Rapid Freeform Sheet Metal Forming: Technology Development and System Verification (RAFFT)

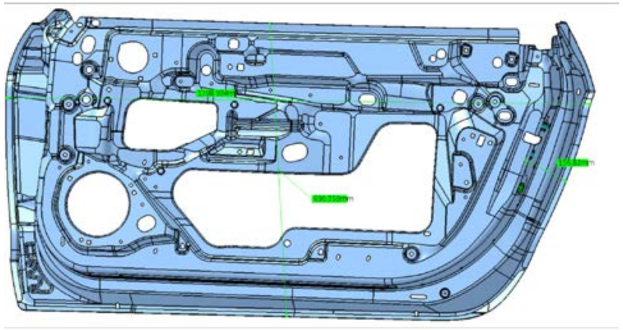
DE-EE0005764
Ford Motor Co, The Boeing Company, MIT, Penn State Erie
Budget Period 2

Dr. Vij Kiridena, Ford Motor Company

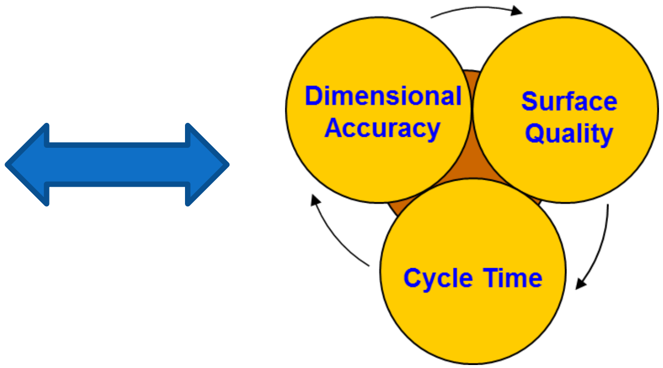
U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
June 14, 2016

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

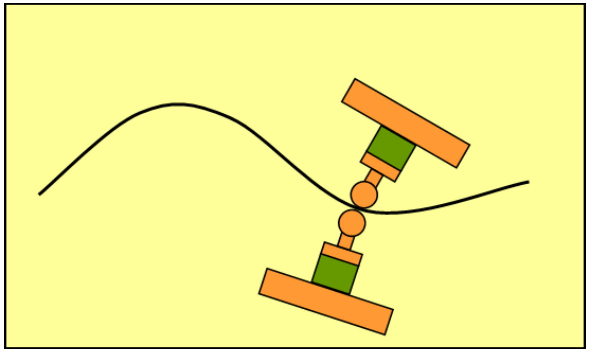


Technical Innovation

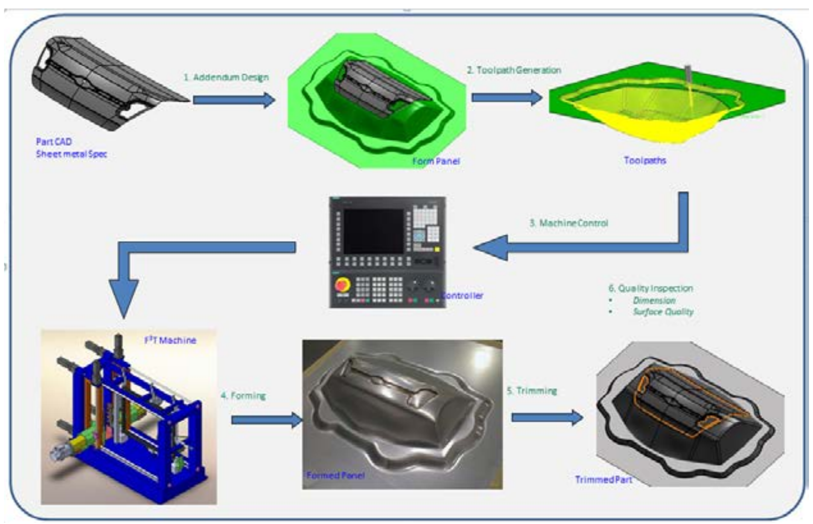
Current Methods of prototyping sheet metal parts	Pros and Cons
• Machined matched die set	• Most common and reliable • Cost: $25K to $500K • Parts are available between 8 weeks - 24 weeks
• Single sided machined zinc (Kirksite) dies	• Cost can reach up to tens of thousands of dollars • Parts available between 1 week – 8 weeks • Limited number of stamped parts (10 – 50) • Not suited for all materials, thicknesses and geometries
• English Wheel	• Need highly skilled craftsmen • Relatively inexpensive • Parts can be made available quickly
• Hand Tools	• Need highly skilled craftsmen
• Amino NC Forming Technology	• Technology is commercially available • Based on single sided incremental forming • Parts are formed against a <u>soft die</u>

Technical Innovation – Dieless Free Forming

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



RAFFT (DSIF) Concept



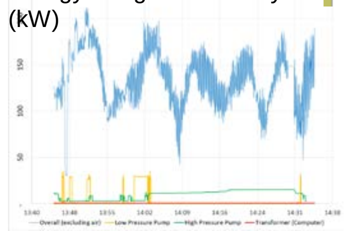
RAFFT Process

RAFFT Machine

0.4 scale 2017 Mustang Hood

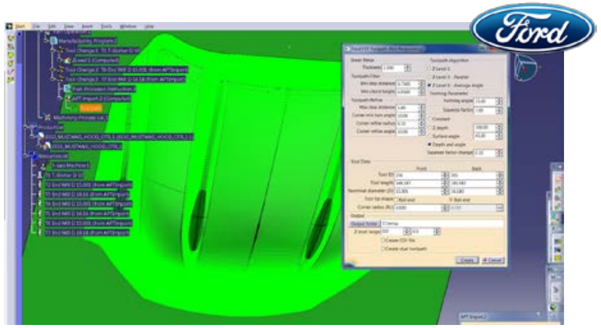
Technical Approach

Energy Usage for One Cycle (kW)

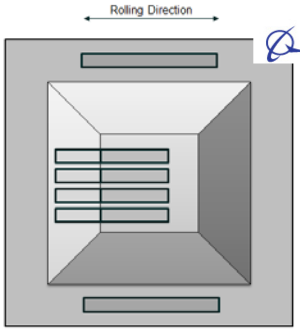


Energy, cost & environmental Impact models

RAFFT Machine

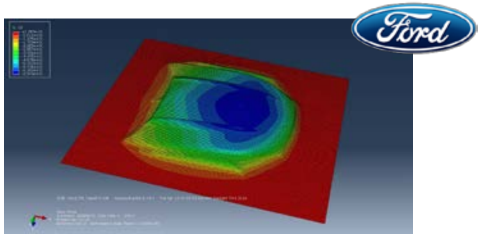


RAFFT Software



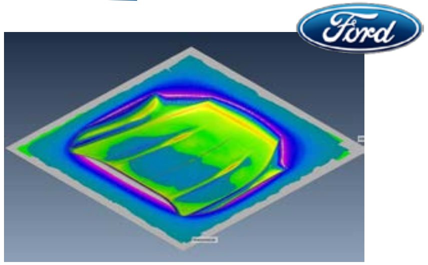
Material Characterization

0.75 Scale 2017 Mustang Hood
~6 Hour Cycle Time



RAFFT Simulation Methodologies

Pre-processing of material
Post-processing of parts



Dimensional verification

Transition and Deployment

End Users:

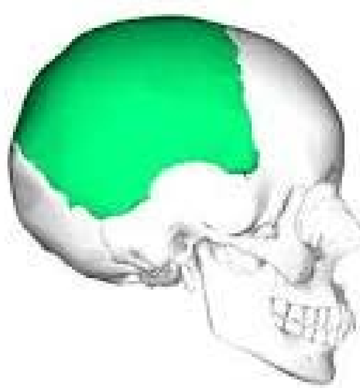
- Automotive Industry:

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

  Concept Vehicles *Low-Volume Production*

- 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: *Creative sculptures*

Aerospace



Biomedical

Automotive

Transition and Deployment

Transition:

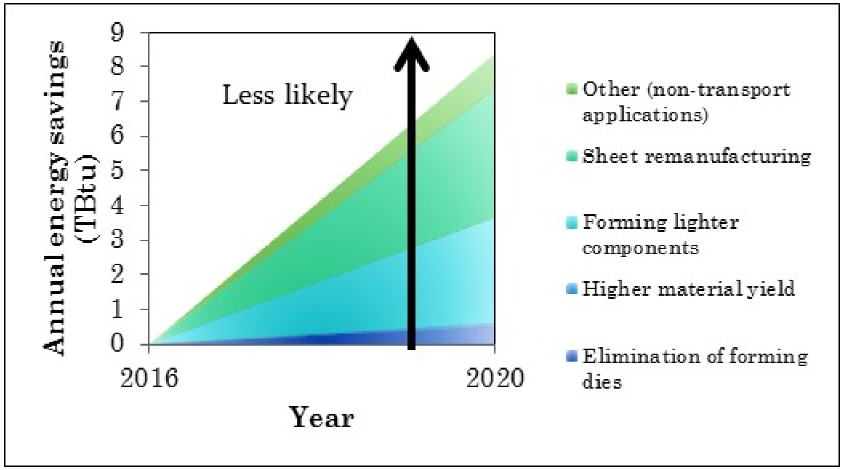
- Adopt a “scalable” machine tool architecture and a reconfigurable software system architecture.
- Increase RAFFT technology awareness through demonstrations, media announcements journal/conference publications, etc.

Deployment & Commercialization Opportunities:

- Create a “RAFFT technology” package and establish a technology licensing framework.
- Make “RAFFT technology” available through third parties.
- Technology adaptation by industry may include:
  - Dedicated systems at OEM and large manufacturing facilities.
  - Service providers to serve occasional or smaller customers.
  - Deployment of smaller units for educational initiations and for technology enthusiasts.

Measure of Success

- RAFFT has the potential to revolutionize sheet metal prototyping and low-volume production:
  - <u>Energy Efficient and Environment-Friendly</u>: eliminate extensive energy consumption associated with casting and machining forming dies. No wasteful by-products.
  - <u>Ultra-Low Cost and Fast Delivery Time</u>: 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 with an aluminum hood and a titanium gearbox container. (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 2015 AMO Review:

- **Energy, cost and environmental impact modeling:**
  - Quantified power consumption of DSIF on RAFFT machine. Collected energy data on stretch forming, superplastic forming and hydroforming. Analyses have been completed and extended to the construction of a generalized model
- **Hardware:**
  - Commissioned the RAFFT/F3T Gen II machine and fully equipped RAFFT Lab at Ford Research and Innovation Center in June, 2015.
- **Software:**
  - Developed and released Version 3 of the tool path generation software built with CATIA environment. Created a platform for exchanging data among all software applications being used for modeling, analysis and testing.
- **Modeling:**
  - Developed methodologies for simulating RAFFT (DSIF) models in Abacus and LS-Dyna. Current models produce results in ~ 30% of the time used by the original models.
- **Material Characterization:**
  - Completed mechanical property measurements on tensile bars excised from 18 truncated pyramid panels fabricated using the RAFFT machine. Developed a series of "Design of Experiments" to quantify fatigue behavior.
- **Pre-processing of material and Post-processing of parts:**
  - Demonstrated application of electricity to reduce springback.

Results and Accomplishments