Architectural Effects on Impact Resistance of Uncoated MI SiC/SiC Composites

R.T. Bhatt, L.M. Cosgriff, and D.S. Fox
NASA Glenn Research Center
Cleveland, OH 44135

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Background

- Turbine components are subjected to impact damage by soft and hard projectiles.
- Projectile impact can cause spallation of surface coating, substrate damage, and eventual loss of components depending on impact velocity.
- Understanding influence of impact damage on properties and methods of avoiding or reducing impact damage are essential for development of CMC components.
Impact Study

• Objectives
  Near Term
  - Determine influence of fiber architecture on impact damage mechanisms of uncoated MI SiC/SiC composites at room and high temperatures.
  Long Term
  - Determine influence of oxidation on properties of impact tested uncoated and environmental barrier (EB) coated MI SiC/SiC composites.

• Approaches
  - Impact test room and high temperatures
  - Vary impact testing parameters
  - Evaluate impact damage using NDE techniques
  - Deposit EB coatings on MI SiC/SiC composite specimens
  - Expose impact tested specimens in moisture environment at high temperatures
  - Measure residual mechanical properties at room temperature
Material and Experimental Variables

- **Material**
  - Composite Vendor: Goodrich
  - Composite characteristics: BN/SiC coated Hi-Nicalon-S SiC fibers, 8 ply, 0/90, 5HS Weave, 18 epi and 2 different 2.5D woven structures, Melt infiltrated (MI) matrix.

- **Impact test variables**
  - Projectile: 1.59mm dia steel balls
  - Projectile velocity: 115 to 300 m/s
  - Test temperature: 25\(^\circ\)C and 1316\(^\circ\)C
  - Test environment: Air

- **Characterization methods**
  - Optical microscopy, Thermography, Computed Tomography (CT)
Fiber Architecture

(a) Harness satin weave

(b) Layer angle interlock
Optical Photographs of the Cross Section of 2-D and 2.5D MI SiC/SiC Composites
Impact Specimen Geometry

Note: All dimensions are in inches
Impact Facility

High-temperature capability up to 1500°C
Optical Photographs of 2-D MI SiC/SiC Composites Impact Tested at 1316°C in Air

Impacted side

Back side

115m/s

Impacted site

160m/s

Damage zone

220m/s

300m/s
Thermographic Images of 2-D MI SiC/SiC Composites Impact Tested at 1316°C in Air

Impacted side

115 m/sec

160 m/sec

220 m/sec

300 m/sec

Back side
CT Images of 2-D MI SiC/SiC Composites
Impact Tested at 1316° C in Air

115 m/s

160 m/s

220 m/s

300 m/s

325 m/s
Optical Photographs of 2.5-D (Type II) MI SiC/SiC Composites Impact Tested at 1316°C in Air

Impacted side

115 m/s

160 m/s

220 m/s

300 m/s

Back side
Thermographic Images of 2.5-D (Type II) MI SiC/SiC Composites Impact Tested at 1316° C in Air Using 1.53-mm Dia. Steel Projectiles

- Impacted side

- Back side

115m/sec

160m/sec

220m/sec

300m/sec
CT Images of 2.5D (Type II) MI SiC/SiC Composites Impact Tested at 1316°C in Air

115 m/s

160 m/s

220 m/s

300 m/s
Comparison of Damage Zone Width with Projectile Velocity for 2D and 2.5-D MI SiC/SiC Composites Impact Tested at 25°C In Air (Thermography Data)
Comparison of Damage Zone Width with Projectile Velocity for 2D and 2.5-D MI SiC/SiC Composites Impact Tested at 1316°C in Air (Thermography Data)
Comparison of Damage Zone Width with Projectile Velocity for 2.5-D (Type I and II) MI SiC/SiC Composites Impact Tested at 25° and 1316°C in Air (Thermography Data)
Variation of Damage Zone Depth with Projectile Velocity for 2-D and 2.5D MI SiC/SiC Composites Impact Tested at 1316°C in Air (CT Data)
Summary of Results and Conclusion

Summary of Results
Impact tests were conducted on uncoated 2D and 2.5D MI SiC/SiC composite specimens at room temperature and 1316°C in air. The specimens were analyzed before and after impact using optical microscopy, pulsed thermography (PT) and computed tomography (CT). Preliminary results indicate the following.

• Both 2-D and 2.5D composites show increase in surface and volumetric damages with increasing impact velocity. However, 2-D composites are prone to delamination cracks.
• In both 2D and 2.5D composites, the magnitude of impact damage at a fixed impact velocity is slightly greater at room temperature than at 1315°C.
• At a fixed projectile velocity and test temperature, the depth of penetration of the projectile into the substrate is significantly lower in 2.5D composites than in 2D composites.

Conclusion
Fiber architecture plays a significant role controlling impact damage in MI SiC/SiC composites.
Future Plans

• Determine influence of impact damage on properties of uncoated and environmental barrier coated MI SiC/SiC composites.
• Develop analytical models to predict impact damage