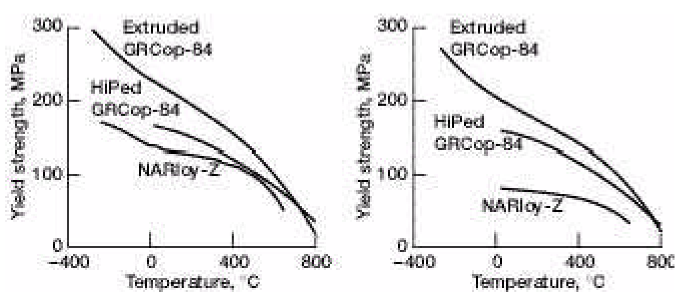
GRCop-84 Developed for Rocket Engines

GRCop-84 (Cu-8 at.% Cr-4 at.% Nb) was developed at the NASA Glenn Research Center for use in regeneratively cooled rocket engines. This alloy possesses an excellent combination of conductivity, thermal expansion, strength, creep resistance, ductility, and low-cycle fatigue (LCF) life. In comparison to the currently used alloy, NARloy-Z (Cu-3 wt % Ag-0.5 wt % Zr), GRCop-84's significantly better properties (refs. 1 and 2) give it the potential for significant gains in engine performance and reliability.

For GRCop-84 to be safely used in a rocket engine, it is critical to develop a detailed data base of the important thermophysical and mechanical properties. Work has focused on five major properties: thermal conductivity, thermal expansion, tensile strength, creep resistance, and LCF life. The analysis went beyond simply measuring the data and reporting averages. A detailed statistical analysis was conducted that allowed regression of the data over the entire temperature range tested and establishment of design minimums. The design values were expressed as simple mathematical formulas that are highly amenable to use in computer codes such as in finite element analysis and related computer modeling work.

During 2000, work was completed for all five properties. The thermal expansion of GRCop-84 was found to be at least 7 percent lower than for NARloy-Z. Lowering the thermal expansion lowers thermal stresses and increases liner life. The thermal conductivity of GRCop-84, which is 70 to 83 percent the conductivity of copper, is slightly lower than that of NARloy-Z but is much higher than for most alloys with similar strengths. The yield strength of GRCop-84 is approximately twice that of NARloy-Z over the temperature range tested. It also retains more of its strength following simulated brazing than NARloy-Z does, as can be seen in the following figure. The higher temperatures experienced during hot isostatic pressing (HIPing) somewhat degrade the properties, but HIPed GRCop-84 still retains significant advantages over NARloy-Z. The modulus of GRCop-84 is lower than that of pure copper. Lowering the modulus lowers the thermal stresses and again increases life.



Yield strength of extruded GRCop-84. Left: As-produced. Right: Following a simulated braze cycle at 935 °C (1715 °F).

Hot fire testing of a GRCop-84 spool piece.

Creep and LCF lives are much greater than for NARloy-Z. Subjecting the material to a simulated braze cycle at 935 °C (1715 °F) did not adversely affect the LCF lives.

The ultimate test is to actually make a liner and test it in a rocket engine. Working with NASA Marshall Space Flight Center, two 15.2-cm- (6-in.-) long liners with inner diameters of approximately 5.1 cm (2 in.) were fabricated at the NASA Marshall Space Flight Center using vacuum plasma spraying (ref. 3) and tested at Glenn. Twenty-seven tests accumulating 482 sec of hot fire testing using fuel ratios up to 7:1 were conducted. The liners showed no signs of degradation following testing.

In addition to being able to be extruded, HIPed, and vacuum plasma sprayed, GRCop-84 has been shown to be highly workable at low to moderate temperatures (250 to 350 °C). Sheet product approximately 22.9 by 50.8 cm (9 by 20 in.) has been rolled to a thickness of 0.1 cm (0.040 in.).

References

1. Ellis, David L.; and Michal, Gary M.: Mechanical and Thermal Properties of Two Cu-Cr-Nb Alloys and NARloy-Z. NASA CR-198529, 1996. http://gltrs.grc.nasa.gov

2. Ellis, David L.; and Keller, Dennis J.: Thermophysical Properties of GRCop-84. NASA CR2000-210055, 2000. http://gltrs.grc.nasa.gov

3. Holmes, Richard; Ellis, David; and McKechnie, T.: Robust Low Cost Aerospike/RLV Combustion Chamber by Advanced Vacuum Plasma Process. Proceedings of the 36th Annual Space Conference, Cape Canaveral, FL, 1999.

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