Rapid Freeform Sheet Metal Forming: Technology Development and System Verification

DE-EE0005764

Ford, Northwestern Univ, Boeing, MIT, Penn State Erie

Budget Period 1

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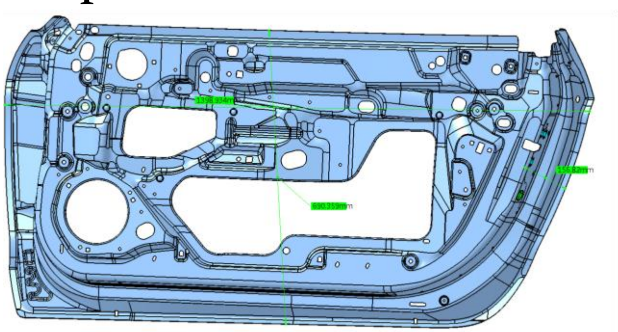
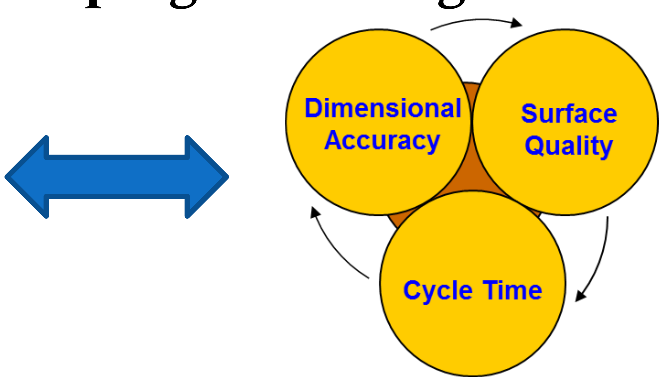
U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
May 28-29, 2015

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**.

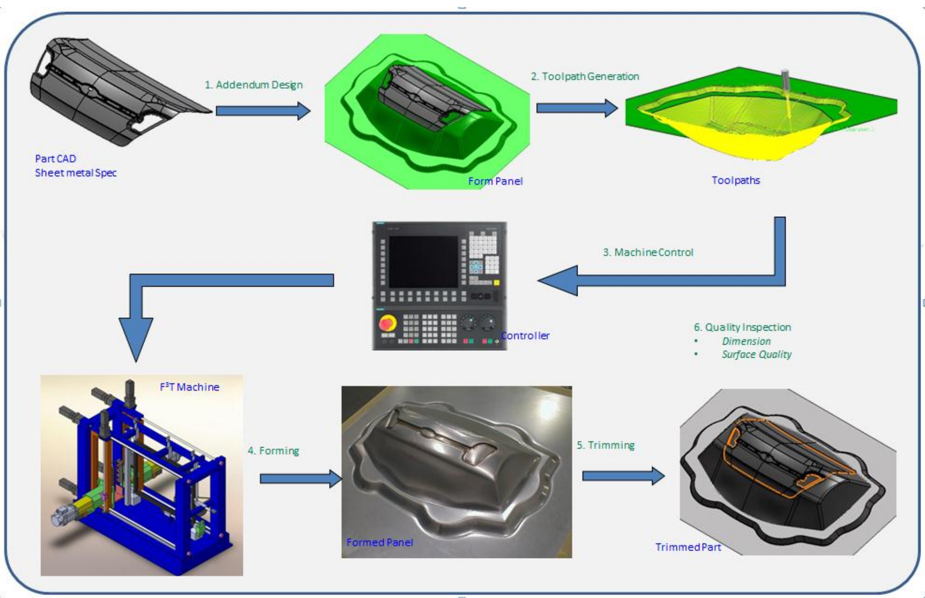


A Door Inner



Technical Approach

- RAFFT is based on the concept of double-side incremental forming, first developed and proved out by this team.
- The project will bring the technology from TRL4 to TRL6 - demonstrating capability to make automotive and aerospace production parts.

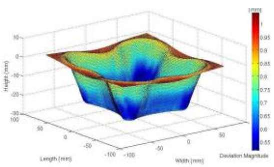


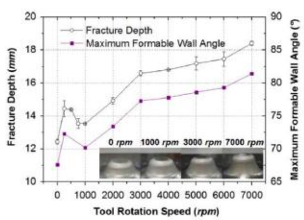
- Design, build and commission RAFFT/F^3T Gen II Double Sided Incremental Forming (DSIF) machine.
- **Develop**
  - *Postprocessor, machine & controller simulators*
  - *Methodology for designing addendums*
  - *Methods for Quality Inspection, process capability and performance evaluation*
  - *Models for validating DSIF applications in automotive and aerospace industries*
- Integrate tools, methods and processes from NU, Boeing, MIT and Penn State to a single unified platform for making DSIF parts

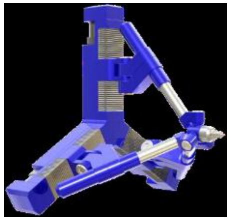
RAFFT/F^3T Gen II Machine

Technical Approach *(cont.)*

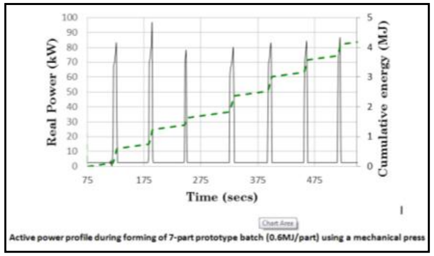
- **Develop:**
  - *Algorithms for DSIF path generation*
  - *Simulation methodologies for predicting failure modes*
  - *DSIF process modeling & optimization*
  - *Design and build a DSIF machine based on kinematotropic machine architecture*



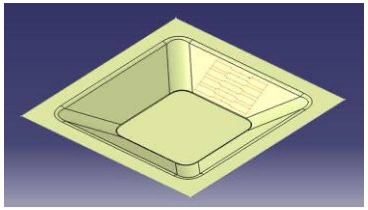




- Develop efficiency models for DSIF impact on energy, cost & environment
- Perform sensitivity analysis, size effect analysis and scale up model for anticipated markets
- Validate (above) models for applications in automotive and aerospace industries

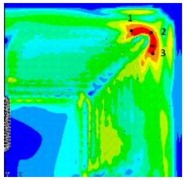


- **Material Characterization**
- **Material performance**
  - *Mechanical & Fatigue*
- **Determine:**
  - *Optimal heat treatment for forming and impact of post thermal treatment*
  - *Effect and control of lubricants on DSIF*



Truncated pyramid for making tensile coupons

- Investigate the effect of in-situ thermal processing on material deformation, residual stress & effects on springback during DSIF
- Develop CAE model for thermally assisted incremental sheet forming
- Develop methodology for localized stiffening incrementally formed shapes.



Apply electricity at strategic locations to reduce springback

Transition and Deployment

End Users:

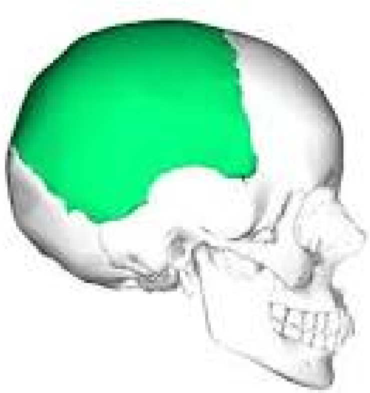
- Automotive Industry:

  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:

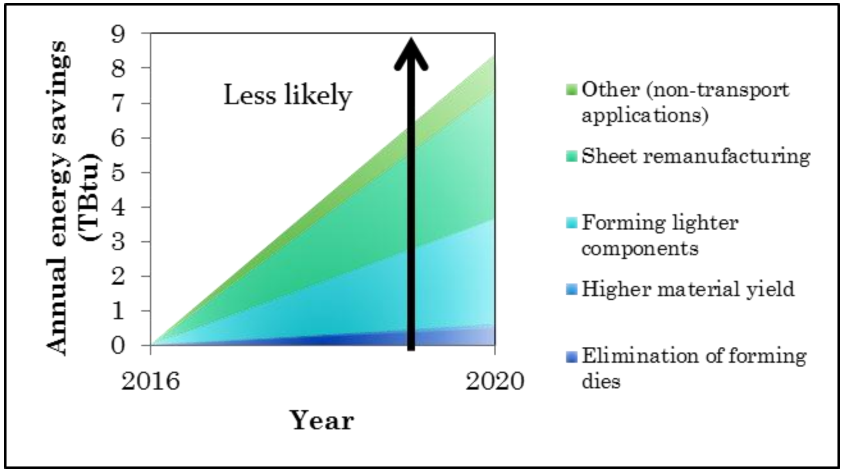
- Adopt a “scalable” machine tool architecture and a reconfigurable software system architecture.
- Increase RAFFT technology awareness through demonstrations, media announcements journal/conference publications, etc.

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:
  - 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**: 42 months (07/2013 – 12/2016)
- **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:**
  - ✓ 08/2014: Complete design and engineering of RAFFT machine and control system.
  - ✓ 03/2015: Complete the build of the RAFFT hardware.
  - 03/2016: Complete toolpath generation software 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)

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

Results and Accomplishments

Major Accomplishments Since Last AMO Review:

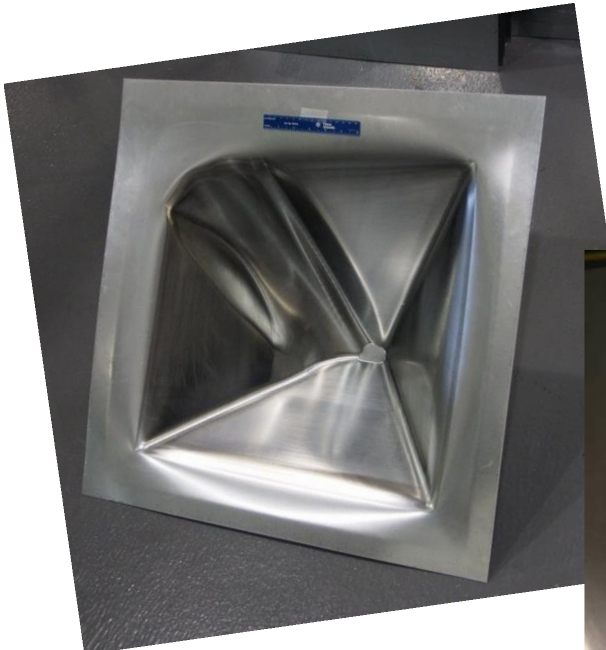
- Commissioned the RAFFT/F3T Gen II machine at Ingersoll Production Systems on March 26th, 2015.
- Formed truncated pyramids of seven different materials using F3T Gen I machine and sent the panels to Boeing in order to characterize the mechanical properties.
- Developed and implemented a framework for toolpath generation combining various double sided incremental forming strategies.

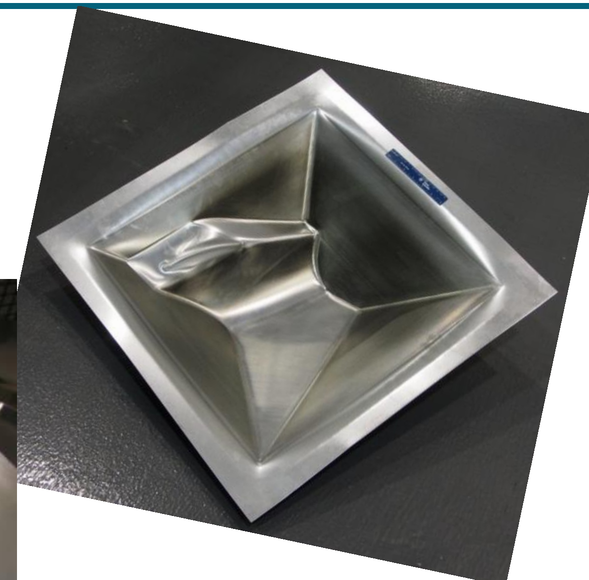
Commissioning of the RAFFT/F3T Gen II machine on March 26th, 2015

- Started Developing formability and fracture models for double sided incremental forming
- Enhanced the energy management & environmental impact models, validate by comparing with operations such as superplastic forming, hydro-forming, etc.

Next Major Milestone:

- Make prototype sheet metal parts in less than 3 days from receiving a CAD model while maintaining a surface profile tolerance of +/- 1 mm by March 2016.



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