Simulation of the Additive Process of Forming 3D Products from HSLA Steel 09G2S

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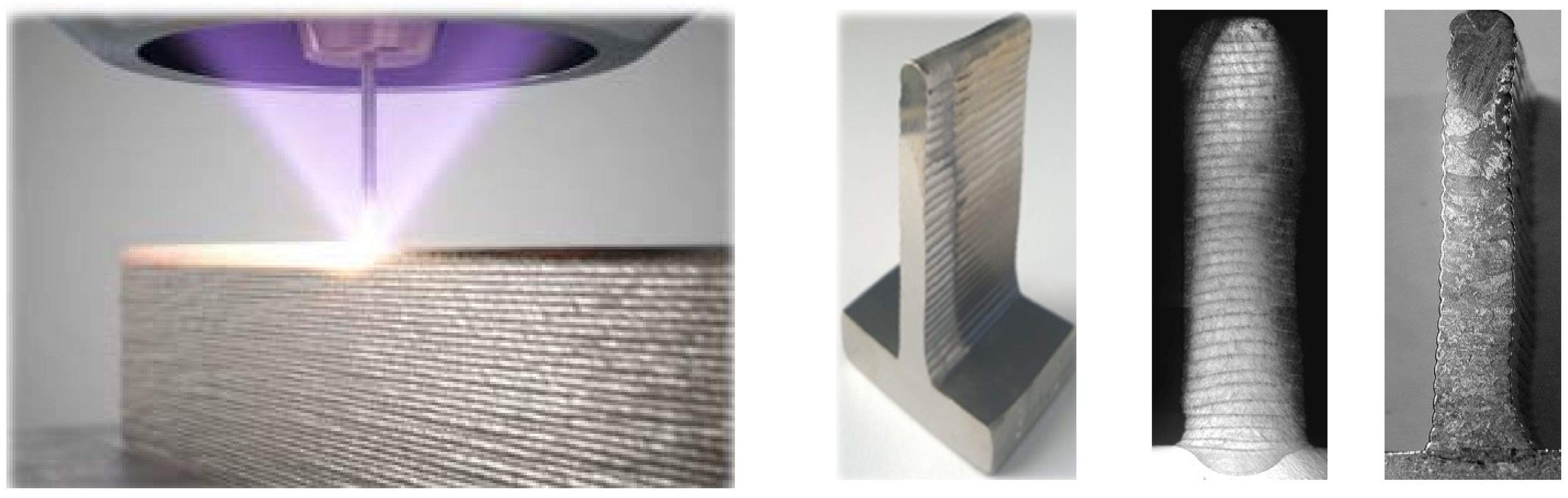
Introduction: Additive technology is a new high-performance metallurgical method for structures development in current engineering. Using wire additive technology have higher efficiency than additive powder methods. They have higher energy efficiency, high material utilization rate, provide larger mass productivity. At the same time, non-uniform fields of temperatures, stresses and deformations are formed in the technologies using a wire [1, 2]. High residual stresses and deformations appearing in deposition of metallic wire should be considered. They can significantly reduce performance characteristics of the products.

Aim of the work lies in optimizing the parameters of additive process of layer-by-layer formation of 09G2S steel billet based on calculation of temperature fields, stresses and strains forming in deposition.



a b

Figure 1. Electron beam surfacing (a) and structure of surfacing (b)

Computational Methods: It was assumed that the additive process is a process of successive deposition of liquid metal droplets. To simplify model it was assumed that the drops are the elements of regular shape 1x3x1 mm size. To simulate the additive process the interfaces Heat Transfer, Solid Mechanics, Geometry Deformed were used. Control equations were used for numerical analysis of kinetics of change of temperature, stress and deformation in the deposited layers:

$$\rho C_p\left(\frac{\partial T}{\partial t}+u\cdot\nabla T\right)=\nabla\cdot\left[k(T)\nabla T\right] \qquad \rho\frac{\partial^2 u}{\partial t^2}=\nabla\cdot(F*S)+f_{vol}$$

boundary conditions

$$k(T)\frac{\partial T}{\partial n}=\begin{cases} h(T-T_{ext}) \\ \text{in zone of contact with substrate} \\ h(T-T_{ext})+\varepsilon\sigma_o(T^4-T_{ext}^4)-q_{arc}-q_{wire} \\ \text{on free surfaces}\end{cases}$$

q_{arc} – heat flux from arc; q_{wire} – heat flux from wire

Mesh geometry for wall and ring

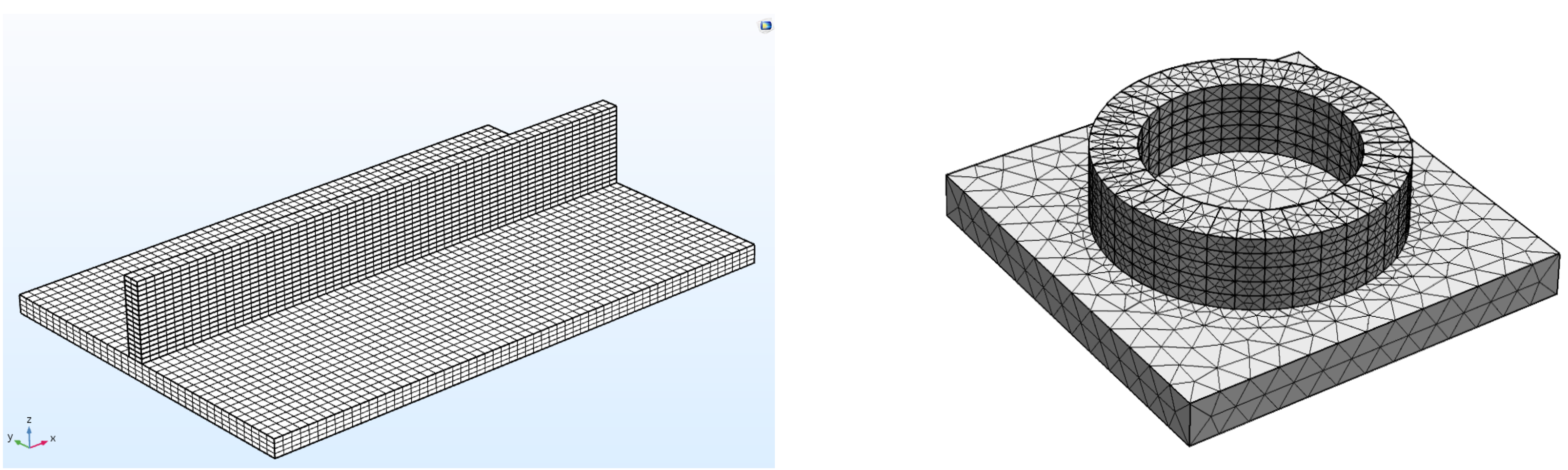


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Figure 2. Mesh geometry

Results: The results of numerical experiments were used for calculation of temperature, von Mises stresses, deformations and displacements field at each moment of time at subsequent depostion of additive layers.

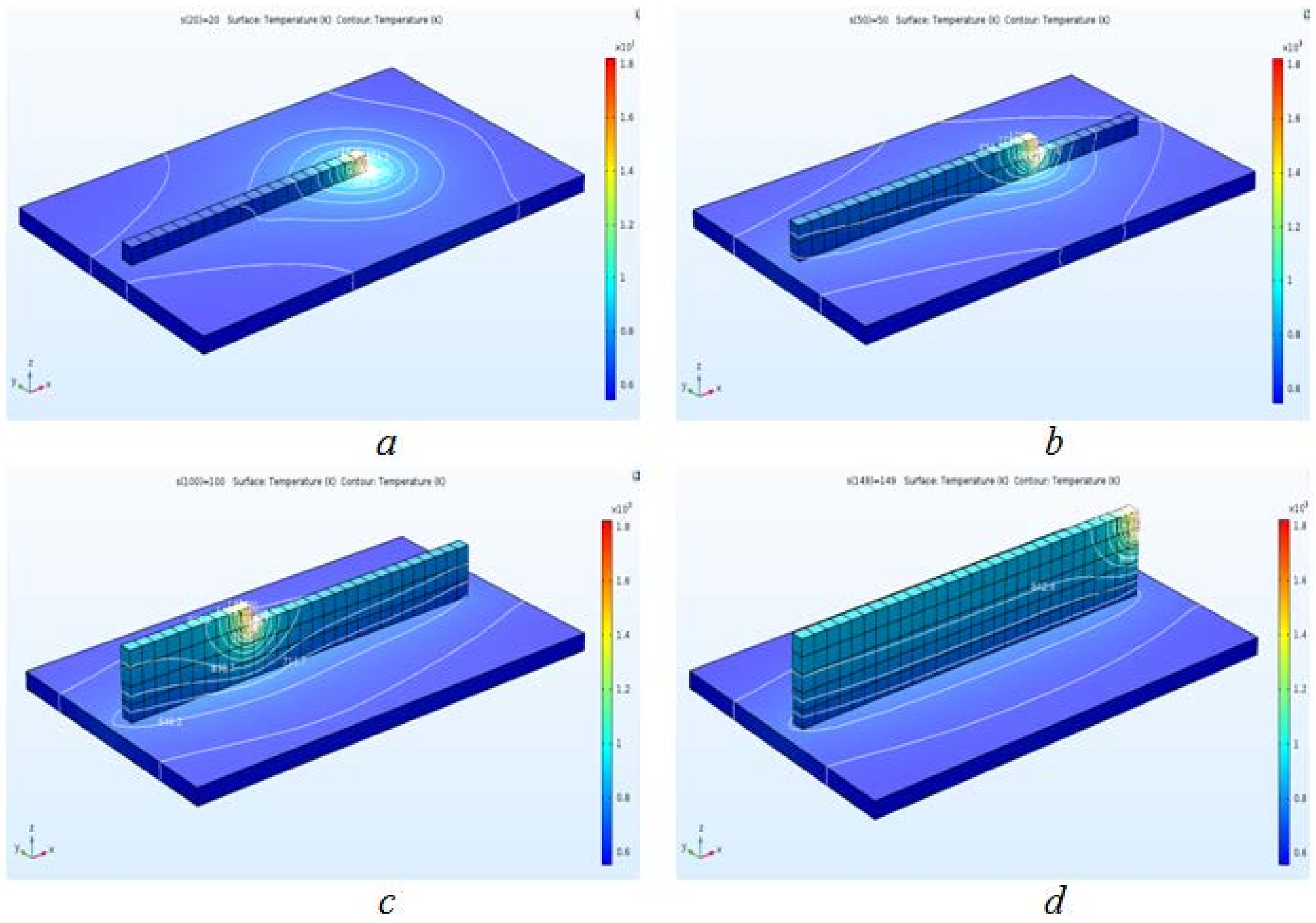

Figure 3. Kinetics of change of temperature fields in time: a – 20 s, b – 50 s, c – 100 s, d – 149 s.

Analysis of the results of modeling showed that the level of stresses at additive layer/substrate boundary varies from 280 to 320 MPa, and relatively small (< 50 MPa) at the boundaries of additive layers.

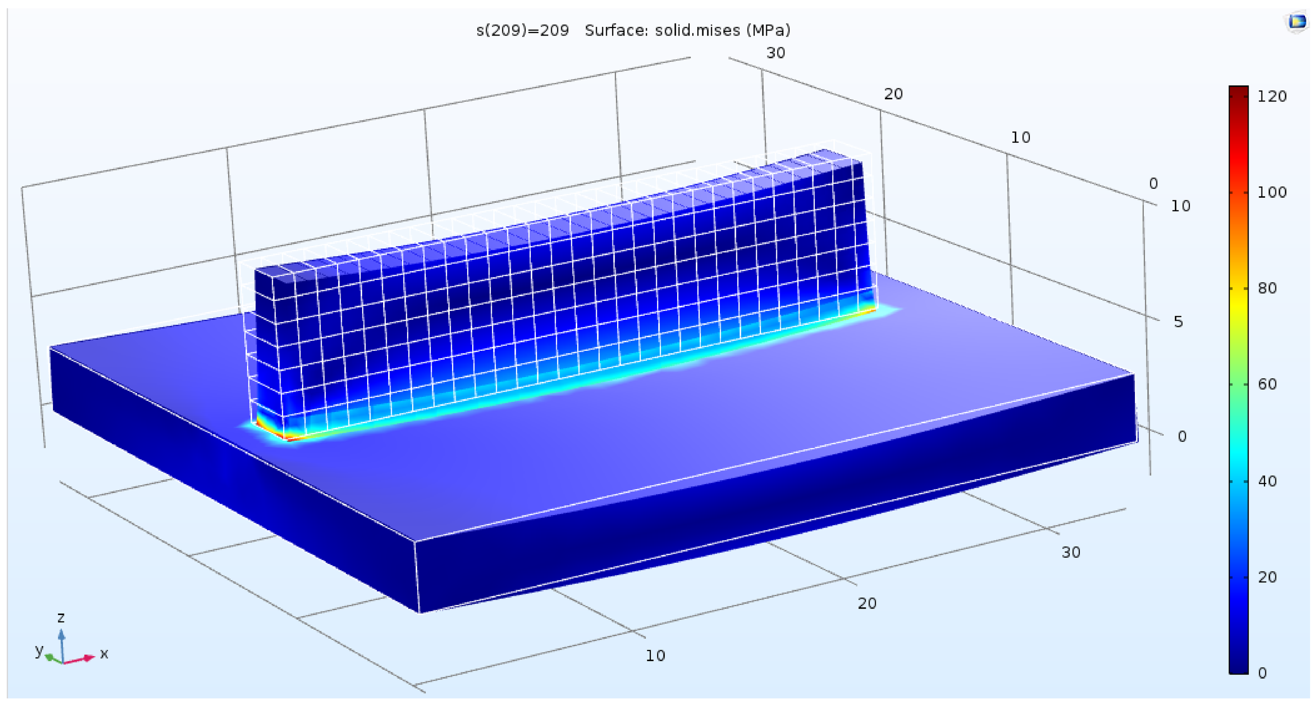

Figure 3. Stresses in deposition of 7 additive layers

Conclusions: The highest level of residual stresses and deformations is reached at the boundary of first layer and substrate and makes 280 - 320 MPa in additive deposition of steel 09G2S on the substrate. Stresses between the deposited layers are significantly lower (up to 50 MPa). It is determined that increase of number of deposited layers provokes gradual rise of the level of stresses at additive layer/substrate boundary and in time does not depend on number of the deposited layers. The stationary deposition mode is reached after 7-8 layers deposition.

References:

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2. Grigirenko G. M., Zhukov V.V. and Shapovalov V.A. Additive manufacturing of metal products (Review), The Paton Welding Journal,No.5-6, pp.137-142,(2016)