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Resistance Welding Simulation

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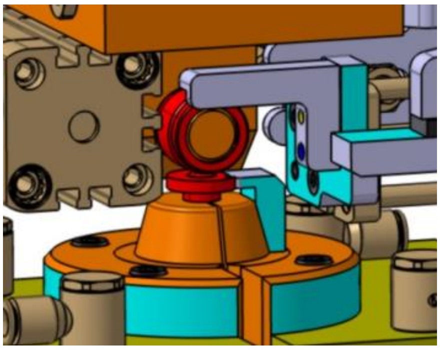
Abstract. Simulation of technological processes are very useful for the assessment of its parameters. Conveniently chosen parameters can do process more effective, economic and results more quality. This contribution deals with the simulation of resistance welding process. The simulation is carried out for the welding of the rod and connecting-rod for car shock-absorber. The aim of this simulation is to show the methodics of coupled thermal-electric analysis and the temperature dependency of material constants is taken into account.

Introduction

Simulation of technological processes are very useful for the assessment of its parameters. Conveniently chosen parameters can do process more effective, economic and results more quality. This contribution deals with the simulation of resistance welding process. The simulation is carried out for the welding of the rod and connecting-rod for car shock-absorber, see Fig. 1. The aim of this simulation is to show the methodics of coupled thermal-electric analysis and the temperature dependency of material constants is taken into account. The welded parts are manufactured of the carbon steel C40.



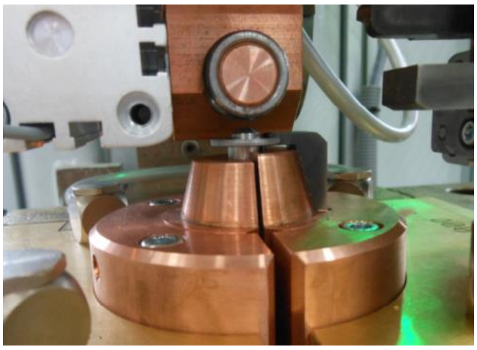


Fig.1: The rod and connecting-rod on welding press – CAD model and real situation, [1]

Temperature dependency of material constants

In case of welding the material is exposed to a large range of temperatures (from 20°C to melting point approx. 1500°C). Thus, the temperature dependency of material constants such as modulus of elasticity, thermal conductivity or electrical resistivity should be taken into account. The temperature behaviour for modulus of elasticity can be seen in Fig. 2. There is evident decrease of the modulus of elasticity round the temperature 700°C, which corresponds to the crystal structure change from ferrite to austenite.

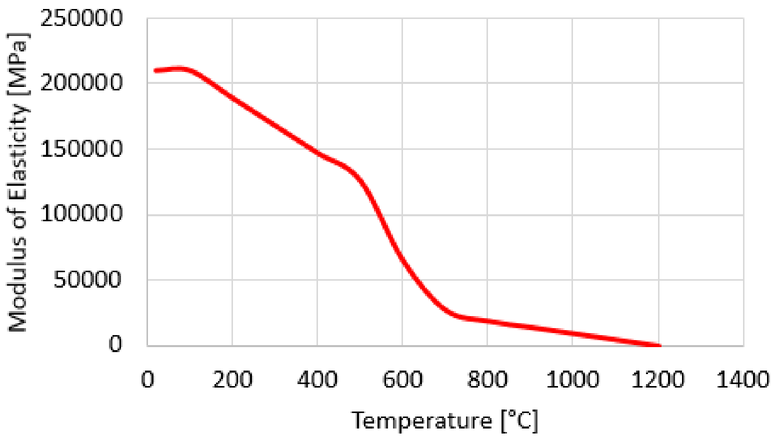


Fig. 2: Temperature behaviour of modulus of elasticity (steel C40), taken from [2]

Analytical verifications

Some subtasks of complete thermal-electric analysis with mechanical loading are carried out independently and they are verified by analytical calculations, for example stationary heat transfer with electrical heat source. The heat power P and the volumetric heat source $\dot{Q}$ is defined by the Eq. 1 and Eq. 2 respectively.

$$P = RI \quad (1)$$

$$\dot{Q} = \frac{P}{V} \quad (2)$$

R is the electrical resistance, I is the current and V is the volume of the part. One-dimensional analysis of the electrical heating of the block is performed and it is compared with FEA results. The schema of this verification including the boundary conditions can be seen in Fig. 3

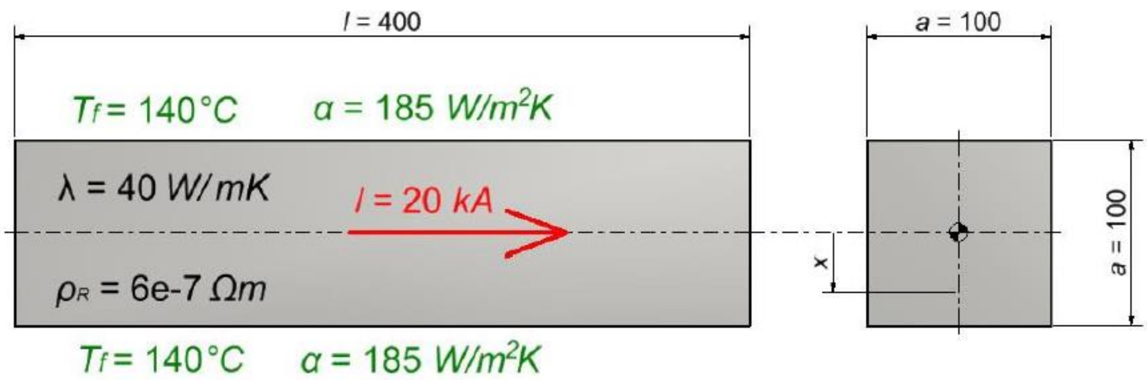


Fig. 3: The schema of the verification example, [1]

The heat flow is described by the Fourier heat equation in Eq. 3

$$\lambda \frac{d^2T}{dx^2} + \dot{Q} = 0 \quad (3)$$

Where λ is the thermal conductivity of the material. The result equation for the temperature follows.

$$T(x) = T_f + \frac{\dot{Q}}{2\lambda}\left(\frac{a}{2}\right)^2\left[1 + \frac{4}{Bi} - \left(\frac{2x}{a}\right)^2\right] \tag{4}$$

T_f is the outer temperature and a is the transversal dimension of the block. The Biot number *Bi* is defined as follows, α is the heat transfer coefficient.

$$Bi = \frac{\alpha a}{\lambda} \tag{5}$$

The FEA was performed and obtained results (maximum and minimum temperature) were compared, see Table 1.

Table 1: Comparison of analytical and FE solution

Quantity	Analytical solution	FEA	Ratio
T_{max} [°C]	863.6	863.6	1.0
T_{min} [°C]	788.6	788.6	1.0

Further subtasks, such as non-stationary heating by the passage of electric current and non-stationary analysis of free cooling, were performed and verified by analytical solution.

Simulation model

Simulation model is created in *FEM* software *Abaqus CAE*. The assembly of the rod and connection-rod and derived FE model is shown in Fig. 3. The hexagonal finite elements for space deformations, electric potential and temperature Q3D8 are used.

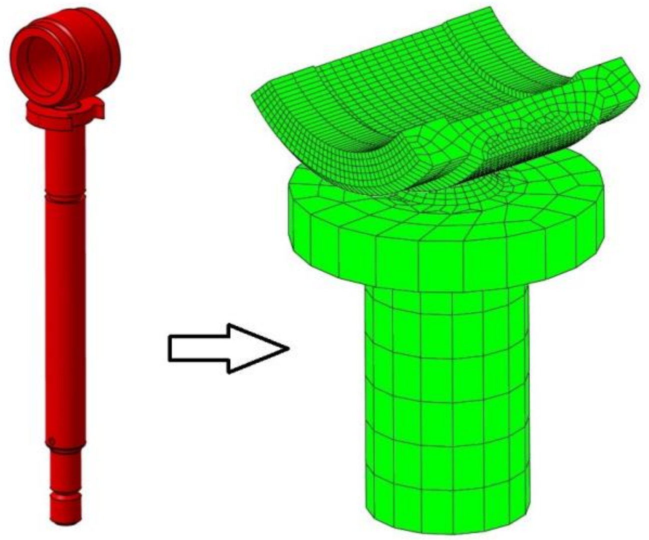
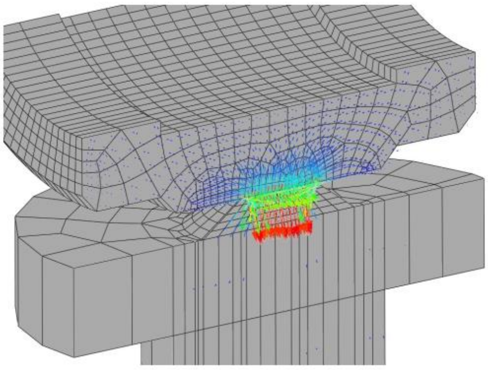


Fig. 3: The assembly of the rod and connection-rod and derived FE model, [1]

The rod and connection-rod are coupled by the *Surface to Surface Contact* and they are pressed to each other in *Static, General Step*. For the combination of thermal-electric analysis and mechanical loading (pressing of both parts to each other) the *Coupled Thermal-Electrical-Structural Step* is used, [3]. The temperature dependent data for steel C40 are used. The current is modeled as alternating with frequency *50 Hz*. Thus the direction of the current density is oscillating as can be seen in Fig. 4.



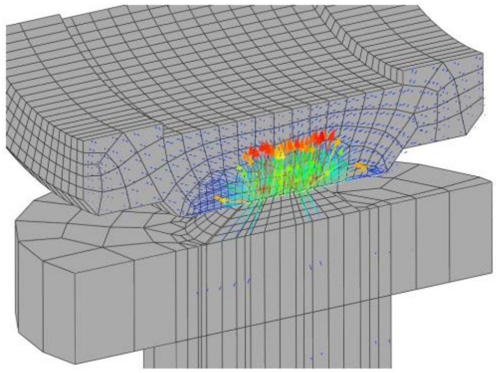


Fig. 4: Oscillating current density, time *t=0.005 s* (left) and time *t=0.015 s* (right), [1]

The maximum contact pressure at time *t=0 s* is $\sigma_{t=0}^{max} = 3140\ \mathrm{N/mm^2}$ and at time t=0.54 s $\sigma_{t=0.54}^{max} = 1820\ \mathrm{N/mm^2}$. That is the result of decreasing material stiffness due to the temperature. The result thermal field is shown in Fig. 5.

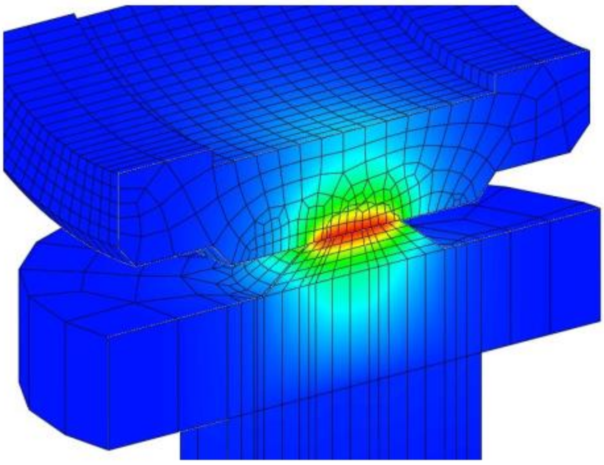


Fig. 5: Result thermal field in welded parts, [1]

Results and conclusions

Specialized software is usually used for this kind of simulations. This contribution shows the methodics for simulation in non-specialized engineering software *Abaqus CAE*. The simulation also gives the general information about required welding parameters for quality welds such as pressure, current and time. Because of the large temperature range, the necessity of temperature dependent material model is shown.

Acknowledgements

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