2011 EL Project Title and Number: Sustainability of Unit Manufacturing Processes

Program Title: Sustainable Manufacturing

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Summary: To advance sustainable manufacturing practices and promote resource efficiency, the US industries need reliable measurement methods to evaluate sustainability performances such as energy and material consumption, emissions, waste, and water usage of manufacturing processes. However, the current use of ad-hoc methods and unstructured data to describe sustainability of specific manufacturing processes cannot effectively support the development of the needed reliable measurement methods. Accordingly, this project develops the needed measurement science, and structured information base for unit manufacturing processes that will allow evaluation of sustainability performances and facilitate industry adoption of resulting standards for sustainable manufacturing.

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Objective: Provide the measurement science and methodology to evaluate sustainability performance metrics (such as energy and material consumption, emissions, waste, and water usage) of unit manufacturing processes by 2014.

What is the new technical idea? The US manufacturing industry lacks the measurement science to measure and effectively compare the performance of unit manufacturing processes (UMP) with respect to sustainability[1]. The current use of ad-hoc methods to describe sustainability of UMP results in inaccurate and ambiguous comparisons of these processes. Further, with the current fragmented efforts such as generating textual descriptions of manufacturing processes for sustainability, there is no reliable and structured information base for industry reference.

The new technical idea addressing the lack of measurement science is to develop the science-based assessment methodology and structured information, based on the fundamental sustainability characterization of UMP[2].UMP are those individual operations (e.g., casting, machining, and surface treatment) that transforms raw material and adds value to the work piece as it becomes a final product. The measurement science activities for *Sustainability characterization methodology* will comprise of (1) definitions of key performance indicators and common computable sustainability metrics; (2) formal information model that defines the analytics for computing the manufacturing process sustainability; and (3) manufacturing process-specific data sets that instantiate the information models and enables execution of computable metrics. Such sustainability characterization will support the required evaluation of sustainability performances by allowing science-based rigorous assessment of manufacturing processes.

Besides the development of a standard methodology for sustainability assessment, the sustainability characterization effort will facilitate the development of a structured information base by making available a *Standard Reference Data for Unit Manufacturing Process* (SRDUMP) consistent with NIST's SRM[3], and SRD[4] efforts.

What is the research plan? To develop a science-based methodology for sustainability characterization of UMP, major tasks under this project are planned along four phases. Phase one involves the tasks related to the fundamental sustainability characterization (FY2012-2014). Research activities involve requirements gathering, characterization methodology development, science-based measurement procedures for UMP, and sustainability process data representation. Phase two involves the tasks aligned with performance modeling of manufacturing processes using information generated through sustainability characterization (FY2013). Research activities involve the development of sustainability focused manufacturing process classification and analytical models to compute sustainability performance of UMP. Phase three involves the tasks that lead to the standard on sustainability assessment methodology for identified processes and the SRDUMP (FY2014) and phase four involves the verification and validation of the methodology and standards created (FY2014).

Phase1 (FY2012-14) a) Identify participants, understand the current state-of-the-art by conducting a focused working meeting; verify the measurement science issues, and identify participant responsibilities with candidate manufacturing processes b) Set up the methodology and measurement framework for sustainability characterization to objectively evaluate and compare different processes; c) Develop generic templates and corresponding information models that enable the creation of SRDUMP facilitated through a standards development

[1]White Papers on Advanced Manufacturing Questions, STPI, 2010, whitehouse.gov
[2]Unit Manufacturing Processes: Issues and Opportunities in Research, National Research Council 1995
[3] Standard reference materials, http://www.nist.gov/srm/
[4]Standard reference data, http://www.nist.gov/srd/

organization like ASTM E60[5]and form a consortium comprising of industry[6], universities[7] and other federal agencies[8]. This effort will contribute to the development of the structured information base for the UMP.
Phase 2 (FY2013) a) Develop a sustainability focused UMP classification and define key performance metrics for sustainable manufacturing; b) Develop the necessary analytical models and toolsets using a set of computable performance metrics. The outcome is a common set of performance metrics to ensure consistent comparisons across manufacturing processes and resources. c) Demonstrate through case studies how manufacturing process-specific data sets instantiate the information models and enable execution of computable metrics for decision making.
Phase 3 (FY2014) a) Develop a generic science-based methodology for sustainability characterization; b) Develop the initial SRDUMP repository for identified manufacturing processes, setting the stage for other manufacturing processes. The objective is to establish a generic procedure to follow in setting up a successful SRDUMP repository.
Phase 4 (FY2013-2014) a) Develop the standards for the science-based assessment methodology and components of sustainability characterization: performance metrics, information model, and process-specific data sets. b) Work with the consortium as a clearing house for the SRDUMP.

Major Accomplishments:

Recent Results: As a new project, initial results include information gathering for sustainability in manufacturing processes, preliminary models for energy estimation in machining and injection molding processes, case studies identifying sustainability related information in manufacturing, and interest creation and collaboration through meetings and teleconferences.
Relevant outputs include: internal reports (3), journal papers (3), and conference papers (5).

Standards and Codes: Standards involvement and development is planned though a NIST led consortium comprising of industry, standards organizations, universities and other federal agencies. This facilities 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 for sustainability characterization of UMP; b) Contribute to **ISO 50001** to define the UMP energy measurements; c) Contribute to **ISO/TC39/WG12** on methods to evaluate energy efficiency of machine tools and machine components (through ISO 14955-2).
Dissemination of best practices, standards and codes are planned through ASME, IMS[9], IEEE, CO2PE![10]

[5] http://www.astm.org/COMMIT/SUBCOMMIT/E6080.htm
[6]Tentative partners: GM, Wrigley's, Cummins, Rockwell Automation and some SME's. Industry associations (NCDMM, NCMS)
[7]University of Maryland, Wichita State University Unit process life cycle inventory (uplci), Washington State University, Oregon State University, Penn State University
[8]Manufacturing related programs within DARPA, DoD, EPA, GSA
[9]MTP Project: M4SM - Maintenance for sustainable manufacturing, http://www.ims.org/node/1309
[10] CO2PE! Initiative Cooperative effort of process emissions in manufacturing, http://www.mech.kuleuven.be/co2pe!/index.php/