Problem Solving Environment for Integrated Weld Process-Microstructure Modeling

S. S. Babu, M. S. Summers**, and G. Sarma***
**Metals and Ceramic Division, **Computer Science and Mathematics Division*
Oak Ridge National Laboratory, Oak Ridge, TN

Introduction

Welding process involves thermo-mechanical-metallurgical interactions. An overwhelming goal of the welding engineer is to describe the above interactions based on prior experience and develop a finished product that meets the required design criteria. In the last decade, Sandia National Laboratory developed SmartWeld® system that allowed for concurrent model based product and process design system for optimizing and manufacturability of welded components [1]. The above approach was extended by Fuerschbach et al [2] to develop optimization software for designing welding process parameter for wide range of alloys. Supporting the design of the welds final microstructure, commercial Finite Element Analysis (FEA) code, SYSWELD®, has incorporated methodologies to integrate microstructure evolution through user defined parameters in a kinetic model [3].

However, the above models are not easily accessible by the welding engineers due to the level of expertise and training required by the component models. In addition, the above models are not flexible; as a result, the user cannot evaluate the sensitivity of the results to the use of various models that describe either the thermal history as a function of process parameters or the effect of thermal cycles on the microstructure. The models are also difficult to integrate since they were developed on different computer platforms (e.g., Unix, Linux, Windows, and Macintosh) and by different industries, universities and national laboratories. Due to the above reasons, existing integrated welding process tools are usually limited and do not allow for the generic use of a wide range of material and process models. The present research addresses these problems through a framework of networked computational tools.

Procedure

An integrated welding process model was developed based on the Problem Solving Environment (PSE) Concept. A PSE is a complete, integrated software environment for the computational solution of a particular problem, or class of related problems, that provides an end user with easy-to-use problem solving power based on modular state-of-the-art algorithms, tools, and software infrastructure [4]. In this research, we used an Internet client-server based approach employing Java® technology as a framework. The details of this framework are shown Figure 1. In the first prototype of PSE system, we have developed an integrated model to predict variation of hardness in the weld metal (WM) and the heat-affected-zone (HAZ) of a steel weld. The engineer utilizes the PSE by running a JAVA-based client the (the PSE-Welding Client) on any computer anywhere in the world. This client collects engineer inputs, manages the computations of a set of process sub-models running on various servers, and provides the graphics that permit the engineer to visualize the data produced by these sub-models. The client first interacts with a welding-process model that resides within a UNIX server (the PSE-Process Server). This process server is accessed through a set of JAVA servlets that respond to requests from the PSE-Welding client. The PSE-Process Server is based on a welding process model developed with ABAQUS® FEA software for a bead-on-plate geometry. The PSE-Client also interacts with another set of JAVA servlets on a third machine, the PSE-Microstructure Server. These servlets provide access to a microstructure analysis program written in the FORTRAN programming language. The servlets are linked directly to the FORTRAN code through the Java Native Interface. The Fortran code implements a microstructure model that is based on a model developed by Ion et al [5].

Results and Discussion

The input interface of the welding client is shown in Fig. 2*a*. After selecting the required parameters, the PSE-Process Server is run first. The PSE-Process Server usually takes 5 to 10 minutes to complete its' calculations. After this step, the PSE-Welding Client attains thermal histories at different material locations from the PSE-Process Server. When the user clicks on a particular location, the thermal history for that location and the weld composition are transferred to the PSE-Microstructure Server. Using this information, the location's microstructure and hardness are then calculated and the results are transferred to back to the PSE-Weld Client. The results are displayed as shown in Fig. 2*b*. Although, the above research demonstrated the proposed concept, the research has highlighted different limitations that need to be addressed in the future. The main issue is that significant model expertise is still needed to address the "errors" that may be generated by component computational models. Another important issue is the need for standardization of the input and output data formats used by different alternative sub-process models. Currently the servlets achieve interoperability by converting component model data into a prototype specific common format. As the system grows, standards will be required so that component models can be readily "plug-replaceable". Functionally, the most important issue is that the integrated model is still limited to serial operations, i.e., the microstructure model and process models are not completely coupled during analysis. Future research will consider the above limitations. It is noteworthy that the PSE concept also has to deal with the software licensing issues when using commercial software codes as component models. However, this can be solved though using a public domain software repository similar to the Materials Algorithm Project [6] or by using a server-supported pay-per-use licensing scheme.

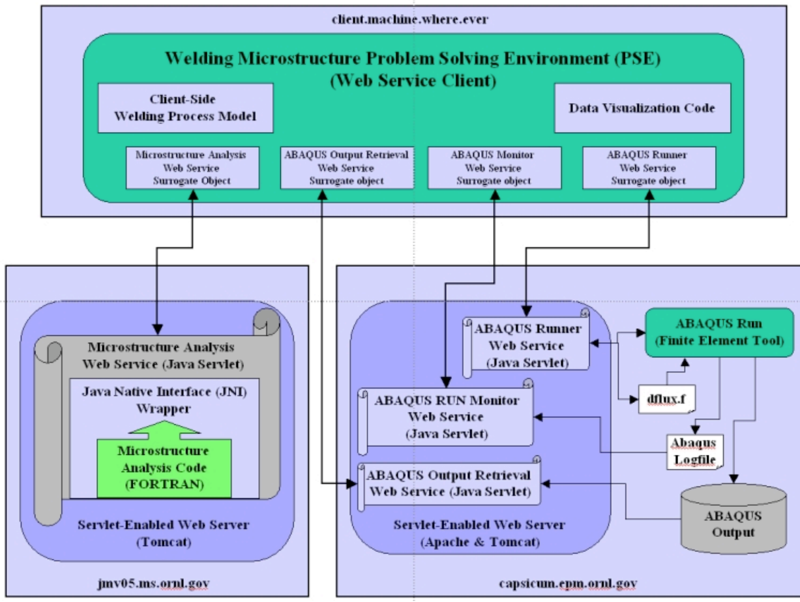

Fig. 1 Overview of the PSE framework developed to describe microstructure evolution as a function of welding process parameters.

Conclusions

An integrated welding process–microstructure model has been developed based on the problem solving environment concept. The above Welding PSE prototype has demonstrated that it is possible to link sub-process models that describe different physical processes developed by various researchers and residing on different computer systems using a flexible interface based on Internet technology. Moreover, with further development, it is possible for a welding engineer to use select from alternate component models implementing state-of-the-art welding process and microstructure developments in order to predict the final performance of the weld.

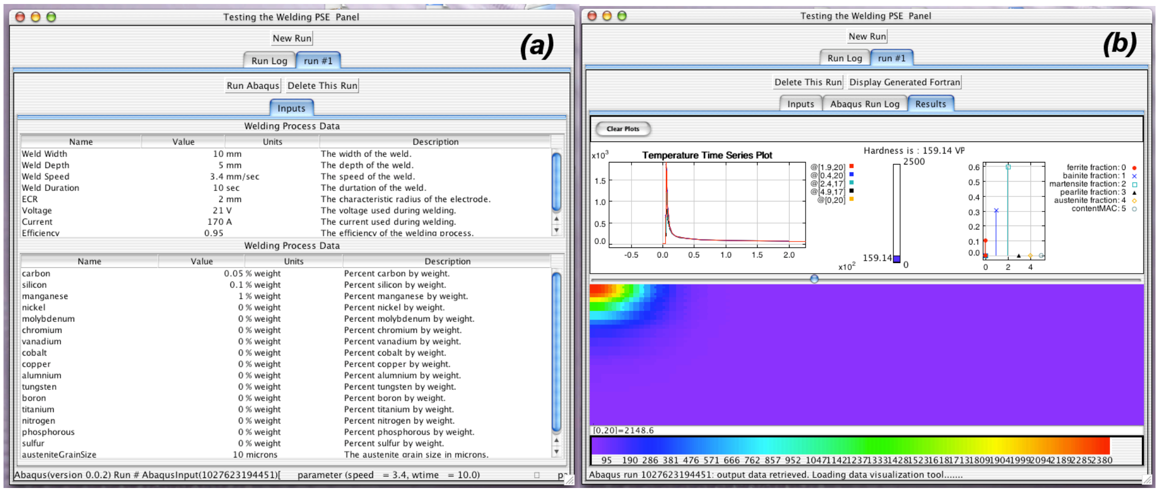

Fig. 2 (*a*) Image of input window of the Welding PSE-Client interface and (*b*)) Image of results window of the Welding PSE-Client interface

Acknowledgements

Research sponsored by the Laboratory Directed Research and Development Program of Oak Ridge National Laboratory (ORNL), managed by UT-Battelle, LLC for the U. S. Department of Energy under Contract No. DE-AC05-00OR22725. The authors thank Prof. D. Walker of University of Cardiff, UK (formerly at Computer Science and Mathematics Division of ORNL), Drs S. A. David and M. L. Santella of ORNL for initial discussions.

References

1. http://www.sandia.gov/organization/div6000/ctr6500/partner.html
2. P. W. Fuerschbach, G. R. Eisler and R. J. Steele, "Weld Procedure Development with OSLW – Optimization Software for Laser Welding," 5th International conference on Trends in Welding Research, Pine Mountain GA, (1998).
3. SYSWELD® software, http://www.esi-group.com/products/sysweld/overview.html
4 E. Gallopoulos, E. N. Houstis, and J. R. Rice, "Workshop on Problem-Solving Environments: Findings and Recommendations," *ACM Computing Surveys*, Vol. 27, No. 2, pages 277-279, June 1995.
5. J. C. Ion, K. E. Easterling, and M. F. Ashby, "A 2nd report on diagrams of microstructure and hardness for heat-affected-zones in welds," *Acta Metall*., 1984, **32**, p. 1949
6. Materials Algorithm Project, http://www.msm.cam.ac.uk/map