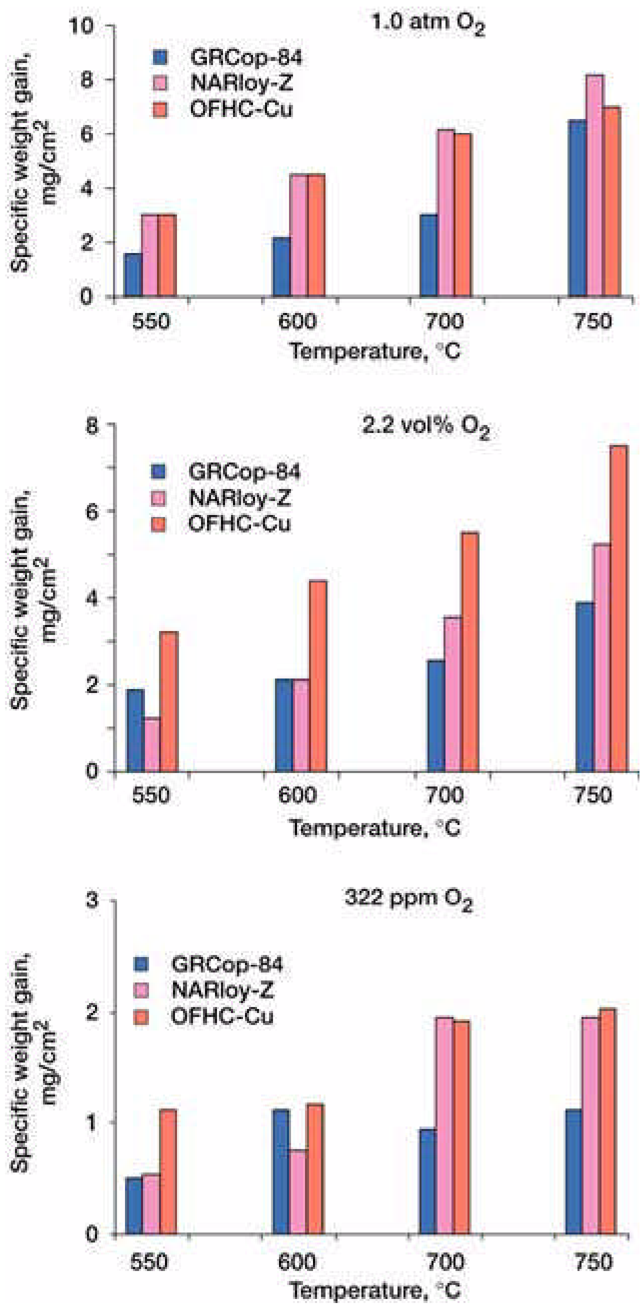
Oxidation Behavior of GRCop-84 Copper Alloy Assessed

NASA's goal of safe, affordable space transportation calls for increased reliability and lifetimes of launch vehicles, and significant reductions of launch costs. The areas targeted for enhanced performance in the next generation of reusable launch vehicles include combustion chambers and nozzle ramps; therefore, the search is on for suitable liner materials for these components. GRCop-84 (Cu-8Cr-4Nb), an advanced copper alloy developed at the NASA Glenn Research Center in conjunction with Case Western Reserve University, is a candidate. The current liner of the Space Shuttle Main Engine is another copper alloy, NARloy-Z (Cu-3Ag-0.1Zr). It provides a benchmark against which to compare the properties of candidate successors.

The thermomechanical properties of GRCop-84 have been shown to be superior, and its physical properties comparable, to those of NARloy-Z (ref. 1). However, environmental durability issues control longevity in this application: because copper oxide scales are not highly protective, most copper alloys are quickly consumed in oxygen environments at elevated temperatures. In consequence, NARloy-Z and most other copper alloys are prone to blanching, a degradation process that occurs through cycles of oxidation-reduction as the oxide is repeatedly formed and removed because of microscale fluctuations in the oxygen-hydrogen fuel systems of rocket engines. The Space Shuttle Main Engine lining is typically degraded by blanching-induced hot spots that lead to surface roughening, pore formation, and coolant leakage. Therefore, resistance to oxidation and blanching are key requirements for second-generation reusable launch vehicle liners. The rocket engine ambient includes H_2 (fuel) and H_2O (combustion product) and is, hence, under reduced-oxygen partial pressures. Accordingly, our studies were expanded to include oxygen partial pressures as low as 322 parts per million (ppm) at the temperatures likely to be experienced in service.

The figure compares 10-hr weight gains of GRCop-84, NARloy-Z, and pure copper in 0.032, 2.2, and 100 percent oxygen from 550 to 750 °C. In 2.2 vol% and higher oxygen content, GRCop-84 oxidation was slower than that of NARloy-Z or Cu, but that advantage was lost or diminished in 322-ppm O_2. Over longer (50-hr) exposures in 1.0 atm O_2, however, the advantage of GRCop-84 increased significantly, its oxidation rate becoming approximately 10 times slower than those of Cu and NARloy-Z from 500 to 700 °C. Weight gains were moderate and the kinetics parabolic for all three materials in 2.2 vol% and higher oxygen content; however, in 322-ppm O_2, the scales were nonprotective below about 650 °C, as reflected in linear kinetics and large weight gains (see the figure). The superior oxidation resistance of GRCop-84 is likely related to the kinetics of extra oxygen consumption to form the additional oxides of Cr and Nb detected beneath the GRCop-84 oxide layer (ref. 2).

While we continue to evaluate the blanching resistance of GRCop-84 in other tests, these oxidation results indicate that GRCop-84 is suitable as a reusable launch vehicle liner, and in applications where it is desired to use a copper alloy but without the risk of oxidative failure.



Specific weight gains of GRCop-84, NARloy-Z, and pure copper in 10-hr thermogravimetric analysis oxidation under various oxygen partial pressures.

Long description

Three bar charts comparing overall specific weight gains by each of the three materials studied. The top chart is for oxidation in 1.0 atm of oxygen, the middle is for 2.2% oxygen (balance argon), and the bottom is for 0.0322% oxygen. GRCop-84 outperforms the other two materials, showing the least weight gain in nearly all cases.

References

1. Ellis, David L.: GRCop-84 Developed for Rocket Engines. 2000 Research & Technology, NASA/TM-2001-210605, pp. 24-25.

2. Thomas-Ogbuji, Linus U.; and Humphrey, Donald L.: Oxidation Behavior of GRCop-84 (Cu-8Cr-4Nb) at Intermediate and High Temperatures. NASA/CR-2000-210369, 2000.

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