Resistance-Based Sensing in Carbon Nanotube Composites Under Dynamic Loads

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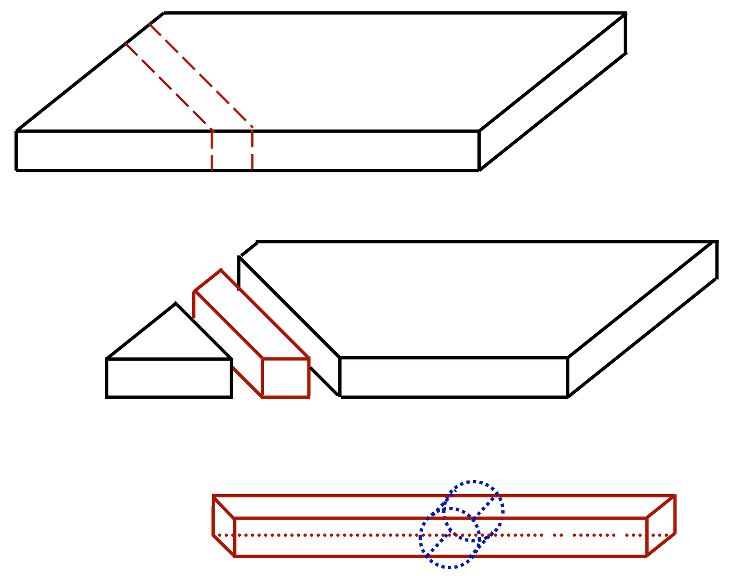
MOTIVATION

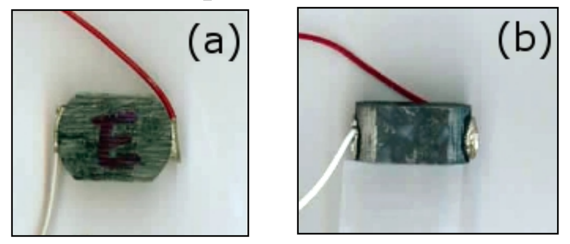
- **Failure prediction in advanced materials is critical to their success in high-performance applications.**
  - In FRPs, the onset of failure due to matrix cracking and interphase debonding often occurs without a significant decrease in load-carrying capability.
- **Nondestructive damage sensing approaches:**
  - off-line (e.g., ultrasonic C-scanning, X-ray microtomography and liquid penetrant)
  - real-time (e.g., time-domain reflectometry, acoustic emission and electrical resistance measurements)
- **Resistance-based sensing allows for both off-line and real-time health monitoring.**

Conductively modified carbon nanotube-based composites and their electrical response to dynamic loading is the focus of this research.

RESISTANCE-BASED DAMAGE SENSING

- **Preform: twenty plies of plain woven E-glass fabric**
  - Fabric is treated with a carbon nanotube-based sizing agent then infused with SC-15 epoxy resin.
- **Carbon nanotubes are deposited at the fiber surface resulting in electrical percolation in a composite specimen.**
  - The resistance of this nanotube network is particularly sensitive to interphase debonding and delamination.
- **Panel is cut to yield 45º off-axis specimens**

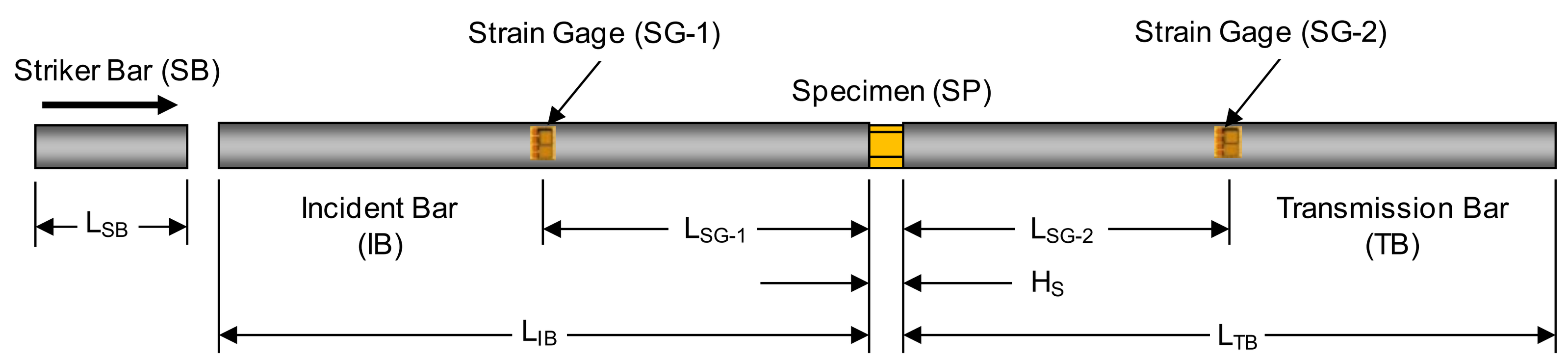




Lim, An, Chou and Thostenson (2010) Mechanical and electrical response of carbon nanotube-based fabric composites to Hopkinson bar loading. **Composites Science and Technology** 71:616-621

SPLIT HOPKINSON PRESSURE BAR

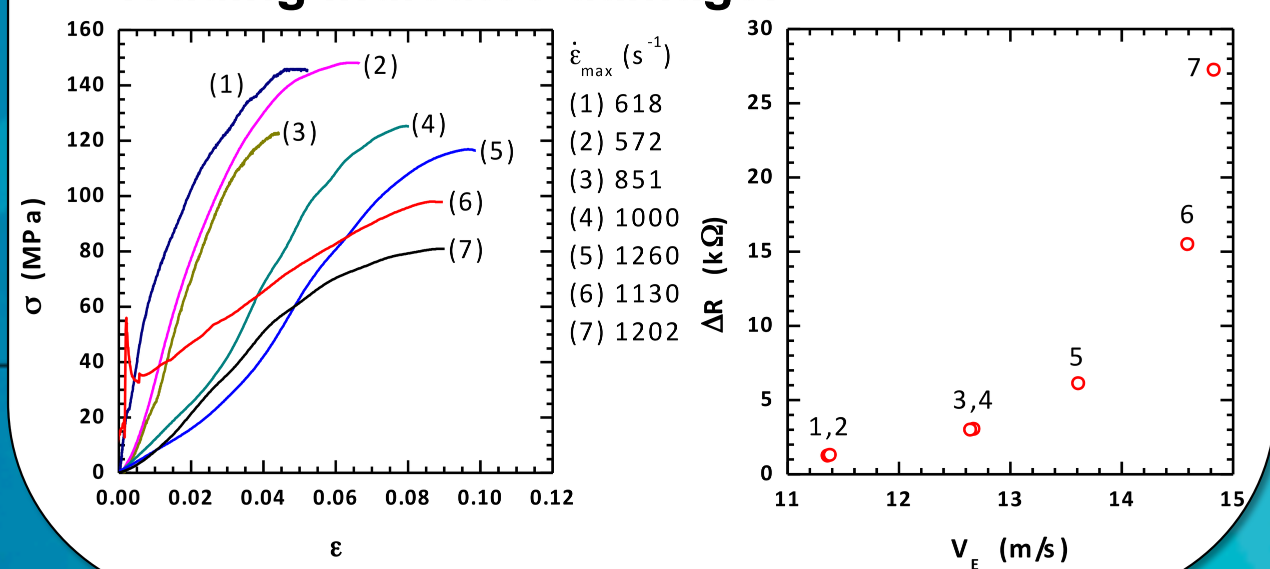
- **Consists of a striker bar (SB), incident bar (IB) and transmission bar (TB)**



- **A gas gun propels the striker bar, which impacts the incident bar.**
  - This results in a stress wave to propagate through the incident bar (σ_I) to the bar-specimen interface.
  - The degree of acoustic impedance mismatch and the specimen geometry control the amount of stress reflected back through the incident bar (σ_R) and transmitted through the transmission bar (σ_T).
- **Measures the mechanical response of a specimen to dynamic compression loading.**

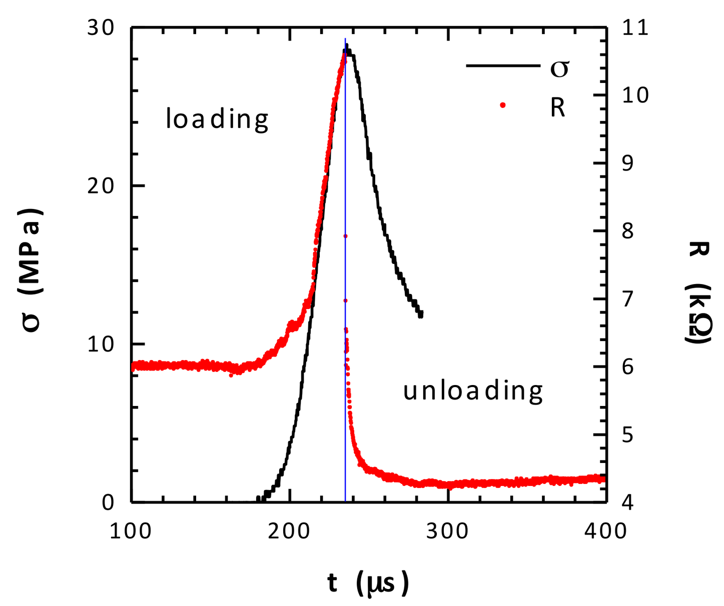
RESULTS

- **Single specimen impacted multiple times at increasing energy**
  - Stiffness decreases after each impact.
  - Anomaly in stress response due to large delamination during impact (6)
- **Permanent resistance changes after each loading indicates damage.**



CURRENT RESEARCH

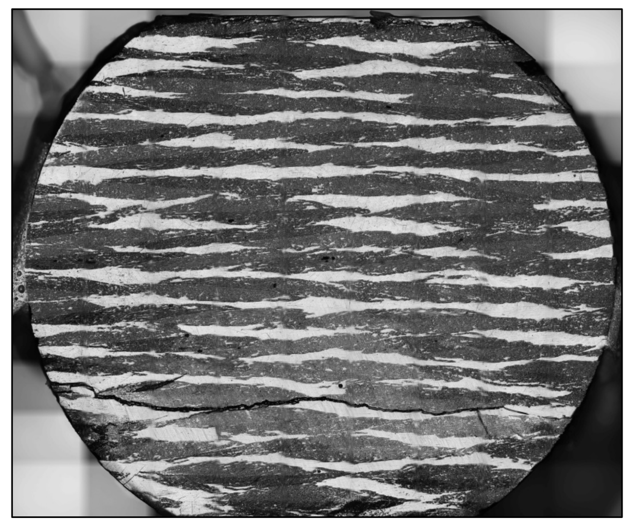
- **Record resistance on the experimental timescale (~300 μs)**
  - Stress and resistance are plotted vs. time below:



- **Resistance increases during compression due to radial electrode configuration**
  - Specimens undergo axial compression and radial tension (Poisson's effect).

DAMAGE BEHAVIOR

- **Delamination occurs in these 45º off-axis specimens.**
- **Future work includes:**
  - Exploring electrode configurations which are more sensitive to this mode of failure and
  - Measuring the resistance response to dynamic compression-induced shear failure



CONCLUSIONS

- **Achieved electrical percolation in a thick section composite using a carbon nanotube-based fiber sizing agent.**
- **Demonstrated effectiveness of the carbon nanotube network in sensing damage during dynamic compressive loading.**

ACKNOWLEDGEMENTS

U.S. Army Research Office
Grant No. W911NF-09-1-0114
Dr. Bruce LaMattina

U.S. Office of Naval Research
Grant No. N00014-09-1-0365
Dr. Yapa Rajapakse