Improving Weld Productivity and Quality by means of Intelligent Real-Time Close-Looped Adaptive Welding Process Control through Integrated Optical Sensors

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ABSTRACT:

Objective and Relevance: This proposal aims at developing a novel close-looped adaptive welding quality control system that will enable real-time weld defect detection and adaptive adjustment to the welding process conditions to eliminate or minimize the formation of weld defects. It specifically addresses the needs in NEET-1 on "advanced (high-speed, high quality) welding technologies" for factory and field fabrication to significantly reduce the cost and schedule of new nuclear plant construction.

Background and Description: Welding is one of the most important fabrication techniques for a variety of nuclear reactors. The weldments of nuclear structural materials must be of high quality due to the criticality of the demanding service. Today, welding parameters are pre-determined based on weld qualification trials. It is very difficult to proactively adjust in real-time the welding conditions to compensate unexpected variations in real-world welding causing the formation of welding defects. Repair and correction of the weld defects after the weld is made is very time-consuming and expensive.

This proposal aims at developing a real-time welding monitoring and control system to minimize the formation of weld defects. To ease the application of the technology, an integrated optical sensing unit will be applied with advantages of non-contact and fast response time. It consists of a digital camera, an infrared (IR) camera, an auxiliary illumination source and some optical filters. The sensing unit will be capable of concurrently measuring, in real-time, the changes in the welding temperature field (via IR camera), the mechanical strain field and the weld pool surface profile (via digital camera). On the control side, an artificial intelligence based closely-loop adaptive welding control unit will correlate the above measurement signals to the weld quality and provide feedback control signals in real time to the welding power source to adaptively adjust welding parameters producing defect-free high-quality weld. Extensive experiment as well as numerical simulations will be applied to establish the correlation among welding parameters, the corresponding changes of the measured signals and the formation of weld defects. The system will be integrated in a compact and cost-effective way, so that it can be easily integrated and widely used in manufacturing plants.

The expected outcomes and impacts of this innovation will be significant. Successful development of the proposed control system will drastically reduce weld defects and therefore the rework required for defect mitigation. We anticipate that there is a large potential to decrease the welding fabrication cost, and therefore accelerate the deployment schedule by minimizing the schedule delay due to reworking.

We have assembled an excellent project team for the proposed R&D. Based on the recent technology innovation in in-situ strain and temperature measurement, as well as the experience in developing on-line welding monitoring system for automotive applications, ORNL will lead the system development and integration (hardware, control algorithm and software) with assistance from University of Kentucky on weld pool surface measurement. EPRI will provide welding procedures, guidance, materials and testing sites, as well as the safety concerns involved in nuclear power plant constructions.