

2012 EL Project Title and number: Integrated Production Processes

Program Title: Sustainable Manufacturing

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Summary: Sustainable manufacturing is an emerging research subject in the manufacturing industry. Many companies have focused on assessment of energy and material consumption, and their impacts on environment and human health, at the unit manufacturing and assembly process level. Current approaches are ad-hoc and informal; consequently, the assessment results are inconsistent and fragmented. There exists no traceable analytic method for sustainability performance assessment, and no standards for representing, reporting, and exchanging the results of that assessment. The project's primary objective is to develop a methodology for sustainability assessment of part and assembly designs. That methodology will assess the sustainability performance of process plans for those designs through a composition of sustainability metrics for unit manufacturing and assembly processes. This project also will develop a manufacturing process information model and a production resource information model to support the proposed methodology. This project also will validate and demonstrate the assessment methodology in a Computer-Aided Engineering (CAE) systems environment.

Project Team

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Objective: The project will develop the measurement science to (1) analyze the sustainability performance of a manufacturing process plan for a part/assembly/product, (2) evaluate the sustainability impact of alternative process plans, and (3) optimize the manufacturing process and routing decisions to maximize energy and material efficiencies according to corporate sustainability goals.

What is the new technical idea? The project addresses the US manufacturing industry's need to perform sustainability assessments of the process plans used to manufacture part and assembly designs. It will build on product models, sustainability requirements, and sustainability metrics developed for other projects in the SM program. There are two new technical ideas in this research project: build a science-based assessment methodology and validate that methodology using real-world part and assembly designs. The first technical idea is a science-based assessment methodology that integrates various measurement metrics for unit and assembly processes into a composite sustainability indicator. The indicator, which can include a number of individual sustainability impact factors, will reflect a manufacturing process plan's overall sustainability. Individual factors could be energy-, materials-, economic-, health-, or safety-related. User can specify the relative importance of each such factor to reflect the company's overall sustainability goals and strategies.

The methodology will assess the sustainability performance of the process plan by assessing the impact factors of the plan's unit and assembly process requirements and resource needs such as materials, energy, machines, tooling, chemicals, water, and air, among others. These individual impact factors will be integrated into a composite sustainability indicator. Integration will be achieved using quantitative decision techniques such as Analytic Hierarchy Process (AHP). Formal process and production resource information models needed by both the assessment methodology and CAE systems integration will also be developed.

The second technical idea is the validation and demonstration of the sustainability assessment methodology and composite sustainability indicator. Project staff will work with participating software vendors and manufacturers to determine the parts, the process plans, the processes, the resources, and the software environment needed for the validation and demonstration. Everything will be done within a single production facility where raw material or castings will traverse through a number of unit and assembly processes such as machining, plating, heat treating, or welding.

Working with a commercial software vendor, two major U.S. manufacturers, and other SM projects, this project will enable and demonstrate an automated or computer-assisted sustainability assessment. The CAE systems environment to be developed in collaboration with partners will go beyond the manual spreadsheet approach. The project will demonstrate how a manufacturer can measure its sustainability performance for all of the parts and assemblies it manufactures. The results of this project will be used by the sustainability for manufacturability project to assess product designs and by the production network supplier characterization project to enhance supplier's sustainable performance – using the same measurement and information infrastructure.

What is the research plan?

First year will focus on development of the sustainability assessment methodology at the part level within a plant with alternative process plans. Major tasks include:

- Establish industrial partners and engage a university to participate in the project.

- Establish partnership with a Computer-Aided Engineering (CAE) vendor to participate in the project.
- Review the current efforts on sustainability relevant to the proposed methodology.
- Review and select a product information model from the industrial partners who do discrete part/assembly modeling.
- Define the requirements for a case study with input from the industrial partners.
- Compile relevant sustainability metrics for unit manufacturing processes in collaboration with industrial partners.
- Establish corporate sustainability goals by working closely with the industrial partners.
- Develop a reference manufacturing process information model and a production resource information model for sustainable part manufacturing according to the needs of the case study.
- Define the composite sustainability indicator and develop the sustainability assessment technique for a part's manufacturing process with input from industrial partners.
- Develop the systems interface for the CAE systems environment.
- Specify the requirements to enhance the partner's CAE system to enable the sustainability assessment.
- Implement and test the sustainability assessment methodology with close collaboration of the industrial partners.
- Conduct a workshop and demonstrate how the sustainability assessment methodology works with the case study.
- Develop a workshop report.

First out-year will focus on the sustainability assessment capability and the manufacturing process information model and the production resource information model to handle single-level assembly products with alternative process plans and production resources within a plant. The major tasks include:

- Extend the capability of the sustainability assessment methodology to single-level manufacturing-assembly process plans, and optimize the manufacturing-assembly process plan with production resources in a plant.
- Identify additional sustainability metrics to support the proposed methodology.
- Implement and test the enhancements to the partner's CAE system to enable the sustainability assessment.
- Implement and test the assessment methodology for assembly products with alternative manufacturing-assembly process plans and production resources in a plant.
- Conduct a workshop and demonstrate how the sustainability assessment methodology works with the case study.

Second out-year will focus on the sustainability assessment capability and the manufacturing processes model and the production resource information model to handle multiple-level assembly products with alternative process plans and production resources inside a plant and from its suppliers. The major tasks include:

- Extend the capability of the sustainability assessment methodology to multiple-level assembly manufacturing process plans, and optimize the process plan with production resources in a plant and from its suppliers.
- Develop, if they do not exist, additional sustainability metrics to accommodate additional assembly processes and resource requirements, integrate them into the composite sustainability indicator.

- Extend the CAE system enhancements and the CAE systems environment for multiple-level assembly products.
- Implement and test the assessment methodology for multiple-level assembly products with alternative manufacturing and assembly processes plans, and production resources in a plant and/or from its suppliers.
- Conduct a workshop and demonstrate how the sustainability assessment methodology works with the case study.
- Promote adoption and implementation of the sustainability assessment methodology as the manufacturing best practices for different industry sectors.
- Facilitate software vendors to incorporate the composite sustainability indicator and the sustainability assessment methodology into their commercial product offerings to support sustainability assessment.

Major Accomplishments:

Recent Results: This is a new research and technical area. The project team is made up of technical personnel with more than 50 years of experience in manufacturing enterprise systems, product life cycle management, production systems design, process modeling, and manufacturing processes including casting, forging, injection molding, sheet metal forming, machining, surface finishing, joining, welding, assembly, and heat treatment among others, for aerospace, automotive, engineering tooling, and other consumer products industries.

Recent accomplishments include:

- Energy audit and study in machine shops at the first tier suppliers as part of the Sustainability Aerospace and Manufacturing Initiative (SAMI).
- Energy consumption and carbon footprint emissions in machining operations and simulation with real time data collected using the MTCConnect standard.
- Energy management simulation of GM metal casting lines for engine production.
- LCA, simulation, and lean manufacturing for efficient sustainable manufacturing

Standards and Codes: Standards involvement and development is planned through a NIST led consortium comprising of industry, standards organizations, universities and other federal agencies. This facilitates the identification of specific standards requirements, participation in relevant standards development organizations, and the evaluation and adoption of standards. Following are the standard related activities through the course of the project: a) Work with **ASTM E60** to create a new technical committee on developing the manufacturing assessment methodology and corresponding information models; b) Contribute to **ISO 50001** to define manufacturing process energy assessments; c) Contribute to **SISO-STD-008-2010 and SISO-STD-0010-2011-Draft/Core Manufacturing Simulation Data (CMSD)** to include sustainability assessment related information.