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MASTER

U. S. Atomic Energy Commission
Chicago Operations Office
P. O. Box 59
Lemont, Illinois

Attention: Mr. Steven V. White, Director
Research Contracts Division

Subject: Contract No. AT(11-1)-742

Gentlemen:

This informal letter report is the third of a series of monthly letter reports for the contract year, 15 March 1959 to 15 March 1960, describing the progress made on the research program, "Study of Factors Influencing Ductility of Iron-Aluminum Alloys", Contract No. AT(11-1)-742.

The objective of the program is to determine the effect of variations of aluminum content, heat treatment and basic slip mechanism upon the room temperature ductility of Fe-Al alloys. Since alloys containing in excess of 10% aluminum are subject to order-disorder transformations, heat treatment will provide the opportunity to study the effects of complete disorder, incipient order and varying degrees of long-range order on the plastic properties. With a fundamental understanding of the deformation and fracture behavior of these alloys, it should then be possible to devise means to effect significant improvements in their room-temperature ductilities by a combination of heat treatment and minor alloying additions.

It is estimated that approximately 25 percent of the proposed research has been completed over the first three and one-half months of the contract period.

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Bany Steele
Authorizing Official
Date: 2-20-67

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Deformation Analyses

The program to determine gross deformation mechanisms of the Alfenols as a function of aluminum content was continued during the past month. Tensile specimens machined from 0.035 inch thick stock were critically strained and annealed to produce coarse grains varying from 1/8 to 1/2 inch in diameter. The specimens were deformed after a heat treatment of 1200°C followed by rapid cooling, and were consequently in a condition of complete disorder.

The deformation was interrupted early in the plastic range in the instance of the more ductile materials (8- and 10.18- Alfenol) so that the slip traces could be analysed shortly after their initial development. At the earlier stages of plastic deformation the traces are straighter, the orientation of the crystal can be obtained more accurately and the analysis is consequently more reliable. In the case of the 13.83- and 16.18- Alfenols, the initiation of plastic flow was followed very closely by fracture.

Two grains were analysed in the 8- Alfenol specimen. One grain exhibited extensive slip of a segmented and wavy character, the traces of which could not be correlated with any crystallographic plane. Continued deformation produced an increase in the density of the slip traces within this grain, and eventually fracture occurred by shear along the glide planes. No twins were observed in the vicinity of the fracture. A second grain in the 8- Alfenol specimen deformed along a set of straight slip traces which were identified with the {110} plane. It would appear that the mechanism inhibiting basal glide in the Alfenols with increasing aluminum content is in a transitional state at the 8% aluminum level, being very sensitive to orientation and the relative complexity of the operating stress systems. The fact that fracture occurred by shear rather than by cleavage at this composition also may help account for the high ductility of 8- Alfenol in comparison with higher aluminum Alfenols.

In the 10.18- Alfenol grains analysed it was found that all of the slip traces were rectilinear and could be identified with the {110} planes. The slip traces were bent and wavy near grain boundaries at the initiation of plastic flow, and upon further deformation the traces became wavy throughout all the heavily deformed regions. Fracture occurred by cleavage, and twins were frequently present in the material adjacent to the fracture. In one 10.18- Alfenol tensile specimen, slip was confined to a single large grain which extended across the entire section area. A kink formed during the early stages of deformation, and flow was considerable prior to fracture.

TABLE I

Tension Analyses of Coarse-Grained Alfenols

%Al	No. of Grains	No. Cor- relation	{110} Slip	{100} Cleavage	{112} Twins
8	2	3	1	--	--
10.18	4	--	8	1	3
13.83	1	--	2	3	1
16.18	3	--	6	3	--

The 13.83- and 16.18- Alfenols exhibited the same type of crystallographic slip as the 10.18- Alfenol alloy, except the extent of flow was severely limited by the advent of fracture. Twinning after fracture was observed in the 13.83- Alfenol, but was not found in the 16.18- Alfenol. Typical deformation and fracture structures of the Alfenols are reproduced in Figure 1. A summary of the results of the analyses is presented in Table I.

The above analyses of deformation in the various Alfenols in the disordered condition will be used as a criterion for comparison with the 13.9- Alfenol and Thermenol in future heat-treated conditions which promote relatively high ductilities, to determine if a basic change in deformation mechanism is responsible for the improved ductilities.

Resistivity Measurements

The Kelvin double-bridge resistivity apparatus has been received and assembled for elevated-temperature resistivity measurements. The sensitivity of this new instrumentation is $\pm 1 \mu\text{-ohm}$. The specimen configuration and furnace arrangement will remain the same as described in the preceding report.

An electrical resistivity curve vs. temperature was determined for a specimen of 13.83- Alfenol upon slow cooling ($30^\circ\text{C. per hour}$) from 700°C. The contours of this curve confirmed the results of the curve presented in the preceding report, which was obtained with an improvised apparatus. The resistivity decreases with lower temperatures to a minimum at 535°C. , and then rises to a peak at 490°C. before dropping abruptly at lower temperatures. In the present study it has been found that cooling tensile specimens into the range between 490° and 535°C. followed by oil quenching produces the best elongations observed to date.

The reproducibility of the experiment and the determination of absolute resistivity values with the sensitive instrumentation will permit prediction of the magnitude of this incipient order-disorder reaction in other Alfenol and Thermenol materials and will indicate the optimum temperatures for heat treatment. A 16-Alfenol specimen and a Thermenol specimen will be run in the near future.

Tensile Tests

A number of tensile tests have been performed to evaluate the effect of microstructure, specimen size, and heat-treated condition (order-disorder) on the tensile elongation of 13.83-Alfenol. Of major importance to this testing program is the current availability of two recent publications* concerning the order-disorder transformations in iron-aluminum alloys.

The investigators responsible for these reports used dilatometry and electrical resistivity measurements to ascertain the elevated temperature equilibria and kinetics of the order-disorder reactions in the Fe-Al system. The series of isothermal annealing curves now available will be useful for correlating degrees of order quenched in from various temperatures with the resulting ductilities.

A furnace chamber capable of heating tensile specimens up to testing temperatures of 600°C., was constructed during the past month. This apparatus will be used principally to determine ductilities at temperature of specimens subjected to various degrees of ordering at relatively low temperatures (200° to 350°C.).

*"Order-Disorder Transformations in Iron-Aluminum Alloys" -- Final Report, H. J. McQueen and G. C. Kuczynski, Office of Naval Research Contract NONR 1623(03), Project NR 031-529 - May 1958.

"Kinetics of Superstructure Transformations of Fe₃Al Alloy", V. E. Rode, Bulletin of the Academy of Sciences of the USSR - Physical Series, Trans. of the Third Conference on the Physics of Magnetic Phenomena, p. 1225.

Future Considerations

During the next report period, emphasis will be concerned with continuing and expanding the correlation work between the electrical resistivity data of 13.83- Alfenol subjected to various heat treatments and the resulting tensile ductilities.

Respectfully submitted,

Frank C. Perkins
Frank C. Perkins

Joseph F. Nachman
Joseph F. Nachman

A

B

Figure 1. Deformation and Fracture Structures of Alfenols.

A. 8-Alfenol

B. 10-Alfenol

75X

C.

D.

Figure 1. (Continued). Deformation and Fracture Structures of Alfenols.

C. 13.8-Alfenol

D. 16-Alfenol

75X

8 2 007