

High Thermal Conductivity NARloy-Z-Diamond Composite Liner for Advanced Rocket Engines

Project Manager(s)/Lead(s)

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Sponsoring Program(s)

Marshall Space Flight Center/Center Management
and Operations
Technology Investment Program

Project Description

NARloy-Z (Cu-3Ag-0.5Zr) alloy is state-of-the-art combustion chamber liner material used in liquid propulsion engines such as the RS-68 and RS-25. The performance of future liquid propulsion systems can be improved significantly by increasing the heat transfer through the combustion chamber liner. Prior work¹ done at NASA Marshall Space Flight Center (MSFC) has shown that the thermal conductivity of NARloy-Z alloy can be improved significantly by embedding high thermal conductivity diamond particles in the alloy matrix to form NARloy-Z-diamond composite (fig. 1). NARloy-Z-diamond composite containing 40vol% diamond showed 69% higher thermal conductivity than NARloy-Z. It is 24% lighter than NARloy-Z and hence the density normalized thermal conductivity is 120% better. These attributes will improve the performance and life of the advanced rocket engines significantly.

The research work consists of (a) developing design properties (thermal and mechanical) of NARloy-Z-D composite, (b) fabrication of net shape subscale combustion chamber liner, and (c) hot-fire testing of the liner to test performance. Initially, NARloy-Z-D composite slabs were made using the Field Assisted Sintering Technology (FAST) (fig. 2) for the purpose of

determining design properties. In the next step, a cylindrical shape was fabricated to demonstrate feasibility (fig. 3). The liner consists of six cylinders which are sintered separately and then stacked and diffusion bonded to make the liner (fig. 4). The liner will be heat treated, finish-machined, and assembled into a combustion chamber and hot-fire tested in the MSFC test facility (TF 115) to determine performance (fig. 5).

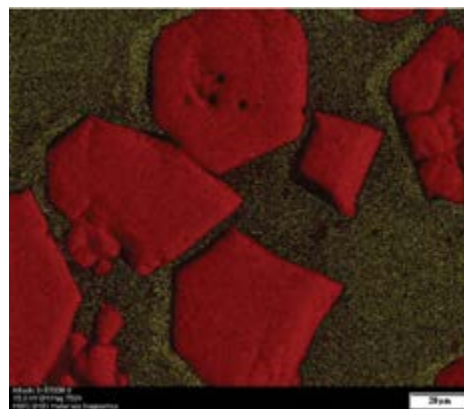


Figure 1: NARloy-Z-diamond composite microstructure (diamond particles shown in red).



Figure 2: Sintering at high temperature using FAST at Applied Research Laboratory, Pennsylvania State University.



Figure 3: NARloy-Z-40vol% diamond composite cylinder fabricated by FAST.

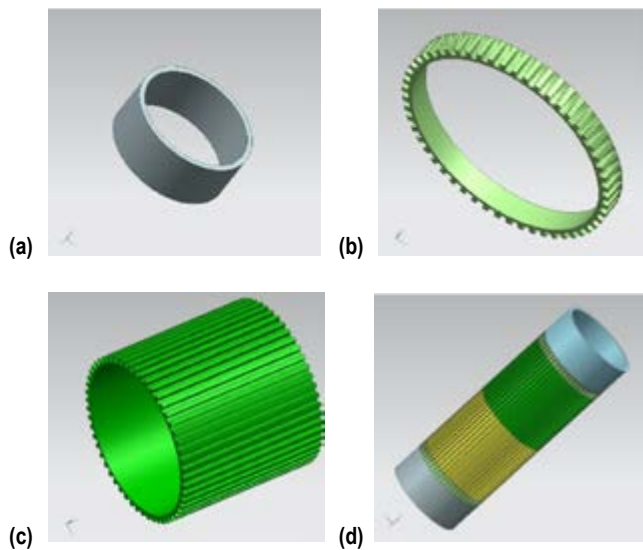


Figure 4: Combustion chamber liner components (schematic): (a) Outer cylinders, (b) inner cylinders, and (c) middle cylinders. Six cylinders will be fabricated, stacked, and diffusion bonded to make the liner (d).

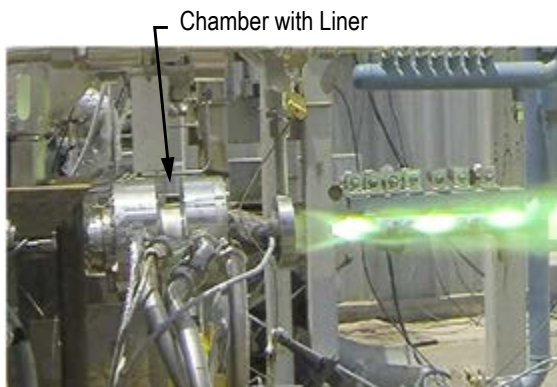


Figure 5: Hot-fire testing in TF 115.

Anticipated Benefits

This project will demonstrate the capability to make our future propulsion systems lighter and higher performing using a higher thermal conductivity material for the combustion chamber liner. Turbo pump power is expected to increase up to 2×. Increased heat transfer will directly result in increased thrust. There is potential for an increase in specific impulse for regeneratively cooled rocket engines such as the RL-10/NGE, RL-25E/F, and J-2X. Significant weight savings are possible due to the use of lightweight and higher thermal conductivity material. System-level trades need to be conducted to determine the overall weight savings, but as one example, it may be possible to maintain the current performance and reduce the engine mass.

Potential Applications

This project addresses an important material technology area that has high payoff in terms of affordability and performance of rocket propulsion systems. It will advance the Technology Readiness Level (TRL) from current TRL-3 to TRL-5, at which point it will be ready for implementation in an engine program such as RL-10/NGE, RL-25E/F, and/or J-2X. Furthermore, the high thermal conductivity NARloy-Z-diamond composite material developed in this program will have many applications in the industry, e.g., thermal management for computer hardware (heat sinks), heat exchangers, etc.

Notable Accomplishments

NARloy-Z-40vol%diamond cylinders have been successfully sintered using the FAST process (fig. 3). Diffusion bonding tests have been successful and showed acceptable bond strength.

References

1. Bhat, B.N.; et al.: “Copper-Multiwall Carbon Nanotubes and Copper-Diamond Composites for Advanced Rocket Engines,” 60th JANNAF Joint Subcommittee Meeting, Colorado Springs, CO, April 28–May 3, 2013.

TIP