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### SCRAPPED COMPOSITE ICE-HOCKEY STICK SHAFTS FOR RESUSE IN CRASH ENERGY ABSORBERS

Patrik Fernberg<sup>1</sup>, Thomas Bru<sup>2</sup>, Roberts Joffe<sup>1</sup>

<sup>1</sup> Dept of Engineering Sciences and Mathematics, Luleå University of Technology, Sweden <sup>2</sup>Dept of Polymers, Fibres and Composites, RISE Research Institutes of Sweden, Sweden



## RESTART

### Re-use of ice-hockey sticks in energy dissipating structures

"... a pre-study with aim to evaluate possibility to reuse scrapped ice-hockey sticks for crash energy absorbing components ..."

### In collaboration with :





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# **Project** aim

- Draft a road-map for a tentative icehockey stick reuse value chain
- Studies with respect to:
  - Identify research and development needs
    - evaluate overall technical potential
  - Make first assessment of potential market through inventories on
    - market size
    - value of re-use components
    - potential partners in value chain



# **Ice-hockey sticks**



- Shaft-wall made from 15-30 layers of carbon fibre reinforced epoxy
- Fibres oriented with distinct orientation within each layer
- Different fibre-orientations in different layers
  - Most layers are with +45° and -45°orientation
  - A few in with 0° and 90°-orientation
- Around 50-60% fibre (by volume)



0°

# The challenge

- Hockey-sticks are extremely lightweight and with tailored flexibility but:
  - with design that prioritize performance over margins against failure
    - often fails
    - hockey-players consumes large amounts of sticks
    - up towards 100 sticks/player/year in extreme case
  - expensive
    - 150-300 Euro/piece at retailers
  - difficult to recycle to constituents
    - epoxy thermoset
    - long continuous carbon fibres
- Energy recovery as only practically viable alternative currently









Photo: \*PT/Gunnar Westergren, \*\* w ww.thestickguru.com





# **Reuse potential**

- Segments of sticks are intact after failure
- Intact segments may be reused
  - As construction elements from hollow straight carbon fibre structures with length ranging from 100
    – 1900 mm
- Many ice-hockey players\*:
  - 1 563 749 licensed players globally
  - 1 064 680 (Canada + USA)
  - 61 547 (Sweden)
  - 80 452 (Nordic countries excl. Sweden)
- Well known that composite tubes absorbs large amounts of energy during crushing
  - Efficient crash absorption elements
- RESTART question: How can segments from scrapped hockey-stick shafts be reused for lightweight crash absorbing components e.g. in cars?

\*iihf.com/en/static/5324/survey-of-players, accessed June 2022 UNIVERSI

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### **Results -Mapping/inventory of 130 m scrapped shafts**



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### **Results** -

### Tensile modulus in direction along shaft





LTU Project report, *Ethan Seguera Estevez*, Biobased/environmentally benign products for outdoor leisure/sport LTU Project report, *Vanessa Hauschel*, Utilization of sport equipment after service life



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### **Results -Quasi-static crushing of single shaft sections**





- 50 kN servo-hydraulic testing machine
- Quasi-static compressive crushing (5 mm/min) between parallel steel plates



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## **Results -Energy absorption of single shaft sections**





#### Specific Energy Absorption (SEA)

- between 87±4 kJ/kg to 112±12 kJ/kg for five different stick models



### **Results** -

### Crushing of single shafts vs virgin composites

25 0 50 75 100 Steel structures Aluminium structures Carbon composite Feraboli 2007 structures Thornton 1979 & published data **RESTART** min 87 TEKNISK **RESTART** max 112

Ref:

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Specific energy absorption (kJ/kg)

## **Results** -

### **Preparation and testing of multi-shaft samples**

- 7 samples each with 6 parallel shafts
- Chamfered edges on shaft-ends to trigger progressive crushing
- Steel band over-wrapping to prevent splaying
- Compression crush tests in test machine 1000kN "Rörpressen" at RISE, Borås, Sweden
- Tests at constant displacement rate 10 mm/min







## **Results -Testing of multi-shaft samples**





#### Crushing of sample 7

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- Six valid test
- Generally a stable failure process
- Substantial variation in response
  - Non-progressive crushing away from triggered edge for some elements after some time appears to be main cause for gradual load decrease with increasing crush distance
  - Variation in segments performance

# Work in progress

- Preparation of multi-shaft demo crash-boxes
- To be installed and mounted on actual car front-end test structure
- Impact testing at relevant conditions planned for June 2023.









# Conclusions

- Scrapped shafts are high quality composite structures with reuse potential
- The mechanical performance of shaft wall material is high
  - although variation in properties exist between models and individual sticks
- Quasi-static tests on single shafts indicate that specific energy absorption capacity in crushing is very high
  - on par with the best composite structures available
- High quasi-static crushing performance is achieved for first generation multi-section samples
  - Larger tendency to have failure away from triggered edge than for individual segments
  - Sensitivity to triggering of progressive failure is hence higher with multi-section samples
- All results observed so far confirm the reuse potential of hockey-stick shafts in energy absorption applications



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Energimyndigheten **VINNOV** 

# Thank you for your attention!

