HYDRIDE ORIENTATIONS AND MECHANICAL PROPERTIES OF THIN-WALLED ZIRCALOY TUBING

USAEC-AECL COOPERATIVE PROGRAM

MONTHLY PROGRESS REPORT

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by

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INTRODUCTION

Additional study of the orientation of zirconium hydride platelets in thin-walled Zircaloy tubing is being sponsored at the Savannah River Laboratory by the Technical Advisory Committee of the USAEC-AECL Cooperative Program. The SRL study will first define the relationship of the fabrication techniques and associated Zircaloy structures to the susceptibility of the tubing to preferred hydride orientations. Second, the work will assess qualitatively the effects of oriented hydride platelets on the mechanical behavior of tubes under several stress conditions. The following types of tubing with diameters of 2 to 3-1/2 inches will be tested.

- Extruded, tube-reduced, and roll-formed by Harvey Aluminum and Gomar Engineering
- Extruded and tube-reduced by Harvey Aluminum
- Extruded and tube-reduced by Tube Reducing Corp.
- Extruded by Harvey Aluminum
- Extruded and drawn by Harvey Aluminum
- Extruded, swaged, and tube-reduced by Wolverine Tube

SUMMARY OF PREVIOUS WORK

Previous work at the Laboratory had shown that preferred orientations of hydride platelets were related to the deformation history prior to precipitation and to the stress conditions during precipitation, and that the tensile ductility of the Zircaloy was very sensitive to the amount of platelets oriented normal to the deforming stress.

Last month the specimen for the stress orientation test was redesigned to reduce machining, preparation, and testing costs. After several tests under extreme conditions had demonstrated the acceptability of the new design, longitudinal and transverse specimens for the stress orientation tests were machined. The first report in this series was DPST-63-74-6.

SUMMARY OF LATEST WORK

The first stress orientation tests were run on circumferential specimens from the six types of tubing. Work was also begun on the preparation of specimens for texture measurements by X-ray diffraction. Since the final texture results were approximately two months away, the primary textures of the tubing were estimated by analysis of previously published texture data and the anisotropy of strain behavior during tensile tests. These preliminary data indicated that the susceptibility to stress orientation of the hydride platelets varied widely between tubing with similar textures and/or fabricated by nominally similar processes.

Discussion

Stress orientation tests on circumferential specimens of the six types of tubing were run at stresses of zero and 12,000 psi and were analyzed as follows.

The specimens were hydrogenated to 50 ppm at 400°C in a Sieverts-type apparatus, assembled in a constant-load creep machine, and solution annealed for 16 hours at 350°C. While at temperature, the specimens were loaded to the desired stress, held for an hour and then cooled under stress to room temperature in six hours to precipitate the hydride. The elongation during this treatment was less than 0.5%. The orientation of the hydride platelets was determined at two locations on each specimen by counting the platelets on a photomicrograph through an overlay grid that contained lines at 45 degrees to the stress axis. The platelets reported as "normal" (perpendicular) were those within approximately 50 to 90 degrees of the stress axis; similarly, the platelets reported as "parallel" were those within approximately 40 to 0 degrees of the stress axis. The platelets within approximately 5 degrees of the grid line were recorded as a separate group. These three groups of platelets were expressed as fractions of the total and denoted f_N, f_P, f_{45}, respectively. A material is said to be susceptible to stress orientation if the value of f_N increases markedly when the specimen is stressed. A summary of the results of the stress orientation tests and the analysis of the texture data is shown in the table.

Two interesting comparisons can be drawn from these preliminary results. First, the orientation of hydride platelets in unstressed specimens of tubes A, B, C, and F varied considerably even though the textures were similar. It is possible that the variations in hydride orientations resulted from variations in the direction of metal flow during fabrication. Such variations would be expected in view of the differences in fabrication history. As described in the introduction, previous work at SRL has defined deformation, per se, as one of the causes of preferred hydride orientations. Second, the susceptibility of the various types of tubes to stress orientation of the hydrides did not appear to be related to Zircaloy texture. Samples of tubes B and D with dissimilar textures showed the highest susceptibility to stress orientation, i.e., the highest increase in f_N when stressed. Further, samples of tubes A and B, which contained similar textures, showed very low and very high susceptibility, respectively.

The comparisons discussed in the previous paragraph must be considered to be tentative, because of the preliminary nature of the texture information.

FUTURE PROGRAM

The stress orientation tests of circumferential specimens will continue with higher applied stresses, possibly as high as 30,000 psi. The details of the fabrication histories will be gathered and analyzed for correlation with stress orientation data. X-ray diffraction measurements of the preferred orientation in the candidate tubing will be continued.

SUMMARY OF STRESS ORIENTATION AND TEXTURE DATA

(Circumferential Specimens)

Tubing Code	Fabrication	Texture[a]	Stress (ksi)	Orientation of Hydride Platelets[b] f_N	f_{45}	f_P
A	Tube-reduced and roll-formed	Radial (X, TS)	0	.01	.19	.80
			12	.06	.24	.70
B	Tube-reduced - Harvey	Radial (TS)	0	.21	.56	.23
			12	.64	.28	.08
C	Tube-reduced - Tube Reducing Corp.	Radial (X, TS)	0	.17	.36	.47
			12	.37	.41	.22
D	Extruded	Circumferential (L, TS)	0	.12	.09	.79
			12	.59	.05	.36
E	Drawn	Circumferential (X, TS)	0	.25	.41	.34
			12	.47	.34	.19
F	Swaged and tube-reduced	Radial (X, TS)	0	.10	.44	.46
			12	.22	.42	.36

(a) The direction listed is the estimated predominant orientation of the poles of the basal plane [0001], based on the sources of data as noted.

X - texture measurement on similar material at SRL
L - literature review of texture measurements of a variety of material
TS - analyses of strain anisotropy in sheet tensile specimens at SRL

(b) See text for method of measurement.

f_N = fraction of platelets normal to stress axis
f_P = fraction of platelets parallel to stress axis
f_{45} = fraction of platelets near 45° to stress axis