Rapid Freeform Sheet Metal Forming: Technology Development and System Verification

DE-EE0005764

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

Project Period: 1

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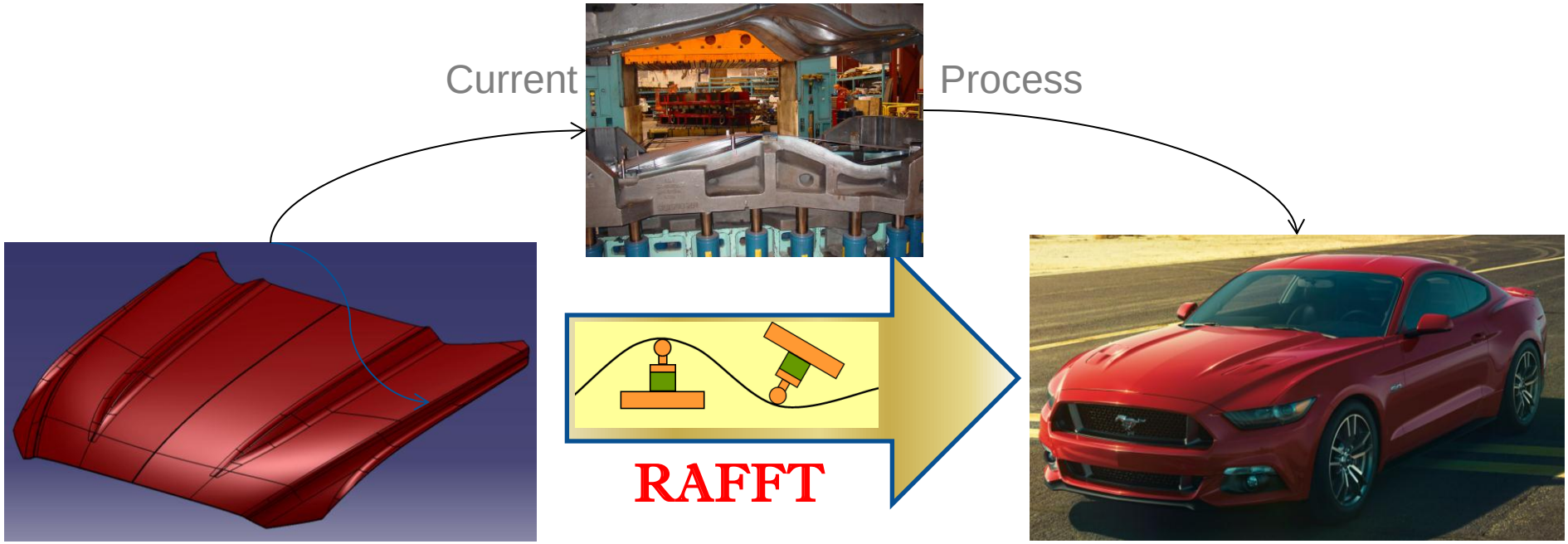
Project Objective

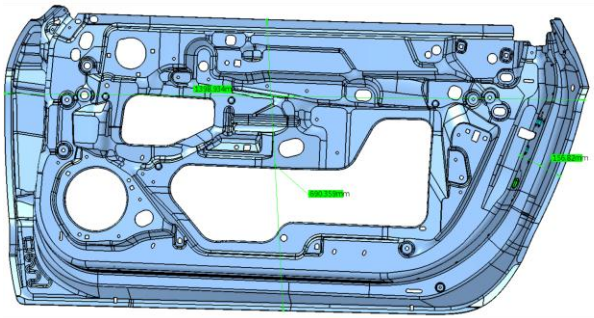
- Develop a transformational RApid Freeform Sheet Metal Forming Technology (RAFFT) in an industrial environment, with the complete elimination of geometric-specific forming dies.
- Current processes for sheet metal forming, even for prototyping and low-volume productions, requires the design, casting, machining and assembly of at least one-side die, which is time-consuming, energy intensive and costly.
- The goal is to deliver a full-size sheet metal part with required dimensional accuracy and surface quality in *3-day total time* from receiving the CAD file.



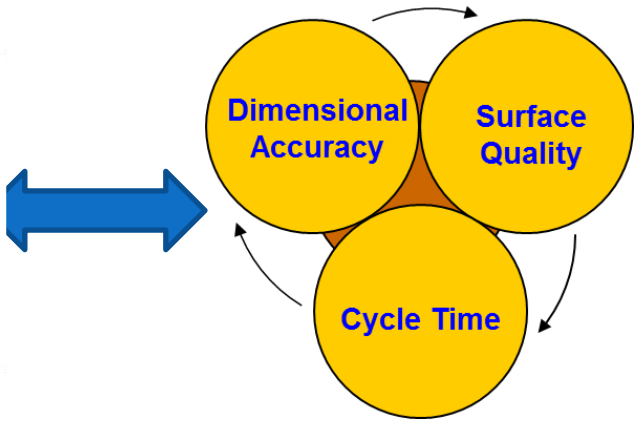
Technical Approach

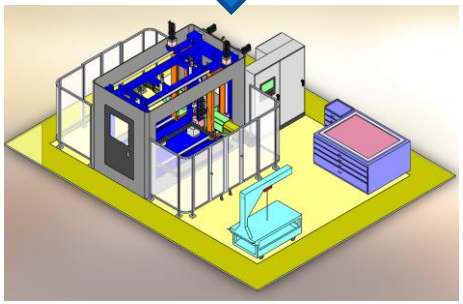
- RAFFT is based on the concept of double-side incremental forming, first developed and proved out by this team.
- The project will bring the technology from TRL4 to TRL6 with a demonstration of making automotive and aerospace production parts.
- Major Technical Challenges:
  - *Complex Geometry → Multi-Pass Toolpath Generation Strategy for formability and fast cycle time*
  - *Dimensional tolerance of <1.0mm lateral deviation over an 1500mm panel → Machine Precision + Process Control.*
  - *Up to 10km tool travel lengths with continuous localized deformation → Predictive modeling for springback and forming feasibility*

F3T system at Ford, with 400mm x 400mm work space (TRL4)



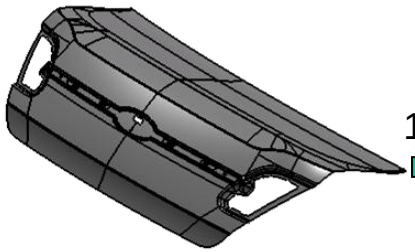
A Door Inner





RAFFT System, with 2000mm x 1500mm workspace (TRL6)

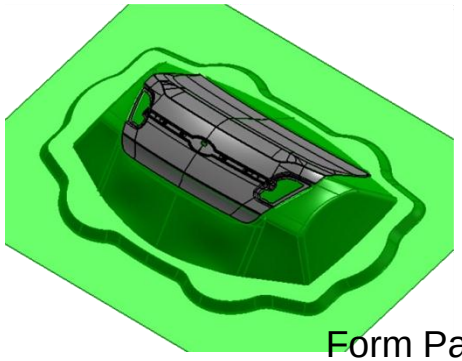
Technical Approach



Part CAD
Sheet metal Spec

1. Addendum

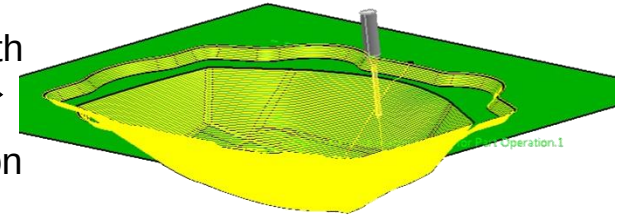
Design



Form Panel

2. Toolpath

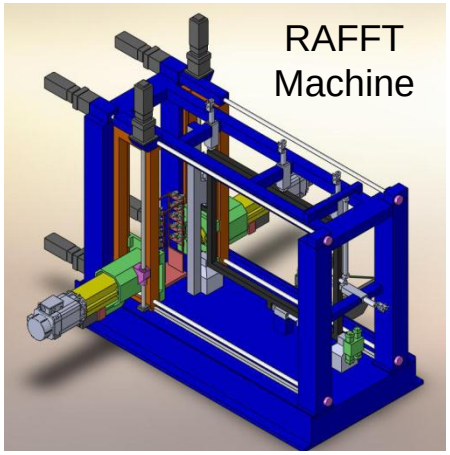
Generation



Toolpaths

3. Machine Control

Controller

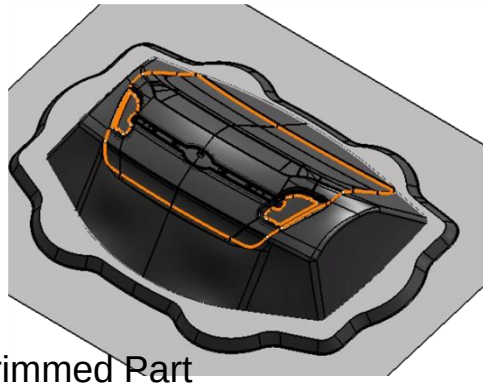


RAFFT
Machine

4. Forming

Formed Panel

5. Trimming



Trimmed Part

6. Quality Inspection
- *Dimension*
- *Surface Quality*

Transition and Deployment

End Users:

- Automotive Industry:

  Prototype Vehicles *Vehicle Personalization* *Classic Cars Restoration*

  Concept Vehicles *Low-Volume Production* *After-Market Part Service*

- Aerospace and Defense: *low-volume production; on-field replacement parts.*
- Biomedical: *customized medical devices (ankle support etc.)*
- Appliance: *prototyping and after-market services*
- Art and Entertainment: *human faces and creative sculptures*

Commercialization Approach:

- Specialized machine tool builders/ system integrators.
- Dedicated system at large manufacturers; service providers to occasional or smaller customers.

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 suggest that RAFFT technology could save as much as 5.28 TBtu and $44.67 billion per year in US when it is fully deployed. These estimates are calculated based upon an analysis of savings in material production, component manufacture and product use.

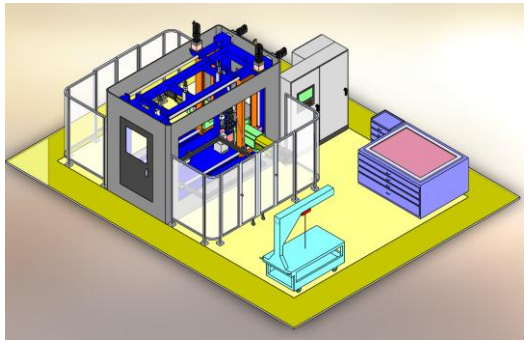
Project Management & Budget

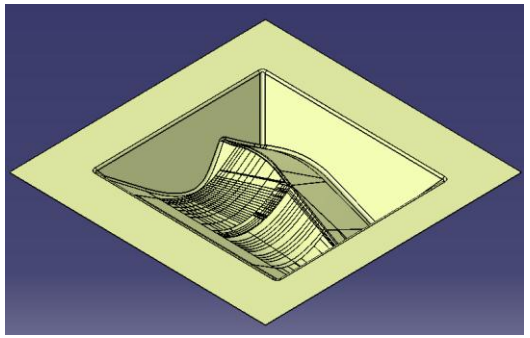
- **Project Duration:** 42 months (07/2013 – 12/2016)
- **Major Tasks:**
  - Task 1: Energy Management & Environmental Impact Modeling
  - Task 2: Development, Integration and Verification of RAFFT System
  - Task 3: Tool Path Generation Algorithm, Process Modeling and Optimization
  - Task 4: Thermally-assisted 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.

Total Project Budget	
DOE Investment	$7,037K
Cost Share	$2,373K
Project Total	$9,510K

Results and Accomplishments

- The project was kicked-off in August 2013.
  - *Completed design concept for the RAFFT system and selected Ingersoll Production Systems as the machine builder.*
  - *Developed a mixed toolpaths strategy for improved geometric accuracy.*





  - *Established a methodology that will be used over the course of this project to accurately quantify the potential U.S. energy, CO2 and cost savings associated with RAFFT's successful development.*
- Next Major Milestone:
  - *03/2015: Complete the build of the RAFFT hardware.*