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

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**Project Objective**

- Develop a transformational RApid Freeform sheet metal Forming Technology (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**.
## Technical Innovation

<table>
<thead>
<tr>
<th>Current Methods of prototyping sheet metal parts</th>
<th>Pros and Cons</th>
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| • 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 soft die |
RAFFT is based on the concept of double-sided incremental forming.

**RAFFT (DSIF) Concept**
Technical Approach

RAFFT Machine

Material Characterization

Pre-processing of material
Post-processing of parts

Energy Usage for One Cycle (kW)

Energy, cost & environmental impact models

0.75 Scale 2017 Mustang Hood
≈6 Hour Cycle Time

RAFFT Software

RAFFT Simulation Methodologies

Dimensional verification
Transition and Deployment

End Users:

- **Automotive Industry:**
  - Prototype Vehicles
  - Concept Vehicles
  - Low-Volume Production
  - Vehicle Personalization
  - After-Market Part Service

- **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
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 “RAFT” technology” package and establish a technology licensing framework.
- Make “RAFT” 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.
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 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

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<tr>
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<th>Amount</th>
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<tbody>
<tr>
<td><strong>DOE Inv.</strong></td>
<td>$7.47 M</td>
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<tr>
<td><strong>Cost Share</strong></td>
<td>$2.63 M</td>
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<tr>
<td><strong>Project Total</strong></td>
<td>$10.10 M</td>
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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