Development of an Undergraduate Welding Laboratory for Research and Education

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Abstract:

The shortage of welders in Hampton Roads area, where many shipyards are located, is becoming severe for shipbuilding in coming years. Many welding engineers graduated from universities located out of state, tend to go back to companies near their home, after receiving couple years of welding experience at Hampton Roads shipyards. Therefore, it is critical to train local welders. In order to address the welding workforce needs of Hampton Roads, the Department of Engineering Technology at Old Dominion University has recently launched an initiative for developing a laboratory for welding processes (LWP) for supporting educational and research activities in its Mechanical Engineering Technology program. This laboratory consists of various welding processes such as gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), shielded metal arc welding (SMAW), laser welding, and ultrasonic metal welding. Most importantly, this is the first and only educational institute laboratory in Hampton Roads area that includes equipment for metallography; it is critical for welders to understand the physics behind welding processes. Equipment in this laboratory is intended to provide hands-on training to both mechanical engineering technology and mechanical engineering students by complementing and extending their welding expertise and better prepare students to handle the new industries demanding welding workforce. LWP is also can be used for wire arc additive manufacturing (WAAM) in order to introduce students to additive manufacturing (AM) technology. It is currently utilized to complement one elective existing course in Mechanical Engineering and Mechanical Engineering Technology programs. The Department of Engineering Technology aims to add 3 more welding related courses in order to offer a welding minor for Mechanical Engineering Technology students. In this paper, we mainly discuss the challenges and opportunities of integrating welding technologies in mechanical engineering technology curriculum based on our experiences at the Department of Engineering Technology at Old Dominion University. We will also present our recent welding processes laboratory initiative and discuss the use of LWP in supporting instruction and research in engineering technology.

1. Introduction

Recent trends in the industry have led to an increased need for engineers with welding training. Not many universities in the US offer welding courses at the undergraduate level. This issue is more visible in Hampton Roads area where many shipyards are located, and problems arise from a shortage of welders for these industries. Many welding engineers graduated from universities

located out of state, tend to go back to companies near their home, after receiving couple years of welding experience in Hampton Roads shipyards. Therefore, it is critical to train local welders. To address this need, Department of Engineering Technology at Old Dominion University has recently established a Laboratory for welding processes (LWP) for supporting ship and other manufacturing industries in east Virginia. This laboratory consists of various welding processes such as gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), shielded metal arc welding (SMAW), laser welding, and ultrasonic metal welding. Most importantly, this is the first and only educational institute laboratory in Hampton Roads area that includes equipment for metallography; it is very critical for welders to understand the physics behind welding processes. This paper reports the challenges and opportunities of integrating welding technologies in mechanical engineering technology curriculum based on our experiences at the Department of Engineering Technology at Old Dominion University.

2. Welding Laboratory Overview

It is important that students are exposed to various welding machines and learn the basic knowledge of welding technique through hands-on experience. Therefore, a LWP was established in Engineering Technology (ET) Department at ODU. The LWP was partially funded by a state equipment grant which was recently awarded to the ET Department. The state grant was used to acquire three GMAW machines, two GTAW machines, one Oxyfuel welding kit, one Piranha Ironworker machine, and one ultrasonic metal welding machine. In addition, Stihl Company has donated a 400 W welding machine to LWP. Sine the LWP space was not designed for welding originally, it did not include a fume extraction system. The instructor, with the support of ET Department, designed and placed a ventilation system for welding processes in the LWP.

The main difference between the LWP and any welding lab in the region is that it is equipped with metallography tools, such as TechCut5 for sectioning the welding samples, polishing machine, and a high-resolution microscope for analyzing the microstructure of weldment. This equipment was funded by the ET Department (see Figures 1 and 2).

3. Applications in the Engineering Technology Curriculum

Being a senior level course, the emphasis of this course is to deliver in-depth of physical and chemical phenomena that occur in welding. In the same time, for most students, this is their first course in welding, which requires a broad scope of topics. For that reason, broad welding-related topics are covered in the three-hour long blocks, as follows:

- Safety in welding, basic principles of welding, brazing, and soldering, and their differences, welding terminology and symbols
- Heat transfer in welding
- Theory of nucleation and solidification
- Theory of rapid solidification, microstructure development in welding
- Development of residual stresses in welds, strength of welds
- Defects in welds. Inspection and testing of welds, weldability tests
- Analysis of best practices in SMAW, GMAW, and GTAW processes, models of melting rates in those processes

- Weldability of steels, weldability of irons
- Weldability of aluminum and its alloys, weldability of titanium and its alloys

Figure 1. Some of the welding equipment used in LWP: a. ventilation system with GMAW machine; b. Piranha Ironworker machine; c. laser welding machine.

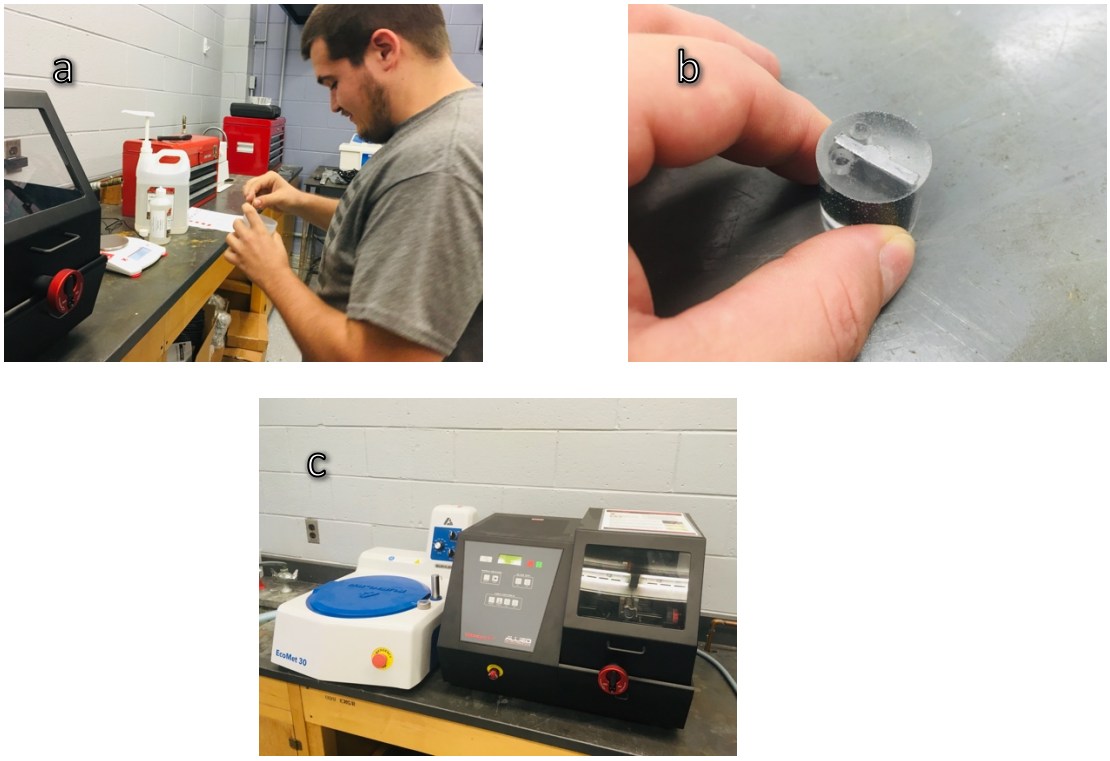

Figure 2. Metallography equipment: a. mounting process; b. mounted sample; c. left: polishing machine, right TechCut 5 machine for sectioning

3.1 Welding Process Experiences

In the welding training at LWP, two experiments are scheduled:

- During the first welding practice, students make bead-on-plate welds on 1018 steel using autogenous GTAW while timing the weld. Welds shall be far enough to avoid overlapped heat affected zones. After the samples cool down, they measure the bead width.

- During the second experiment, students perform SMAW, GMAW, and GTAW with added filler material. The base material is 1018 steel. In this experiment, they focus on the soundness of welds. They also make multi-pass single-V-groove welds using SMAW and GMAW methods. The weld soundness is tested with a guided bend testing method, performing face and root bends. Students have the opportunity to compare efficiencies between SMAW and GMAW and how much cleaning slag between passes influence welding efficiency and quality of welds. They will also learn to appreciate the importance of adhering to recommendations in order to successfully weld these materials.

3.2 Term Project

In addition to a lecture every week, the students at ODU are exposed to learn metallography of welds through experimentation [1]. About week 4, all students are provided with a project outline and detailed steps. This project usually lasts at least 8 weeks. The main objective is that students learn how to analyze the weld by examining the microstructure of welds. They are trained to produce professional micrographs through various polishing steps and etching. They

become skilled to take quality macro and micrographs of weld cross sections. More importantly, they will be practiced to take micro hardness readings on the weld surface and weld boundaries. The project steps are as follows:

- Project assigning
- Create welds
- Cut specimens and bend tests
- Mount specimens
- Polish specimens
- Etch specimens
- Image specimens
- Hardness test specimens

4. Applications in Research, Community Engagement and Outreach

There are various opportunities that we anticipate the LWP will deliver to ODU students and Hampton Roads community.

4.1 Utilizing LWP in Student Research through Senior Design Capstone Course

The students completing this course at LWP will be tracked in other mechanical and manufacturing courses. For example, students use their welding experience in capstone design projects, undergraduate research. The LWP encourages them to pursue graduate studies in welding areas.

The LWP also increases the interaction with local industries. As the industry is lacking people with advanced welding knowledge at the engineering and engineering technology level, there is a need for more courses that are focused on an in-depth overview of material science and the engineering behind the welding. We interact with local industries such as Newport News Shipyard as closely as possible to understand their needs and adjust our welding course based on those needs. We plan to add more welding courses to offer a welding minor, thanks to LWP.

4.2 Offering STEM Workshops for Area High Schools

Since LAW is new in the area, every semester we reach out to regional high schools and community colleges and invite groups of students to visit our campuses with the aim of increasing and stimulating their knowledge and motivation towards engineering by focusing on developing and offering welding-themed activities in workshops.

4.3 Wire and Arc Additive Manufacturing

Additive manufacturing has become a game changer for the manufacturing industry [2]. Wire and arc additive manufacturing, which is a repetitive welding process, uses electrical welding arc as a heat source to melt and deposit a wire feedstock layer by layer onto a substrate to generate desired structural components. The LWP is used to conduct research in the area of WAAM by producing parts as shown in Figure 3. In the LWP, we investigate various parameters that affect mechanical performances of the WAAM parts.

Figure 3. WAAM samples built from 304 stainless steel

5. Conclusions

In many ways, the LAW initiative presented in this paper has been a significant addition in supporting instructional and research activities of the ET Department at Old Dominion University. The Department of ET, with a baccalaureate major in Mechanical Engineering Technology, utilizes the new welding lab equipment to complement instruction in welding courses. The LWP prepares MET students for professional careers in a wide range of local welding industries including shipbuilding, heavy equipment, automotive, aerospace, industrial equipment, material handling, welding equipment, additive manufacturing, etc. They are trained to be involved in a variety of activities such as design, inspection, quality, problem-solving, and improving manufacturing efficiencies by choosing the best welding process and material. In the LWP, students learn the science and language of welding and engineering so that they will be able to span the gap between design and manufacturing at the undergraduate level.

Through the LWP equipment investments and educational program enhancements presented in this paper, we are poised to significantly impact the available workforce for the in-demand occupations of welding and manufacturing engineers and technicians.

References

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Biographical Information

Dr. HAMID EISAZADEH is an assistant professor of Mechanical Engineering Technology at Old Dominion University. Dr. Eisazadeh has more than 12 years of experience in education, having taught at Clarkson University and Chabahar Maritime University. His engineering experience includes manufacturing, welding, additive manufacturing. He has been lecturing in Introduction to Welding Processes, Manufacturing Processes, Material Science, and Additive Manufacturing courses.

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