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"STRENGTHENING OF CHROMIUM-MAGNESIA COMPOSITES"

April 18, 1963

Department of the Navy, Bureau of Naval Weapons

Contract N600(19)59647 (C.P.F.F.)

Interim Report No. 1

Covering Period 29 January 1963 through 31 March 1963

BENDIX PRODUCTS AEROSPACE DIVISION
THE BENDIX CORPORATION
SOUTH BEND 20, INDIANA

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ABSTRACT

This report describes the work accomplished during the first two months of a program aimed at strengthening chromium-ceramic composites by alloying. The initial phases of this program were directed toward better definition of the ductility of currently produced chromium-magnesia composites and improvements therein, if required. The notch tensile properties of Chrome-30 were determined at several stress concentration levels. Extrusions representing variations in the ceramic addition and in processing were prepared for investigating potential methods of improving ductility and lowering the impact transition temperature.

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of this program is to investigate strengthening of chromium-ceramic composites by means of alloying. It was decided that the initial efforts should be directed toward defining the tensile notch ductility of Chrome-30. This chromium-magnesia composite represents current state-of-the-art production material. If the notch ductility of Chrome-30 should prove unsatisfactory, an effort should be made toward improving these properties. This approach aims at achieving good ductility before beginning the solid solution strengthening investigation since the latter work can be expected to result in some loss in ductility.

The following work was completed during the period January 29, 1963 - March 31, 1963:

2.0 INVESTIGATION OF TENSILE NOTCH DUCTILITY OF Cr-MgO COMPOSITES

2.1 Establishment of Evaluation Parameters:

2.1.1 At the outset of this program it was necessary to select a test specimen configuration and to establish specimen fabrication & testing procedures. The selection of a round notched tensile specimen was based on a number of considerations. A large body of tensile data for unnotched round tensile specimens of Chrome-30 (Cr-MgO composite) was already available. This eliminated the need for obtaining unnotched data on a different type of specimen in order to provide notched/unnotched strength ratio information. A brief review of the literature indicates that round notched tensile specimens are routinely used by such groups as the National Bureau of Standards, Battelle Memorial Institute, and The Boeing Company. An abbreviated list of references giving a few typical examples of such usage is attached to this report[1], [2], [3].

The tensile bar size was selected so that the diameter of the notched bar at the base of the notch root was the same as the reduced section diameter of the unnotched bars previously tested. The notch configurations required for various stress concentration values were calculated on the basis of information presented by Peterson[4]. A preliminary investigation of various methods for producing the notches indicated that grinding with a template-dressed wheel produced the most accurate notches. Since some cold-work could result from the machining operations, an annealing schedule of one hour @1800°F in vacuum was specified for each bar before testing. The notches were inspected on a shadowgraph at 50X magnification before and after annealing to check the root diameter, root radius, and general quality. Photographs were made of typical notch silhouettes using a 40X magnification. Notched tensile specimens would be particularly sensitive to any misalignment of the test equipment. Therefore, a special alignment procedure was carried out prior to initiating the notched specimen tests. This followed generally the alignment procedures outlined in the Boeing reference previously cited(3).

2.2 Definition of Notch Tensile Properties of Chrome-30:

2.2.1 The notch strength of many materials possessing moderate ductility can be appreciably reduced by increasing the stress concentration factor. For this reason it was felt that the data would be more meaningful if Chrome-30 were evaluated using several different notches giving K_T values ranging from 2 to 8 (the latter value representing the sharpest notch that could be practically ground). Accordingly tests were run on notched bars having K_T's of approximately 2, 3, 4.4, 6, and 8. In instances where two tests were run at a given K_T, the reproducibility of data was excellent. It was originally intended to run two tests at each K_T but some of the bars were accidentally broken in handling. The effects of using higher strain rates and unannealed specimens were also separately evaluated using notched bars with a K_T of 3.

2.2.2 The data obtained with notched bars of Chrome-30 was compared with the average ultimate strength obtained previously in 108 tests run with unnotched bars of similarly processed material. All of the notched specimens were made from one lot of extruded material. The average ultimate strength exhibited by the unnotched specimens was 49,000 psi. The notched/unnotched strength data for Chrome-30 were found to be essentially independent of stress concentration level through a K_T of 8 (when tested at room temperature and a constant strain rate). Increasing the strain rate by a factor of 10 resulted in a slight increase in notched strength. Elimination of the annealing cycle produced a 20% decrease in notched strength. The data from these tests is summarized and plotted in Sections 5.1 and 5.2.

2.2.3 In view of the nature of the data obtained at room temperature and the limited time available for the total program, it was decided to omit the proposed notch tensile study at elevated temperatures. It was felt that these tests wouldn't yield enough additional information to be justifiable.

3.0 REDUCTION OF IMPACT TRANSITION TEMPERATURE

3.1 Preparation of Extrusions for Evaluation:

3.1.1 Since the tests described previously revealed a notched/

unnotched ultimate tensile strength ratio of approximately 1 at several K_T's, no drastic improvement in tensile notch toughness was called for. Therefore, the effort originally proposed for improving the notch tensile behavior could be transferred to attempting to lower the impact transition temperature. The approach to either problem would be essentially the same in so far as compositional and processing variables were concerned. Consequently billets were prepared for investigating several potential methods of reducing the impact transition temperature. They were extruded at the ASD Metals and Ceramics Laboratory at Wright-Patterson Air Force Base. Impact test specimens are currently being machined from the resulting extrusions. A total of seven variables will be studied. These are:

a. Variations in MgO content (0, 3, 6, & 9 weight %) aimed at minimizing the stress concentration effect of the oxide particles while retaining the beneficial aspects thereof.

b. Two processing variations aimed at reducing the oxide particle size and improving dispersion.

c. Substitution of ThO_2 for MgO to provide a more inert oxide dispersion that will exhibit improved resistance to coalescence at elevated temperatures.

3.1.2 In the meantime, a number of refinements have been made in the impact test equipment that will be used for evaluating these specimens.

4.0 FUTURE PLANNING

4.1 The Following Work is Planned for the Next Reporting Period:

4.1.1 Evaluation of impact strength of the various extruded materials described above with the objective of lowering the impact transition temperature.

4.1.2 Evaluation of room temperature notched and unnotched tensile properties of materials exhibiting the best impact results.

4.1.3 Selection of base composition representing the best tensile and impact properties for use in subsequent solid solution strengthening investigation.

4.1.4 Selection of alloying parameters (additives, percentages, processing, etc.) for solid solution strengthening investigation.

4.1.5 Preparation of extrusion billets required for solid solution strengthening investigation.

5.0 APPENDIX

(These items are found on the following pages)

5.1 Table of Room Temperature Notched Tensile Data for Chrome-30.

5.2 Plot of Notched/Unnotched Ratio vs K_T for Chrome-30.

5.3 References.

5.4 Distribution List - Contract N600(19)59647.

5.1 TABLE OF ROOM TEMPERATURE NOTCHED TENSILE DATA FOR EXTRUDED CHROME-30

K_T	Annealed	Ultimate Strength 1000 PSI	0.2% Yield 1000 PSI	Notched/ Unnotched Ratio	Area Reduction %	Strain Rates (Cross Head Travel in/min.) To Yield	Strain Rates (Cross Head Travel in/min.) Above
(1)*	(Yes)	(49.0)	(29.0)	(1)	(12.7)	(.005)	(.05)
2	"	53.3	45.6	1.09	4.6	.01	.01
2	"	54.6	48.0	1.11	3.3	.015	.02
3	"	49.0	45.5	1.00	4.0	.01	.01
3	"	47.5	44.5	0.97	5.8	.01	.01
4.4	"	47.7	41.0	0.97	1.8	.007	.01
4.4	"	42.5	38.6	0.87	0.8	.009	.009
6	"	44.5	-	0.91	0	-	.04
8.2	"	48.4	-	0.99	0	.006	.006
3	No	40.0	-	0.82	0	-	.0053
3	"	37.6	-	0.76	0	-	.0059
3	Yes	55.6	-	1.13	0	-	.04
3	"	52.6	-	1.07	0	-	.055

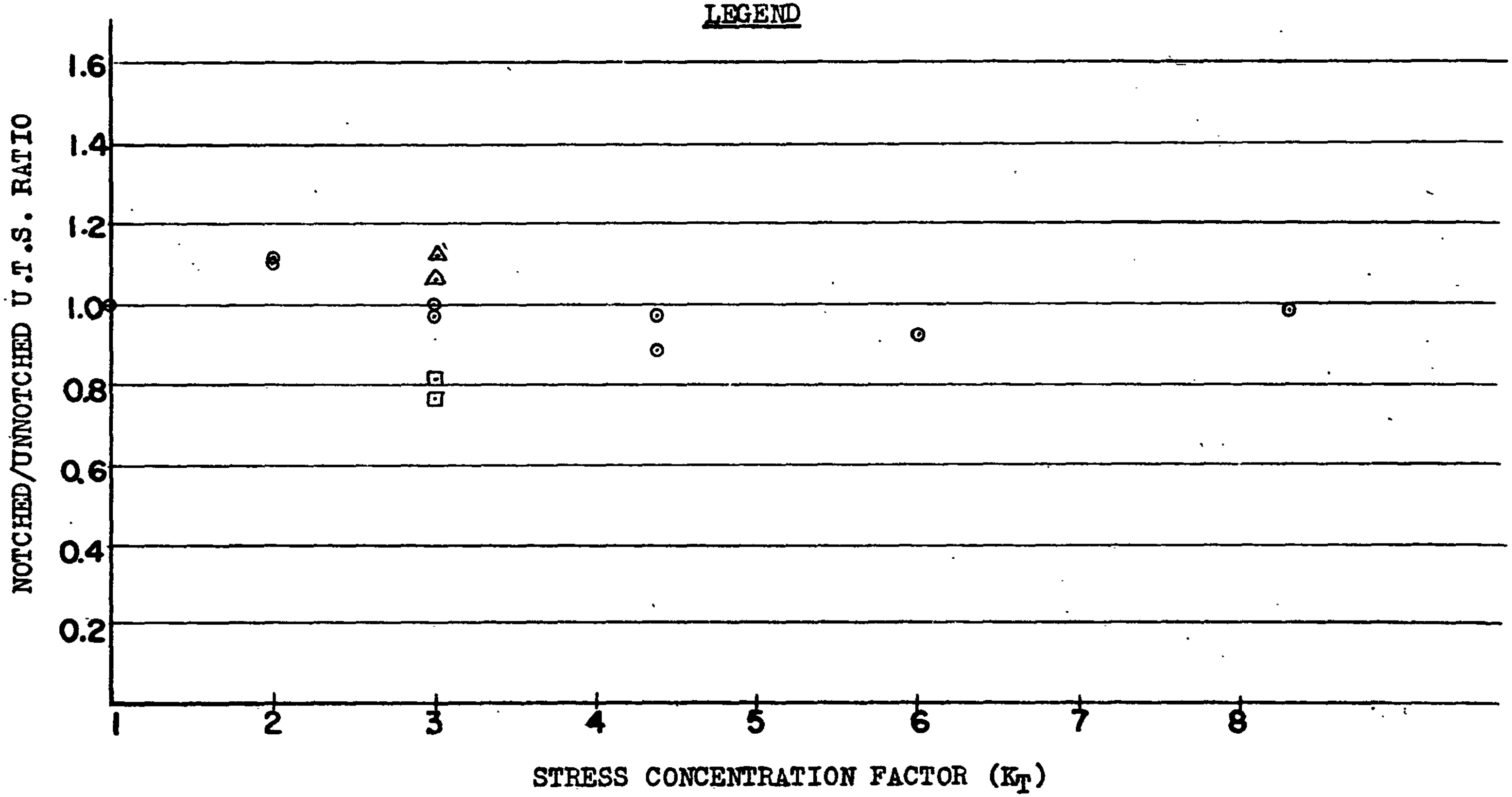
*Average data from 108 tests of unnotched bars of similar material evaluated in a previous program.

5.2 PLOT OF NOTCHED/UNNOTCHED RATIO VS K_T FOR CHROME-30

(Room Temperature Data)

⊙ Annealed; Strain Rate ~ .01 in/min
△ Annealed; Strain Rate ~ .05 in/min
⊡ Unannealed; Strain Rate ~ .01 in/min

LEGEND



5.3 References:

5.3.1 Geil, G.W., and Carwile, N.L., "Fracture Characteristics of Notched Tensile Specimens of Titanium and a Titanium Alloy", ASTM Bulletin (January, 1961).

5.3.2 Ingram, A.G., et al, "Notch Sensitivity of Refractory Metals", Battelle Memorial Institute, ASD-TR-61-474, AF33(616)-7604 (January, 1962).

5.3.3 Johnson, B.G., and Wadsworth, G.B., "Standardization of Methods of Testing for Hydrogen Embrittlement", The Boeing Company, ARTC Project No. 13-59, Boeing Wichita Report No. D3-3655 (May, 1961).

5.3.4 Peterson, R.E., Stress Concentration Design Factors, N.Y., John Wiley & Sons, 1953.

5.4 <u>Distribution List - Contract N600(19)59647</u>:

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5.4.10 National Aeronautics and Space Administration, 1520 H Street N.W., Washington 25, D.C., Attn: Mr. Richard Raring.

5.4.11 National Aeronautics and Space Administration, Lewis Research Center, 21000 Brookpark Road, Cleveland 35, Ohio.

5.4.12 Pratt and Whitney Aircraft Company, United Aircraft Corporation, East Hartford, Connecticut.

5.4.13 General Motors Corporation, Allison Division, P.O. Box 894, Indianapolis 6, Indiana.

5.4.14 National Aeronautics and Space Administration, Langley Research Center, Langley Field, Virginia.

5.4.15 Battelle Memorial Institute, 505 King Avenue, Columbus 1, Ohio, Attn: Defense Metals Information Center.

5.4.16 General Electric Company, Applied Research Operations, Flight Propulsion Laboratory, Cincinnati 15, Ohio, Attn: Mr. L.P. Jahnke.

5.4.17 General Electric Company, Nuclear Materials and Propulsion Operation, Cincinnati 15, Ohio.

5.4.18 U. S. Atomic Energy Commission, Document Library, Germantown, Maryland.

5.4.19 Technical Information Service Extension, U. S. Atomic Energy Commission, P.O. Box 62, Oak Ridge, Tennessee.