IN-26
50109
P. 6

NASA Technical Memorandum 106910

A New Cu–8 Cr–4 Nb Alloy for High Temperature Applications

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June 1995

National Aeronautics and
Space Administration

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Various applications exist where a high conductivity alloy with good strength at elevated temperatures is required. Potential uses include welding electrodes, brazing fixtures, electronics packaging and heat exchangers. NASA Lewis Research Center has undertaken a program to develop a new alloy for the combustion chamber of the next generation of regeneratively cooled rocket motors. From this effort a promising Cu-8 at.% Cr-4 at.% Nb (Cu-8 Cr-4 Nb) alloy has been developed. The alloy consists of a nearly pure copper matrix strengthened with approximately 13 vol.% Cr_2Nb precipitates. The alloy has shown exceptional strength, low cycle fatigue (LCF) resistance and creep resistance while maintaining at least 72% of the thermal conductivity of pure copper.

The thermal conductivity was tested at the Thermophysical Properties Research Laboratory at Purdue University using the laser flash technique [1]. As shown in Figure 1, the alloy retains between 72% and 82% of the thermal conductivity of pure Cu over the temperature range tested. A minor increase in thermal conductivity occurs between room temperature and 700°C. Above 700°C, the thermal conductivity decreases slightly due to the dissolution of the precipitates into the Cu matrix.

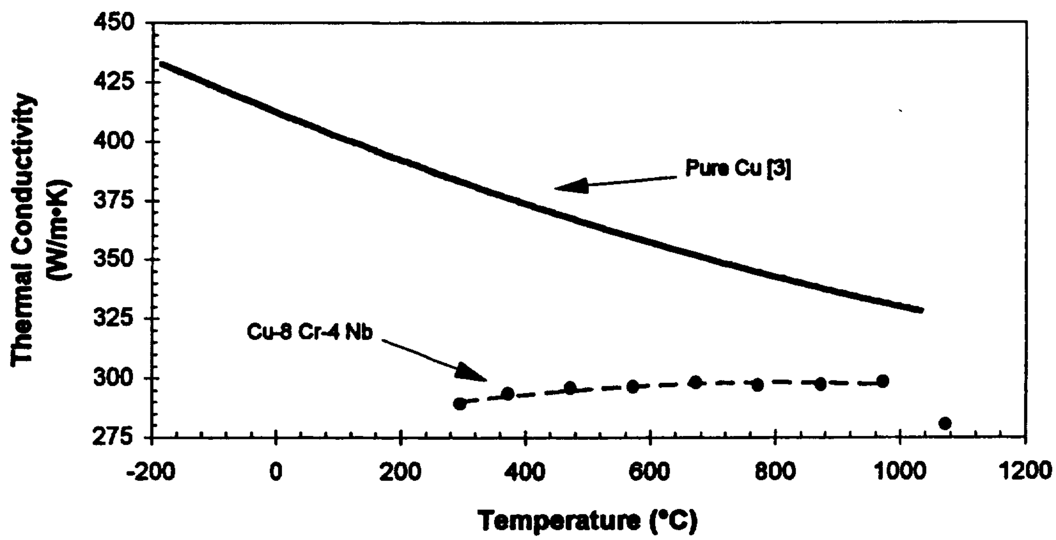

Figure 1 - Thermal Conductivity Of Cu-8 Cr-4 Nb

Anderson et al. [2] have conducted detailed transmission electron microscopy (TEM) on Cu-8 Cr-4 Nb to examine the effect of aging on the size of the Cr_2Nb precipitates and Cu grains. The reusults show that the size of these precipitates does not change significantly during subsequent aging at temperatures up to 1050°C for 100 h. The Cr_2Nb precipitates also act to stabilize the Cu grain size. During the worst case, aging at 1050°C for 100 h, the Cu grains only grow from approximately 2.7 μm to 4.7 μm. The fine, stable grain size contributes to the strengthening of the alloy by a Hall-Petch mechanism.

Figure 2 shows the 0.2% yield strength of Cu-8 Cr-4 Nb bars produced by extrusion. Bars were extruded at 860°C using a round die with a 16:1 reduction in area. Minimum design values for NARloy-Z [3], a Cu-3 wt.% Ag-0.5 wt.% alloy commonly used in high temperature applications, are also presented. As can be seen, the strength of Cu-8 Cr-4 Nb is significantly greater than NARloy-Z The strength also tends to persist to higher temperatures with a yield strength of 100 MPa maintained to approximately 700°C. The ductility of Cu-8 Cr-4 Nb shown in Figure 3 is lower than NARloy-Z, but still acceptable for most applications.

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Samples were also exposed to a simulated braze cycle consisting of heating the sample to 927°C, holding for one hour, and furnace cooling. Figure 2 shows that the Cu-8 Cr-4 Nb alloy did exhibit some loss in tensile strength, but not as much as NARloy-Z subjected to the same simulated braze cycle.

The creep resistance of Cu-8 Cr-4 Nb is shown in Figure 4. Minimum design values for NARloy-Z [3] are again presented for comparison. Cu-8 Cr-4 Nb enjoys a significantly greater life than NARloy-Z at these temperatures. Alternatively, for a given life requirement, Cu-8 Cr-4 Nb can support a much greater load than NARloy-Z.

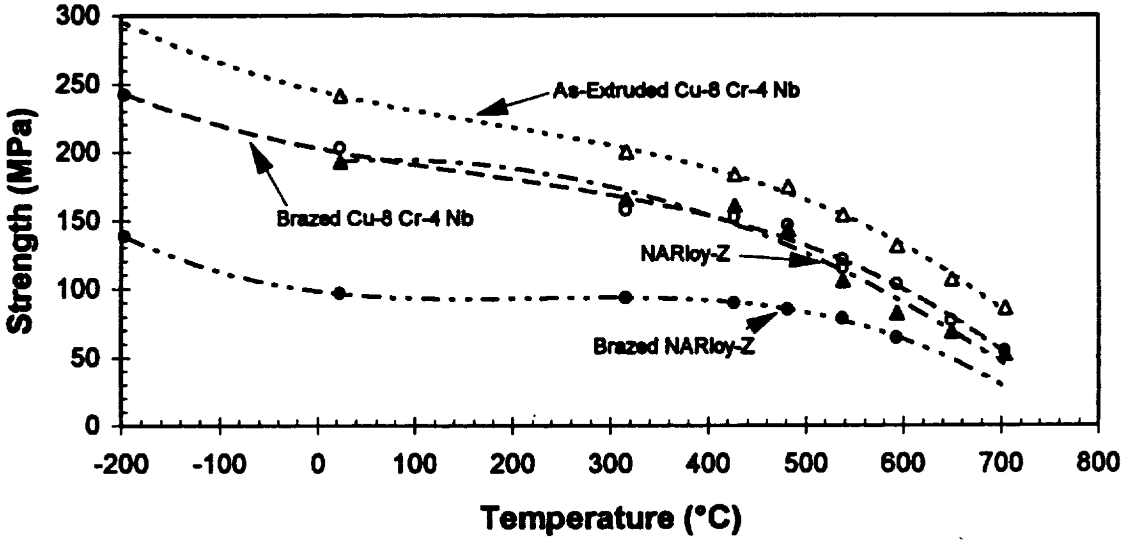

Figure 2 - 0.2% Yield Strength of As-Extruded and Brazed Cu-8 Cr-4 Nb

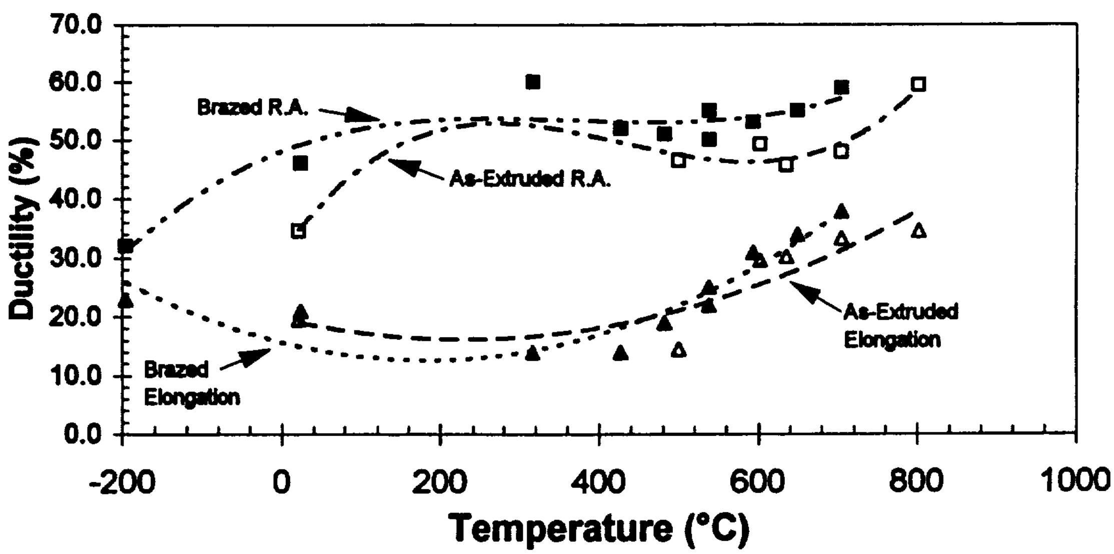

Figure 3 -Ductility of As-Extruded and Brazed Cu-8 Cr-4 Nb

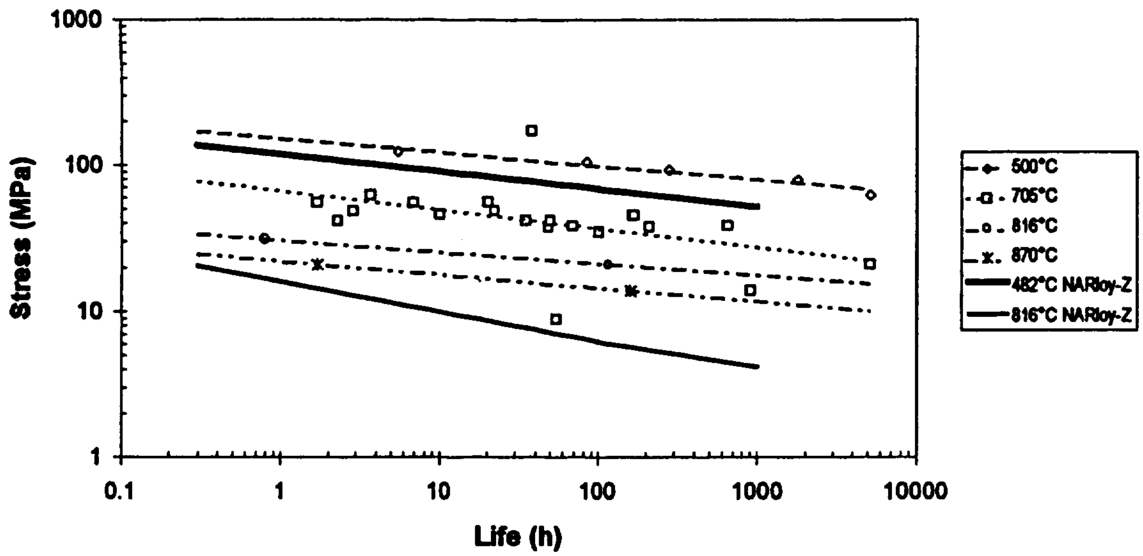

Figure 4 - Stress Rupture Life of Cu-8 Cr-4 Nb at Various Temperatures

Both Cu-8 Cr-4 Nb and NARloy-Z were tested using fully-reversed, strain-controlled low cycle fatigue (LCF) tests to determine their lives at room and elevated temperatures. Figure 5 shows the LCF life for Cu-8 Cr-4 Nb and NARloy-Z [4]. While the ductility of Cu-8 Cr-4 Nb is lower than NARloy-Z, Cu-8 Cr-4 Nb has a much greater LCF life, particularly at elevated temperatures.

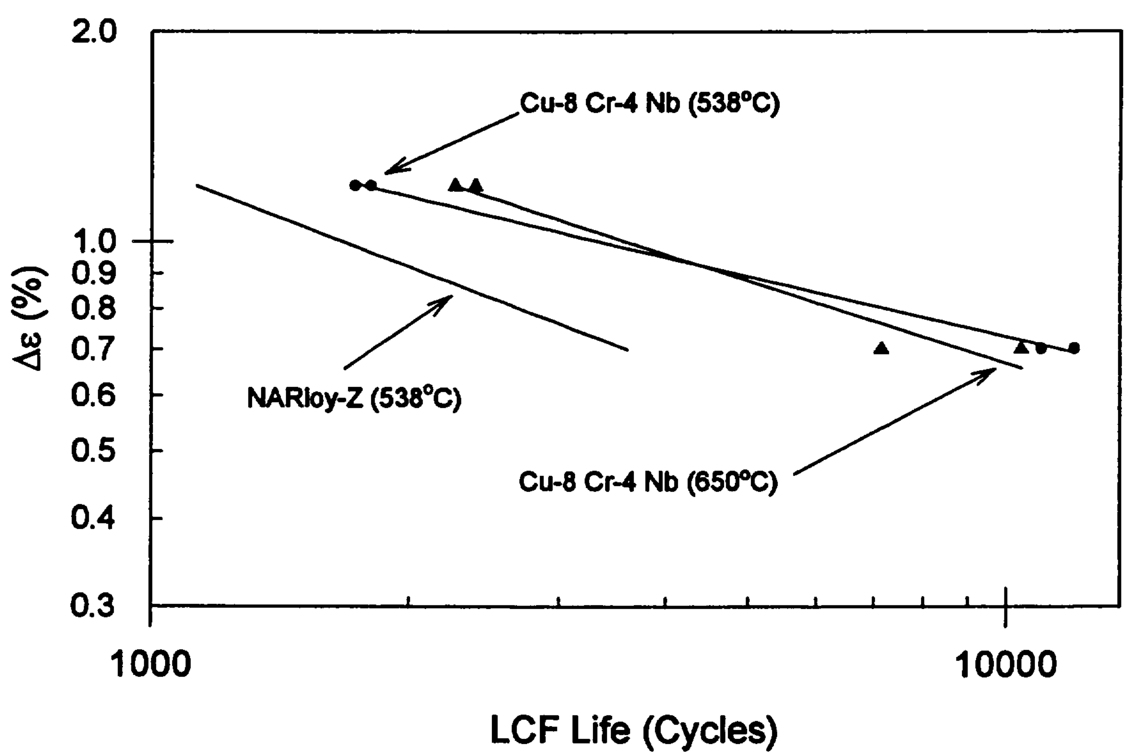

Figure 5 - Low Cycle Fatigue Life of Cu-8 Cr-4 Nb

In summary, a high strength, high conductivity Cu-based alloy for use at temperatures up to approximately 700°C has been developed. By designing the alloy to have a nearly pure Cu matrix, the thermal conductivity was kept above 72% that of pure Cu. The alloy exhibits exceptional strength, LCF resistance, creep resistance and microstructural stability over the temperature range of interest. In addition to the original application, other applications such as welding electrodes, brazing fixtures and cooling plates can also benefit from the greatly improved properties of the alloy. NASA Lewis Research Center welcomes any additional requests for information from interested parties.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 1995	Technical Memorandum

4. TITLE AND SUBTITLE

A New Cu-8 Cr-4 Nb Alloy for High Temperature Applications

5. FUNDING NUMBERS

WU-242-20-06

6. AUTHOR(S)

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
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Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E-9612

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, D.C. 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM-106910

11. SUPPLEMENTARY NOTES

D.L. Ellis, Case Western Reserve University, Cleveland, Ohio 44106 and NASA Resident Research Associate at Lewis Research Center (work funded by NASA Cooperative Agreement NCC3-94); G.M. Michael, Case Western Reserve University, Cleveland, Ohio 44106; and R.L. Dreshfield, NASA Lewis Research Center. Responsible person, R.L. Dreshfield, organization code 5120 (216) 433-3267.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 26

This publication is available from the NASA Center for Aerospace Information, (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

Various applications exist where a high conductivity alloy with good strength and creep resistance are required. NASA LeRC has developed a Cu-8 at.% Cr-4 at.% Nb (Cu-8 Cr-4 Nb) alloy for these applications. The alloy is designed for use up to 700°C and shows exceptional strength, low cycle fatigue (LCF) resistance and creep resistance. Cu-8 Cr-4 Nb also has a thermal conductivity of at least 72% that of pure Cu. Furthermore, the microstructure and mechanical properties of the alloy are very stable. In addition to the original application in combustion chambers, Cu-8 Cr-4 Nb shows promise for welding electrodes, brazing fixtures, and other applications requiring high conductivity and strength at elevated temperatures.

14. SUBJECT TERMS

Copper alloy; Mechanical properties

15. NUMBER OF PAGES

6

16. PRICE CODE

A02

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	