Aligning Technology and Talent Development

Recommendations from the APLU- and NCMS-led Expert Educator Team

Report 3

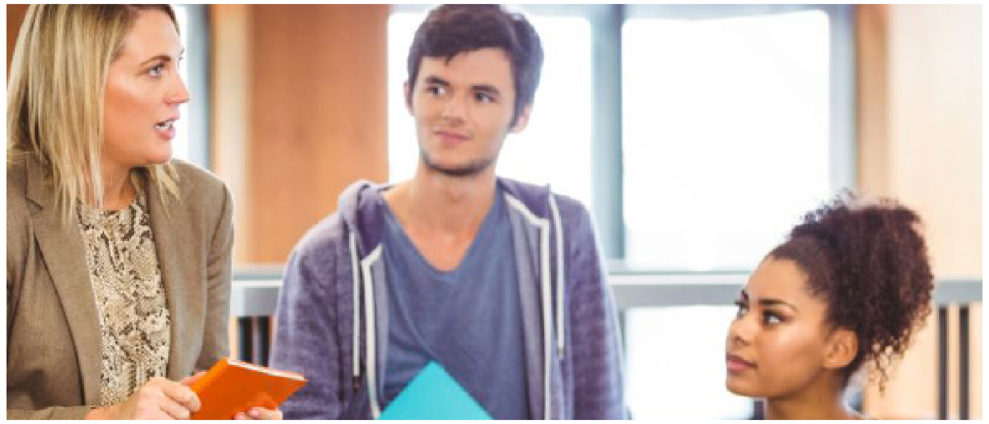
Summer 2018

lift

Association of Public & Land-Grant Universities

NCMS National Center for Manufacturing Sciences

Table of Contents



Introduction: Developing Education and Workforce Recommendations

Manufacturing is becoming more cutting-edge every day, and workers are expected to have advanced math skills and scientific prowess to join the workforce and continue driving innovation. Historically, much of the manufacturing workforce has been developed in two education silos: the technician, assembly, and skilled trades through apprenticeships and skilled training programs in vocational education and community colleges; and the engineers in university programs of study.

Now, the infusion of technology across all manufacturing sectors and at all levels of design and production requires the workforce to have multidisciplinary, higher level skills and a significant set of competencies related to new technologies, materials, and processes. Strong partnerships are needed between post-secondary education and industry. If community and technical colleges and universities are not incorporating the evolving needs of industry into their curriculum and training opportunities, their students will not be prepared for the world of innovation in advanced manufacturing.

The Aligning Technology and Talent Development initiative is an effort led by the Association of Public and Land-grant Universities (APLU) and the National Center for Manufacturing Sciences (NCMS), in partnership with the Lightweight Innovations for Tomorrow (LIFT) manufacturing institute. The initiative has established an **Expert Educator Team** (EET) from universities and community colleges to help identify the knowledge, skills and abilities workers at all levels will need to deploy the technologies, materials, and processes created at LIFT. The team is helping in **aligning LIFT technology development plans with training competencies and strategies**, strengthening the connection between emerging technologies and educational programs of study by identifying the competencies related to using these technologies in the design or production environment, to better prepare students to enter the workforce after graduation.

Ultimately, the initiative aims to **encourage more industry-driven, technology-aligned work- and-learn curricula** in university and community college programs to produce graduates more capable and confident in using new manufacturing technologies and processes. Furthermore, the effort targets the skills development needs of the incumbent workforce and engaging higher education institutions in addressing these needs. Our work also recognizes that the STEM skills foundation developed in secondary education is critical in developing postsecondary learning opportunities for both production and design, and a re-emphasis on materials science in high school will be important in creating an education/career pathway.

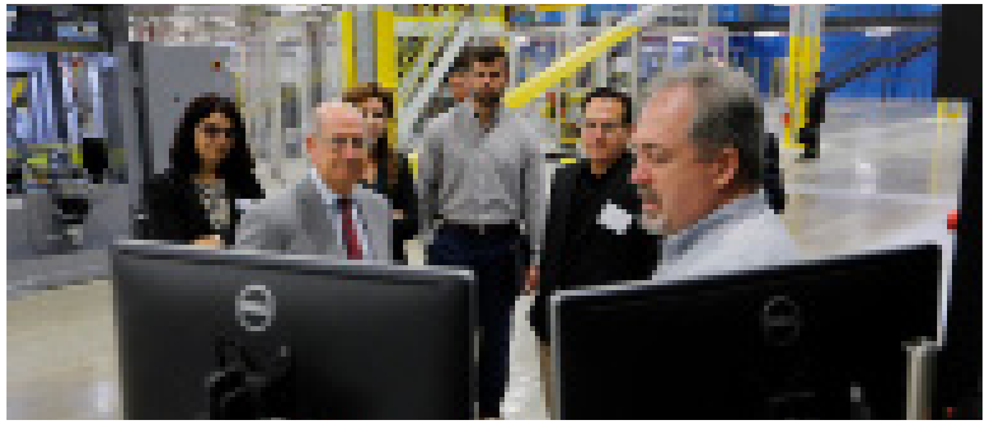
Central to implementation of the initiative is a series of quarterly meetings of the EET, at which the group works to identify workforce competencies and develop strategies aligned with LIFT technology development plans and industry goals. The third such meeting of the EET took place on November 31 and December 1, 2017. Based on presentations and discussions at the May meeting on four LIFT technology and process focus areas, the EET has developed this report including recommendations about competencies and education/workforce strategies.

Recommendations for Leveraging LIFT Infrastructure

LIFT has already invested significantly in a wide array of technical and intellectual infrastructure that can support the delivery of the kinds of education and workforce strategies outlined in this report. Members of the Expert Educator Team were asked to develop recommendations about how LIFT could best leverage existing education and workforce infrastructure to help achieve competency development.

In this section, we present strategies for leveraging: 1) the LIFT High-Bay and Learning Lab, and 2) the many education and workforce initiatives that LIFT has already supported.

Section 1: The High-Bay and Learning Lab



Overview

As mentioned in the EET's first two publications, the machines and equipment being installed in the high-bay, combined with the adjacent learning lab facilities, represent a powerful opportunity to create work-and-learn experiences for students and teachers, and to bring together industry and education professionals to deliver world-class education and training. In addition to the recommendations proposed in Reports One and Two, the EET developed the following additional recommended strategieis for leveraging LIFT infrastructure to carry out talent and workforce development.

Recommendations

The EET recognizes the value of the LIFT-IACME Learning Hub, and recommends that efforts be undertaken to significantly enhance that value, drive traffic to the site, and increase the use of the Learning Hub for curricular enhancement. Since the Learning Hub was launched, over 1100 visitors have searched the site for materials. Top searches have included "composites," "car," "titanium," "metal," "alloy," "graphene," "casting," and "plastic." The Learning Hub can and should represent a significant opportunity to share the assets of LIFT HQ with teachers and learners everywhere. Recommendations 1 through 3 below relate specifically to the Learning Hub.

Recommendation 1: Turn the High-Bay into a Learning Hub Modules Production site

Expert Educator Team members have consistently noted the need for technology-specific modules that college faculty can use to enhance existing curricula and also develop new curricula. Many of the needed competencies are already being addressed in college technician and engineer programs, but additional teaching material is needed to relate the competencies to the emerging technologies being developed by LIFT and its industry and academic partners. The High-Bay represents an unprecedented opportunity to produce media-rich modules demonstrating emerging technologies and their link to core technical and design concepts and skills. LIFT should identify and deploy resources to regularly produce materials (videos, virtual and augmented reality, interviews with technical experts, etc.) to be posted in the Learning Hub and mapped to the competencies advanced by the EET.

Recommendation 2: Add new features to the Learning Hub—a regular ask the expert item, a series of "LIFT Talks," and/or a blog that curates Learning Hub materials and instructs faculty how best to package and use the materials in existing courses

LIFT can leverage the High-Bay and also its access to experts by expanding the kinds of resources that are available in the Learning Hub. Experts on the technologies can be interviewed in ask the expert style. LIFT could invite experts who are also good speakers to give "LIFT Talks," like TED Talks which could be webcast live and/or recorded for inclusion in the Learning Hub. A regular "On the Hub" blog could be developed, with guest educators authoring Learning Hub round-ups, pointing to multiple Hub resources on a given topic, and providing tips on how and where to use Learning Hub resources in the curriculum.

Recommendation 3: Undertake a virtual reality, augmented reality, and simulation development effort and publish results in the Learning Hub.

Capturing and modeling the expertise of a knowledgeable operator completing specific manufacturing processes and maintenance can be a powerful opportunity. Building virtual reality, augmented reality, and simulations using the equipment installed at LIFT High Bay can expand LIFT's education and workforce reach to provide remote learners with improved access to the knowledge, skills, and abilities needed for deployment of emerging technologies. The EET recommends that LIFT use the High bay and Learning Lab to develop a virtual reality environment designed to support remote learner interactions with simulated expert knowledge, skills, and abilities. Students across the country would be able to use this environment remotely to learn about newly developed materials processing techniques. There are several resources provided by simulation software companies and LIFT could use existing products as the basis for simulation resources and tools. These materials can be included in the Learning Hub, along with instructor resources to assist with including them as a part of the existing curriculum. LIFT could also conduct faculty development workshops to enhance adoption.

Recommendation 4: Perhaps as an extension of the Learning Hub, develop a database or multiple databases of experimentally produced parts and develop guidelines and specifications to produce parts using LIFT technologies.

Through the ongoing project research being undertaken by LIFT technology teams, valuable data is being generated. The collection and organization of the data in a format that can be searched and analyzed would create a resource that could be used by many in industry and academia. The basics of many of the LIFT technologies are covered in existing comprehensive courses on manufacturing processes. However, to enhance the course contents, this database of experimentally produced parts could be incorporated into existing coursework to create more robust curriculum, responsive to the workforce needs emerging from these developing technologies. If LIFT developed standard metadata for experimentally produced parts, this could help make to make this data accessible in a standard format.

Recommendation 5: Fully implement Learning Lab plans.

Many EET recommendations will be fulfilled if LIFT executes on plans underway for the Learning Lab. Understanding that the vision is for a Learning Lab above the High Bay (computers and workspace on a platform overlooking the High Bay) and a Learning Lab in the High Bay (hands-on experiences with High Bay equipment), the EET suggests that ideas like the following could be realized through the Learning Lab vision:

- On-site training using the latest technologies available at LIFT, which could be made available to LIFT members and academic and research partners. For example, if a LIFT member needs people trained in the use of robotics for incremental forming, offer work-and-learn experiences to train the incumbent workforce.
- Offer a "software carpentry toolkit" workshop that introduces software capabilities available through LIFT. Beginner and follow-up advanced training could be provided. LIFT could also provide workshops on Integrated Computational Materials Engineering (ICME) success stories to increase awareness and introduce people to the available tools.
- Provide tours and possible career exploration workshops.
- Leverage the work-and-learn capacity provided by the Learning Lab. The main difference between the Learning Lab compared to labs at colleges is the opportunity to work directly with new tools while the equipment and processes are still emerging.
- Use expanded Learning Hub features recommended above to extend the Learning Lab virtually. Online, video webcast training sessions with schools that have makerspaces, or with companies that want to provide convenient training sessions.

Section 2: Existing LIFT-Supported Education and Workforce Initiatives

Overview

Included in the underlying principles of the LIFT work plan is a commitment to "link and leverage the assets available." As each of the projects were reviewed, members of the EET were asked to capture how these projects could work with existing LIFT supported education and workforce initiatives. The goal is to develop initiatives to build educational pathways and link them via stackable credentials across the education continuum. Essential elements are captured in the recommendations below.

Recommendation: Encourage the LIFT-supported education and workforce initiatives to incorporate the High Bay and Learning Lab into their plans.

The High Bay and Learning Lab can likely be vital resources to the existing LIFT-supported education and workforce activities. Program leaders for these initiatives should be encouraged to develop mechanisms to incorporate the High Bay and Learning Lab, and the Learning Hub, into their efforts. Future RFP's for LIFT education and workforce funding could even require such integration in proposals. LIFT will benefit from broad dissemination of their valuable infrastructure, and the initiatives will benefit in many ways, too. One opportunity for the LIFT-supported programs is enhancement of their offerings to include more content beyond the technician level.

Recommendation: Mine existing education and workforce initiatives, as well as resources available from other providers, for needed technology-specific learning modules and get them into the Learning Hub.

Recommendation 1 above notes that learning modules are needed for each of the new technologies under development to help instructors augment their curricula. Many of the existing education and workforce initiatives supported by LIFT may be developing learning materials related to the emerging technologies. The initiatives should be asked to make materials available in the Learning Hub. Additionally, discipline- and trade-specific organizations and societies should also be called upon to provide materials for the Learning Hub, including materials related to product specifications and standards. Members of the EET have also noted that some educational institutes and professional organizations have already developed sound course materials or lab experiments in metallurgy and welding, as an example.

Recommendations for LIFT Technology Projects

Members of the Expert Educator Team were provided with four projects to review at LIFT on November 30 and December 1, 2017. A synopsis of each of the four projects follows:

Refill Friction Stir Spot Welding
Using rivets to join metal components can drastically increase cost, depending on the complexity and stress requirements of the part. Both the rivets and installation contribute to cost increases. This project is exploring the use of friction stir welding, in which to parts are joined by a tool that softens the metal of both parts at the joint and rotates to stir the parts together. The refill friction stir spot welding allows development of pins that meet the material, stress and geometry requirements of rivets. The project is using the pins to mount aircraft "skin" (outer surface of most of the wings and fuselage) to the airframe structure.

Joining Titanium to Steel
The ability to reliably join dissimilar materials, such as joining titanium to steel, has gained attention recently as manufacturers strive to design and produce lightweight components that can meet the performance and reliability standards of the automotive, aviation, aerospace and defense industries. To lower production cost, titanium and its alloys are often welded to steel to achieve high performance and cost-efficiency. However, reliable titanium/steel joints can be difficult to produce, due to poor compatibility and the formation of hard and brittle characteristics in the joint. Developing advanced computational methods which accurately predict material and joint properties of titanium to steel joins will significantly impact lightweight component design for transportation industries. Eliminating more complex joints will lead to more efficient designs, reduced weight, and reduced production time and cost.

Inorganically Bonded Sand Molds
This project has been developed to economically produce thin-wall, lightweight iron castings from inorganically bonded, recyclable printed sand molds. Sand molds are more eco-friendly, because they do not create gases, odors and fumes. Printed sand molds and cores also allow for greater design freedom, because there is no requirement to taper or angle (draft) cast parts to facilitate mold removal. The lack of a need for draft angles allows for component complexity not possible with conventional casting processes.

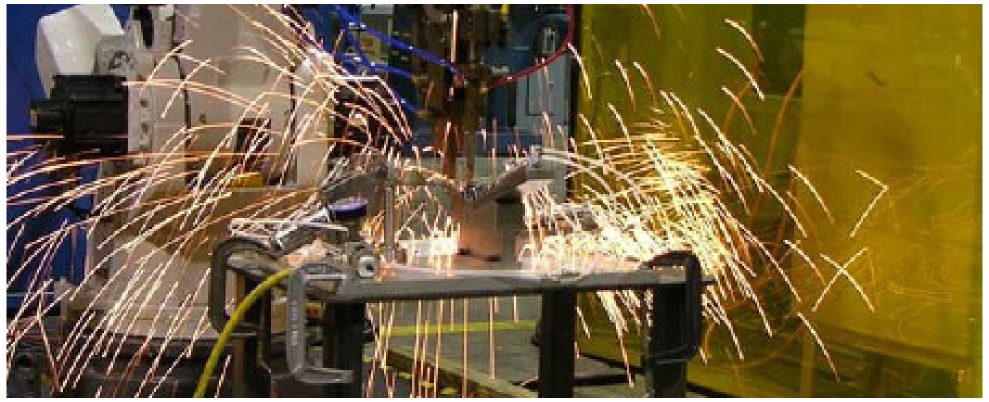
Friction Stir Extrusion
The requirement for improved strength and versatility of hydroformed (shaped with high pressure water) parts is ever increasing. Hydroformed aluminum tubes are typically made from alloys that are not high-strength. There is a need for technology that enables the use of higher-strength aluminum alloys, to provide an increase in strength-to-weight ratio and also improved corrosion resistance. Such a technology would help achieve a substantial decrease in lifecycle cost of hydroformed aluminum components. Benefits of this technology will be realized in the transportation industry by reducing vehicle mass and promoting more efficient builds. The technology will also benefit the heat exchanger industry by improving the life of process tubing in marine applications.

Each of the following sections relates to these four LIFT technology projects. Notes from members of the EET have been compiled and integrated into these sections:

- Overview
- Competencies Required at Technical/Production Level (Community College)
- Competencies Required at Design/Engineering Level (4-yr University)
- Recommended Strategies for Education and Workforce Development

Recommendation
The Expert Educator Team recommends that the technology teams review these recommendations and adopt appropriate content related to both competencies and strategies in their technology work plans.

Section 1: Refill Friction Stir Spot Welding



1.1 Overview

- Refill Friction Stir Spot Welding is a technology development project within LIFT's Joining and Assembly pillar.
- This project has been developed to create joining of parts without rivets.
- To develop recommendations related to Refill Friction Stir Spot Welding, the EET reviewed the technology work plan Joining R2-4: Processing and Properties Database for Refill Friction Stir Spot Welding of Aerospace Materials.
- A presentation on Refill Friction Stir Spot Welding was delivered by Pingsha Dong, Professor of Naval Architecture and Marine Engineering at the University of Michigan.
- Currently, the education and workforce section of the technology plan for Refill Friction Stir Spot Welding notes the availability of information and materials generated by the project for inclusion in standards, company briefings to designers, and dedicated training modules.
- In addition to reviewing the following technology-specific competencies and strategies, the Expert Educator Team recommends that the technology team review this section for content that can be included.

1.2 Competencies

The Expert Educator Team recommends the inclusion of the following competencies in the education and workforce sections the technology development plan for Refill Friction Stir Spot Welding.

1.2.1 Refill Friction Stir Spot Welding Competencies Required at Technical/ Production Level (Community College)

Technical- and production-level competencies are required for workers on the shop floor. The delivery context for content that addresses these competencies is most likely a **community college certificate or degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Materials and Process Basics:

- Awareness of microstructure-properties relationships for advanced aerospace materials
- Properties of materials
- Quality assurance techniques (statistical process control)
- Geometric dimensioning and tolerance
- Manufacturing processes
- Introduction to robotics and programmable logic controllers (PLC)

Welding:

- Materials joining
- Welding specification and blueprint reading
- Advanced spot welding skills
- Weld quality inspection and assessment
- Knowledge of solid state welding
- Advantage/disadvantages of different types of welding processes

1.2.2 Refill Friction Stir Spot Welding Competencies Required at Design/ Engineering Level (4-year University)

Design- and Engineering-level competencies are required for manufacturing engineers. The delivery context for content that addresses these competencies is most likely a **4-year engineering degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Materials and Process Basics:

- Knowledge of processing-microstructure-properties relationships/material behavior for advanced aerospace materials
- Properties of materials
- Design of experiments
- ICME (Integrated Computational Materials Engineering)-based modeling
- Design for manufacturability

Welding:

- Knowledge of solid state welding, including welding parameters and process development
- Advantage/disadvantages of different types of welding processes
- Welding quality inspection
- Fracture and fatigue
- Corrosion at the joint/interface
- Residual stress and stress/strain analysis at joint
- Corrosion at the joint/interface

Data and computing:

- Data informatics
- Machine learning

1.3 Recommended Strategies for Refill Friction Stir Spot Welding Education and Workforce Development

The EET recommends developing the following Refill Friction Stir Spot Welding education and workforce development strategies in partnership with community colleges and/or 4-year universities.

1.3.1 Recommendation: Course Development and Enhancement

Refill Friction Stir Spot Welding (RFSSW) requires curriculum enhancement at both the technician and engineer level. While welding is part of many two-year programs, courses on welding and solid-state joining/solidification processes are not generally included in materials engineering programs. Such courses, as well as courses in physical metallurgy and materials characterization (microstructure and properties), should be considered for development and inclusion in the engineering curriculum. Other helpful courses or course content include that related to metallurgy, modeling tools like SYSWELD, quality specifications and standards, data informatics, machine learning, engineering drawings and lab experiments.

Competencies might also be addressed through enhancement of existing courses, perhaps using cases focused on FSSW. Courses in advanced manufacturing, or existing courses that cover friction stir welding (but not RFSSW) could include a RFSSW case study, for example.

Section 2: Joining Titanium to Steel

2.1 Overview

- Joining Titanium to Steel is a technology development project within LIFT's Joining and Assembly pillar.
- This project has been developed to improve the strength and characteristics of titanium to steel joints, ultimately leading to more efficient designs, lighter weight, and reduced production times and costs.
- To develop recommendations related to Joining Titanium to Steel, the EET reviewed the technology work plan Joining-R2-1: Development of Technologies for Joining Titanium to Steel.
- A presentation on Joining Titanium to Steel was delivered by Pingsha Dong, Professor of Naval Architecture and Marine Engineering, at the University of Michigan.
- Currently, the education and workforce section of the technology plan for Joining Titanium to Steel is focused only on involving graduate students in the

technology development.
- In addition to reviewing the following technology-specific competencies and strategies, the Expert Educator Team recommends that the technology team review this section for content that can be included.

2.2 Competencies

The Expert Educator Team recommends the inclusion of the following competencies in the education and workforce sections of the Joining Titanium to Steel technology plan.

2.2.1 Joining Titanium to Steel Competencies Required at Technical/ Production Level (Community College)

Technical- and production-level competencies are required for workers on the shop floor. The delivery context for content that addresses these competencies is most likely a **community college certificate or degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Basics:
- Experimental design

Welding:
- Skills for joining/welding dissimilar materials
- Knowledge about welding processes
- Awareness of challenges in multi-material joining
- Capability to test quality and performance of multi-material welds
- Properties of joints
- Welding defects at interfaces and quality control
- State-of-the-art knowledge on advanced welding processes
- Blueprint reading

2.2.2 Joining Titanium to Steel Competencies Required at Design/Engineering Level (4-year University)

Design- and Engineering-level competencies are required for manufacturing engineers. The delivery context for content that addresses these competencies is most likely a **4-year engineering degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Materials and Manufacturing Process Basics:
- Microstructure of non-ferrous and ferrous materials
- Processing-structure property relationships
- Properties of materials
- Quality assurance techniques (statistical process control)
- Geometric dimensioning and tolerance
- Advantage/disadvantages of different types of welding processes
- Design for assembly
- Introduction to robotics and programmable logic controllers (PLC)

Joining and Welding:
- Knowledge of mechanical/chemical/metallurgical challenges to multi-material (including titanium to steel) interfacing
- Knowledge for tooling and die design for multi-material joining
- Product design with multi-material joints
- Knowledge of corrosion issues with multi-material interfaces
- Properties of joints at interface
- In-depth knowledge of joining process
- Welding defects at interface and quality control
- State-of-the-art knowledge on advanced welding processes
- Mechanics at the joint or interface of two materials

Data and computing:
- Data informatics
- Machine learning

2.3 Recommended Strategies for Joining Titanium to Steel Education and Workforce Development

The EET recommends developing the following Joining Titanium to Steel education and workforce development strategies in partnership with community colleges and/or 4-year universities.

2.3.1 Recommendation: Course Development and Enhancement

As with Refill Friction Stir Spot Welding (RFSSW) described in the previous section, Joining Titanium to Steel requires curriculum enhancement at both the technician and engineer level. While welding is part of many two-year programs, courses on welding and joining are not generally included in materials engineering programs. Such courses, as well as courses in physical metallurgy, materials characterization (microstructure and properties), multi-metal joining, and product design with multi-material joints should be considered for development and inclusion in the engineering curriculum. As with the previously-described technology, other helpful courses or course content include that related to metallurgy, modeling tools like SYSWELD, quality specifications and standards, data informatics, machine learning, engineering drawings and lab experiments.

Competencies might also be addressed through enhancement of existing courses, perhaps using cases focused on Joining Titanium to Steel. Courses in advanced manufacturing, computation, and design for assembly could include a Joining Titanium to Steel case study, for example.

Section 3: Inorganically Bonded Sand Molds

3.1 Overview

- Inorganically Bonded Sand Molds is a technology development project within

LIFT's Melt Processing pillar.

- This project has been developed to economically produce thin-wall, lightweight iron castings from inorganically bonded, recyclable printed sand molds, which are eco-friendly and allow for greater design freedom because there is no requirement to taper or angle (draft) cast parts to facilitate mold removal.
- To develop recommendations related to Inorganically Bonded Sand Molds, the EET reviewed the technology work plan Melt R2-5 - Inorganically Bonded Sand Molds Printed at Line Speed.
- A presentation on Inorganically Bonded Sand Molds was delivered by John "Chip" Keough, Development Engineer at JoyWorks affiliated with LIFT.
- Currently, the education and workforce section of the technology plan for Inorganically Bonded Sand Molds is evolving, and little information about education and workforce strategies is included.
- In addition to enhancing this section for technology-specific competencies and strategies, the Expert Educator Team recommends that the technology team review this section for content that can be included.

3.2 Competencies

The Expert Educator Team recommends the inclusion of the following competencies in the education and workforce sections of the Inorganically Bonded Sand Molds technology plan.

3.2.1 Inorganically Bonded Sand Molds Competencies Required at Technical/ Production Level (Community College)

Technical- and production-level competencies are required for workers on the shop floor. The delivery context for content that addresses these competencies is most likely a **community college certificate or degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Basics

- Awareness of cast iron processing-microstructure-properties relationships
- Skills for mold production
- Skills for post processing of cast components
- Knowledge of heat transfer
- Basics of sand casting & microstructures
- Knowledge of metallurgical properties
- Awareness of ICME methodologies and modeling tools

Metal Casting and Foundry

- Casting design
- Casting modeling
- Casting molds and mold materials
- Systems design/product design
- Development of manufacturing processes
- 3D printing for mold making
- Additive manufacturing
- Design for assembly

Materials/Metallurgy

- Mechanical properties of metal
- Concepts of stress and strain
- Yield and plastic flow
- Metallurgy, structure property and processing relationships
- Solidification and phase transformations
- Microstructural characterization
- Heat transfer principals
- Quality control

3.2.2 Inorganically Bonded Sand Molds Competencies Required at Design/ Engineering Level (4-year University)

Design- and Engineering-level competencies are required for manufacturing engineers. The delivery context for content that addresses these competencies is most likely a **4-year engineering degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Basic

- Knowledge of cast iron processing-microstructure-properties relationships
- Additive manufacturing
- Metal casting
- Understanding of post processing requirements for thin walled components
- Mechanical properties of metal
- Concepts of stress and strain, yield and plastic flow
- ICME methodologies and modeling tools
- Heat transfer
- Solidification

Metal Casting and Foundry

- 3D Printing using inorganically bonded sand
- Detection of casting defects
- Design for casting, post-processing of cast parts
- Cast iron processing-microstructure-properties relationships
- Mold design with inorganic binder systems
- Solidification
- Casting design
- Heat transfer

Materials/Metallurgy

- Design of experiments
- Thermodynamics
- Solidification and phase transformations
- Microstructural and grain size characterization
- Design for assembly
- Mechanics/stress-strain analysis
- Fracture and fatigue

3.3 Recommended Strategies for Inorganically Bonded Sand Molds Education and Workforce Development

The EET recommends developing the following Inorganically Bonded Sand Molds education and workforce development strategies in partnership with community colleges and/or 4-year universities.

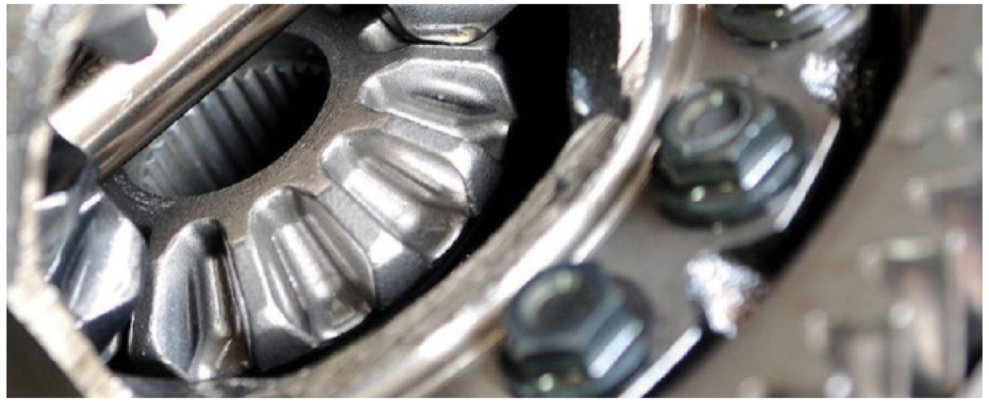
3.3.1 Recommendation: Address gaps in current curriculum.

If institutions have courses that cover sand casting at all, it is likely in passing and not addressing the advances in this technology. Once educators are made aware of the technology through the kinds of resources discussed in recommendations 1 through 6 in Section 1, courses in microstructure and mechanical characterization, and exposure to statistical process control as it impacts this new technology, should be considered for development and inclusion in the materials engineering curriculum. In addition, institutions should develop or add modules to include iron casting, metal metallurgical properties, and 3D sand printing technology (additive manufacturing).

3.3.2 Recommendation: Revisit Report 2, Recommendation 1.3.1

As noted in the second report from this group, on page 13, very few schools (4-year or community college) offer any sort of hands-on casting experience. It is likely that less than a dozen schools in the U.S. have this capability. The EET recommends, in support of advancing competencies in Inorganically Bonded Sand Molds, development of an education and training network among hands-on casting sites and foundries at colleges and universities. This recommendation was previously made regarding Thin Wall Ductile Iron Castings.

Section 4: Friction Stir Extrusion



4.1 Overview

- Friction Stir Extrusion is a technology development project within LIFT's Thermo-Mechanical Processing Pillar
- The project will investigate the use of new friction stir extrusion processing technology for the manufacture of automotive frames.
- Compared to the traditional extrusion press method, the new process is expected to drastically reduce the mass and weight of automotive frames.
- The friction stir extrusion process utilizes a rotating mandrel with a featured tip to generate frictional heat and cause severe plastic deformation as the material exits the die creating an equiaxed fine-grain microstructure in the tubular product.
- The objective of this project is to use the fine-grained tubular product in applications where traditionally extruded tubing has not been considered previously.
- Two of the early applications identified are 1) hydroforming the tubes to make lighter automotive frames, and 2) installing the tubes in marine heat exchangers to reduce product life-cycle costs.

4.2 Competencies

The Expert Educator Team recommends the inclusion of the following competencies in the education and workforce sections of the Friction Stir Extrusion plan.

4.2.1 Friction Stir Extrusion Competencies Required at Technical/Production Level (Community College)

Technical- and production-level competencies are required for workers on the shop floor. The delivery context for content that addresses these competencies is most likely a **community college certificate or degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Basic
- Knowledge of extrusion and friction stir welding
- Mechanical properties of metal
- Advanced welding skills including friction stir welding
- Knowledge of corrosion testing
- Capabilities in basic welding
- Understanding of heat transfer principles
- Quality Assurance

Project and Process Management
- FSE equipment setup and operation
- Extrusion hydroforming process
- Mechanical properties of metal
- Concepts of stress and strain
- Yield and plastic flow

Materials/Metallurgy
- Awareness of mechanical and metallurgical properties of materials
- Ability to perform QA of incoming materials and finished products
- Processing-microstructure-properties relationships
- Materials and part quality assessment
- Heat transfer

4.2.2 Friction Stir Extrusion Competencies Required at Design/Engineering Level (4-year University)

Design- and Engineering-level competencies are required for manufacturing engineers. The delivery context for content that addresses these competencies is most likely a **4-year engineering degree program**—the following competencies would be elements within courses in such certificate and degree programs.

Basic
- Capability in extrusion and friction stir welding
- Development of manufacturing processes
- Tooling design
- Engineering drawings
- Design of experiments
- Heat transfer
- Statistical analysis

Project and Process Management
- Knowledge of and capabilities for equipment design for FSE
- Solid-state joining process
- Understanding of hydroformed part design using FSE

- Knowledge of data acquisition and analytics
- Awareness of systems design/product design
- Understanding of the development of manufacturing processes

Materials/Metallurgy

- Knowledge of mechanical and metallurgical properties of materials
- Phase transformations
- Microstructural and grain size characterization
- Mechanical testing
- Heat transfer and statistical analysis
- Processing-structure-properties relationships
- Testing joint quality and performance

4.3 Recommended Strategies for Friction Stir Extrusion Education and Workforce Development

The EET recommends developing the following Friction Stir Extrusion education and workforce development strategies in partnership with community colleges and/or 4-year universities.

Recommendation 1: Develop new course work to enhance existing curriculum for Friction Stir Extrusion.
Most institutions have existing coursework in mechanical deformation, microstructures and mechanical properties which can prep students for the complexities of FSE. However, the curriculum should contain relevant modeling and simulation modules, solid state joining processes, metal forming and severe plastic deformation. In addition, demonstration videos and case studies of this technique would be useful to improve exposures and understanding to students.

ABOUT LIFT – LIGHTWEIGHT INNOVATIONS FOR TOMORROW

LIFT is a Detroit-based, public-private partnership committed to the development and deployment of advanced lightweight metal manufacturing technologies, and implementing education and training initiatives to better prepare the workforce today and in the future. LIFT is one of the founding institutes of Manufacturing USA, and is funded in part by the Department of Defense with management through the Office of Naval Research.

ABOUT APLU

The Association of Public and Land-grant Universities (APLU) is a research, policy, and advocacy organization dedicated to strengthening and advancing the work of public universities in the U.S., Canada, and Mexico. With a membership of 237 public research universities, land-grant institutions, state university systems, and affiliated organizations, APLU's agenda is built on the three pillars of increasing degree completion and academic success, advancing scientific research, and expanding engagement. Annually, member campuses enroll 4.9 million undergraduates and 1.3 million graduate students, award 1.2 million degrees, employ 1.2 million faculty and staff, and conduct $43.9 billion in university-based research.

ABOUT NCMS

The National Center for Manufacturing Sciences, the largest cross industry collaborative Research & Development consortium in North America, is dedicated to driving innovation in commercial, defense, robotics and environmentally sustainable manufacturing. NCMS' vast experience in the formation and management of complex, multi-partner collaborative R&D programs, is backed by corporate members representing virtually every manufacturing sector.

Association of Public & Land-Grant Universities

1307 NEW YORK AVENUE, N.W., SUITE 400
WASHINGTON, D.C. 20005-4722
(202) 478-6040
WWW.APLU.ORG

FACEBOOK.COM/APLUNEWS @APLU_NEWS YOUTUBE.COM/APLUNEWS