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Numerična simulacija varjenja - Izvedba in dokumentacija (ISO/DIS 18166:2025)

Numerical welding simulation - Execution and documentation (ISO/DIS 18166:2025)

Numerische Schweißsimulation - Ausführung und Dokumentation (ISO/DIS 18166:2025)

Simulation numérique de soudage - Exécution et documentation (ISO/DIS 18166:2025)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document has been prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, working group 5, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 121, *Welding and allied processes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces the Technical Specification ISO/TS 18166:2016 which has been technically revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html. Official interpretations of TC 44 documents, where they exist, are available from this page: https://committee.iso.org/sites/tc44/home/interpretation.html.

Introduction

This document is not intended for use in a specific industry or with a specific software. Commercial tools are not excluded. This document is beneficial for the design and assessment of a wide range of components if the physical phenomena, software and numerical methods meet the specifications of the scientific computational tools (SCTs) defined in Annex A.

This document can be used by industrial bodies or companies to define their requirements for specific applications of computational welding mechanics (CWM).

Numerical welding simulation — Execution and documentation

1 Scope

This document specifies the execution, validation, verification and documentation of a numerical welding simulation within the field of computational welding mechanics (CWM) and performed with a Scientific Computational Tool (SCT).

This document is applicable to the thermal and mechanical finite element analysis (FEA) of arc, laser and electron beam welding processes for the purpose of calculating the effects of welding processes, and in particular residual stresses and distortion, in support of structural integrity assessment.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 25901-1:2016 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
calculation scheme
set of modelling choices to perform a numerical simulation

Note 1 to entry: A calculation scheme defines the choice of physical models and of the coupling physics between models, the correlations, the discretization both spatial (meshing) and temporal (time step), the calculation options.

3.2
calibration
process of adjusting modelling parameter values of the scientific computing tool

Note 1 to entry: Calibration improves agreement between the calculated values and the reference values.

3.3
greedy algorithm
algorithm that follows the problem-solving heuristic of making the locally optimal choice at each stage

Note 1 to entry: In many cases, a greedy strategy does not produce an optimal solution, but a greedy heuristic can yield locally optimal solutions that approximate a globally optimal solution in a reasonable amount of time.

3.4
heat flux
rate at which thermal energy is transferred through a unit area of surface

3.5
heat source (numerical)
spatial and temporal numerical distribution of the thermal energy transferred to the weldment by the welding process

3.6
numerical simulation
implementation of one or more SCTs, with calculation schemes and input data, to produce numerical results describing the evolution of a physical situation

3.8
power density
amount of thermal power absorbed or generated per unit volume

3.9
scientific computing tool (SCT)
software for numerical simulation of physical phenomena

Note 1 to entry: An SCT can consist of one or more solvers and include pre- and post-processors

Note 2 to entry: SCTs use computational methods to solve science and engineering problems.

Note 3 to entry: Refer to Annex A for technical specifications of SCTs.

3.10
reference scientific computing tool
scientific computing tool (SCT) for which the predictive performance is considered to be superior to that expected of the scientific computing tool to be validated

3.11
scope of utilization
situations and scenarios studied using the SCT for CWM

3.12
spatial discretization
distribution and type of the geometric units for subdividing the geometric model

3.13
temporal discretization
step size and number of time units for subdividing the duration being modelled

3.14
validation case
data set considered to be pertinent and selected for carrying out separate effects or integral validation of an SCT

Note 1 to entry: Data set can be experimental test, operating experience feedback, simulation using a reference scientific computing tool, analytical solution, etc.

3.15
validation experiment
experiment designed to validate the simulation results taking into account all relevant data and their uncertainty

3.16
validation file
document in which all the results of the validation of an SCT are inventoried

3.17
verification file
document in which all the results of the verification of an SCT are inventoried

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in Table 1 apply.

Table 1 — Symbols and abbreviated terms

Symbol or abbreviated term	Definition
2D	two dimensional
3D	three dimensional
CTE	coefficient of thermal expansion
CWM	computational weld mechanics
EBW	electron beam welding
FEA	finite element analysis
GMAW	gas metal arc welding
GTAW	gas tungsten arc welding
HAZ	heat-affected zone
PIRT	phenomena identification ranking table
PWHT	post weld heat treatment
QI	quantities of interest
SAW	submerged arc welding
SCT	scientific computation tool
SMAW	shielded metal arc welding
TIG	tungsten inert gas
WPS	welding procedure specification
WPQR	welding procedure qualification record

5 Principle

The thermomechanical numerical simulation of welding is mainly based on the finite element method. It consists of a WPS implemented in an SCT for CWM, pre- and post-processing tools, and verification and validation methods (see [18] and [19]).

The CWM problem is generally defined as a three-dimensional solid element model employing a moving heat source with simultaneous calculation of temperature, microstructure, displacement and stresses, utilizing time dependent elastoplastic constitutive law based on material properties ranging from room temperature up to the melting temperature.

It requires the geometric modelling of the part to be joined in the form of a mesh, the modelling of the initial and boundary conditions and the definition of materials behaviors. From the spatial and temporal discretization, the SCT allows the resolution of a heat transfer problem with transient heat source, with possibly the determination of metallurgical transformations and the thermomechanical calculation of residual stresses and distortions. The pre- and post-processing tools may be different from the SCT. However, it is the set of tools used for the intended studies that is the subject of the recommendations of this document.

6 Scientific Computation Tools (SCTs)

A SCT for numerical welding simulation has specific capabilities compared to conventional FEA software. The SCT shall enable the calculation of the quantities of interest for the intended scope of utilization with uncertainty values appropriate to the needs of the studies for intended use. The SCT shall enable the implementation solution of a CWM problem following all the recommendations of this document.

In order to follow all the recommendations of this document the SCT shall:

— create 2D and 3D meshes of single and multi-pass welded joints;

— visualize and export the quantities of interest;

— define and verify the heat source according to space and time coordinates;

— access to solver parameters of accuracy, convergence, numerical schemes in order to be able to carry out a spatial and temporal convergence study;

— simulate the spatio-temporal evolution of the temperature;

— simulate the phase transformations if any;

— couple thermomechanics with metallurgical effects, simulation of residual stresses.

The SCT should:

— simulate the addition of filler metal;

— activate and deactivate elements during a simulation;

— consider viscous and creep effects especially when PWHT is of concern;

— simulate the temperature and the cyclic behaviour of the materials, recovery effects, and transformation induced plasticity.

The SCT should use and have a library of:

— validated and verified material data;

— cases for verification and validation.

The user can also add their own data.

7 Required data for simulation

In order to ensure a representative modelling, the user shall have enough information on the way the welding was carried out that may be obtained from a welding book, from the description and qualification of the welding procedures specifications (WPS) or production report.

The user shall have access to the following:

— fabrication procedure records, detailing how the structure was constructed;

— design / construction drawings defining the nominal component geometry and dimensions;

— weld groove geometry (from drawings or WPS);

— weld procedure information, type of process, heat input per unit length of weld (welding voltage, current and welding speed, deposit flow rate, type of cover gas, filler metal, welding position, number and arrangement of passes, their trajectory, their sequence as well as the requirements for finishing and root passes, and buttering. The characteristics of external clamping devices, interpass and pre and post temperatures requirements;

— applied mechanical restraint;

— basic materials data from test certificates (or specifications);

— plant survey data characterising the constructed weldment geometry and dimensions (actual dimensions, distortion effects, root penetration, presence of cap etc.);