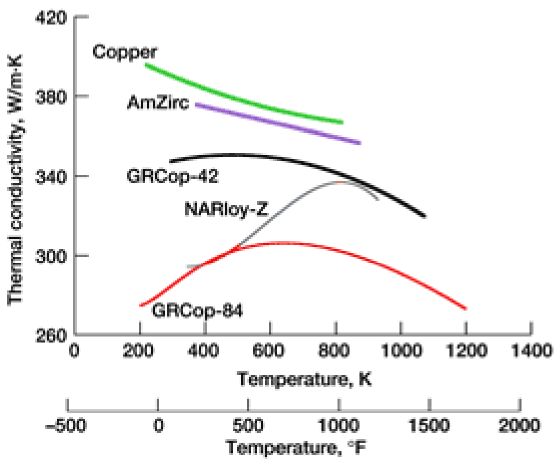
Conductivity of GRCop-42 Alloy Enhanced

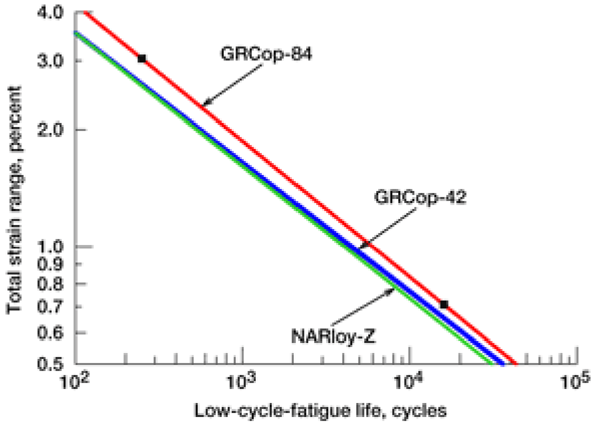
GRCop-84, a material developed at the NASA Glenn Research Center, has shown considerable promise for staged combustion rocket engine cycles such as the Space Shuttle Main Engine. However, for an expander cycle rocket engine, the transfer of heat to the fuel is a paramount factor in determining the efficiency of the engine. Examples of current and potential future expander cycle rocket engines are the Pratt & Whitney RL-10, RL-60, and RLX engines. Development of a higher conductivity version of GRCop-84 was undertaken to meet these needs.

All expander cycle engines need a main combustion chamber liner with the maximum possible thermal conductivity. In an effort at Glenn to trade some of the greatly increased mechanical properties of GRCop-84 for improved thermal conductivity, the amounts of chromium and niobium were halved. The new Cu-4 at.% Cr-2 at.% Nb alloy was designated GRCop-42.



Comparative thermal conductivity of GRCop-42.

The thermal conductivity of GRCop-42 is compared with those of four other materials--GRCop-84, NARloy-Z, AMZIRC, and pure copper. The GRCop-42 thermal conductivity at room temperature is 344 W/m·K in compared to 280 W/m·K for GRCop-84, 296 W/m·K for NARloy-Z, 380 W/m·K for AMZIRC, and 396 W/m·K for pure copper. The relative ranking remains the same up to 1000 °C, although the thermal conductivity for NARloy-Z becomes close to that of GRCop-42 around 500 °C



Low-cycle-fatigue life comparison.
The low-cycle-fatigue lives of GRCop-42, GRCop-84, and NARloy-Z are compared. GRCop-84 has the highest life at any given total strain range. GRCop-42 and NARloy-Z are approximately equal. Their lives are approximately half that of GRCop-84 for any given total strain range.

The top graph shows the result of lowering the alloying content on thermal conductivity. GRCop-42 has a sizeable improvement in thermal conductivity relative to GRCop-84. GRCop-42 also easily exceeds the thermal conductivity of the current Space Shuttle Main Engine liner alloy, NARloy-Z (Cu-3 wt%, Ag-0.5 wt%, Zr).

The cost of the improved thermal conductivity is minimal. The bottom graph shows the low-cycle-fatigue (LCF) lives of GRCop-42. LCF is generally the dominant failure mode for liners. There is a small, but statistically significant, decrease in the LCF life of GRCop-42 in comparison to that of GRCop-84. However, the lives are equivalent to that of NARloy-Z. Additional testing showed that the strength of the GRCop-42 is almost equal to that of GRCop-84 up to 800 °C (1472 °F) and much greater than that of NARloy-Z. However, the creep stress for a 15-hr life at 500 °C (932 °F), a typical value for a liner, is reduced by approximately 25 percent relative to GRCop-84. Even with the reduced creep stress, GRCop-42 retains an advantage in creep stress over NARloy-Z and most other alloys.

Additional testing is underway to generate a database similar to that already done for GRCop-84. Work will include characterizing the microstructural properties and determining the thermophysical and mechanical properties before and after the alloy is subjected to a simulated brazing thermal cycle. Following testing, the database will be made available to industry for their evaluation of GRCop-42 in potential high-heat-flux applications.

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