U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ADVANCED MANUFACTURING OFFICE

Clean Energy Manufacturing Initiative Midwest Regional Summit: Lightweighting Breakout Session Summary

June 21, 2013

The DOE Office of Energy Efficiency and Renewable Energy (EERE)'s Advanced Manufacturing Office works with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance the global competitiveness of the United States.

Prepared for DOE / EERE's Advanced Manufacturing Office by Energetics Incorporated.

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Introduction

In 2013, the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) launched the Clean Energy Manufacturing Initiative (CEMI). The initiative supports the new American Energy and Manufacturing Competitive (AEMC) Partnership between EERE and the Council on Competiveness to *bring together top minds and leaders …generate new insight into our energy and manufacturing challenges… and devise real solutions to prioritize and solve these challenges.*[1] CEMI will focus on fostering American manufacturing of clean energy products and boosting U.S. competitiveness through major improvements in manufacturing energy productivity. The Initiative will bring together relevant EERE and DOE offices, federal agencies, research institutions, and private sector partners to obtain information, and map out and implement a strategy to ensure that U.S. manufacturers are leaders in the global clean energy marketplace.

Based on input from a CEMI working group, topics for discussion focused on volume manufacturing of lightweighting materials (LWMs) with exceptional strength-to-weight ratios as a critical means to create significant reductions in manufacturing and energy costs, enable a wide array of consumer and industrial products, realize next-generation wind turbines, and improve vehicle and aerospace efficiencies. Examples of LWMs include advanced high-strength steels (AHSS)[2], magnesium (Mg) alloys, aluminum (Al) alloys, ceramic composites, carbon fiber, and carbon fiber composites (CFCs). Lightweighting is the development of technologies that reduce the weight of a product, component, or system while meeting or exceeding performance requirements, durability, and affordability. For example, in the automotive sector, it is estimated that LWMs could replace up to 50% of cast iron and traditional steel components in a vehicle's body and chassis. This will, in turn, improve fuel economy: a 10% reduction in vehicle weight can improve fuel economy by 6% to 8%.[3] Other industries will show similar efficiency improvements with LWM integration. In addition to advancing the LWM fundamental material properties, their capabilities, and using them in new applications, ensuring plentiful supplies of these materials will be important to advance manufacturing competitiveness goals.

The CEMI Midwest Regional Summit, one of three to be conducted in 2013, was held on June 21, 2013. Business leaders, technologists, state and municipal policymakers, economic development organizations, and university leaders participated in the summit to hear a range of keynote addresses and panels and participate in small group breakout sessions covering a number of topic areas focused on strengthening regional innovation capacity for clean energy manufacturing. The Summit's goals included the following:

- Showcasing regional clean energy manufacturing activities, opportunities, priorities, and recent successes
- Highlighting EERE and federal clean energy manufacturing resources
- Seeking input from participants on an individual basis on how the initiative can strengthen national and regional manufacturing competitiveness
- Fostering regional stakeholder networking and partnerships

Discussion topics for the Summit breakout sessions included batteries, bioenergy, fuel cells, building materials, industrial energy efficiency, photovoltaics, wind systems, and LWMs.

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[1] Advanced Manufacturing Office CEMI webpage (http://www1.eere.energy.gov/manufacturing/amp/cemi.html).
[2] Applications of AHSS allow for use of low mass formats.
[3] Duleep, K. G., "Analysis of Light Duty Vehicle Weight Reduction Potential," July 2007; World Steel Association, "Environmental Case Study: Automotive," September 2008.

The LWMs breakout session, led by the Advanced Manufacturing Office (AMO) and the Vehicle Technologies Office (VTO), focused on three key areas:

- Midwest's key opportunities and challenges in fostering innovation for competitive manufacturing of LWMs
- Greatest needs to enhance the Midwest's capacity to develop innovative technologies for enhanced manufacturing competitiveness
- Big ideas for technical innovation that will achieve significant advances in competitiveness and a renaissance in American manufacturing

Six questions were used to guide the discussion during the LWMs breakout session. This document captures views of individual participants for improving the Midwest's capacity to develop innovative LWM technologies, enhancing manufacturing competitiveness, and comparing the Midwest's production capabilities to other regions in the United States and to other countries. Participants shared their opinions but did not come to consensus. A summary and a list of participants are provided at the end of the document. The Appendix includes a summary discussion with some session participants.

Technologies and Processes for Manufacturing Competitiveness

Question 1: Are there near-term manufacturing technologies and processes that could provide you with a competitive advantage over manufacturing in other regions and countries?

Table 1 summarizes participants' comments on a number of important near-term manufacturing technologies and processes that could provide a competitive advantage over manufacturing in other regions and countries.

Table 1: Summary of participants' comments related to technologies and processes that could augment the Midwest's manufacturing competitiveness in making lightweight materials
Materials
Carbon fiber • Rapid (<2 minute) carbon fiber product manufacturing *Metallurgy* • 'Next-generation' (new) primary metals processing and refining/upstream operations • Identification of steel microstructures to gain strength and ductility • Syntactic matrix metallics—handling powders and consolidating them at high speed • Better understanding of third- and fourth-generation AHSS to accurately simulate them • Precision control of material manufacturing to have a consistent quality *Other* • Tough barrier coatings and composite ceramics and metals (cermets) for enhanced engine efficiency • Quick, easy *pro forma* agreements to develop technologies with national labs • Nanofiber, high-strength, silk-like material • Materials capable of being fabricated with existing equipment and infrastructure • Hybrid material technology (e.g., additive manufacturing) • Recycling and reclaiming of carbon fiber components
Processing
• In-mold coating (for painting or plating) • Fabrication processes for very thin/multi-thickness material (Al and Mg) using stamp-mold process with quench in <5 second • High-volume, large structural casting process optimization • Forming capabilities: large-scale Al sheet for automotives; combined solution treatments during Al forming; warm forming of AHSS; alternative forming methods, e.g., electromagnetic; and high-strain-rate • Direct production of sheet metal from melts • Structural/functional elements integrated with electrical systems to lower part count and cost • Vertically integrated supply chain (from ore) for very large castings • Advanced automated (rapid) manufacturing/new body-in-white process for composite vehicle production with tunable holistic design optimization for high-volume platforms
Infrastructure
• Rapid tooling manufacturing and additive technologies • Low-temperature stamping with high-strength and high-deformability material • Die technology for forming AHSS/Al/Mg
Modeling
• Predictive modeling and simulation tools for composites • Integrated computational materials engineering (ICME) for steel

Table 1: Summary of participants' comments related to technologies and processes that could augment the Midwest's manufacturing competitiveness in making lightweight materials
Joining and corrosion capability
• Corrosion studies for multi-material joining • Joining and corrosion pilot facilities for manufacturing prove-out of multi-material systems • Processes, systems, and methods for joining dissimilar materials (e.g., carbon fiber parts to steel parts)

Question 2: What technical issues need to be overcome/addressed for them to come to fruition? e.g., equipment cost, supply chain immaturity?

Table 2 summarizes participants comments on barriers associated with previously identified technologies, that when overcome, will enable technology utilization.

Table 2: Summary of participants' comments related to barriers that could augment the Midwest's manufacturing competitiveness in making lightweight materials
Rapid carbon fiber production
• A lack of resins with truly dynamic viscosity properties, which limits the capacity for rapid production of CFCs • A cumbersome process for producing CFCs, which makes CFC fabrication equipment expensive and incompatible with the simpler stamping operations used with other material systems
Aluminum forming
• Limited (or absent) integration of solution treatments in forming processes for Al, which constrains the development of high-strength products in complex shapes • A lack of good processes for forming large-area Al sheet • Inadequate modeling of the strains vs. temperatures in forming large-area Al sheet (to support warm forming of Al sheets and to reduce the overall costs in producing Al sheet)
Syntactic matrix metallics (SMM)
• Though current processes for handling and consolidating SMMs at high speed are adequate, the challenge of casting and forming these powders while ensuring dispersion of the matrix components remains
Third-and fourth-generation AHSS
• Constraints on current theoretical and experimental knowledge of new steel materials' behavior, which limit the ability to create models and simulations of their performance and to enhance their joining capabilities • A lack of new processing and manufacturing techniques, along with limited availability of the required production infrastructure (e.g., warm-forming) and equipment, makes AHSS difficult and expensive to obtain for R&D or for end use in parts
Manufacturing infrastructure
• Inability to quickly build new tools across many length scales • Inadequate attempts to identify and exploit materials with properties conducive for reusing existing tools • High cost of enabling and/or extending closed-loop manufacturing techniques, additive manufacturing methods, and other complex processes • Technical challenges associated with in-mold coating processes for painting or plating (e.g., the ability to color match/select palate in-mold) that could reduce the steps and time required to create finished parts
Joining and corrosion
• An absence of appropriate joining technologies that would enable new light metals and composite materials to be put into practice • Insufficient understanding of the basic mechanical and chemical bonding mechanisms (from the macro to molecular scales) for dissimilar materials bonding • A lack of fundamental knowledge related to joining, which in turn limits the understanding of secondary corrosion processes that appear when different materials are welded together • Inadequate knowledge base to support the creation of models for both joining and corrosion
Modeling and simulation tools
• An absence of higher-fidelity predictive modeling and simulation tools for composites and metals • A lack of anisotropic material condition modeling and relevant corresponding databases

Enabling Factors for Manufacturing Competitiveness

Question 3: Are there enabling factors (e.g.. automation, precision/control systems) that provide a distinct competitive advantage in your processes?

Table 3 presents participants' ideas for other enabling factors that might improve the competitiveness of the Midwest's manufacturing facilities.

Table 3: Summary of participants' comments related to enabling factors that can improve the Midwest's manufacturing competitiveness in making lightweight materials
Materials
• Robust structural adhesives for multi-material systems (e.g., steel, aluminum, magnesium, and carbon fiber without pretreatments) • Global material specifications for steel • Use of coated particles to maintain isolation while still allowing consolidation for aggregate characterization (during dispersion processing) • More innovation and education in structural materials
Processing
• Automated tape layup for CFCs that can scale to many sizes • Better speed and control of thermal cycles for part fabrication • Improved sensor and computer in-line control to improve manufacturing quality consistency • Ultra-high-speed dynamic control of local (and bulk) thermal conditions during additive manufacturing • Ability to heat, mold, and cool mold forming surfaces in <1 min • Snap cure resin chemistry for composites • A best-practices library for manufacturing multi-materials
Modeling and data
• Standards for CFC predictive engineering tools for crash modeling • Better math models for different microstructures of steel • Enhanced and expanded databases of composites for ICME • A commercial national database of validated property data for Al, Mg, steels, and polymer composites
Testing and joining
• Advances in solid-state joining processes • Non-destructive test methods of damage ability/tolerance for composites in autos; leverage experience from aerospace industry • Effective non-contact, non-destructive evaluation methods for evaluating performance of bonded LWM
Other
• Methods to protect intellectual property (IP) while enabling collaboration • Life-cycle analysis tool for all materials • Collaborative regional networks, especially between universities, LWM researchers, manufacturers, and materials suppliers (supply chain) (University ←→ Research ←→ Manufacturing + Supply Chain) • Evaluation of funding policy (e.g., mandatory in-kind funding from U.S. companies, more funding for academic research) • Workforce with the right technical skills, beyond entry level

Question 4: Are there enabling factors that need more development to support and enable competitiveness?

Table 4 lists participants ideas on these enabling factors that if improved could make larger impacts and better support manufacturing competitiveness.

Table 4: Summary of participants' comments related to factors that demand focused improvement to make larger impacts and better support manufacturing competitiveness
Equipment for CFCs
• Scaled-down versions of large, automated layup machines (common in the aerospace industry) to enable production of smaller parts
Thermal cycles for part fabrication
• Advanced rapid and low thermal mass thermal cycling processes
Sensor and computer in-line control
• Improved in-line measurement technology for deformation, displacement, force, and temperature (among other properties) that could improve part manufacturing quality and consistency
Mold forming
• Ability to deliver large part counts in shorter and shorter cycle times (< 1minute) • A better understanding of material microstructure and the results from quench cool-down of molded components (produced from heated mold or cool mold forming tools), which could further the ability to increase the produced part count
Data for mathematical models
• Mathematical models that provide opportunities to screen the capabilities of high-performance materials without having to actually fabricate them • Higher fidelity of the materials' data, especially for novel material systems • Experiments to generate validated data on the microstructures and mechanical properties of steel, Al, Mg, and polymer composites, which would bolster the dependability of the integrated computational materials engineering models and associated fundamental property databases that are used in numerous higher-order models and simulations (e.g., crash models) • The creation of a national database for materials' properties and the ability to access its information while fully addressing IP concerns (to facilitate greater dissemination and application of the newly generated information)
Non-destructive capabilities
• New and/or better non-destructive evaluation technologies for lightweight materials and their joint areas (to ensure product quality and for damage assessments)
Funding allocations
• The design of novel funding mechanisms to targeted recipients (e.g., focused funding for academics or start-ups)
Workforce
• An employee pool with the right technical skills and job skills, beyond entry-level capabilities • Ensuring a steady supply of students, faculty, and technicians in the material sciences and manufacturing sciences

Supply Chain Competitiveness

Question 5: Are certain parts of your supply chain positioned better/worse for competitive production in the United States?

Table 5 provides participants' ideas on the parts of their company's specific supply chains that make manufacturing more or less conducive to being competitive in the United States. An effective supply chain is one aspect of an efficient manufacturing capacity.

Table 5: Summary of participants' comments related to competitive viability of existing supply chain for lightweighting materials or systems
Factors making domestic supply chain more viable for competitive production in the United States
• Abundance of bio-fiber resources in North America • Leading research education centers located in the United States • Plentiful and low-cost domestic iron ore, coal, pet coke, and natural gas supply • Wage structures and newly implemented policies that encourage foreign reinvestment in U.S. industry • Formable sheet stock that better aligns with existing manufacturing capital equipment
Factors making domestic supply chain less viable for competitive production in the United States
• Low volume of domestic carbon fiber production • Decline in primary Al smelting and processing • Reduced volume of domestic Al sheet production (compared to international Al sheet manufacturing) • Limited domestic supplies of Mg • Little domestic availability or access to rare earth raw materials (due to closed mines and unused rail lines) • Inability to keep technical and manufacturing expertise in the United States • No domestic supply chain for third-generation AHSS/high quality steel • Weakened domestic die casting capabilities • IP issues related to testing/prototyping with foreign suppliers • No new manufacturing facilities for production of composite-intensive vehicles • Lack of U.S.-produced life cycle analysis tools • Limited AHSS and Mg alloy availability in North America • Dwindling number of local equipment manufacturers and testing suppliers • Lack of domestic resin manufacturing (even though resin supply is developed in the United States) • Limited domestic supply of rare earth elements for alloying Mg • Overseas governments' financial support for companies that work in the areas of primary materials production and R&D (foreign governments provide company support which is not usually available in United States)

Question 6: Are parts of the supply chain at risk, in the near-term, mid-term and long term?

Table 6 captures participants' input related to aspects of the supply chain that were at risk of moving out of the United States, the potential timeframe, and a possible reason. No parts of the supply chain were identified as being at risk in the near-term.

Table 6: Summary of participants' comments related to the supply chain parts at risk for leaving the United States, with rationale

Aspect of the supply chain	Rationale for moving abroad
Mid-term	
• No domestic supply chain for third-generation AHSS/high quality steels	• Offshore base for next generation of steel manufacturing
• Scarcity of rare earth materials due to limited extraction	• Offshore supply of rare earth materials • Offshore development of replacement materials for rare earths
• Abundance of bio-fibers in the U.S. for carbon fiber production • Overseas resin production for resins developed in the United States	• Inadequate domestic resin processing and supply
• Insufficient Al sheet production to meet domestic demand	• Lack of investment in Al sheet for automotive applications in North America
• No new manufacturing facilities for production of composites-intensive vehicles (structures/semi-structures)	• *No information provided*
Long-term	
• Impacts on U.S. production and supply economics caused by overseas governments' subsidies for primary metals production and R&D	• Better financial support for national/local companies
• Mg supply risk for next-generation alloy development	• U.S. tariff on imported Mg (primary)
• Weakened die casting capacity in the United States (Mg)	• *No information provided*
• Decline in primary Al smelting and processing	• Rapid overseas expansion (China) and cost of energy domestically (United States)

Session Summary

The first CEMI Midwest Regional Summit, held on June 21, 2013, included an AMO-VTO led breakout session focused on key opportunities and challenges related to fostering innovation of lightweighting materials for competitive manufacturing in the Midwest.

Participants' comments suggested a number of **near-term manufacturing technologies and processes** that might provide a competitive advantage over manufacturing in other regions and countries. These areas include the following:

- Carbon fiber rapid production
- Aluminum forming
- Syntactic matrix metallics processing
- Sufficient third- and fourth-generation AHSS processing knowledge and adequate production supply
- Augmented manufacturing infrastructure
- Increased joining and corrosion knowledge
- Improved modeling and simulation tools

Participants identified **other enabling factors** that can improve the competitiveness of the Midwest's manufacturing facilities. These areas include the following:

- Equipment design for CFCs
- Thermal cycle processes for part fabrication
- Sensor and computer in-line control hardware and software
- Mold forming capabilities
- Data for mathematical models
- Non-destructive evaluation capabilities
- Funding allocations for federal projects to targeted audiences
- Focused training or re-training of a relevant workforce

Finally, workshop participants identified **aspects of the U.S. manufacturing supply chain that were important to competitive manufacturing in the United States.** These include the following:

- Supply chain for AHSS/high quality steels
- Rare earth materials extraction/R&D of substitute materials
- Resin development for CFCs
- Al sheet production
- Manufacturing facilities for production of composite-intensive vehicles
- Primary metals—AHSS, Mg, Al—R&D and production
- Magnesium supply
- Die casting capacity
- Primary Al smelting and processing

Participants in the LWMs breakout session expressed the opinion that progress in these areas can help position the Midwest and the United States to take greater leadership in LWM research, manufacturing, and application.

Further, the participants stated that while manufacturing of structural systems at nearly every level of the supply chain can be competitive in the United States, the lack of innovative novel lightweight material systems in supply chain assembly and integration technologies for the automotive, aerospace and maritime industry could be considered a weakness. At issue is the challenge of joining dissimilar advanced materials and the lack of innovative approaches to prevent corrosion. Supporting the full implementation of innovative novel lightweight material systems at the assembly and integration steps at the top of the manufacturing supply chain will assist the competitiveness of domestic operations further down the supply chain.

Appendix 1: The "Big Idea" Discussion

Big Idea Question: Of all the suggestions to support innovation, advance competitiveness, and create a renaissance in American manufacturing put forth today, which is the most important, and why?

While manufacturing of structural systems at nearly every level of the supply chain can be competitive in the United States, the lack of innovative novel lightweight material systems in supply chain assembly and integration technologies for the automotive, aerospace and maritime industry could be considered a weakness. At issue is the challenge of joining dissimilar advanced materials and the lack of innovative approaches to prevent corrosion. Supporting the full implementation of innovative novel lightweight material systems during the assembly and integration steps at the top of the manufacturing supply chain will assist the competitiveness of domestic operations further down the supply chain.

Appendix 2: Participants

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