Rapid Freeform Sheet Metal Forming: Technology Development and System Verification

DE-EE0005764
Ford Motor Co, The Boeing Company, MIT, Penn State Erie
Budget Period 3

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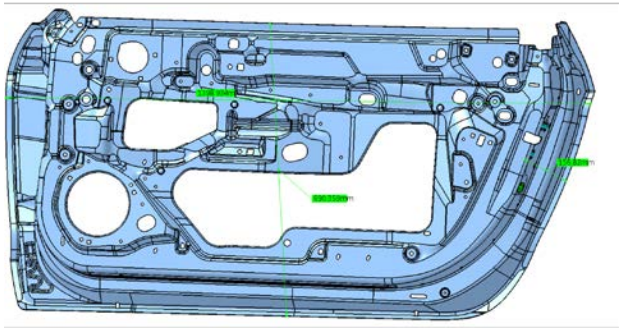
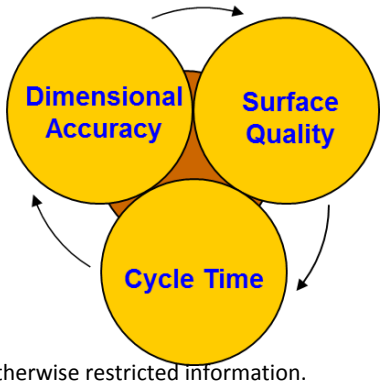
Project Objective

- Develop a transformational **RA**pid **F**reeform sheet metal **F**orming **T**echnology (RAFFT) to deliver:
  - A sheet metal parts (up to 2.0 m x 1.5 m)
  - Dimensional accuracy (± 1.0 mm) & surface finish (Ra < 30 μm)
  - 3-day art to part total time from receiving CAD model
  - Low per unit variable cost
  - Robust enough to operate in an industrial environment
  - Low energy - utilize a fraction of the energy c.f. conventional stamping
- Current process for sheet metal forming requires costly die design, casting, extensive machining and assembly (Even prototyping and low-volume production)
  - Time-consuming
  - Energy intensive
  - Expensive
- RAFFT is a new type of "Rapid Prototyping" technology for making sheet metal parts that **eliminates stamping & forming dies**.

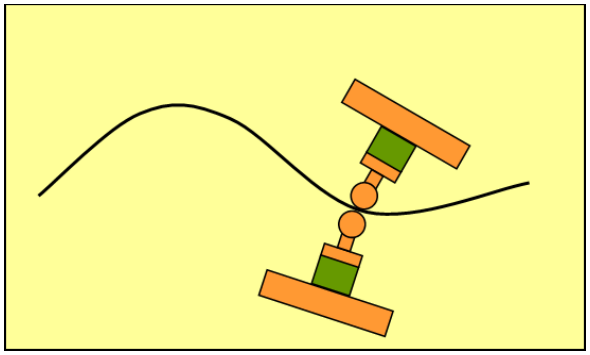


A Door Inner

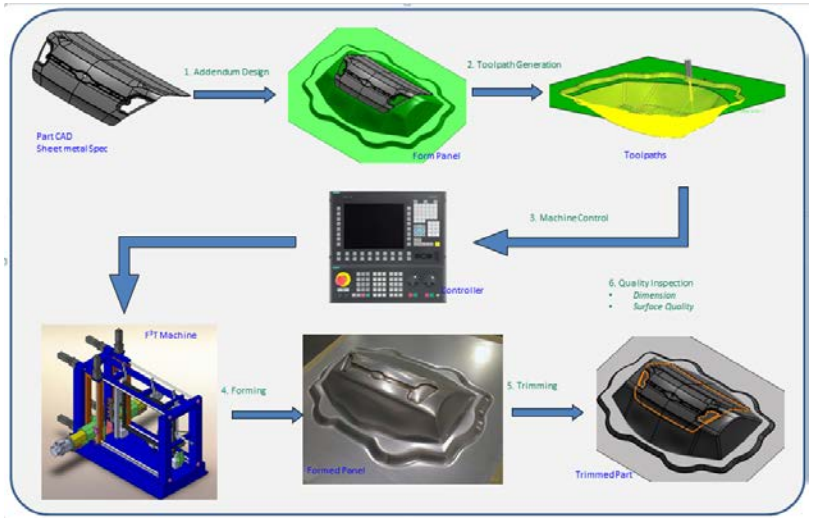


Technical Innovation: Die-less Freeforming

- RAFFT is based on the concept of double-sided incremental forming.



RAFFT (DSIF) Concept

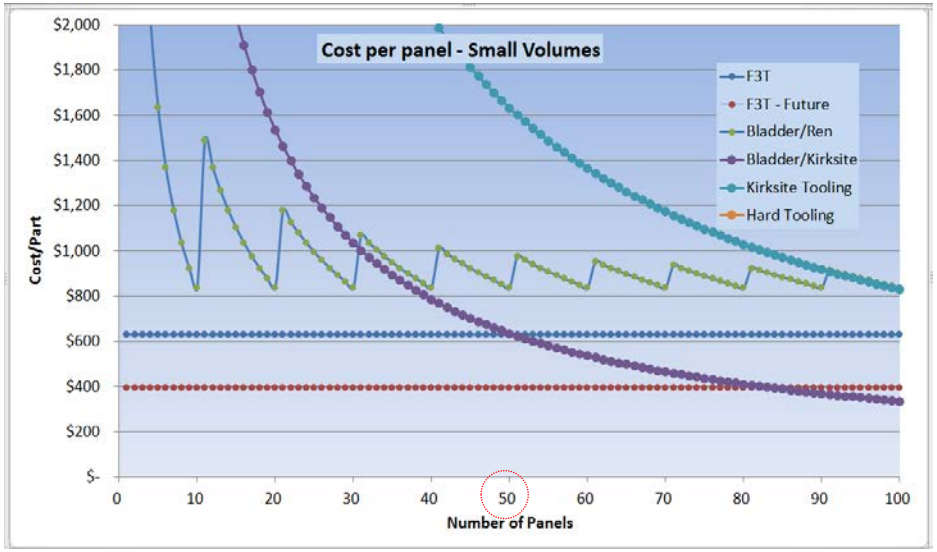


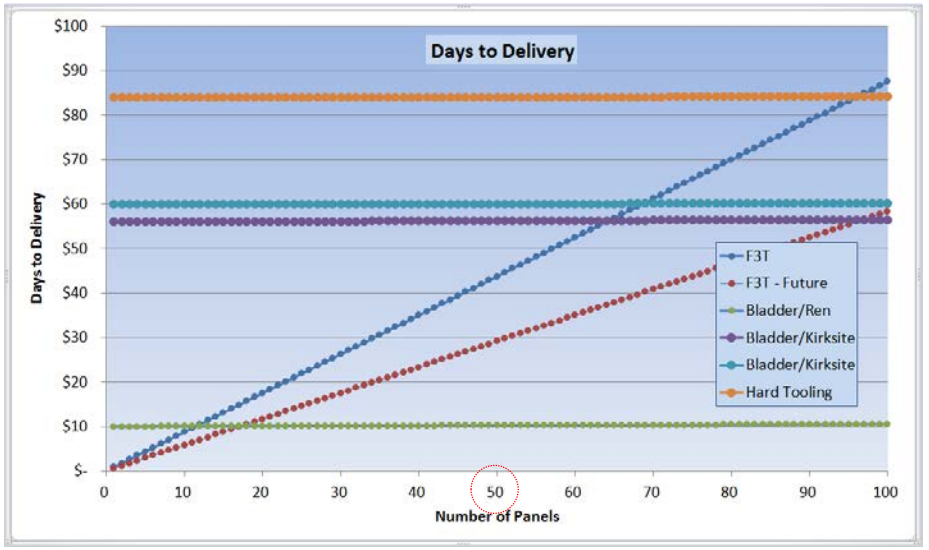
RAFFT Process

RAFFT Machine

Full Scale Panel – Swing Gate

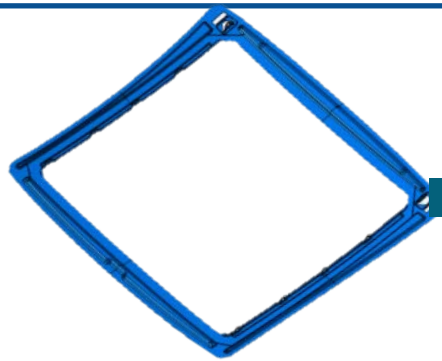
Technical Innovation: RAFFT Cost & Timing Benefits



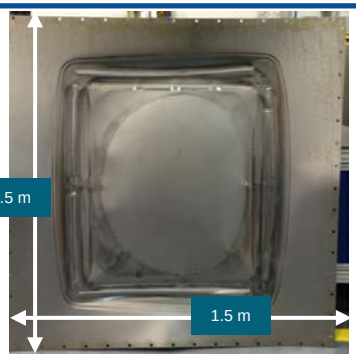


- RAFFT is the lowest cost option for prototype stamping up to ~50 panels.
- Lowest cost option compared to bladder press with ren-board for all volumes
- Depreciation of the machine is included into cost/panel

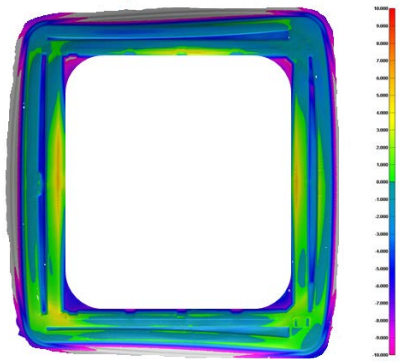
- Fastest option for the first panel and a total delivery of ~12 panels



CAD Model



Formed Panel

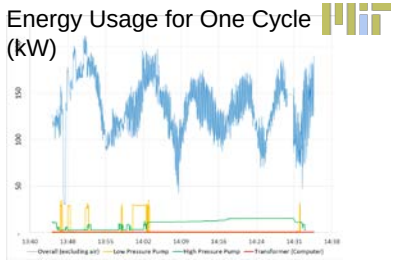


Scanned Results

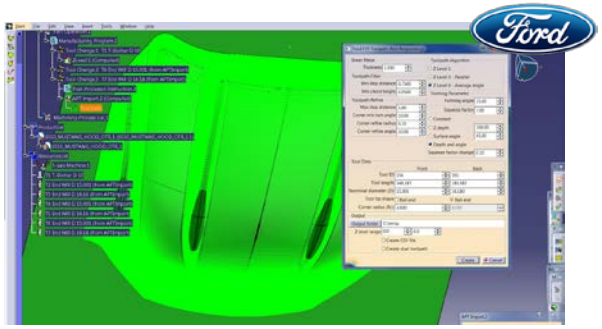
Finished Part
(Roof Module)

Technical Approach

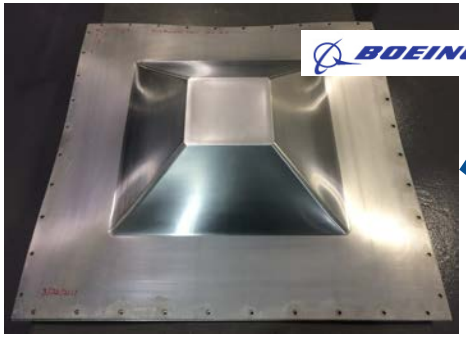
RAFFT Machine



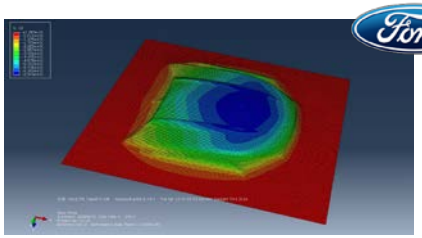
Energy, cost & environmental Impact models



RAFFT Software

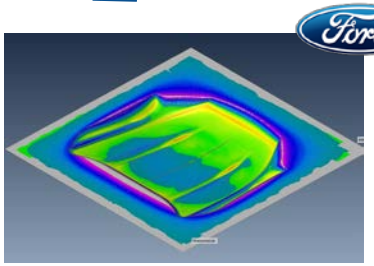


Material Characterization



RAFFT Simulation Methodologies

Pre/post processing



Dimensional verification

Transition (beyond DOE assistance)

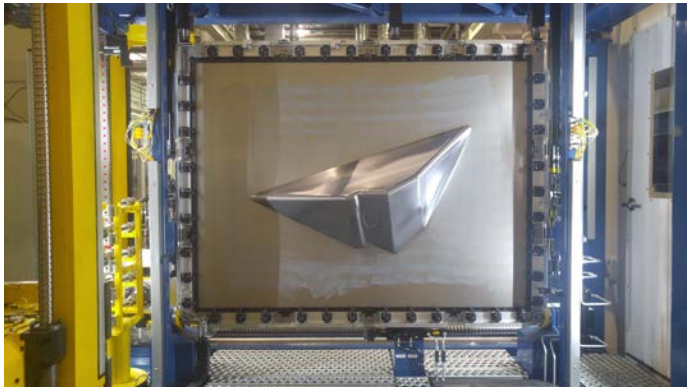
End Users:

- Automotive Industry:

  Prototype Vehicles *Vehicle Personalization* *After-Market Part Service*

  Concept Vehicles *Low-Volume Production* *Performance Racing*

- Aerospace and Defense: *Low-volume production; in-theater replacement parts.*
- Biomedical: *Customized medical applications (e.g. Cranial plate, ankle support etc.)*
- Appliance: *Prototyping and after-market services*
- Art and Entertainment: C*reative sculptures*



RAFFT Formed Panel

Trimmed Part

Installed and Tested in Mustang GT4

Transition (beyond DOE assistance)

Transition:

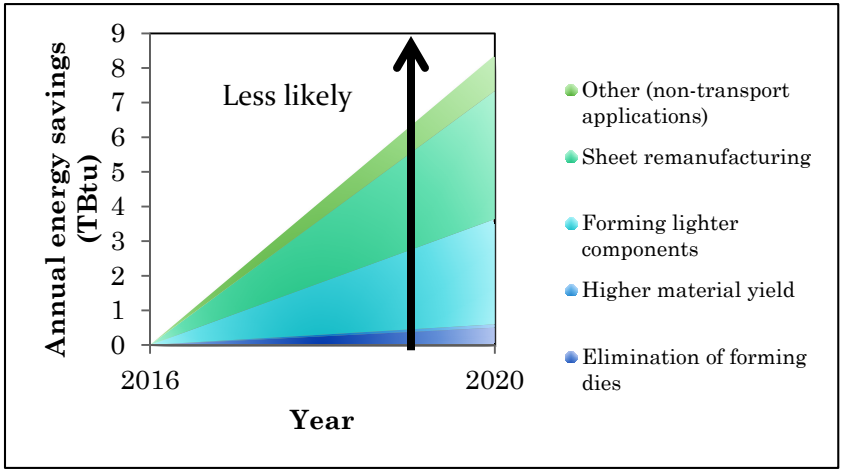
- Adopted a "scalable" machine tool architecture and a reconfigurable software system architecture.
- Increased RAFFT technology awareness through cite visit demonstrations, journal & conference publications, etc.

Deployment & Commercialization Opportunities:

- Ford is developing a value based commercialization. Planning to share with DOE AMO by September 2017.
- Technology adaptation by industry may include:
  - Dedicated systems at OEM and large manufacturing facilities.
  - Service providers to serve smaller industry / unique customers.
  - Deployment of small scale RAFFT units to educational institutions, Industrial R&D labs, Gov't R & D Labs, National Defense Labs and incubation companies.

Measure of Success

- RAFFT has the potential to revolutionize sheet metal prototyping and low-volume production:
  - Energy Efficient and Environment-Friendly: eliminate extensive energy consumption associated with casting and machining forming dies. No wasteful by-products.
  - Ultra-Low Cost and Fast Delivery Time: eliminate cost and time associated with die engineering, construction and tryout.
- Preliminary estimates (MIT) suggest RAFFT technology could save ~ 8.4 TBtu and **$12.3** billion per year in US when fully deployed. Estimates are calculated based upon an analysis of savings in material production, component manufacture and product use.



Project Management & Budget

- **Project Duration**: 54 months (07/2013 – 12/2017)
- **Major Tasks**:
  - Task 1: Energy Management & Environmental Impact Modeling
  - Task 2: Development, Integration and Verification of RAFFT System
  - Task 3: Tool Path Generation Algorithm, Process Modeling and Optimization
  - Task 4: Thermally-assisted Freeform Sheet Metal Forming
  - Task 5: Material Characterization & Performance Validation
- **Key Milestones:**
  - ✓ 03/2015: Complete the build of the RAFFT hardware.
  - ✓ 12/2015: Complete toolpath generation software (V 1), data exchange platform and integration with RAFFT hardware system.
  - 12/2016: Complete process optimization and technology demonstration for making panels
  - 08/2017: Complete process optimization and technology demonstration for making parts (Achieve TRL6)
  - 12/2017: Complete project and make RAFFT technology available for commercialization.

Total Project Budget	
DOE Inv.	$7.47 M
Cost Share	$2.63 M
Project Total	$10.10 M

Results and Accomplishments

Major Accomplishments Since 2016 AMO Review:

- **Modeling:**
  - Developed new modeling methodology and implemented in ABACUS to achieve an order of magnitude efficiency improvement for simulating double sided incremental forming (RAFFT)
- **Software:**
  - Redesigned and implemented path generation software on a new architecture and dynamic data structures. Version 4 of the tool path generation software built in to CATIA environment.
- **Energy, cost and environmental impact modeling:**
  - Completed RAFFT energy impact study within the context of stretch forming, superplastic forming and hydroforming. Analyses have been completed and extended to the construction of a generalized model
  - Understanding of RAFFT recycling impact is underway
- **Material Characterization:**
  - Experiments are complete (truncated pyramids) with fatigue testing underway at Westmoreland Testing Services.
- **Commercialization:**
  - Ford has assembled a diverse team with business experience to develop commercialization plan
  - Demo' d RAFFT to personal from National labs, National Defense and Non-competing business entities
- **Applications:**
  - Ford specific real world parts were made, installed and tested (hood outers, roof panels swing gate, pan roof module, oil tank cover, and brackets)

Questions?