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SINGLE BEND TESTS ON WELDED ZIRCONIUM AND ZIRCONIUM-TIN ALLOYS

by

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SINGLE BEND TESTS ON WELDED ZIRCONIUM AND ZIRCONIUM-TIN ALLOYSPurpose

To determine if welding of zirconium or zirconium-tin alloys affects the ductility of these materials.

Introduction

Since it has been found that zirconium and zirconium-tin alloys may be embrittled by certain heat treatments, it was decided to determine if welding of these materials affects their ductility in any way. A single bend test in both the longitudinal and transverse directions was used for evaluation of the variables considered.

Part I - Effect of heat treatment on the ductility of welded zirconium and zirconium-tin alloys.

A. Preparation and Testing of Specimens

Specimens were cut from crystal bar zirconium and crystal bar zirconium-tin plates which had been heliarc welded longitudinally through the center. The finished samples were 3-1/8 x 3/4 x 1/6 inches with a 3/4 inch transverse weld through the center. All of the specimens were welded in a dry box under helium atmosphere.

The welded specimens were tested by bending 180° with the face or root of the welded specimens in tension. A special bending fixture, described in the Metals Handbook,⁽¹⁾ was used in making the guided bend tests.

B. Heat Treatment and Results

Zirconium and zirconium plus 2-1/2% tin welded specimens were heat treated for 0 to 6 hours at 1000°F in a helium atmosphere and then furnace cooled.

(1) Metals Handbook, 1948 edition, Page 138

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The zirconium and zirconium-tin samples with no heat treatment showed no cracking in the weld after 180° single bend. Zirconium samples heat treated for one-half hour did not crack in the weld after 180° single bend but zirconium-tin samples given the same treatment did crack in the weld when bent through 180°. After one hour heat treatment the zirconium samples showed no cracking in the weld after a single 180° bend, but the zirconium-tin samples either cracked in the weld or broke after a single 180° bend. Heat treatments of more than one hour caused both the zirconium and the zirconium-tin samples to break in the weld when bent through 180°.

Table I lists the heat treating and bending data for the welded zirconium and zirconium-tin specimens. The effect of heat treating time on the relative ductility of the specimens was measured by noting the angle through which a specimen was bent before cracking appeared. Figure 1 shows a plot of the angle cracking appeared versus heat treating time for the zirconium and zirconium-tin specimens. It can be seen that heat treating for one hour or more causes the ductility of welded material, as measured by the angle at which cracking appears, to decrease very rapidly.*

C. Metallographic Studies

An examination of the microstructure of the heat treated welded zirconium and zirconium plus 2-1/2% tin alloy showed little structural change resulting from heat treatments of less than two hours; however, since the ductility of the zirconium-tin alloy does change, as evidenced by cracking in the 180° bend test, the structural changes may be on a fine scale. The microstructure of the zirconium

*In light of present knowledge concerning the effect of certain elements, as for example hydrogen, on the embrittlement of zirconium and zirconium-tin, the results contained in this memo should probably be checked at some future date using material of known embrittling characteristics.

and the zirconium-tin alloy, after heat treatments of two hours or more, indicates that the materials are homogenized but the decrease in ductility, as shown in Figure 1, indicates that both the zirconium and the zirconium-tin alloy are affected by longer heat treating times.

Part II - Effect of tin content on the ductility of welded zirconium

A. Preparation and Testing of Specimens

The specimens were prepared in the same way as those which were used for the heat treating experiments except that the samples which were welded longitudinally through the center were sheared from a plate before welding. Again all specimens were welded in a dry box under helium atmosphere. The specimens were tested by bending 180° in the special bending fixture mentioned in Part I at the rate of 0.54 inches per minute.

B. Tin Content and Results of Bend Tests

The tin content of the samples tested ranged between 0 and 5 percent. All of the samples took a full 180° bend without breaking or cracking in the weld, heat affected or unaffected zone. The maximum load required to bend the samples was recorded and a plot of average maximum load (five specimens were averaged for each point) required for bending versus percent tin in crystal bar zirconium is shown in Figure 2. Similar data was obtained for sponge zirconium plus 2-1/2% tin and is also shown in Figure 2. Increasing amounts of tin in a welded crystal bar zirconium increases the resistance to bending but does not cause noticeable breaks or cracks in either the weld, heat affected or unaffected zone when bent through 180° .

Part III - Bend test of a subassembly section

The plates of a crystal bar zirconium plus 2-1/2% tin subassembly section were bend back by hand and although the plates broke from the subassembly section,

a 30° bend was required to fracture the metal in the heat affected zone. The fracturing of plates is consistent with the decrease of ductility produced in zirconium-tin alloys by heat treating and subsequent slow cool. Figure 3 is a photograph of the subassembly section. It can be seen that the plates bent 30° in the heat affected zone before fracture occurred while the unaffected zone had bent 90° before fracture occurred

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TABLE I

Effect of Heat Treatment on the Single Bend Test
of Welded Zirconium and Zirconium-Tin Alloys

Sample No.	Material	Heat Treatment		Angle Crack Appeared	Remarks
		Temp. °F	Time, Hrs.		
1	Zr	No heat treatment		No visible crack	Full 180° bend - no cracks
T-1	Zr-Sn	No heat treatment		No visible crack	Full 180° bend - no cracks
2	Zr	No heat treatment		No visible crack	Full 180° bend - no cracks
T-2	Zr-Sn	No heat treatment		No visible crack	Full 180° bend - no cracks
3	Zr	1000°F	1/2 hr. Furnace cool	No visible crack	Full 180° bend - no cracks
T-3	Zr-Sn	1000°F	1/2 hr. Furnace cool	Cracked angle not known	Full 180° bend - crack in the weld
7	Zr	1000°F	1/2 hr. Furnace cool	No visible crack	Full 180° bend - no cracks
T-7	Zr-Sn	1000°F	1/2 hr. Furnace cool	Cracked angle not known	Full 180° bend - crack in the weld
5	Zr	1000°F	1 hr. Furnace cool	No visible crack	Full 180° bend - no cracks
T-5	Zr-Sn	1000°F	1 hr. Furnace cool	Cracked angle not known	Specimen broke
6	Zr	1000°F	1 hr. Furnace cool	No visible crack	Full 180° bend - no cracks
T-6	Zr-Sn	1000°F	1 hr. Furnace cool	No visible crack	Full 180° bend - fine cracks
8	Zr	1000°F	2 hrs. Furnace cool	Cracked angle not known	Full 180° bend - bad cracking in the weld
T-8	Zr-Sn	1000°F	2 hrs. Furnace cool	60°	Specimen broke in weld
9	Zr	1000°F	2 hrs. Furnace cool	78°	Specimen broke in weld
T-9	Zr-Sn	1000°F	2 hrs. Furnace cool	73°	Specimen broke in weld
10	Zr	1000°F	2 hrs. Furnace cool	82°	Full 180° bend but bad cracking in weld
T-10	Zr-Sn	1000°F	4 hrs. Furnace cool	53°	Specimen broke in weld
11	Zr	1000°F	4 hrs. Furnace cool	61°	Specimen broke in weld
T-11	Zr-Sn	1000°F	4 hrs. Furnace cool	34°	Specimen broke in weld
13	Zr	1000°F	6 hrs. Furnace cool	30°	Specimen broke in weld
T-13	Zr-Sn	1000°F	6 hrs. Furnace cool	33°	Specimen broke in weld
14	Zr	1000°F	6 hrs. Furnace cool	60°	Specimen broke in weld
T-14	Zr-Sn	1000°F	6 hrs. Furnace cool	26°	Specimen broke in weld

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END