COMPUTER MODELING OF INNOVATIVE WELDED JOINTS

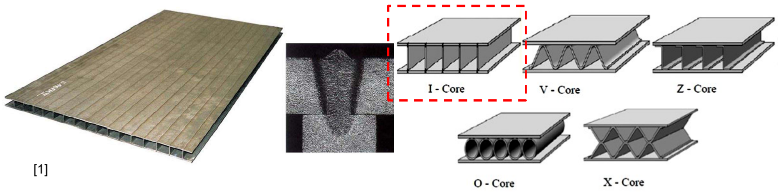
Zbigniew SATERNUS, Tomasz DOMAŃSKI, Marcin KUBIAK

Faculty of Mechanical Engineering and Computer Science
Department of Mechanics and Fundamentals of Machine Design
ul. J.H. Dąbrowskiego 73, 42-201 Częstochowa, Poland

zbigniew.saternus@pcz.pl, tomasz.domanski@pcz.pl, marcin.kubiak@pcz.pl

POLITECHNIKA Czestochowa University of Technology

International Exhibition of Innovation IEI 2023



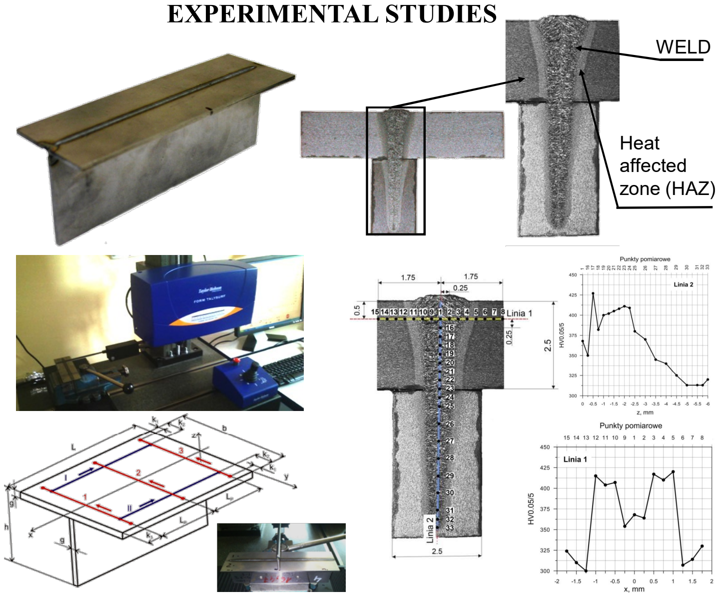
[1]

Implementation of laser welding technology has contributed to the search for new, innovative design solutions, reducing the manufacturing time and costs of production with unchanged mechanical properties of the joint. Obtained in laser welding process, one of the modern welded constructions are sandwich panels of different types, depending on the shape of the stiffening element. In the laser butt-welding process of sandwich panels the beam penetrates the outer surface of the faceplate joining it with a stiffening core. The main issues in these joints are welding deformations affecting the final deformation of the entire large-scale construction.

This work concerns numerical modeling of laser welding of T-joints, made of S355 steel. Numerical analysis of thermomechanical phenomena is performed in ABAQUS FEA engineering software. Additional, author's subroutines are implemented in designed three dimensional model using Fortran programming language. Developed subroutines describe the distribution of volumetric laser beam heat source power, the kinetics of phase transformations in solid state as well as isotropic strain generated by the temperature field and structural strain during heating and cooling of welded steel. Laser welded T-joints are performed on Yb:YAG laser in order to verify the results of numerical simulations. Characteristic zones of the cross section of the joint are compared to numerically predicted geometry of fusion zone and heat affected zone. Numerically predicted displacement in chosen sections of the joint is compared to real displacement, measured using profilographometer New Form Talysurf 2D/3D 120.

[1] Kristensen J.K., *State of art in shipbuilding applications of hybrid laser-arc welding*, Force technology, Denmark

EXPERIMENTAL STUDIES



Deformation measurements scheme

Hardness measurements

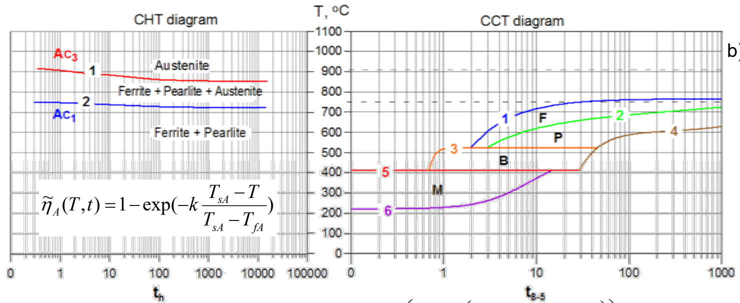
THERMAL ANALYSIS

$$\int_V \rho \frac{\partial U}{\partial t} \delta T \, dV + \int_V \frac{\partial \delta T}{\partial x_\alpha} \cdot \left(\lambda \frac{\partial T}{\partial x_\alpha} \right) dV = \int_V \delta T \, q_V \, dV + \int_S \delta T \, q_S \, dS$$

MECHANICAL ANALYSIS

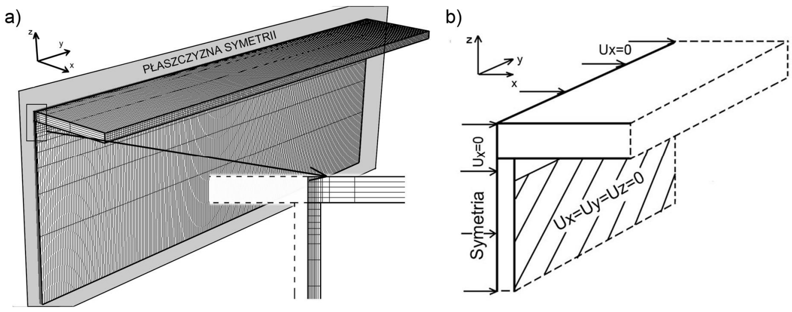
$$\nabla \circ \dot{\boldsymbol{\sigma}}(x_\alpha, t) = 0, \qquad \dot{\sigma}_{ij} = \dot{\sigma}_{ji} \quad \dot{\boldsymbol{\sigma}} = \mathbf{D} \circ \dot{\boldsymbol{\varepsilon}}^e + \dot{\mathbf{D}} \circ \boldsymbol{\varepsilon}^e, \quad \boldsymbol{\varepsilon} = \boldsymbol{\varepsilon}^e + \boldsymbol{\varepsilon}^p + \boldsymbol{\varepsilon}^T$$

PHASE TRANSFORMATIONS

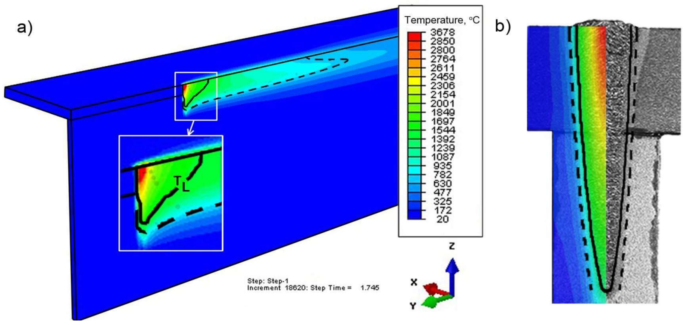


$$\tilde{\eta}_A(T,t) = 1 - \exp\left(-k \frac{T_{sA} - T}{T_{sA} - T_{fA}}\right)$$

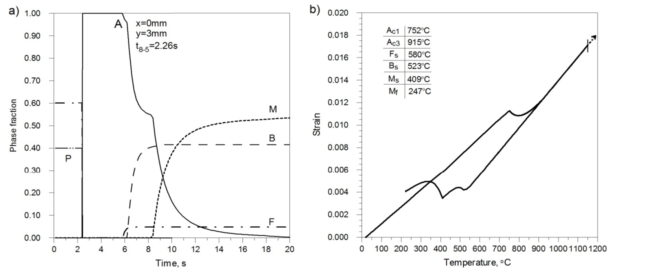
$$\tilde{\eta}_i(T,t) = \eta_{()}^{\%} \tilde{\eta}_A \left(1 - \exp\left(-k \frac{T_s^i - T}{T_s^i - T_f^i} \right) \right) \qquad \tilde{\eta}_M(T) = \eta_{()}^{\%} \tilde{\eta}_A \left(1 - \exp\left(-k \left(\frac{M_s - T}{M_s - M_f} \right)^m \right) \right), T \in [M_s, M_f(v_{8/5})]$$



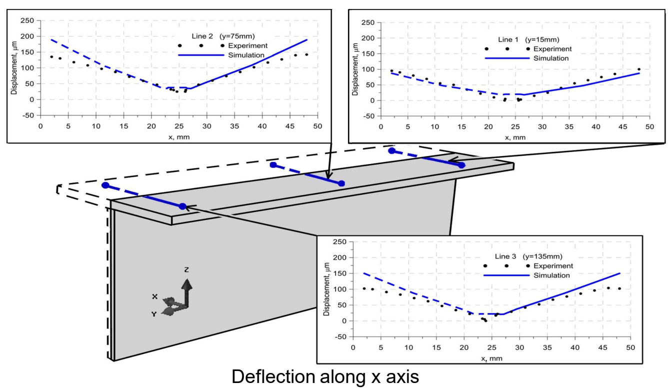
In order to reduce computational time, symmetry of the joint is assumed in calculations taking into account appropriate boundary conditions in the plane of symmetry.



Temperature distribution in T-joint: a) temperature profile, b) comparison of temperature distribution in the cross section of the joint with the real weld.



Calculated a) isotropic strain and b) corresponding kinetics of phase transformations for a chosen thermal cycle placed in the middle of T-joint.



Deflection along x axis

Department of Mechanics and Fundamentals of Machine Design
ul. J.H. Dąbrowskiego 73, 42-201 Czestochowa
tel. +48 34 325 06 20, e-mail: sekretariat.kmpkm@pcz.pl