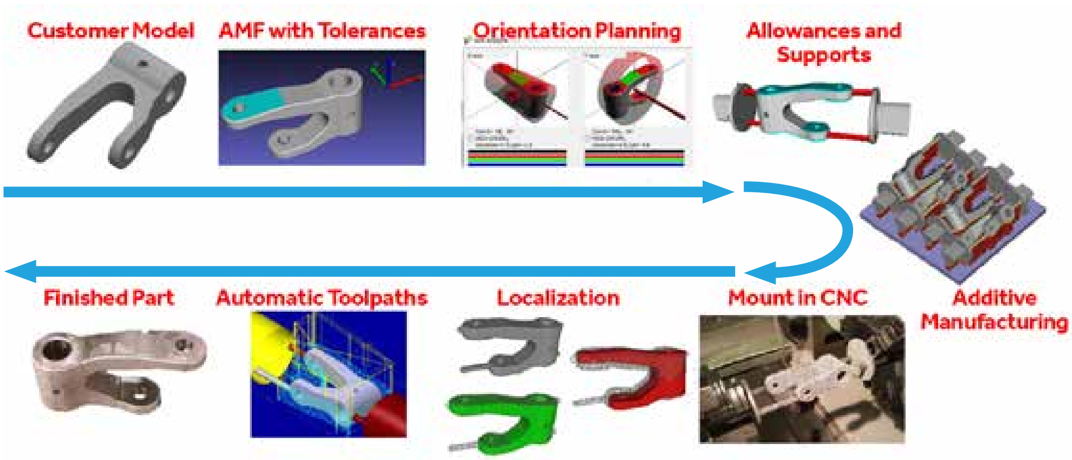
SUCCESS STORY

Hybrid Direct Manufacturing: Integrating Additive and Subtractive Methods

Improving Productivity by Integrating Automatic Finishing with Direct Metal Additive Manufacturing



The graphic on the left shows the functional organization of the additive subtractive hybrid system.

The above photo shows the full progression of a titanium part as printed through post processing. The final part is in the center.

PROBLEM

Nearly all functional additive manufactured (AM) parts require secondary processing that in many cases can more than double the cost of the final part. Hybrid manufacturing systems that incorporate both additive and subtractive processes would enable mechanical parts to be "digitally manufactured" to meet the required final geometric accuracy. Currently, there is no systematic software driven interface to combine additive and subtractive manufacturing allowances in the original STL file. There is also no integrated AM method for creating the sacrificial CNC chuck and bridging features that are predetermined based on a calculation of the CNC cutting tool forces. Finally, there is no current surface vision feedback system integrated with a CNC machining center for part orientation and validation of surface or feature tolerances.

OBJECTIVE

The goals of this project were to:

- Develop a software solution for the integration of additive and subtractive manufacturing.
- Improve existing visibility algorithms to determine the number of finishing orientations required when machining.
- Develop extended feasible placement of sacrificial machining fixtures on AM produced parts.

TECHNICAL APPROACH

The technical approach required considerable software "bridging" that could string together multiple existing software and mechanical techniques into a systematic sequence of relatively harmonized work steps. The AM software included the creation of surface allowances for subtractive machining as well as algorithms for optimizing material scaffolding and overall part orientation for subsequent machining. Subtractive machining would utilize sacrificial part features strong enough for cutting paths and integrated surface scanning technology to direct machining and validation operations.

A collaborative team from industry and academia worked together to:

- Develop software architecture and CAD-based models
- Optimize support fixtures
- Incorporate material-based machining strategy
- Integrate scanning and probing
- Provide system validation

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to: DESIGN

ASTM PROCESS CATEGORY:
Powder Bed Fusion

EQUIPMENT:
Electron Beam Melting
EOS M280

MATERIAL:
Ti-6Al-4V
Stainless Steel

ACCOMPLISHMENTS

As a result of this project, a Direct Additive and Subtractive Hybrid (DASH) manufacturing system was created using both additive and subtractive processing to create mechanical parts that are "digitally manufactured" to meet the final geometric accuracy required.

Three project partners (John Deere, Kennametal, and Advanced Machining) verified the DASH system by producing commercial parts. Functional components were manufactured using the system by first producing a near-net shaped part with additive technology. This part was then final machined in a 4-axis CNC machining center using automatically generated G codes.

Additional accomplishments include:

- Development of data formats to drive both additive and subtractive manufacturing, including dimensions and tolerances
- Development of a system for the automatic addition of machining allowances to critical surfaces
- Development of a system for determining the "best" fixturing axis while accounting for critical surfaces
- Development of a system to generate NC code for the efficient creation of the desired part, given the near-net-shape workpiece
- Validation of the DASH system
- Development of CAD / Additive Manufacturing File (AMF) format interface

PROJECT END DATE

April 2016

DELIVERABLES

- Developed a tolerance CAD format for driving both additive and subtractive processes
- Developed a scheme to automatically generate a workpiece model as-built and as-mounted in an NC machining center
- Systems for the generation of efficient toolpaths from measured material and part conditions
- Improved algorithm to determine number of finishing orientations and feasible placement of sacrificial machining fixtures
- Algorithm to determine maximum cutting forces and size optimization of sacrificial machining fixtures

All downloadable deliverables are available to America Makes members via the Digital Storefront.

FUNDING

$1.64M total project budget
($818K public funding/$818K private funding)

PROJECT PARTICIPANTS

Project Principal:
North Carolina State University

Other Project Participants:
Iowa State University
Advanced Machining
John Deere
Productivity, Inc.
Kennametal
CalRAM

Public Participants:
U.S. Department of Defense
National Science Foundation
U.S. Department of Energy

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