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MATHEMATICAL MODELLING OF YB:YAG LASER BEAM CAUSTICS USED IN WELDING PROCESS

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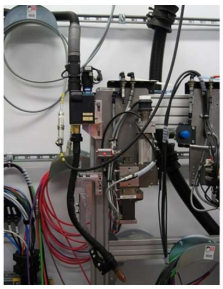
Mostly used lasers in the industry are CO2 lasers and solid state lasers. Solid state disk type YAG lasers with ytterbium-doped gain medium are currently top advanced lasers, characterized by low optical quantum defect and a high efficiency. Yb:YAG laser is used in welding process as a single heat source as well as a hybrid heat source, with accompanying electric arc or a second laser beam (so called dual beam processing).

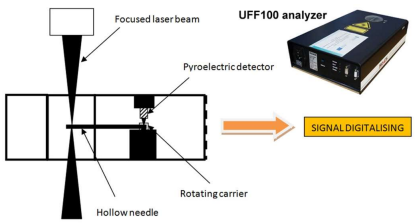
Lot of theoretical studies concern modelling of TEM00 Gaussian lasing profiles. However, prior works showed the extensive difference between the real Yb:YAG laser profile and theoretical gaussian-like laser profile. Previous works show also that laser beam power distribution decreases with increasing depth of material penetration in the function of welding speed. These facts contributed to the development of interpolated heat source model in this study on the basis of kriging interpolation for Yb:YAG laser beam as well as analytical models.

This work presents 3D model of thermal phenomena occurring during welding process of butt-joints made of S355 steel with liquid material flow in FZ taken into consideration. Numerical Chorin's projection and finite volume method (FVM) are used to solve continuum mechanics equations for determination of temperature distribution in the joint and fluid flow in Fusion zone. Numerical algorithms assume effective heat capacity with latent heat of fusion and latent heat of evaporation taken into account. Yb:YAG laser beam heat source is modelled using kriging method. Measurements of Yb:YAG laser intensity for different beam focusing are taken into account in heat source model. Experimental research is performed in Research Network ŁUKASIEWICZ – Welding Institute. Welding tests and measurements of energetic properties of laser beam are made using Trumpf D70 laser head equipped with disk laser TruDisk 12002. Elaborated theoretical models with numerical solutions are used to predict FZ geometry and HAZ geometry in butt-welded plates. Computer simulations are partially verified by results of real welding tests.

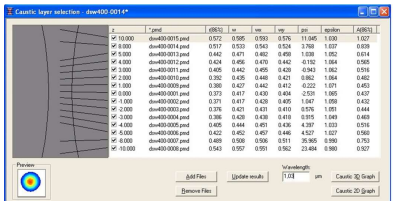
EXPERIMENTAL RESEARCH

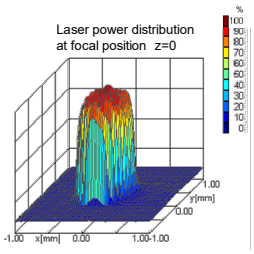


Welding station - laser head



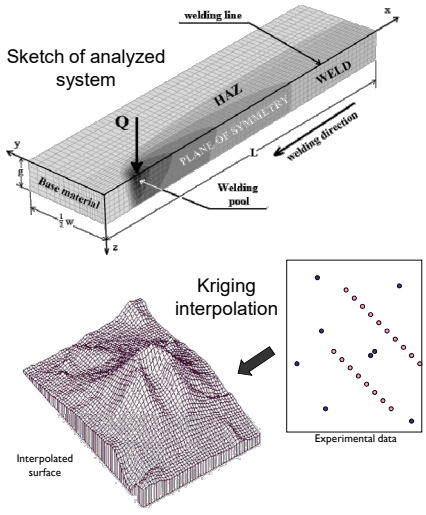
Prometec UFF100 laser beam analyzer – sketch on the measurement of laser beam profile





Laser beam power distribution and beam caustic visualizations

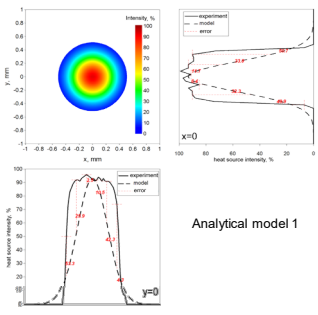
MATHEMATICAL STUDY AND NUMERICAL MODELLING



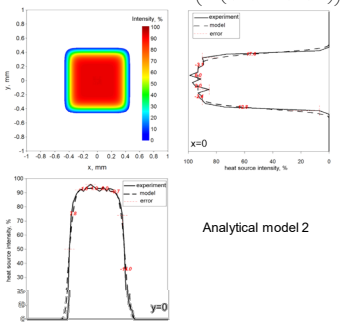
Comparison of different heat source models

$$q(x,y)=\frac{\eta 2P}{\pi\omega_0^2\left(1-\exp(-\alpha L)\right)}\exp\left(-\frac{2r^2}{\omega_0^2}\right)$$

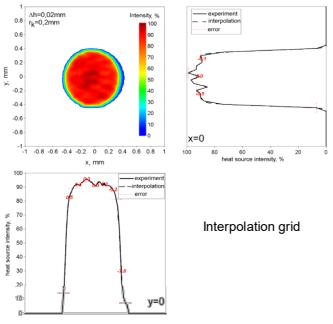
$$q(x,y)=\frac{\eta 2P}{\pi\omega_0^2\left(1-\exp(-\alpha L)\right)}\exp\left(-2\left(\left(\frac{x}{\omega_0}\right)^{n1}+\left(\frac{y}{\omega_0}\right)^{n2}\right)\right)$$



Analytical model 1

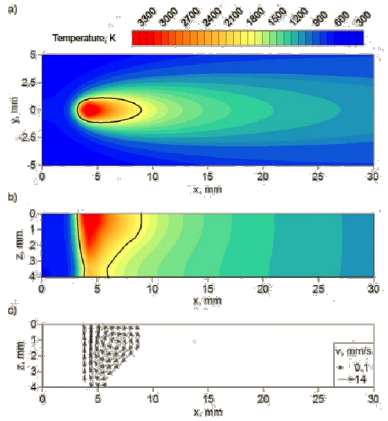


Analytical model 2

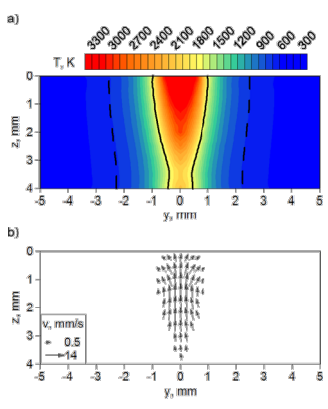


Interpolation grid

Computer simulations of a) temperature field and b) melted material velocity field

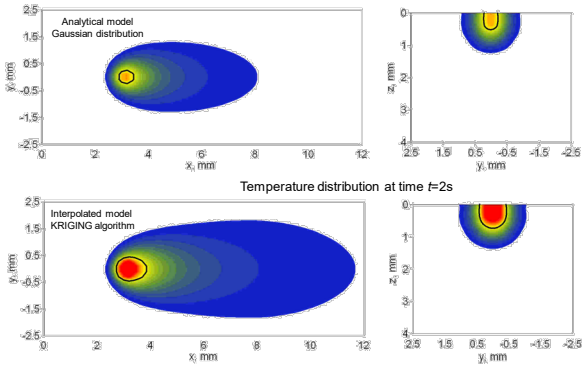


Top surface and longitudinal section



Cross section

Difference between temperature distribution for analytical heat source power distribution and interpolation model based on experimental research



Temperature distribution at time t=2s

Process parameters: Q=900 W, v=3 m/min, r=0.45 mm, λ=35 W/mK, ρ=7800 kg/m^3, c=650 J/kgK, α=50W/m^{2}K, T_0=300 K

Flat dimensions: 250x20x4 mm

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