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SOME MATERIALS PERSPECTIVES FOR SPACE TRANSPORTATION SYSTEMS

Howard G. Maahs
Applied Materials Branch
Materials Division
NASA Langley Research Center

PERSONAL BACKGROUND IN ENTRY SYSTEMS

Graphite Ablation (1964-1971)

- Application: single-use ballistic entry manned vehicle
- Materials identification & characterization
  - Artificial graphite, glassy carbon, pyrolytic graphite
- Performance evaluations (arc jet)
- Erosion rates and mechanisms

Carbon-Carbon Composites (1982-present)

- Applications: reusable airframe TPS or hot structure (generic hypersonic vehicles, NASP)
- Materials identification and characterization
  - Thin, structural oxidation-resistant carbon-carbon composites
- New materials/concepts development
  - Mechanical property improvements
  - Oxidation resistance
- Performance evaluations (mission simulation, arc jet)
- Failure mechanisms

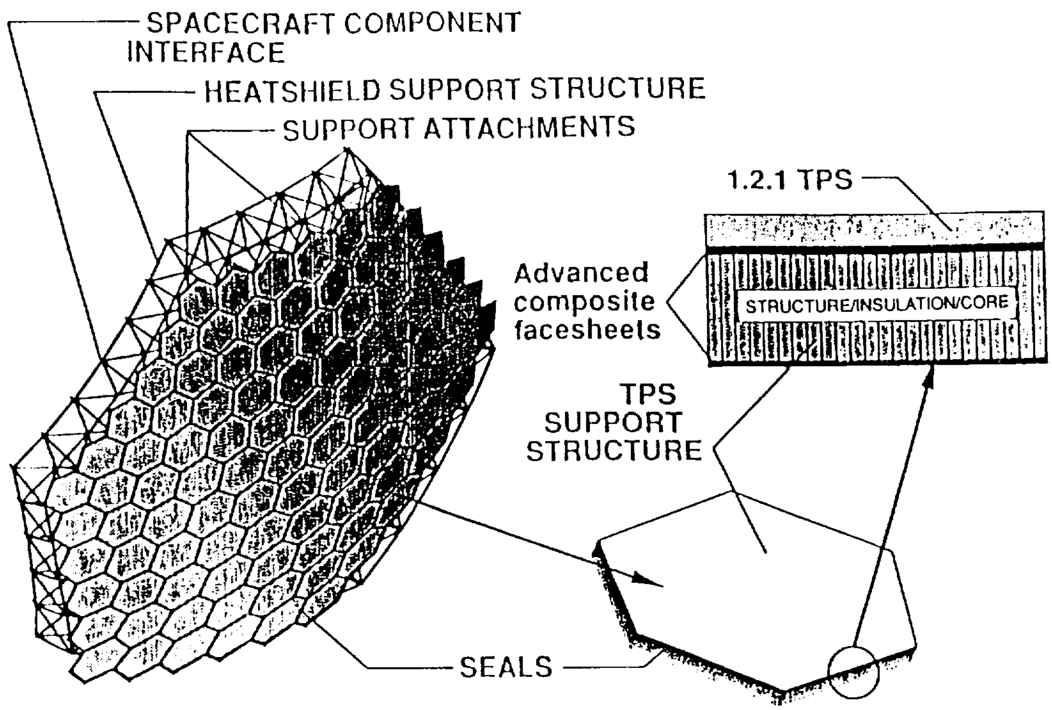
COMMON NEEDS FOR SPACE TRANSPORTATION VEHICLES:

PASSIVE THERMAL PROTECTION SYSTEMS

- Space Shuttle Orbiter
- Shuttle evolution
- Single-stage-to-orbit (NASP)
- Advanced hypersonic vehicles
- Personnel launch system (PLS)
- Lunar transfer vehicle
- Martin transfer vehicle

Additional performance benefits possible if a single material serves dual functions of TPS and structure.

AN AEROBRAKE CONCEPT



BASIC AEROBRAKE CRITERIA

Aerobrake Performance Objectives

- Lifetime
  - Lunar missions: ≥ 7 flights
  - Mars missions: ≥ 2 flights
- Entry velocity range: 6 to 14 km/sec
- Maximum g-loads: 5 to 6
- Aerobrake/vehicle mass fraction: ≤ 15%

Basic Heatshield Requirements (configuration & trajectory dependent)

	Environment composition	Maximum radiation equilibrium temperature, °F	Aeropass time, sec.
Earth entry (Lunar mission)	air	2000-3000°F	100-300
Earth entry (Mars mission)	air	3500-4000°F	100-500
Mars entry	CO_2	2500-3500°F	700-1000

AEROBRAKE MATERIALS

General Materials Requirements

- High temperature capability
- High load bearing
- Lightweight
- Fully reusable (mission specific)
- Space durable in LEO/Lunar/interplanetary environments
- Material data base as a function of temperature
- Verified performance capability in relevant service environments

SPECIFIC MATERIALS NEEDS

Thermal Protection System (TPS)

- Capability to 4000°F
- Tailored thermal conductivity for optimum heat distribution
- Non-catalytic surfaces
- High emittance (≥ 0.8)
- Methodology to predict service performance from ground-based and limited flight data

TPS Support Structure

- Low coefficient of thermal expansion
- High temperature insulative capability
- Load introduction concepts/materials to support structure

TPS Seals

- Same as for TPS
- Compatibility with TPS materials
- Design concepts for minimum leakage
- Acoustic load tolerance

Heatshield Support Structure

- Concepts for heavily loaded structure
- Lightweight materials
- Low coefficient of thermal expansion

SOME HEATSHIELD MATERIALS OPTIONS

- Ablators
- Oxidation-resistant carbon-carbon composites
- Rigid surface insulation
- Flexible ceramic materials
- Ceramic matrix composites

RECENT TECHNOLOGY ADVANCES IN CURRENT PROGRAMS

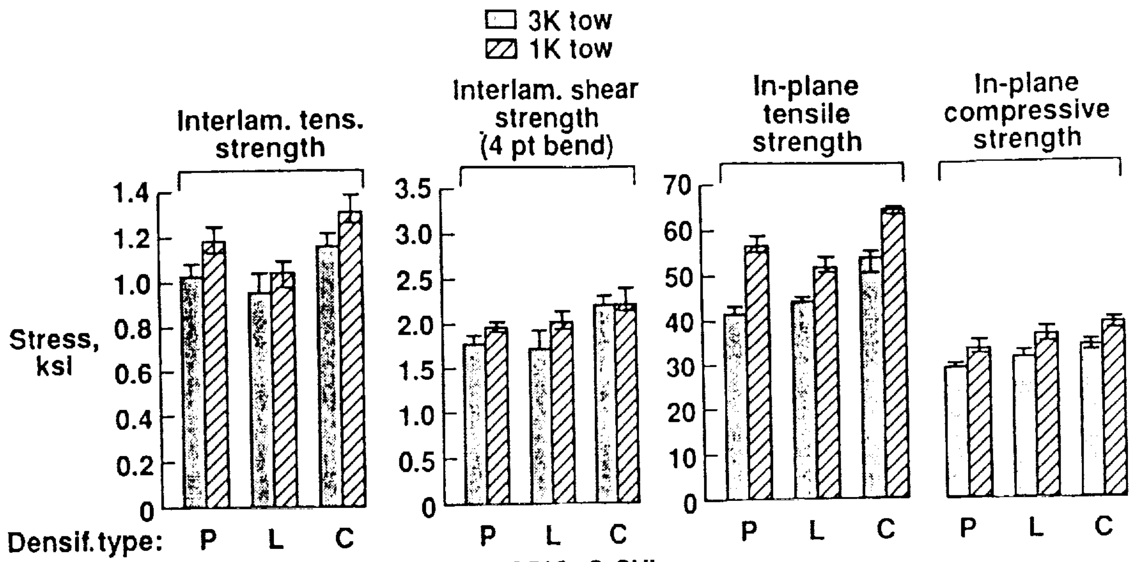
- Carbon-Carbon Composites -

- Mechanical properties (program focus: generic airframe structure)
  - Improved strengths for 2-D constructions
  - Strength benefits of 3-D constructions

- Oxidation resistance (program focus: NASP)
  - Carbon-carbon mission cycling data to 200 hours
  - Carbon-hybrid materials
  - Dynamic (arc jet) test data

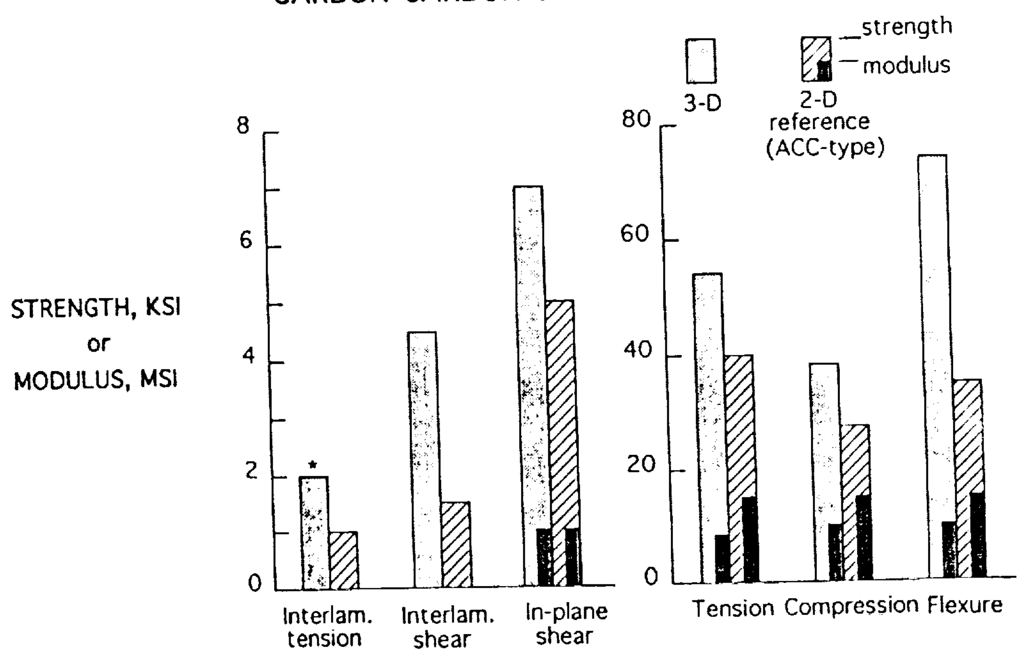
INFLUENCE OF TOW SIZE AND DENSIFICATION TYPE ON SELECTED MECHANICAL PROPERTIES OF 2-D CARBON-CARBON COMPOSITES

Reinforcement: T-300 8HS fabric; 0, 90 layup
Heat stab. temp: 2000°C



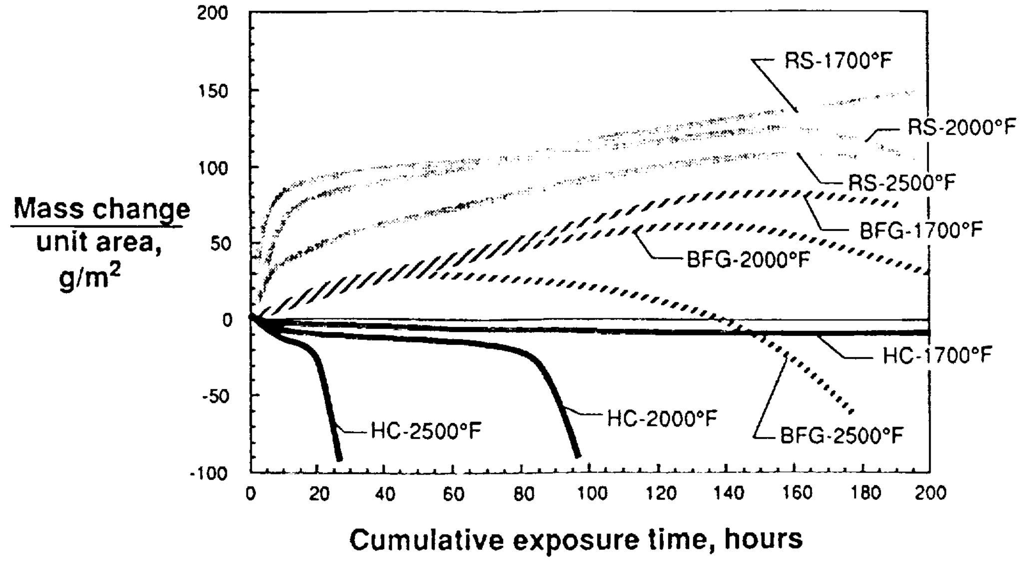
Densification method: P-phenolic, L-LOPIC, C-CVI

STRENGTH BENEFITS OF A CVI-DENSIFIED 3-D ORTHOGONAL CARBON-CARBON COMPOSITE

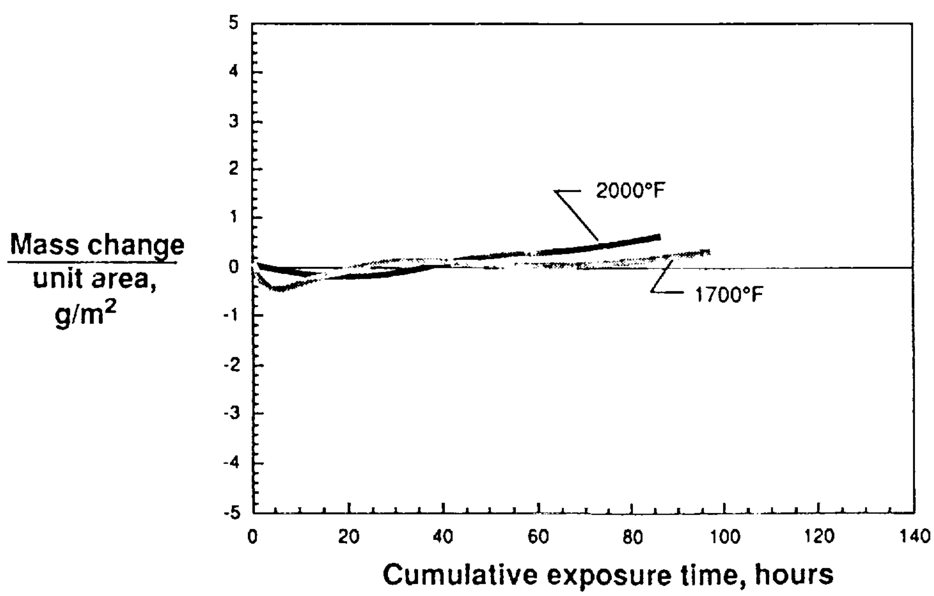


* test capability limit

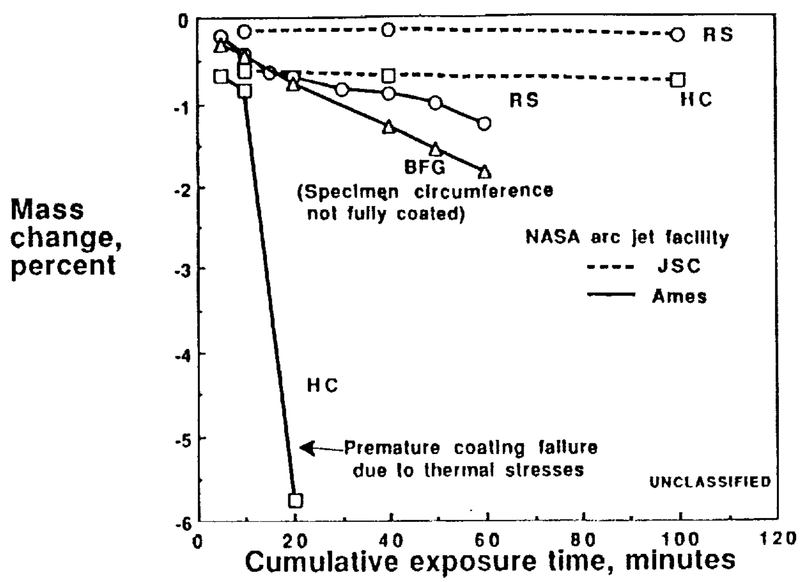
Typical Oxidation Performance Results for HC, RS and BFG Materials



Typical Oxidation Performance Results for Hitco SiC/C Materials



ARC JET TEST RESULTS AT 2500°F (U)



AEROBRAKE MATERIALS AND STRUCTURES TECHNOLOGY NEEDS

- Mission/configuration/trajectory trade studies ⇒ Environmental definition
- Integrated structures/materials concepts trade studies
- Candidate materials identification/development
- Materials screening in relevant environments
- Dynamic (arc jet) tests
- Mathematical models to predict service performance from ground-based test data
- Materials property design data base
- Design and analysis of aeroshell and support structure
- Construct and verify performance of representative subelement assemblies
- Inspection and repair technology
- Flight experiments to verify predictive capability
- Materials performance/durability certification testing

SUMMARY REMARKS

- A common need for all space transportation vehicles is an effective thermal protection system
- An aerobraking vehicle exemplifies many common TPS issues
- Numerous materials and structural options exist
- Current programs in oxidation-resistant carbon-carbon composites provide a strong technology foundation for a combined TPS/hot structure approach
- Major materials and structures technology needs must be identified and addressed

10.3.12 Materials and Structures Technologies for Hypersonics by George F. Wright, Sandia National Laboratory