AERODEF MANUFACTURING

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A Study of Aramid Honeycomb Machining with a High-Speed Camera

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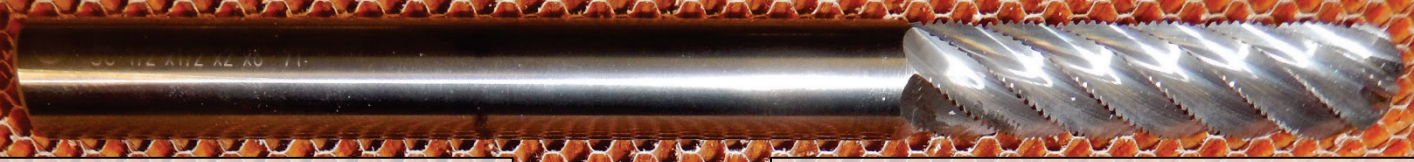
produced by sme

The Team

- Faculty
  - Dr. David Gill
  - Dr. Derek Yip-Hoi
- Undergraduate Students
  - Max Meaker
  - Erica Eggeman
  - Taryn Boni
  - Alex Brennen
  - Aiden Anderson

Students present their research to U.S. Congressman Rick Larsen in our lab

The Application



Nomex Honeycomb

- Lightweight
- Strong
- Machinable
- Available in different cell sizes and shapes
- Can be formed to complex compound curves

Aerospace Applications

- Engine Fairings
- Hatch Covers
- Rotor Blades
- Aircraft Interiors

Other Applications

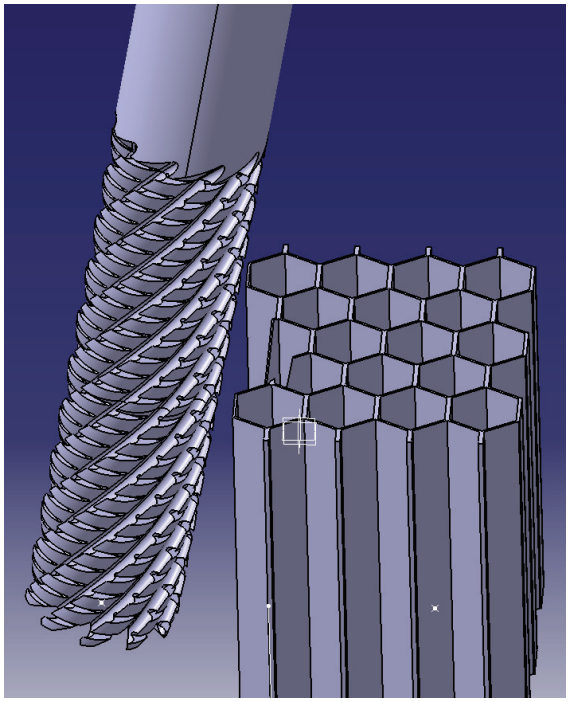
- Electric Vehicles
- High Perf. Vehicles
- High Perf. Marine

The Challenge

- Machining of Aramid Honeycomb experiences high rates of tool wear
- Tools cost $170-$500 each
- Machining times can be only a few hours

But…

- We are machining paper
- 96% of the volume is air
- Sure, there is a phenolic component
  - But Why is Tool Life So Short?



A Parametric Model Created to Study Contact Between the Tool & Honeycomb

How We Studied the Problem

- Began with tool life testing
- Used a woodworking router in a CNC Machine
- Used manufacturer's recommended cutting parameters
- Began with 3.175mm (1/8th in), normally expanded, Nomex honeycomb

A woodworking router mounted in a CNC machine provided recommended spindle speeds and axis feedrates

Total machining time of 97min before repeated tearout

N=17,500rpm, f=3810mm/min (150ipm), doc_a=9.5mm (0.375")
Conventional Milling, 75% radial engagement, 5° Lead, 0° Tilt

Machining Honeycomb

Material is quickly machined producing very long chips

A Word About the Tool

What tool:

- 12.7mm Pocketing Shredder End Mill
- 10 flute carbide tool, AWAC3 coating

Why we chose it:

- Used by partner companies for many machining operations
- Experiences a high wear rate

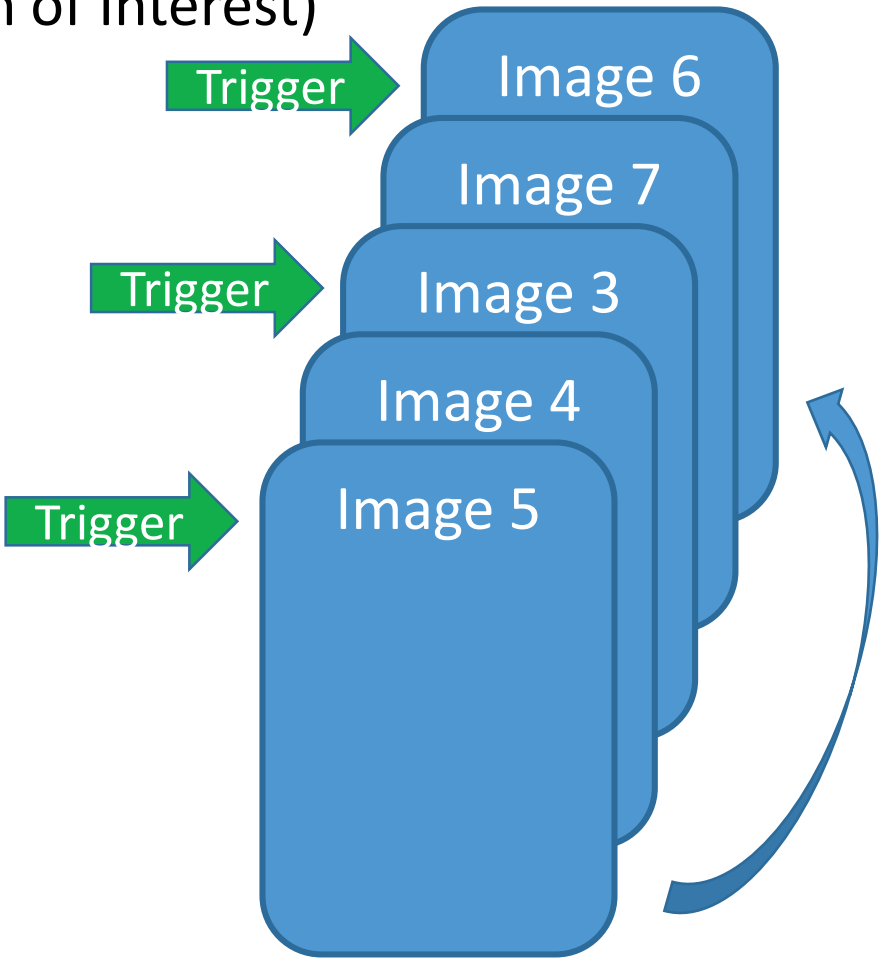
However:

- The companies use 16mm more often, but only 12mm fits in the router – cutting dynamics were assumed to be similar

High Speed Video Camera

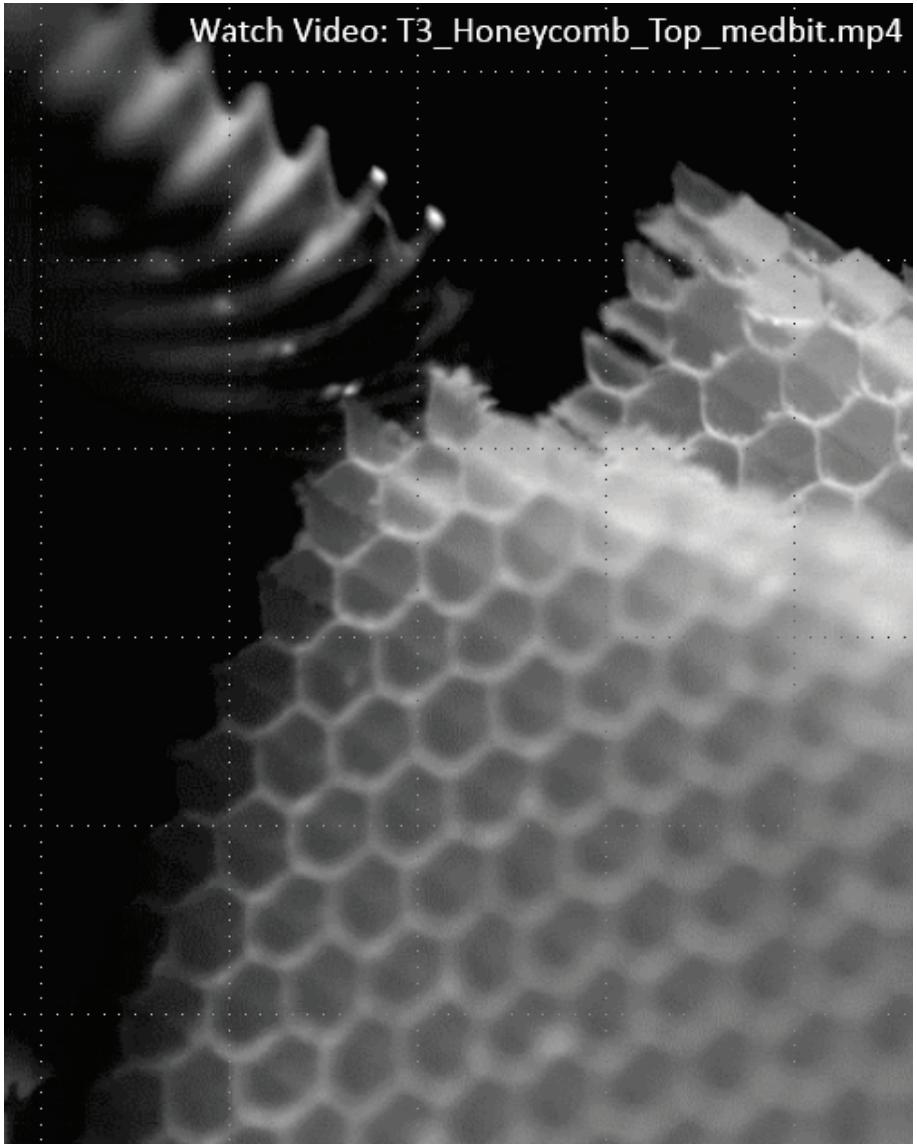
- 20,000 frames/sec
- Get an image every 5.25° tool rotation at 17,500rpm
- ~1.0s of data (depending on Region of Interest)

Photron Fastcam SA-5
- 1024x1024 @ 7,500fps
- 32GB memory
- ISO10,000 (B&W)
- Download speed is fast, but…

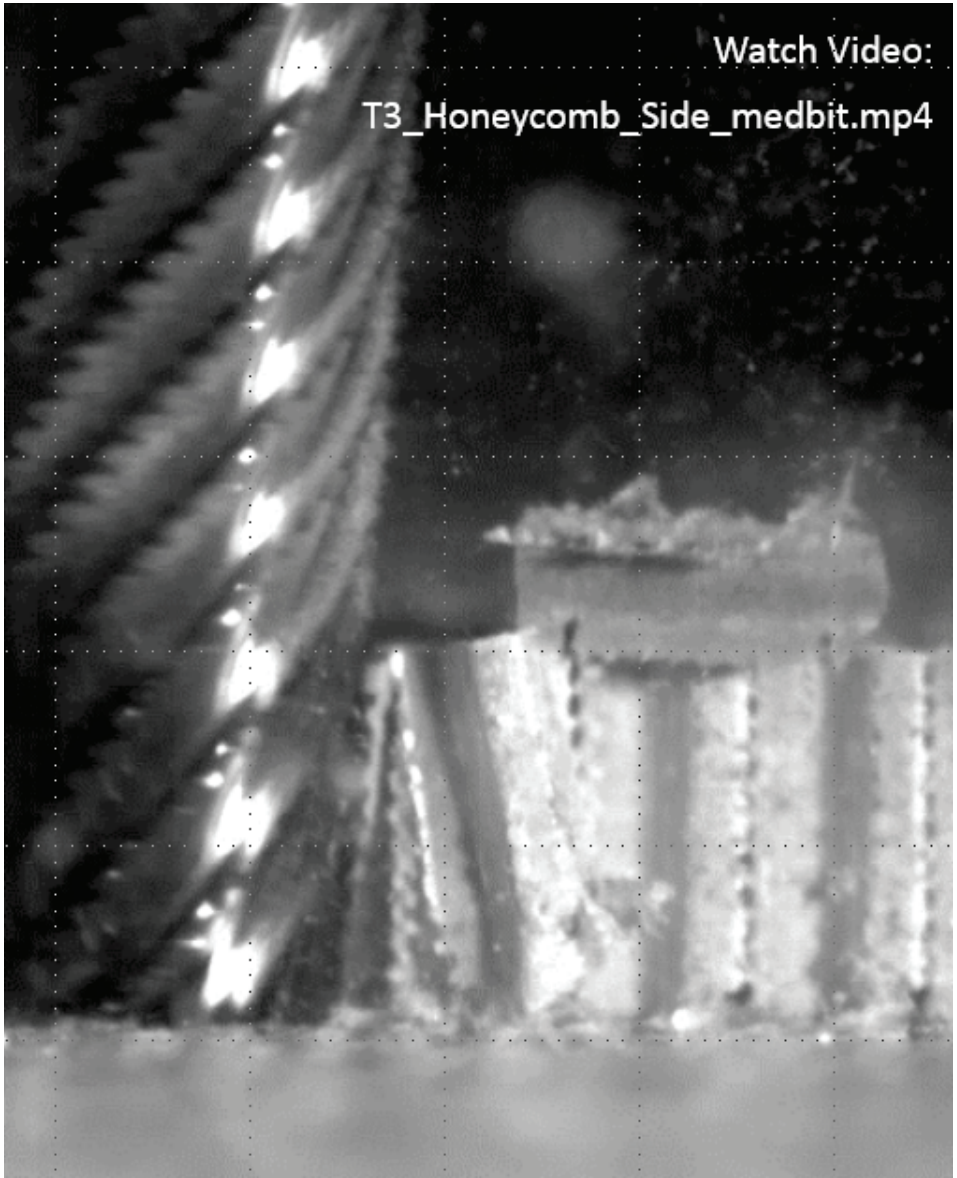


Cutting Honeycomb at 20,000fps

New tool (3 seconds total cut time) deflects cell walls instead of cutting them

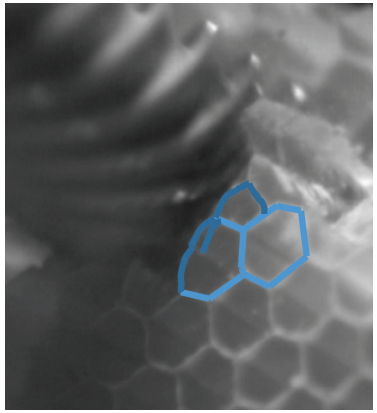


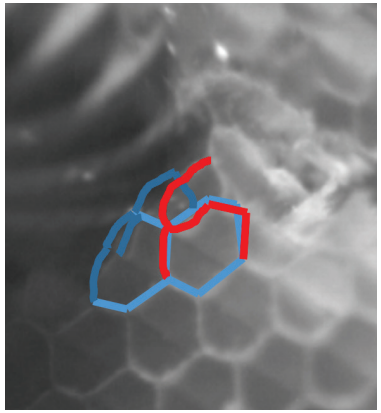
And a Side View

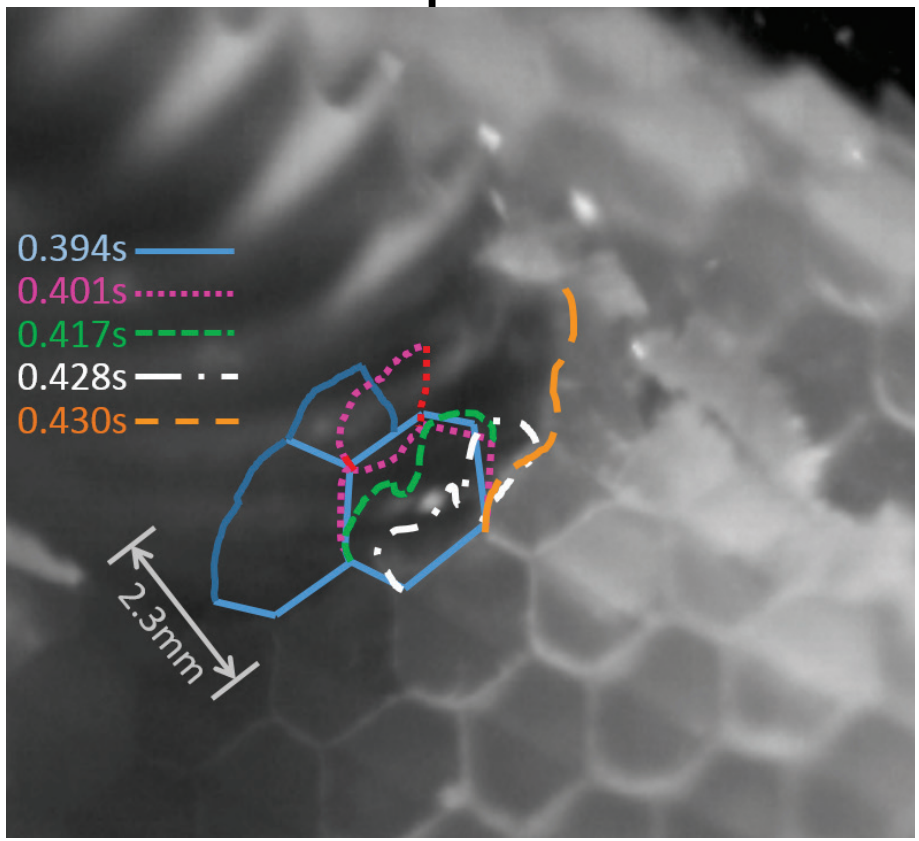


Cell walls rub against tool for extended periods of time

The Cells Collapse

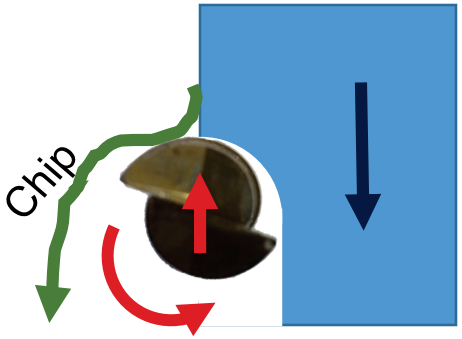




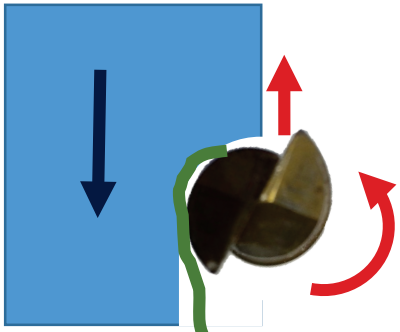


- Cell walls bend and collapse far in front of cutter
- Individual cell wall sections remain connected to the structure long after the tool has passed (orange dashed line in center figure)

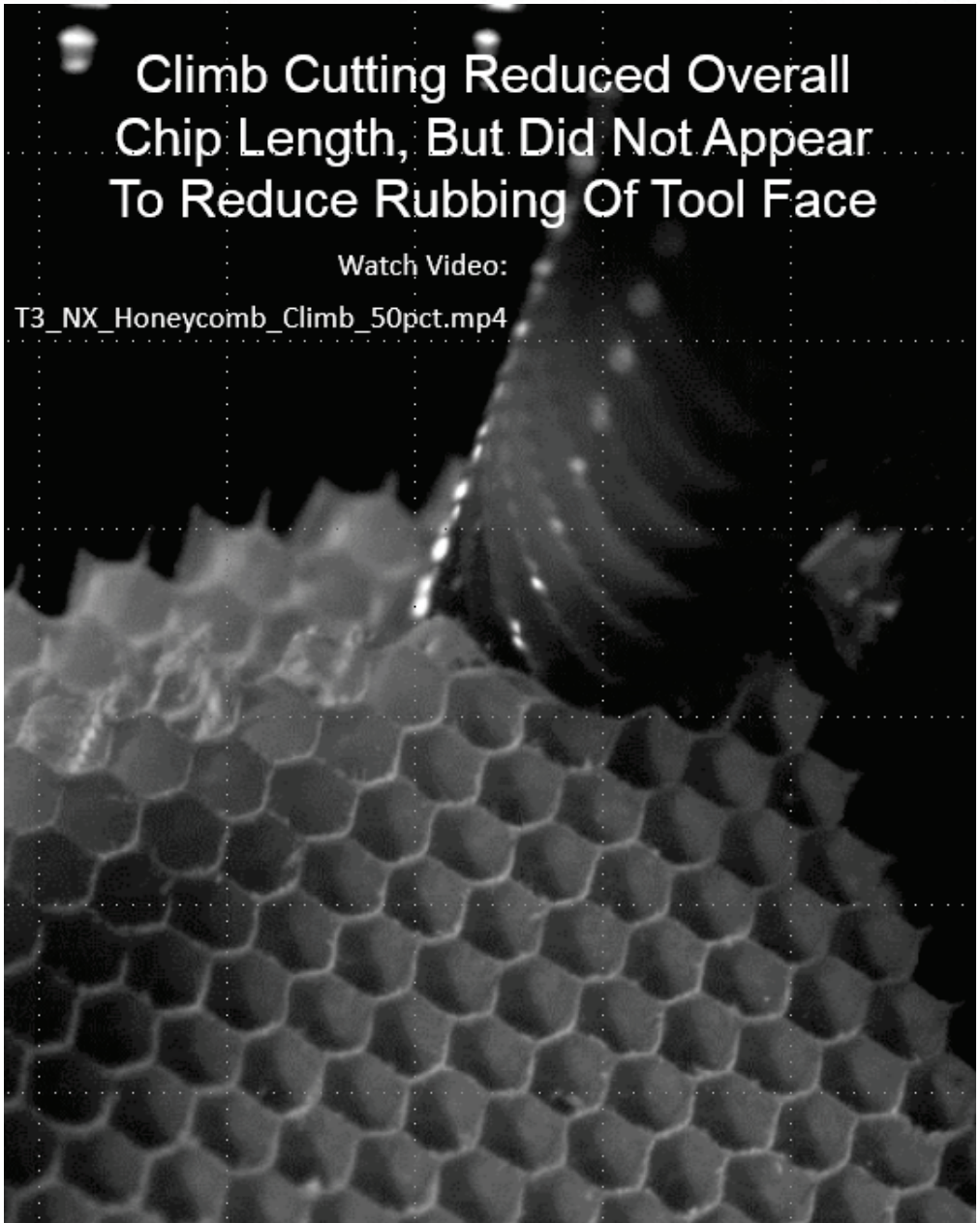
Climb Cutting



Conventional Cutting

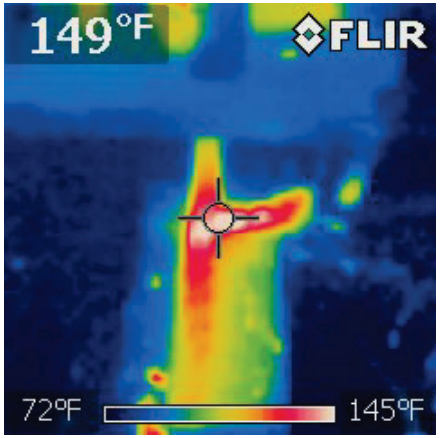


Climb Cutting



An Unsuccessful Attempt to Quantify

- Attempted to take thermal images during machining and immediately upon stopping
- Results showed heat, but not sufficient to cause tool wear
- Camera resolution is likely a problem with this measurement



Infrared image taken during machining

Conclusions

- Shredding action is not proving effective
  - Skinned honeycomb would require the shredding
- Cell wall collapse causes most material to rub on the tool for an extended period of time
- Hypothesized link between tool wear and rubbing is anecdotal and unproven at this point
- High speed videography revealed interesting (and useful?) information about the cutting process

Acknowledgement & Invitation

Thank you to:

- Hexcel, Inc. for aramid honeycomb
- Controx-Neuhauser for tool discounts
- Itronx Imaging Technologies for extra camera days

Invitation for partnership:

- Looking for project partners to continue the work

Questions