1. Background

- Phenolic Impregnated Carbon Ablator (PICA) is a member of the family of Lightweight Ceramic Ablators (LCAs) and was developed at NASA Ames Research Center as a thermal protection system (TPS) material for the Stardust mission probe that entered the Earth’s atmosphere faster than any other probe or vehicle to date.
- PICA, carbon fiberform base and phenolic polymer, shows excellent thermal insulative properties at heating rates from about 250 W/cm$^2$ to 1000 W/cm$^2$.
- The density of standard PICA - 0.26 g/cm$^3$ to 0.28 g/cm$^3$ - can be changed by changing the concentration of the phenolic resin.
- By adding polymers to the phenolic resin before curing it is possible to significantly improve the mechanical properties of PICA without significantly increasing the density.

2. Phenolic Impregnated Carbon Ablator Processing

- Carbon Fiberform
- Resin
- Impregnate with heat treat
- Vacuum impregnation
- Cured in oven (inert atmosphere)
- Dry in vacuum oven
- PICA with phenolic resin impregnated

3. Importance of Morphology in Ablator Systems

Morphology refers to the microstructure of an ablative system and the location of phenolic polymer (or infiltrant) relative to the fiber substrate used.

4. Focus of This Work

1. Improve existing low density PICA-like ablators by reducing brittleness and increasing strength without increasing density.
2. Understand key parameters that control the thermal and mechanical properties of low density, porous ablators using PICA as a model system.
3. Discover and develop new advanced ablators.

5. First Generation Polymer Variants of PICA

Adding polymers to the phenolic resin still resulted in poor morphology due to low concentration of phenolic resin. Densities are similar to low density PICA ($0.24$ g/cm$^3$) due to same concentration of phenolic resin.

6. Second Generation Polymer Variants of PICA

- Low density PICA (control)
- Polymer Variant 1
- Polymer Variant 2
- Polymer Variant 3
- Polymer Variant 4
- Polymer Variant 5

7. Third Generation Polymer Variants of PICA

Adding polymers to the phenolic resin and changing the solvent changed the morphology (compared to the 2nd generation) and the interaction between the polymer and the carbon fibers.

8. Mechanical Properties of Polymer Variants

The best third generation polymer variant PICA samples have an ultimate tensile strength (UTS) greater than three times that of standard PICA controls. Mid-density PICA and high density PICA are PICA made with increased concentration of phenolic resin without additives.

9. Future Work

When funds become available, large-scale arc jet testing will be performed and research will continue to increase the strain-to-failure of polymer variants of PICA.

10. Summary

- Polymers can be added to the phenolic resin used to make PICA to obtain a desirable morphology and improved mechanical properties.
- Data obtained shows that the toughness of PICA can nearly be quadrupled and that the ultimate tensile strength can be tripled by adding polymers to the resin.

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