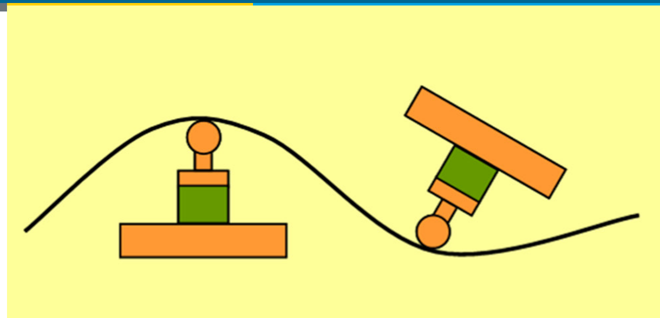
Rapid Freeform Sheet Metal Forming

Technology Development and System Verification of Innovative Forming Process for Rapid Prototyping.



Schematic of possible forming tool positions (left) and a sample part formed at Ford (right). *Graphic and Photo credit Ford Motor Company.*

The automotive, aerospace, and appliance industries use sheet metal forming processes that deform an initially flat sheet of metal into a final three-dimensional shape. A traditional sheet metal stamping process utilizes a set of dies under mechanical force generated by a press to deform the metal sheet. The process is highly effective for high-volume, mass production, with a typical cycle time of less than 10 seconds. However, when production volume is lower, for example, fewer than 1,000 parts, the traditional stamping process, while still used, becomes less attractive with regard to time, energy, and cost since the large die sets have to be engineered, cast, machined, and then tested. Aircraft manufacturers often avoid the construction of dies altogether by directly machining semi-finished pieces of metal. However, this process may waste up to 95% of high grade aluminum alloys used by the aerospace industry.

This project will develop a new manufacturing system for small volume, on-demand production called RApid Freeform Sheet Metal Forming Technology (RAFFT). The core technology in RAFFT is Double Sided Incremental Forming (DSIF), a new concept for sheet forming in which a sheet blank is clamped around its edges and gradually deformed by two strategically aligned stylus-type tools that follow programmed toolpaths. The two tools, one on each side of the sheet blank, can form a part with both concave and convex shapes as well as detailed features. The tools have multiple degrees of freedom, and can be independently controlled or synchronized to achieve desired shapes.

Benefits for Our Industry and Our Nation

By eliminating the need for stamping dies (and their associated heavy machinery and presses), the benefits of RAFFT for making prototypes, small volumes, or on demand customized sheet metal parts include:

- Shortening total cycle times for sheet metal forming from 8-25 weeks to less than 1 week, which significantly improves the design cycle.
- Reducing energy consumption by 50- 90% compared to stamping, hydro-forming, or superplastic forming.
- Significantly reducing material scrap by increased materials utilization efficiency.
- Reducing inventories for replacement parts and/or dies.
- Reducing total cost of low volume production by up to 90%.

Applications in Our Nation's Industry

The RAFFT technology has applications in a number of industries that rely on the manufacturing of sheet metal products. The technology can benefit small businesses with custom products; be used for prototyping and customization in the automotive and appliance industries; provide regular production and on-site repair for civilian and military aircraft components; and could see applications in biomedical and point-of-need products.

Project Description

This project will develop RAFFT in an industrial environment based on DSIF, a process that eliminates the need for geometric-specific forming dies. The system will have an effective working sheet area of 2.0 meters x 1.5 meters (6.5 feet x 5 feet), allowing for the forming of a wide range of sheet metal parts used in automotive and aerospace applications. The success of the project will be demonstrated by producing an aluminum hood outer for a current production automobile, and a titanium gearbox compartment for aircraft. The objective is to produce industrial parts within one week of receiving engineering computer-aided design (CAD) data while also satisfying a set of production metrics including dimensional accuracy, surface finish, and cycle time. This project is technically challenging: it is not computationally practical to perform full 3D deformation simulations for many possible toolpaths for one part, so efficient algorithms must be developed to rapidly generate toolpath programs.

Barriers

- Uncertainties associated with the RAFFT machine architecture with respect to achieving the required stiffness, accuracy and consistency.
- Uncertainties associated with toolpath generation algorithms for complex shapes and features required to achieve dimensional accuracy, cycle time and surface finish while accounting for springback, in-process part distortion, and multi-feature interactions.
- Uncertainties associated with successfully developing real-time process control for the RAFFT system.

Pathways

Project partners are building upon previous research in order to design and build an industrial-scale RAFFT system.

The nearly-complete system includes a reconfigurable clamping design for handling and holding the sheet blank, a system controller for synchronizing tool motions, and advanced forming tools with reduced friction and improved surface finish. Toolpath generation algorithms are being developed; these include single- and multiple- stage forming strategies for complex geometries.

When completed, the system will then be integrated with the process control software and the toolpath generation algorithms for multi-stage forming. Successful integration of the system will be demonstrated by making an aluminum alloy hood outer and a titanium aircraft gearbox compartment within one week of receiving part CAD data while also meeting tolerance and surface finish requirements.

The project includes a lifecycle analysis comparing RAFFT vs. competing processes such as stamping and superplastic forming. Metrics include part weight, energy, carbon equivalent, waste quantities, and cost. Analysis by the MIT team shows breakeven volume levels on the order of several thousand parts and this can guide optimal applications of RAFFT for energy and cost.

Milestones

This project began in 2013, and Ingersoll was selected as the contractor to build the system with their design.

- Manufacture and assemble the industrial-scale RAFFT system to meet design specifications for stiffness, accuracy and consistency (2015).
- Validate an automated DSIF toolpath generation process by manufacturing a series of complex freeform parts (2016).
- Demonstrate successful integration and validation of the RAFFT system with process control software by making an aluminum alloy hood outer (2016).
- Document and validate energy and cost models using available data for RAFFT and three other sheet forming processes used in both the automotive and aerospace industries (2016).
- Successfully demonstrate a TRL6 of the RAFFT system by making an aluminum hood outer for a current production vehicle and a titanium gearbox container for an aircraft with bilateral profile tolerance of 1mm and surface finish Ra < 30µm (2016).

Commercialization

Ford and Boeing have a long history of working with supply chain partners early in a project in order to bring advanced manufacturing technologies into commercial practice. For this project, technology deployment will take advantage of existing infrastructure and capabilities as much as possible. The RAFFT system is being built by Ingersoll (Rockford, IL)—selected through a competitive bidding process. Ingersoll is leveraging its expertise and experience as well as internal resources to build a scalable system to meet the needs of different industries at low capital cost. In addition, toolpath algorithms will be developed and integrated as a module in commercial CAD/CAM software packages.

Project Partners

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DOE/EE-0998 • Updated March 2015