Rapid Freeform Sheet Metal Forming: Technology Development and System Verification

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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.
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
Technical Approach

1. Addendum Design
2. Toolpath Generation
3. Machine Control
4. Forming
5. Trimming
6. Quality Inspection
   - Dimension
   - Surface Quality

Part CAD
Sheet metal Spec

Form Panel
Toolpaths

Controller

RAFFT Machine

Formed Panel
Trimmed Part
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.

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<th>Total Project Budget</th>
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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.