Develop Sustainable Research and Education Capabilities for Advanced Manufacturing in Eastern Kentucky

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The objective of this NSF EPSCoR initiative from Morehead State University is to develop sustainable research and education capabilities in Eastern Kentucky to nurture highly-skilled manufacturing workers to meet the anticipated need of Kentucky's manufacturing industry as the state strives to become an advanced manufacturing center of excellence in the nation. The planned project consists of three major parts: research, education and workforce training, and infrastructure development. The proposed research agenda follows the central theme of Kentucky's Advanced Manufacturing Ecosystem. Education and workforce training are focused on developing manufacturing workforce among students from the rural areas of eastern Kentucky. Infrastructure development is concentrated on improving and upgrading the research and education capacities of MSU's existing facility, the 21st Century Center for Manufacturing Systems, to enable implementing the proposed activities and realizing the stated objective.

Following the broad guide of Kentucky's Advanced Manufacturing Ecosystem on development areas: manufacturing inputs (new materials), design + process, and applications, the proposers identify the following research areas for KY NSF EPSCoR to select. They are briefly described as follows:

1. Develop a virtual industrial lab for more efficient workforce training

Automation is constantly being updated with technological developments, thereby requiring new training in both academia and industry. One issue in academia is the lack of infrastructure that allows students to conduct trials in an industrial environment since both the type and number of the actuators, sensors and processors are limited. This research effort plans to develop a virtual industrial lab in which components possess the real physical and electrical characteristics of the industry. Students in training will be able to connect PLCs to virtual industrial machines by Modbus/TCP communication and program complex automation sequences in real industrial scenarios. They can modify the parameters and the sequences of control without risking the safety of the process or personnel involved.

2. Develop novel high-temperature materials for next-generation aerospace turbine engines

Gas turbines are the choice for force/power generation in aircraft. They are mainly made of Ni superalloys. The constantly increasing demand in performance requires increasing turbine inlet temperatures. The turbine operation temperatures have been pushed close to the melting temperatures of the alloys. Due to the intrinsic limitation imposed by Ni's low melting temperature, any further increase in turbine temperature will be minimal. Next-generation turbines call for more sustainable high-temperature materials. This research proposes developing novel, tri-layer nano/ultrafine Mo alloys to meet the material requirement of future gas turbines for higher speed, better fuel efficiency and less pollution. A layered macrostructure and a nano/ultrafine microstructure are utilized synergistically to address the dilemma between strength and oxidation/corrosion resistance. The layered structure frees up the constraint on material composition selection and creates flexibility to realize an oxidation/corrosion-resistant exterior and a ductile/tough interior in a single bulk piece. The nano/ultrafine microstructure is used to promote the formation of continuous protective scales and address the low-temperature embrittlement reported in Mo alloys. If succeeded, the proposed synthesis approach has a great potential to become a new material processing methodology for realizing a wide range of novel materials with superior properties.

3. Develop virtual design engineering training module for enhancing quality assurance

Standard QA techniques generally fail to consider multiple or complex hazard interactions, which can potentially escalate to create a catastrophic outcome. This research is to develop virtual design engineering training modules that allow for exploring the potential failure modes of a design before it has even been built. Expanding upon this capability, QA engineers can utilize the massive computing power available today to simulate various failure modes and their interactions. The virtual environment would allow students to study extremely difficult situations with respect to quality and hazards by virtually testing various solutions in a cost effective manner. For example, students can use the known physical characteristics of the materials in the product, apply extreme environmental factors such as low temperature and simulate the pressurization of the system.

4. Develop more controllable devices based on piezoelectric materials and electroactive polymers

Piezoelectric transducers and actuators have been developed for a number of applications in advanced manufacturing. These applications include motion and force sensors, actuating elements for miniature mechanical systems, and surface-acoustic wave sensors for detecting very small concentrations of mass. Piezoelectric materials have small amplitude of deformation; in contrast, electroactive polymers can produce large mechanical strains. The research proposed here will investigate the integration of either class of material with electronic circuitry to make more controllable the resulting motions from these devices.

5. Develop statistical models to improve manufacturing productivity by minimizing or negating prototypes

This effort is to develop statistical models and utilize graphics visualization to analyze various design iterations through combining experimental design methods with CAD, FEA and CFD. Prior to the use of FEA & CFD, designers are limited in their exploration into design possibilities and produced limited numbers of physical models to be tested. This excludes many possibilities for consideration and severely limits the total system improvements that can be tested and implemented. This research investigates how the various combinations of these tools can be utilized to optimize final designs of various components while maintaining absolutely minimal requirements for prototype manufacturing or to negate the requirements altogether. This will ultimately lead to an overall more robust and functional design as well as eliminating waste and scrap that would be associated with testing of prototype components.

Technologies and practices in industry keep evolving. As time enters the 21st century, manufacturing is more automatic and computerized. It needs to be more flexible and adaptable in facing faster supply flow, more customization and lower price. A manufacturing worker needs sound skills on automation, robotics, CNC coding and PLC programming. Meanwhile, (s)he has to be versed in lean manufacturing and quality management to minimize downtime, wastes and product defects and increase the overall efficiency and productivity. In response to these new developments, the education and workforce training practices proposed will be closely aligned with the new requirements in workplace. The teaching will emphasize both scientific theories and hands-on engineering approaches. Given that aerospace and automobile industries are the state’s top exports, the planned education and workforce training will be concentrated more on nurturing the advanced manufacturing workers in these two areas.

Research funding and equipment are two principal obstacles to persistently prevent the faculty at MSU from establishing their research programs. Sometimes, external grant proposals with excellent ratings were declined because of the lack of needed research tools. In addition, as the manufacturing in the 21st century becomes more technology-demanding, there is a need to upgrade the existing facility to teach the new set of skills. By considering these actual needs, this project seeks financial support to acquire a number of machines to enable the proposed research activities and upgrade the instructional function of the existing facility. If permissible, this project will ask for seed funding to support new faculty to launch their research programs. These financial supports will be able to help MSU build sustainable research and education capabilities for advanced manufacturing in eastern Kentucky.