Characterization of Graphene-Nickel Composites at Ultrahigh Strain Rates

Alex Coles, Aerospace Engineering
Mentor: Wonmo Kang, Associate Professor
School for Engineering of Matter, Transport and Energy

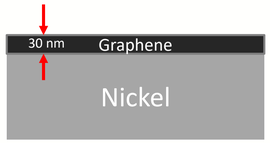
Research Question & Background

Aerospace and Defense Industries require materials to withstand ultrahigh strain rates, such as high velocity debris impacts or ballistics.

Properties of Graphene-Nickel Composites:

- Nickel is highly ductile and thermally stable.
- Graphene has extreme tensile strength.
- Combining the two creates a material more thermally stable and stronger than pure metals

Graphene-Nickel has not been thoroughly explored at ultrahigh strain rates (> $10^6 s^{-1}$)



Research Question: How does the inclusion of graphene affect energy absorption and hardness of nickel in high-velocity impact applications?

Procedure

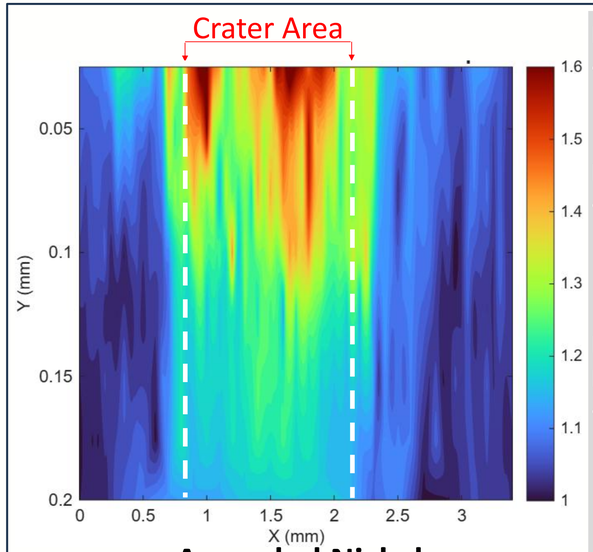
1. Sample Fabrication:
- Prepared samples of annealed pure nickel and graphene-nickel composites via Chemical Vapor Deposition (CVD).

2. Induced Deformation:
- Used Laser Shock Peening (LSP) to induce ultrahigh strain rates in samples.

3. Surface Measurements:
- Measured geometry and crater depth via Optical Profilometry.

4. Hardness Mapping:
- Microhardness testing to map dislocation density and determine energy absorption per area.

Microhardness Mapping

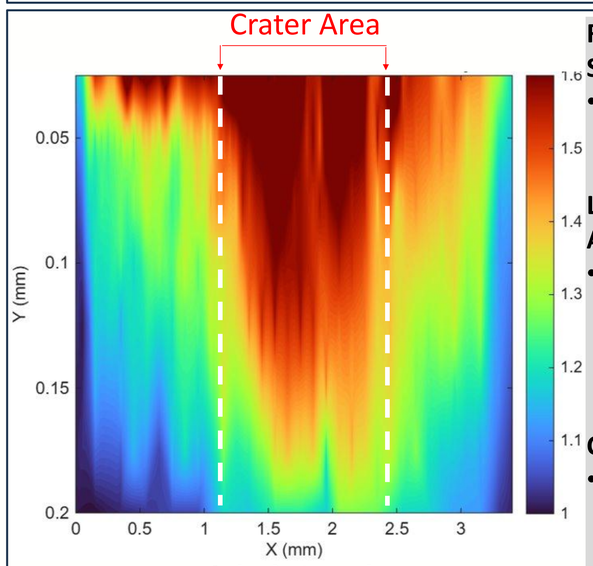


Annealed Nickel

Localized Stress:
- Concentrated impact energy below crater.

Minimal Dispersion:
- Localized dislocation density only, no lateral spreading.

Minimal Harness Increase:
- Overall hardness is much less than the composite material.



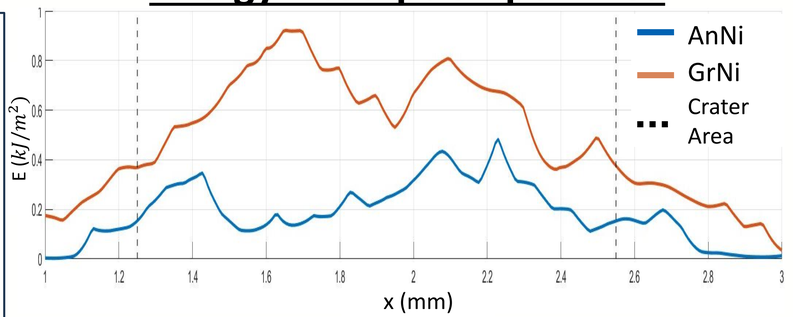
Nickel-Graphene

Redistribution of Stress:
- Stress is dispersed horizontally due to graphene layer.

Larger Energy Absorption:
- Significant increase of hardness indicates larger energy absorption.

Carbon Solution:
- Increased depth suggests potential bulk material strengthening.

Energy Absorption per Area



For the Graphene-Nickel composite, the total energy absorption per area is significantly greater than the annealed nickel on its own, indicating that graphene strengthens the material under ultrahigh strain rates.

Conclusions & Future Work

Impact Performance:
- Graphene-Nickel composites outperform annealed nickel under ultrahigh strain rates.
- The graphene layer redirected stress laterally, resulting in a greater absorption of energy.

Future Exploration:
- The depth of the hardness from the graphene-nickel sample indicates potential carbon solution into the nickel matrix, providing reinforcement beyond surface level.
- Investigating the effects of the graphene layer vs. bulk material strengthening.

Key Takeaway:
The addition of graphene to nickel distributes the stress and leads to wider energy absorption and hardness in ultrahigh strain rate applications.

FURI

Ira A. Fulton Schools of Engineering
Arizona State University