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An American National Standard

Guide for Verification and Validation in Computation Weld Mechanics

American Welding Society®

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Guide for Verification and Validation in Computation Weld Mechanics

1st Edition

Prepared by the
American Welding Society (AWS) A9 Committee on Computerization of Welding Information

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This standard provides guidelines for assessing the capability and accuracy of computational weld mechanics (CWM) models. This standard also provides general guidance for implementing verification and validation (V&V) of computational models for complex systems in weld mechanics.

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Foreword

This foreword is not part of this standard but is included for informational purposes only.

A task group was formed in 2007 under the AWS technical committee structure to investigate the need for computational weld mechanics standards. The task group was reorganized as the AWS A9 Technical Committee on the Computerization of Welding Information and began work in 2008. This is the first standard publication by this committee with more related topics on computational weld mechanics (CWM) planned.

Program managers need assurance that computational models of weld mechanics are sufficiently accurate to support programmatic decisions. As there are multiple acceptable approaches to analyzing the welding process using computational models, a step-by-step Verification and Validation (V&V) process is not practical. However, this guide will provide the CWM community with a common language and conceptual framework to enable communication to non-users of CWM to gain a sense of credibility of the CWM models. This guide will cover a wide range of V&V activities, including simplistic and complex model development, verification of numerical solutions, attributes of validation experiments, accuracy requirements, and quantification of uncertainties. Remaining issues for further development of a V&V protocol are identified.

The AWS A9 Committee plans to pursue the publication of additional standards on computation weld mechanics after this standard. Among those planned are:

Recommended Practice for Describing Thermal Boundary Conditions

Recommended Practice for Modeling Thermo-Mechanical Phenomena

Recommended Practice for Describing Clamps and Fixtures

Recommended Practice for Modeling Microstructure

Recommended Practice for Integrated Models

Recommended Practice for Verification, Uncertainty Estimation, and Sensitivity

Recommended Practice for Documentation

Exceptions and Modifications with reference to Materials 1: Steels

Exceptions and Modifications with reference to Materials 2: Aluminum

Exceptions and Modifications with reference to Fusion Welding—Arc

Exceptions and Modifications with reference to Fusion Welding—Laser

Exceptions and Modifications with reference to Fusion Welding—Resistance

Exceptions and Modifications with reference to Thin and Thick Plate Geometry

Exceptions and Modifications with reference to Large Scale Geometries

It is noteworthy that this document is in alignment with similar activities pursued by other international standards organizations such as the German Institute for Standardization (DIN) and the International Institute of Welding (IIW). For example, the readers of this standard are also requested to refer to DIN SPEC 32534–1, *Numerical welding simulation—Execution and documentation—Part 1: Overview*, published in 2011.

Annex A lists the in-text citations referenced throughout this document.

In this reaffirmation, the following non substantive changes were made:

(1) Clause 2 and 3 – Updated Normative References and Terms & Definitions per AWS Boilerplate language.

(2) Subclause 5.1.2 – Spelling of dependent corrected.

(3) Subclause 5.7.2.1 – Added "a" to the second sentence which now reads "Theoretically, it is simple, but the application of the proper domain loadings with proper values and direction is a relatively time-consuming process."

(4) Clause 6(2) – Spelling of occurrences corrected.

(5) Annex C – Updated per AWS Boilerplate language.

(6) Section 1.3(1) – Removed the word "Material" from the beginning of the text which now reads "Safety Data Sheets supplied by materials manufacturers."

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A9 Committee on the Computerization of Welding Information, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

Table of Contents

Page No.

List of Figures

Guide for Verification and Validation in Computation Weld Mechanics

1. General Requirements

1.1 Scope. This guide introduces computational weld mechanics methodology through an overview of the current technology. It presents current practices for heat transfer, microstructure, residual stress, and distortion calculations. In addition, a framework for developing verification and validation (V&V) procedures for these models is presented through an example related to the prediction of thermo-mechanical conditions. This document establishes the foundation for future V&V operations to allow for other emerging computational weld mechanics tools.

Although this guide is not written with mandatory requirements, mandatory language, such as the use of "shall", will be found in those portions of the document where failure to follow the instructions or procedures could produce inferior, misleading, or unsafe results.

1.1.1 Preface. Computational models have been used routinely to great advantage for more than three decades. This technology has been used in many industries to analyze and assist in the design of many items. From architecture to telecommunications, computational analyses (structural to thermal to fluid) have been used to develop objects from the most complex to commonplace everyday items. Numerical analysis has given engineers the capability to make products better, safer, and more functional with less development costs. The growth in the use of computational models shows that commercial industries have confidence in the accuracy of the codes to reduce costs and delivery times while improving quality. In manufacturing, computational solid mechanics (CSM) and computational fluid mechanics (CFM) have been fully adopted; yet, the use of computational weld mechanics (CWM) has not. It has been suggested that the same level of confidence in CWM analyses does not exist due to relative newness of the tools and the lack of experience in their use. In comparison, CWM is quite complex involving a coupled phenomena of thermal and nonlinear, transient structural analyses. Information regarding material responses due to thermal inputs, microstructure evolution, and to stresses and strains are needed to perform this type of analysis. It is for these reasons that CWM has emerged about two decades later than CSM.

The process to develop confidence in computational modeling can be expedited by a process called verification and validation (V&V). Verification testing ensures that a computational code solves the mathematical state equations that describe the phenomenon with sufficient accuracy, robustness, and reliability. Validation tests that a particular computational model predicts a particular event with accuracy and reliability. Such V&V has been developed for computational solid mechanics [1][1] with Figure 1 illustrating a typical methodology used to develop V&V documents for creating models throughout the design process. This approach can be applied to CWM as well. In welding, the relevant phenomenon might be distortion, residual stress, microstructure, or risk of in-service failure. Once through this process, a computational model can be used repeatedly without physical experimentations with confidence that the output will be accurate and reliable.

Computational models fitted to experimental data before being used are called calibrated models. These types of models cannot be used to predict a particular outcome unless the input values are the same range as the original 'calibrated' model. Any changes in the model require the repetition of the calibration process resulting in multiple computational models and experimental tests. As one can easily see, computational approaches that utilize validated codes and verified approaches are much more expansive and usable in multiple cases than their calibrated computational model counterparts.

1.2 Units of Measurement. This standard does not require units of measure. Therefore, no equivalents or conversions are contained except when they are cited in examples.

[1] See Annex A for in-text citations.