. The future will find thorium becoming an important material in nuclear power production since the U-233 reactor fuel is a product of the neutron bombardment of Th-232, the most common isotope of thorium.[1]

Increased use of metallic thorium has brought out new questions concerning the mechanical properties of this metal. One such question, the effect of strain rate on the tensile properties of thorium, is the subject of this investigation.

DETERMINING THE STRAIN-RATE PROPERTIES OF THORIUM

EXPERIMENTAL WORK

Apparatus

Tensile tests on thorium were performed on a materials testing system (MTS) electrohydraulic, servocontrolled testing machine. This machine operates at conventional testing machine speeds as well as speeds up to 12,000 inches per minute. For all strain-rate tests, load versus piston displacement was photographically recorded using the X-Y mode of an oscilloscope; and, from the resulting photograph, the upper and lower yield stresses, ultimate tensile strength, and breaking strength were determined for each strain rate. Piston displacement was determined by an LVDT-type transducer. Load for the low-rate tests was determined by the use of a strain gage-type load cell; a high-response piezoelectric load cell was used during the high-rate tests.

Ductility of the material was determined by measuring both the elongation and reduction in area of the specimen fragments. The sample elongation was determined by scribing gage marks 1.00 inch apart on the gage section of the specimen and measuring the increase in separation of the gage marks on the reconstructed specimen with dividers after completion of the test. Reduction in area was determined by micrometer measurement of the minimum specimen diameter prior to and after completion of the tensile test.

Modulus values were also determined during the low-rate tests by recording the output of a strain gage-type extensometer and load cell on an X-Y recorder.

Specimens

Specimen configuration used for these tests was a threaded-end specimen with a 1.00-inch gage length and a 0.252-inch nominal diameter (shown in Figure 1). All specimens were taken from the same plate which was produced by forming virgin pellets into an electrode, then double arc melting and forging the ingot into a plate. The plate was further reduced to the desired thickness by cold rolling and was then fully annealed at 725° C. Analysis of the material adjacent to the specimen location gave the impurity content reported in Table 1.

RESULTS AND DISCUSSION

The material used during these tests shows a yield point phenomenon in the stress-strain relationship similar to that found in carbon steels, but of lesser

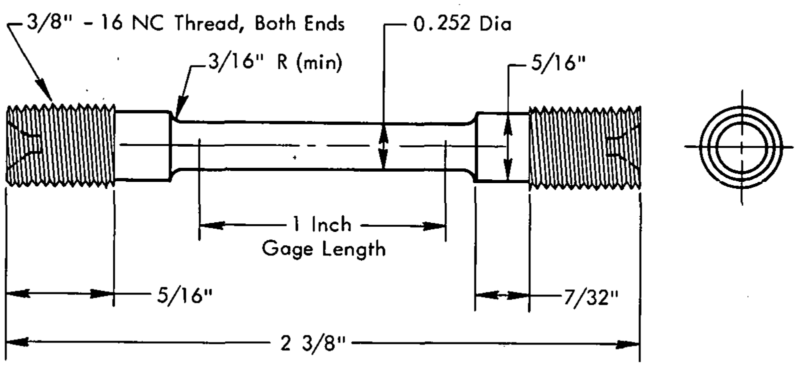

Figure 1. TEST SPECIMEN CONFIGURATION.

magnitude. Hammond[2] reports that a yield point is not always observed for thorium, its presence being dependent upon the method of preparation of the metal. In prior work in compression with material similar to the material used in this study, no yield point was observed.[3] The effect of strain rate on both the upper and lower yield stresses is indicated in Figure 2. Both the upper and lower yield stresses increase as the strain rate increases up to about 10 sec^{-1}. Above this rate, there appears to be only a slight increase in the yield point with strain rate.

The tensile strength (the maximum engineering stress developed during the tensile test) was also found to increase significantly with increasing strain rate. Figure 3 illustrates this effect. The decreasing slope of the rate-sensitivity curves of Figures 2 and 3 may indicate the existence of an upper limit to the strain-rate strengthening phenomenon. Figure 4 shows how the strain rate affects the tensile breaking strength of thorium.

Table 1

IMPURITY CONTENT OF THORIUM
(All Values in ppm)

Impurity	Content
Al	20
B	5
C	300
Cr	30
Cu	45
Fe	144
Ni	125
O_2	780
Si	20
Zr	8

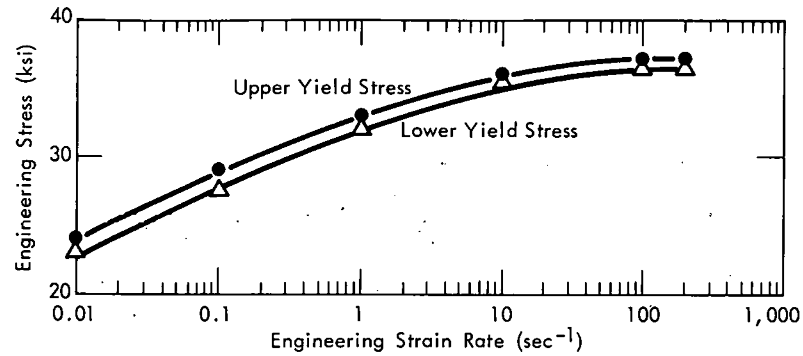

Figure 2. TENSILE YIELD STRESSES AS FUNCTIONS OF THE ENGINEERING STRAIN RATE FOR THORIUM.

The ductility parameters, percent elongation, and percent reduction in area, which are so important to those involved in metal working, are shown as a

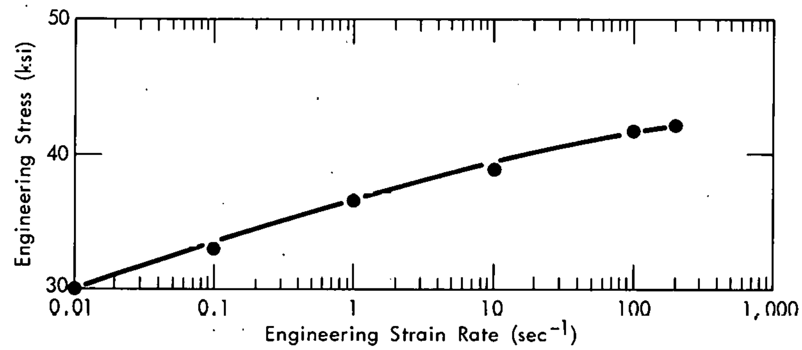

Figure 3. TENSILE STRENGTH AS A FUNCTION OF THE ENGINEERING STRAIN RATE FOR THORIUM.

function of the strain rate in Figure 5. Thorium can be seen to lose relatively little of its ductility with increasing application of the rate of strain.

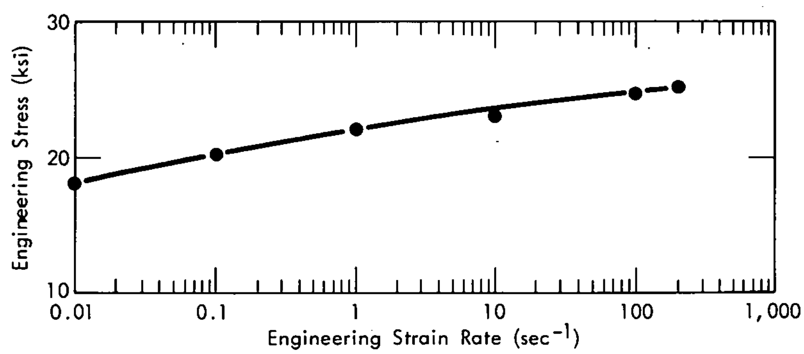

Figure 4. TENSILE BREAKING STRENGTH AS A FUNCTION OF THE ENGINEERING STRAIN RATE FOR THORIUM.

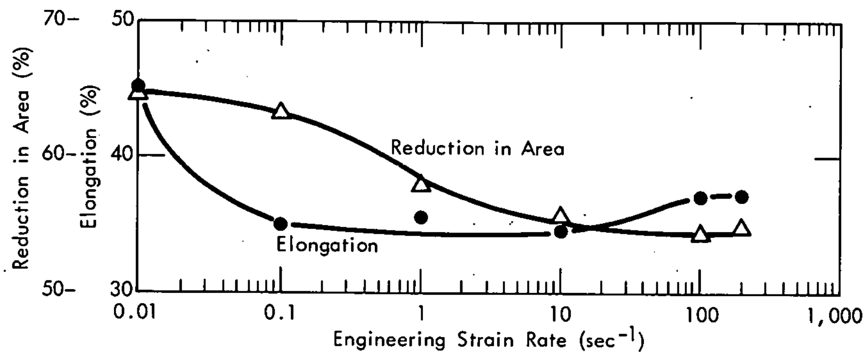

Figure 5. DUCTILITY PARAMETERS AS FUNCTIONS OF THE ENGINEERING STRAIN RATE FOR THORIUM.

Stress-strain relationships at 0.01, 1, and 100 sec^{-1} are seen in Figure 6. The elastic modulus value (8.4×10^6 psi) is the average value obtained during a number of low-rate tests.

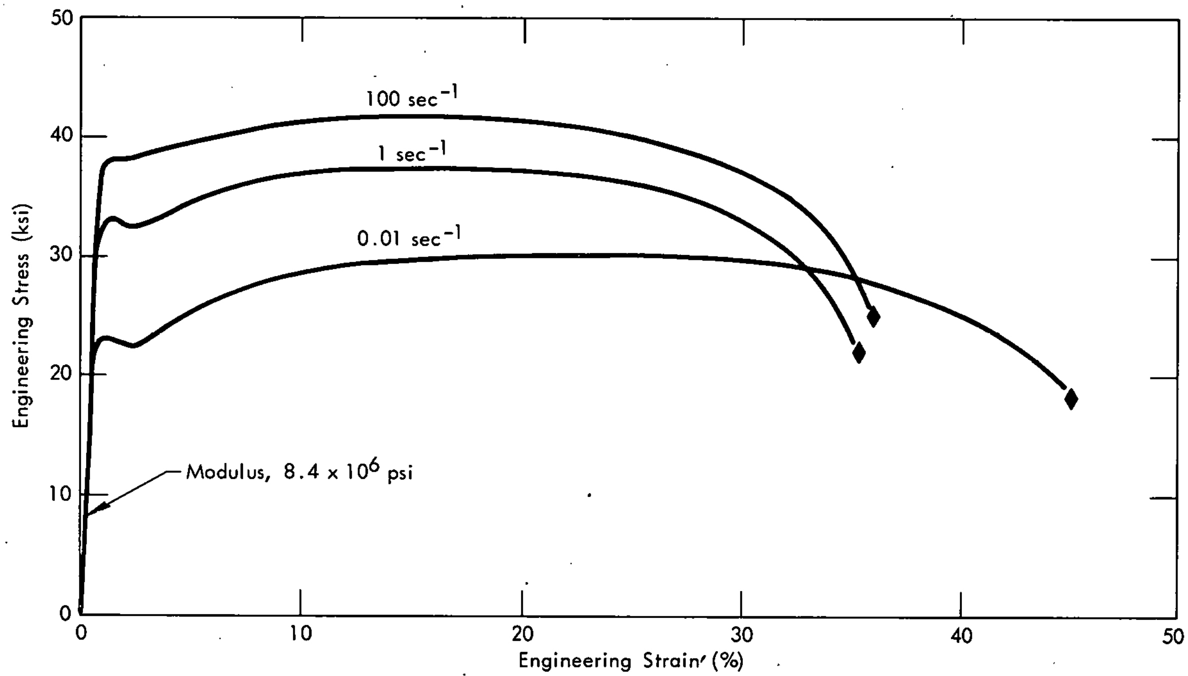

Figure 6. ENGINEERING STRESS AS A FUNCTION OF THE ENGINEERING STRAIN FOR THORIUM IN TENSION.

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