Evaluating Different Techniques for Joining Carbon Fiber Composite Parts

I.A. Rousseau Staff Researcher

GM R&D Polymer Composite Systems Group

High Volume Forming Symposium

Carbon Fiber Composites (CFC): The base resin

Thermoplastics

- Fast forming (~ < 5min)
- “Re-formable”/”De-formable”
- Low(er) strength
- Ductile
- Single layer construction
- Recyclable

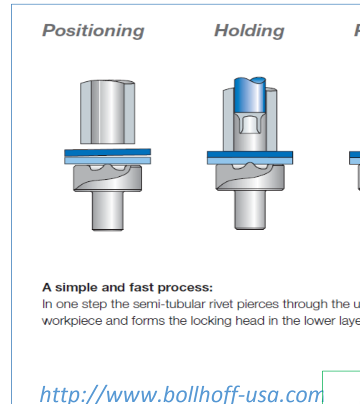
Thermosets

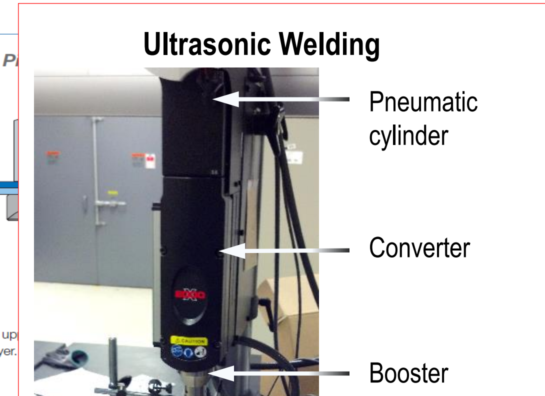
- Slow forming (≥ 20 min)
- Set shape
- High(er) strength
- Brittle
- Laminate construction
- Not easily recyclable

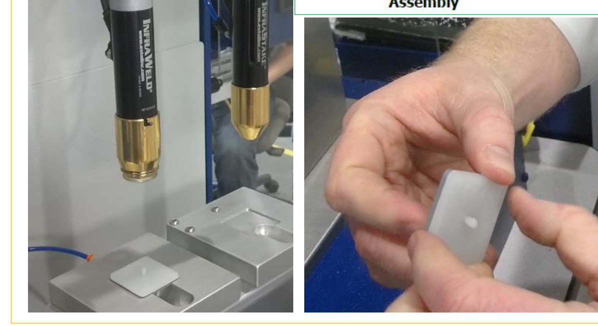
→ The selection of the joining techniques largely depends on the material properties

Polymer & composite Joining Techniques

- Adhesive
- Mechanical – Metal fasteners
  - Riveting (pop, SPR, etc.)
  - Flow drill screw
  - Staking
  - Co-molding of fasteners
- Mechanical – Plastic/composite fasteners
  - Riveting/staking (heat, IR, laser, Ultrasonic)
- Welding
  - Mechanical force (Ultrasonic)
  - Frictional force (Vibration, Spin)
  - Energy source:
    - Conduction (heat)
    - Radiative (laser, IR)
    - Induction (EM)







From Development to Implementation

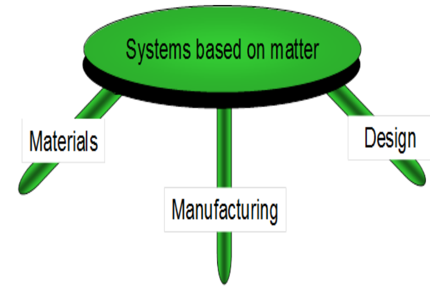
COMPANY VISION, MANUFACTURING STRATEGY & ENGINEERING REQUIREMENTS

Technology Development – *R&D, Supplier, Collaborations, etc .*
- Evaluation (applicability, performance & product requirement, math modeling)
- Process development
- Technology transfer

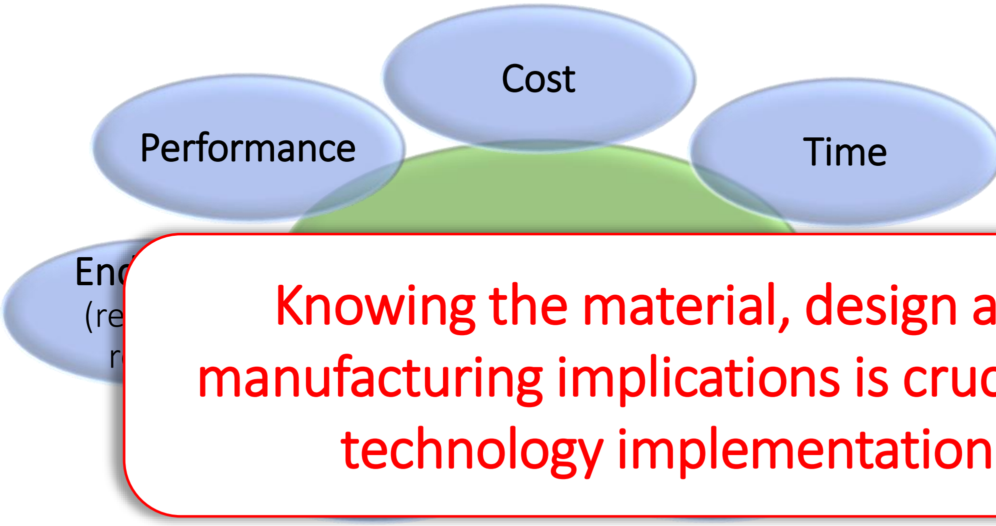
Process Validation - *Manufacturing & Engineering*
- Tool selection for manufacturing environment
- Process & quality monitoring (Fault/No fault, Good/Bad)
- Process development and optimization on selected tools based on product engineering performance requirements.

Process Manufacturing Integration
- Validate assembly process in a scaled-down manufacturing environment with selected process and selected tools
- Math model development and validation
- Production readiness evaluation

Selection Factors



- **Manufacturing integration**



Knowing the material, design and manufacturing implications is crucial for technology implementation

- **Material**
  - Type and properties
  - Manufacturing processes (e.g., co-molding)
- **Application**
  - Use requirement
  - Performance requirements

Joining Techniques: Advantages and Limitations

Joining methods	Resistance Spot Welding	Adhesive	Welding		Mechanical Fastening		Assumptions
			Ultrasonic/Vib.	InfraRed	Plastic (IR, US)	Metal	
Cycle time	≤ 5 s	≥ 20 min	≤ 5 s	≤ 10 s	10-20 s	≤ 10 s	-
Joint Performance	++	Ref.	≈	≈	+	++	Comparable joint design
Cost - Inv.+ maint.	++					++	Comparable cycle time
Cost - Labor	++					--	Robotic/Manual
Design Flexibility	≈					-	Part geometry, accessibility, etc.
Appearance	-	Ref.	≈	≈	≈	--	Customer interface
Corrosion	++	Ref.	≈	≈	≈	--	CF composites
Recyclability	+	Ref.	+	+	+	≈	
Added weight	+	Ref.	++	++	+	-	
Implementation requirement	NA	NA	Development	Development	Development	Improvement	

Mixed Technology Solution:
- Compounds advantages
- Alleviates limitations

Mixed Technologies: An Example

❖ <u>Sealing + Dissimilar material joining</u>:

In "Corvette's carbon hood creates shock and awe," Composites Technology, 2009

❖ <u>Geo-Setting + Strength</u>: Self-Piercing rivets

In "Joining Tomorrow's cars," Autospeed, Issue 144, 2001

<u>Limitations</u>: material type, stack up, part design/dimension

When adhesive bonding is necessary, SPR offers geo-setting capabilities and alleviates adhesive bonding long cycle time

❖ <u>Composite joining</u>: Ultrasonic Welding

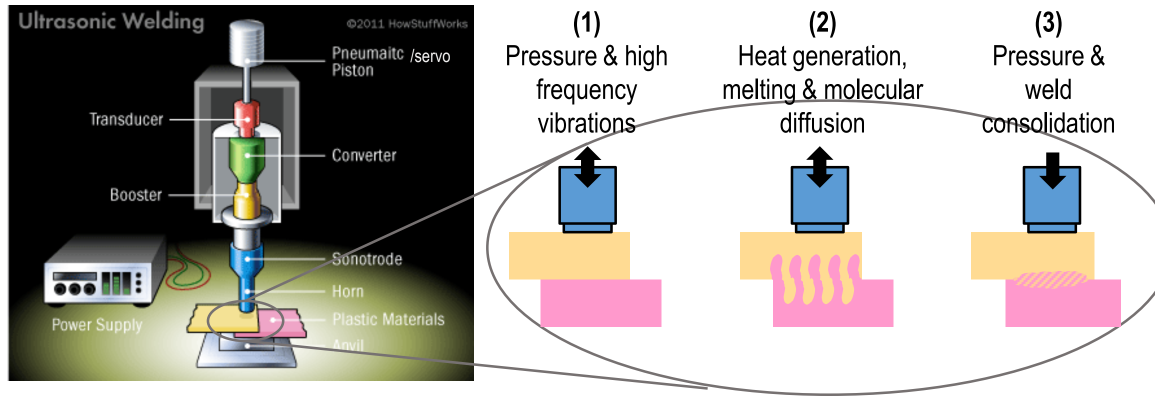
Rapidity, strength, corrosion prevention, cleanliness, weight reduction, recyclability for all other composite joints

Mixed Technologies Example: Development Needs

❖ Self Piercing rivets

- **Material**: Thermoset/Thermoplastic, substrate thickness, rivet material type
- **Joint Design**: Stack-up, material gage, rivet material type
- **Design allowances** for manufacturing implementation
- Joint **Performance**

❖ Ultrasonic Welding



- Manufacturing implementation: **Flexible tooling**
- **Process development**: Specificity
  - Welding schedules
  - Process/quality monitoring
- Joint **performance**

Conclusions

- There is **no "ONE" answer**

  → **Mixed technologies** appear to be the best approach

- **Fast technologies** adapted to composite joining **are not mature** enough for OEM's

  → Require **extensive development** efforts to:

  - Understand the technology and its implications relative to:
    - Joint performance
    - (Automotive) Manufacturing needs
  - Model and predict the joint performance
  - Evaluate **each technology business case** for best implementation