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SUBJECT: Effects of Heat Treatment on Microstructure and Fabricability of 48 wt % Uranium-52 wt % Aluminum Alloys

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NOTICE

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EFFECTS OF HEAT TREATMENT ON MICROSTRUCTURE AND FABRICABILITY OF 48 WT % URANIUM - 52 WT % ALUMINUM ALLOYS

Introduction

It has been reported in the literature[1] that prolonged soaking of 16 wt % uranium-aluminum alloys at elevated temperatures induces a microstructural change termed "conglobulization". This process is essentially a spheroidization of the UAl_4 lamellae of the eutectic -- the eutectic composition in the uranium-aluminum binary system being 13 wt % uranium.[2] Such a structural change should improve the fabricability of uranium-aluminum alloys, since UAl_4 in a spheriodal form will permit the eutectic to deform more readily than will UAl_4 as lamellar platelets. The stress concentrations will be lower around the more geometrically homogeneous shapes.

This investigation was undertaken to establish the feasibility of spheroidizing the eutectic in 48 wt % uranium-aluminum alloys with the ultimate goals being (1) reduction of edge cracking during hot rolling of the core alloy and (2) diminution of dog-boning during hot rolling of composite fuel plates. It was felt that the problems of edge cracking and dog-boning, which were recurrent during development of the 48 wt % uranium-aluminum alloy for Foreign Reactor Program applications, might both be minimized with a heat-treated alloy.

Experimental Work

Four 48 wt % uranium-aluminum alloy billets, each weighing 4500 grams, were air induction-melted in graphite crucibles and cast into graphite molds. The alloy for each casting was allowed to solidify in the crucible three times prior to final remelting and pouring from 1175°C into a mold at 325°C. The mold cavity was 5-1/4 in. wide, 1-in. thick, and 10-1/2 in. high, and was affixed with a feeding head. This pre-solidification treatment was established to reduce the number of subsurface blow holes in the castings resulting from high H_2 solubility in the molten alloy.

After the heads were cropped from each billet and scrapped, the remaining ingots were soaked at 600°C for periods of 4, 50, 100, and 250 hours prior to hot rolling. The billets were then canned in 6061 aluminum alloy picture frames, sealed with a thin aluminum cover sheet, and hot rolled at 600°C to a thickness of 0.255 in. using a previously established rolling schedule. This schedule is listed below:

1st pass - 10% reduction
2nd pass - 10% reduction
3rd pass - 10% reduction
4th pass - 20% reduction
5th pass - 30% reduction
6th pass - 30% reduction
Remove frame
7th pass - 15% reduction

Samples representative of both the cast and hot-rolled materials, after the various soaking periods, were taken for metallographic examination. In addition, two sheet-metal tensile specimens were machined from hot-rolled core plate to evaluate any changes in ductility which might have resulted from heat treatment.

Discussion of Results

Figures 1-4 show the four 48 wt % uranium-aluminum alloy billets after soaking for 4, 50, 100, or 250 hours and hot rolling with the previously described schedule. It can be clearly seen that no improvement in quality of the rolled billets was obtained with the extended heat treatments. All billets edge-cracked to varying degrees and one fractured during rolling.

Data on the tensile properties of these alloys are included in Table I. Examination of this data reveals considerable spread between duplicate specimens for alloys soaked 50, 100, and 250 hours with reasonable agreement being obtained only from specimens soaked 4 hours. It can be said in general, however, that alloys soaked for 50, 100, or 250 hours were not as strong in tension as was the alloy soaked only 4 hours. This observation correlates closely with observed microstructural changes.

The microstructures of both cast and rolled alloys are shown in Fig. 5. A typical cast structure composed of UAl_4 surrounded by a lamellar eutectic can be seen in Fig. 5a while in Fig. 5b it will be noted that after 4 hours the eutectic has begun to spheroidize. Fig. 5c illustrates essentially complete spherodization as do Figs. 5d and 5e -- the platelets having transformed from a high-surface energy form to a shape of low-surface energy. A similar transition is noted in the hot rolled materials shown in Figs. 5f through 5i.

Conclusions

1. Extended soaking of 48 wt % uranium-aluminum alloy billets at 600°C does not improve their hot-rolling characteristics.

2. Soaking periods of 50 hours and greater reduce the tensile and yield strengths of these alloys.

3. Soaking for 50 hours results in complete spheroidization of the eutectic in 48 wt % uranium-aluminum alloys.

TABLE I

TENSILE PROPERTIES OF 48% U-Al ALLOYS AFTER VARIOUS SOAKING PERIODS AT 600°C

Specimen	Soaking Time	Analyzed Uranium Content	Tensile Strength	Yield Strength (0.2% Offset)	Elongation (2-in. gage length)
	Hrs.	Wt % U	PSI	PSI	Per cent
4-1	4	46.10	25,900	17,800	1.5
4-1	4	45.72	25,000	17,700	1.0*
50-1	50	46.88	19,200	14,200	1.0*
50-2	50	46.13	16,700	13,300	2.0
100-1	100	46.04	18,400	14,700	1.5
100-2	100	45.83	19,600	15,300	1.5
250-1	250	45.47	16,400	12,400	2.0
250-2	250	46.24	18,500	13,600	1.0*

*Failed outside gage length.

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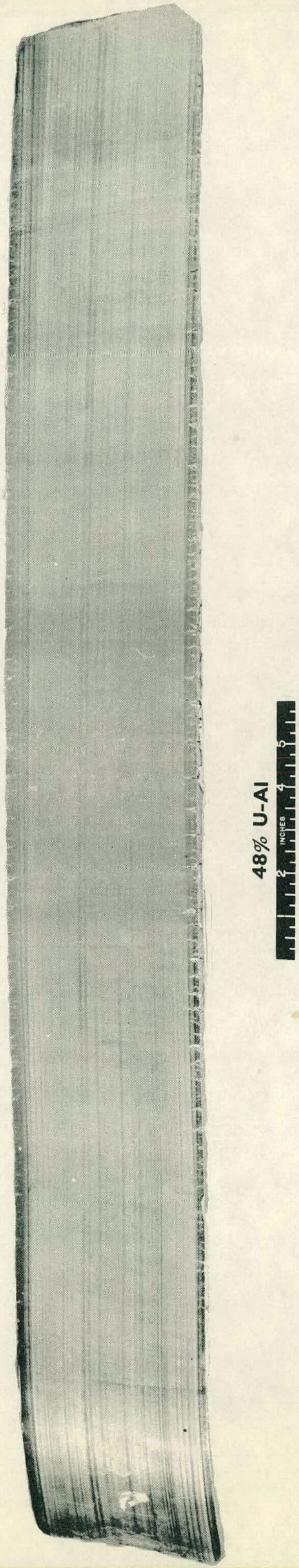

Fig. 1

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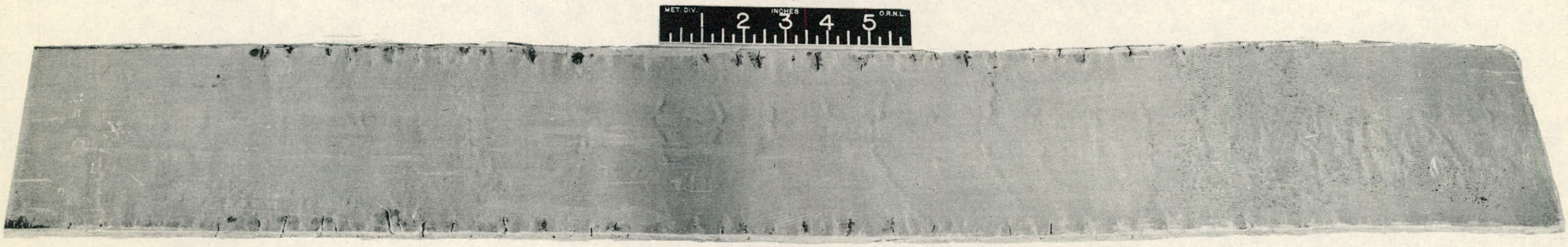

48%U-Al 50 Hr SOAK

Fig. 2

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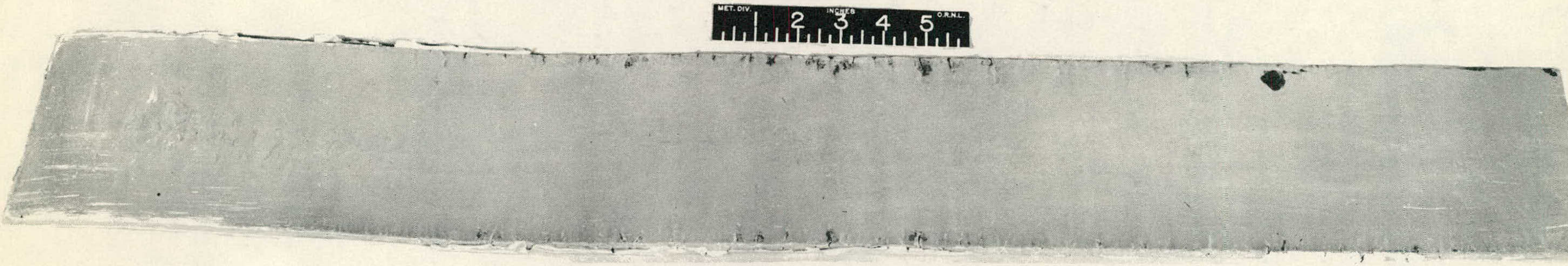

48%U-Al 100 Hr SOAK

Fig. 3

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48%U-Al 250 Hr SOAK

Fig. 4

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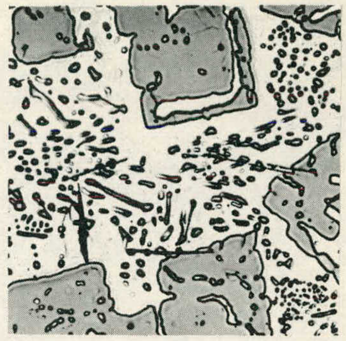
0 hr

5*b* 4 hr



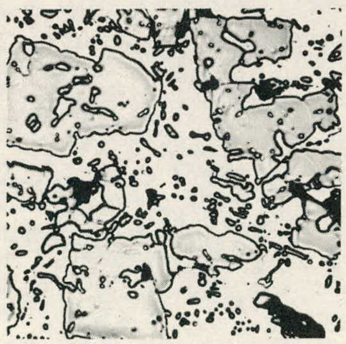
5*c*

5*d* 100 hr

5*e* 250 hr

AS-CAST 48 wt % U-Al ALLOY, SOAKED AT 600°C

5*f* 4 hr



5*g* 50 hr

5*h* 100 hr

5*i* 250 hr

48 wt % U-Al ALLOY, SOAKED AT 600°C AND HOT-ROLLED 75%

Fig. 5.

LIST OF REFERENCES

1. DP-16 Metallurgical Properties of an Aluminum-Uranium Alloy Containing 16 wt % Uranium. W. W. West (1956)

2. BMI-100 Compilation of U. S. and U. K. Uranium and Thorium Constitutional Diagrams.

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Conclusions

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2. Soaking periods of 50 hours and greater reduce the tensile and yield strengths of these alloys.

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