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A STUDY OF PREFERRED ORIENTATION IN ROLLED URANIUM BARS BY MEANS OF SONIC AND ULTRASONIC VIBRATIONS

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Metallurgy and
Ceramics

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IN ROLLED URANIUM BARS BY MEANS OF
SONIC AND ULTRASONIC VIBRATIONS**

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Chief, Declassification Branch

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Abstract

In an earlier report it was found that elastic inhomogeneities existed in certain rolled uranium bars submitted for study by means of flexural vibrations and ultrasonic pulses. A continuation of this investigation has applied the same techniques to new bars of known metallurgical history and in particular to some beta treated samples.

Heat treatment at a temperature above the alpha-beta transition point, referred to as beta treated, reduces the elastic inhomogeneity to a degree not observable by the ultrasonic techniques employed. However, for all of these beta treated bars, flexural vibration results still indicated nonuniformity in behavior best explained by vestigial elastic inhomogeneities.

Introduction

The initial objective for this project was the location of flaws in rolled uranium bars by means of sonic and ultrasonic techniques. However, the commonly encountered defects proved to be of such small size or unfavorable orientation that the available inspection methods could not satisfactorily evaluate the degree of inhomogeneity present in the specimens initially submitted¹.

The requirement that specimens be in nearly the final form of manufacture for reactor applications created severe handicaps. The bars could not be sectioned or cut up in any way. Hence a detailed study of preferred orientation patterns in any cross section could not be made. It was possible, nevertheless, to measure ultrasonic velocity for compressional waves both along the bar axis and the diameters with sufficient accuracy to demonstrate that a high degree of elastic anisotropy existed¹. This also became evident from the flexural modes of vibration at sonic frequencies. Since anisotropy could be undesirable, particularly from the standpoint of dimensional stability when the material experiences large temperature changes, further tests have been made on specimens having known metallurgical histories.

Results

A description of the specimens used for this study is contained in Table 1. The ultrasonic velocity data are contained in Table 2. Figures 1, 3, 5, 7, and 9 display the variation in ultrasonic velocity along various diameters for Group A specimens. The corresponding plot of the flexural mode vibration is given in Figures 2, 4, 6, 8, and 10. These specimens probably represent typical cases of anisotropy that rolled uranium acquires without further heat treatment. Their metallurgical history was not available for inclusion in this report. Figures 11-15 contain the azimuthal patterns of flexural vibration amplitudes for various planes about the rod axis for each specimen of Group B.

A detailed examination of bar number ABC-1-13 of Group B was made to point out that the flexural mode amplitude pattern is independent of both the variations in diameter and the deviation of the rod from a straight cylinder. Bar ABC-1-13 was an extreme example of those which were warped by the

¹ Progress Report for March 1952 through August 1952, NYO-3787

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heat treatment. The plane of the bend is indicated on Figure 15 while the diametral variations are plotted with the vibration amplitudes on Figure 16.

Discussion

The ultrasonic measurements show that a marked reduction in elastic anisotropy has been accomplished by the beta treatment. Alpha bars exhibit velocities along the axis as much as 8% less than that along their diameters. The beta treated bars display nearly the same velocity along all diameters and the axis, about 134,000 inches per second. This velocity is between the extreme values measured in the alpha bars. It is of interest to point out here without explanation that the velocities measured in an unworked cast specimen, a so-called "egg" portion of an ingot, yielded the high value of 139,700 in/sec along two directions through the specimen at right angles with each other.

Another qualitative indication of improvement towards homogeneity is evidenced by the oscillograms in Figures 17 and 18. For the alpha material, Figure 17, the transmitted pulse has been modified while passing through the bar parallel to the axis, so that the first arrival is smaller in amplitude than the immediately following delayed wave train, or subsidiary. In the beta treated material, Figure 18, for the same transmission path length and bar diameter, the character of the arrival pulses differs greatly, the first arrival having greater amplitude than the following subsidiary. A similar phenomenon takes place in a homogeneous material, when the rod length is increased. Energy is drained from the leading pulse and transferred to the subsidiary pulses until a state is attained in which the first subsidiary is stronger than the leading pulse. With sufficiently long travel time this process can reach a stage for which the initial pulse has been completely cannibalized and subsidiaries only are detectable. Although the geometrical conditions for Figures 17 and 18 are identical, the subsidiary generating process has been markedly accelerated in the alpha uranium, implying that the elastic inhomogeneity has had a strong effect upon the transmission. A detailed explanation of the interaction between the inhomogeneity pattern and the ultrasonic waves is not available at this time.

The specially heat treated specimens in Group C still contained considerable anisotropy. However, the spread between axial and diametral velocities was narrower than that found in Group A. There seemed to be a slight dependence of the

[REDACTED]

axial velocity upon the rolling temperature, the highest temperature corresponding with the highest velocity. There was also less variation in the diametral velocity for a given bar, so little in fact, that no azimuthal velocity patterns were obtained. However, there still remained diameters exhibiting optimum transmission.

It is concluded therefore, that for the fabrication sequences studied here, those which include a final heat treatment above the alpha-beta temperature are the most effective in minimizing the preferred orientation induced by rolling.

[REDACTED]

Table 1
Description of Specimens

Bar No.	Diameter (inches)	Length (inches)	Remarks
<u>Group A</u>			
2779-3-16	0.9971 $\pm$.0005	8.05	There are no metallurgical data available on the specimens in Group A.
2889-4-6	0.9874 $\pm$.0002	8.06	
3018-2-20	0.9964 $\pm$.0001	8.05	
3077-F-18	0.9871 $\pm$.0002	8.06	
3077-F-21	0.9877 $\pm$.0001	8.06	
<u>Group B</u>			
2896-1-1(α)	0.936 $\pm$.002	8.07	Heat treated at 600°C 1/2 hour
2892-4-1(α)	0.993 $\pm$.001	8.09	Heat treated at 600°C 1/2 hour
ABC-1-13(β)	0.9904 $\pm$.0003	8.06	Heat treated at 720°C 70 seconds.
2896-2-27(β)	0.9940 $\pm$.0003	8.06	Heat treated at 720°C 70 seconds.
6339-B-22(β)	0.988 $\pm$.001	8.05	Heat treated at 720°C 70 seconds
<u>Group C</u> (12 bars, 4 in each temperature class)			
4D621-A 630°C	0.9270 $\pm$.0002	8.00	Rough rolled to 1-1/2" dia.at 600°C. Finish rolled at 630°C to 1" dia. then ground.
4D621-C 550°C	0.9270 $\pm$.0002	8.00	Finish rolled at 550°C to 1" dia. then ground.
4D621-C 480°C	0.9270 $\pm$.0002	8.00	Finish rolled at 480°C to 1" dia.then ground.

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Table 2

Longitudinal Velocity Measurements
at Room Temperature

Bar No.	Velocity Along the Axis (10 ³ in/sec)	Velocity Along Dia- meters (10 ³ in/sec)	Remarks
<u>Group A</u>			
2779-3-16	128.0	135.3-138.3	Pronounced preferred orientation.
3889-4-6	128.1	136.5-138.5	
3018-2-20	128.0	135.2-138.7	
3077-F-18	129.0	135.1-138.9	
3077-F-21	128.9	135.7-139.2	
<u>Group B</u>			
2896-1-1(α)	129.2	136.0-137.0	Slight variation in transmission along various dia.normal to cylindrical axis.
2892-4-1(α)	129.0	136.0-137.0	
ABC-1-13(β)	132.0	133.6	Two slightly preferred dia. of transmission.
2896-2-27(β)	132.1	132.5	No preferred dia-meters.
6339-B-22(β)	135.4	133.5	
<u>Group C</u>			
4D621 - No. 2			
630°	130.9	134.5-135.0	Slight variation along various dia. normal to cylindrical axis.
550°	129.7	134.5-135.3	
480°	128.6	135.2-135.9	
Cast "Egg"	139.7	139.8	Tested along 2 directions at right angles.

BAR NO. 2779-3-16

AXIAL VELOCITY-128,000 (in./sec)

FIGURE 1

BAR NO. 2889-4-6

AXIAL VELOCITY-128,000 (in./sec)

FIGURE 3

PULSE VELOCITY FOR VARIOUS DIRECTIONS OF TRANSMISSION
NORMAL TO THE BAR AXIS.

BAR NO 2779-3-16

● - 1608 cps
▲ - 1611 cps

FIGURE 2

BAR NO. 2889-4-6

● - 1559 cps
▲ - 1561 cps

FIGURE 4

POLAR PLOT OF THE FIRST FLEXURAL MODE VIBRATION AMPLITUDE..

BAR NO. 3018-2-20

AXIAL VELOCITY - 128,000 (in./sec)

FIGURE 5

BAR NO 3077-F-18

AXIAL VELOCITY - 129,000 (in./sec)
SHEAR VELOCITY - 70,500 (in./sec)

FIGURE 7

PULSE VELOCITY FOR VARIOUS DIRECTIONS OF TRANSMISSION
NORMAL TO THE BAR AXIS.

BAR NO. 3018-2-20

● - 1614 CPS
▲ - 1615 CPS

FIGURE 6

BAR NO. 3077-F-18

● - 1565 CPS
▲ - 1569 CPS

FIGURE 8

POLAR PLOT OF THE FIRST FLEXURAL MODE VIBRATION AMPLITUDE.

BAR NO 3077-F-21

AXIAL VELOCITY-129,400 (in./sec)

FIGURE 9

PULSE VELOCITY FOR VARIOUS DIRECTIONS OF TRANSMISSION NORMAL TO THE BAR AXIS.

BAR NO. 3077-F-21

●- 1565 3
▲- 1569 5

FIGURE 10

POLAR PLOT OF THE FIRST FLEXURAL MODE VIBRATION AMPLITUDE.

FIGURE 11

FIGURE 13

FIGURE 12

FIGURE 14

POLAR PLOT OF THE FIRST FLEXURAL MODE VIBRATION AMPLITUDE.

FIGURE 15 POLAR PLOT OF THE FIRST FLEXURAL MODE VIBRATION AMPLITUDE.

FIGURE 16 A COMPARISON OF THE FIRST FLEXURAL MODE VIBRATION AMPLITUDE WITH THE BAR DIAMETER IN THE PLANE OF VIBRATION.

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FIGURE 17 LONGITUDINAL PULSE TRANSMISSION ALONG AXIS OF BAR
No. 2892-4-1, AN ALPHA SPECIMEN ANNEALED AT 600°C
FOR 1/2 HOUR.

FIGURE 18 LONGITUDINAL PULSE TRANSMISSION ALONG AXIS OF BAR
No. 6339-B-22, A BETA TREATED SPECIMEN ANNEALED AT
720°C FOR 70 SEC.