Dispersion Strengthened Nickel-Base Alloys

Prepared under Navy, Bureau of Naval Weapons Contract N600(19)59891

Progress Report No. 1
1 March to 30 April 1963

by

A. S. Bufferd
R. C. Nelson
N. J. Grant

15 May 1963

New England Materials Laboratory, Inc.
Research Division
Medford, Massachusetts

ABSTRACT

Dispersion strengthened nickel-base alloys (80% nickel - 20% chromium) have been prepared by the mechanical mixing of Ni-chrome and thorium oxide powders. Extruded bar stock was prepared by powder metallurgical techniques and is presently being evaluated with respect to mechanical properties and microstructure.

INTRODUCTION

Dispersion strengthening has been applied successfully to a variety of pure metal matrices including aluminum, copper, iron, nickel and platinum. In terms of the properties achieved, it has been found that a stable dispersion retards recrystallization up to the melting point of the pure base metals when an ultrafine dispersion is achieved. In addition, the flat slope of dispersion strengthened alloys on stress-rupture plots indicates that such alloys become increasingly superior with increasing times and temperatures as compared to the base material.

Some of the more important variables in dispersion strengthening have been shown to be a fine particle size of metal powders, an ultrafine particle size of the dispersed second phase, and the volume percent of the dispersed phase. In addition, the detailed study of a number of dispersion strengthened materials has indicated the importance of the purity of the matrix. If, for instance, the base metal contains an excessive amount of oxygen or in some cases, a very small amount of other impurity elements, the stability of the dispersoid was decreased markedly due to various diffusion reactions.

The strengthening of nickel by dispersion hardening techniques has received considerable attention during the last few years. Although remarkable high temperature properties have been achieved for dispersion strengthened nickel, it is desirable to extend the work to solid solution nickel-base alloys. First, one will get a combined effect of solid solution strengthening and dispersion strengthening. This is of importance when considering room and moderate temperature properties. Secondly, the oxidation resistance of nickel-base alloys, such as nickel-chromium is much better than that of pure nickel whereas the fabricability remains essentially unchanged.

The lack of availability of fine solid solution powders has been the primary barrier to dispersion strengthened solid solution alloys. This problem has been partially solved during the past years by the development of various grinding and atomizing techniques that allow for the preparation of fine metal powders of micron size. Furthermore, these alloy powders can be obtained with a high purity level.

Recent experiments with stainless steel powders have also shown advantages of producing complex alloys without a dispersoid by powder metallurgy techniques. Consolidation of alloyed powders have shown improved mechanical properties without significant loss in ductility or formability. On this basis, the fabrication of complex nickel-base alloys by powder metallurgy techniques seems attractive.

Three areas of investigation are contemplated during this program and include the processing, extrusion and evaluation of the following types of alloys:

1. A standard Udimet 500 composition prepared as minus 250 mesh powder with subsequent extrusion to bar stock.

2. The Udimet 500 composition without titanium or aluminum, prepared as a fine powder and subsequently strengthened with dispersoids such as thorium oxide introduced by such techniques as mechanical mixing or thermal decomposition of oxide bearing salts.

3. A dispersion-strengthened Nichrome prepared by mechanical mixing and thermal decomposition techniques.

RESULTS

During the present report period, work was conducted on dispersion strengthening of the Nichrome composition (80% nickel - 20% chromium). The Nichrome powders were received from Acieries de Gennevilliers, France. The compositions and principal fabrication variables of five extruded alloys are shown in Table I.

Alloy BNW-1 represents the base line alloy for the Nichrome evaluation. The extruded alloy was a direct powder extrusion of as received powder without any intermediate processing. The average particle size of the powder was 9 microns. Alloy BNW-2 was also fabricated to provide a base line for comparison with the dispersion strengthened Nichrome alloys. However, this powder had an average particle size of 4 microns as a result of comminution in an attritor mill. The powder grinding was conducted in alcohol and traces of the solvent were removed before extrusion.

Alloys BNW-3, 4, and 5 were prepared to determine the effect of volume percent of oxide on subsequent properties. The alloys contained 5, 7.5 and 10 volume percent thorium oxide respectively.

In all cases, the Nichrome powder had an average particle size of 4 microns as prepared by comminution in an attritor mill. The thorium oxide was prepared by decomposition of thorium nitrate at 1500° F. X-ray line broadening techniques showed the thorium oxide particle size to be 0.023 microns. The thorium oxide and Nichrome powders were mechanically mixed in a high-speed blender prior to direct powder extrusion.

These alloys are presently being examined with respect to their mechanical properties and microstructure. Specimens are being prepared for tensile tests at room temperature, 1800°, 2000°, and 2200° F. Stress-rupture data will be obtained at 1800° F with the more promising alloys being evaluated at 2000° and 2200° F.

FUTURE WORK

The evaluation of the extruded Nichrome alloys will be conducted according to the schedule discussed above. In addition, dispersion strengthened Nichrome alloys will also be processed utilizing the technique of thermal decomposition of oxide bearing salts.

Udimet 500 powders are expected from the supplier within a few weeks and work will be initiated on this phase of the program.

TABLE I

Principal Fabrication and Extrusion Variables of Alloys Prepared in This Investigation

Alloy Number	Nominal Composition	Size of Base Powder, Microns[a]	Extrusion Ratio[b]
BNW-1	80 Ni 20 Cr[c]	9	32 to 1
BNW-2	80 Ni 20 Cr	4 - 5	36 to 1
BNW-3	80 Ni 20 Cr + $5^{v}/o$ ThO_2[d]	4 - 5	31 to 1
BNW-4	80 Ni 20 Cr + $7/5^{v}/o$ ThO_2	4 - 5	31 to 1
BNW-5	80 Ni 20 Cr + $10^{v}/o$ ThO_2	4 - 5	32 to 1

[a] As determined by Fisher Sub-Sieve analyzer

[b] Extruded at 1800° F

[c] Obtained from Acieries de Gennevilliers, France

[d] Average particle size 0.023 microns, as determined by x-ray analysis

DISTRIBUTION LIST - CONTRACT N600(19)59891

Bureau of Naval Weapons, Department of the Navy, Washington 25, D.C. Internal distribution to be made by DLI-3, as follows: RRMA-23 (6 copies), RMMP-23 (1 copy), RMGA-8 (1 copy), DLI-31 (2 copies)

Armed Services Technical Information Agency, Arlington Hall Station, Arlington 12, Virginia, Attn: Document Service Center (TICSCP), 10 copies

Bureau of Ships, Department of the Navy, Washington 25, D.C., Attn: Code 634B

Naval Ordnance Laboratory, White Oaks, Silver Springs, Maryland Attn: Technical Library

Naval Research Laboratory, Washington 25, D.C., Attn: Metallurgy Department

Office of Naval Research, Department of the Navy, Washington 25, D.C. Attn: Code 423

Naval Air Engineering Center, Aeronautical Materials Laboratory, Philadelphia 12, Pennsylvania

Watertown Arsenal Laboratories, Watertown 72, Massachusetts

Aeronautical Systems Division, United States Air Force, Wright-Patterson Air Force Base, Ohio, Attn: ASRCMP

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

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

Pratt & Whitney Aircraft Company, United Aircraft Corporation, East Hartford, Connecticut

General Motors Corporation, Allison Division, Post Office Box 894, Indianapolis 6, Indiana

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

DISTRIBUTION LIST - CONTRACT N600(19)59891 (cont'd.)

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

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

General Electric Company, Nuclear Materials and Propulsion Operations, Cincinnati 15, Ohio

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

Technical Information Service Extension, U.S. Atomic Energy Commission, Post Office Box 62, Oak Ridge, Tennessee