Approaches for Coupled Numerical Simulation of High Frequency Tube Welding Process

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ABSTRACT

For the production of tubes made of steel (ferritic or austenitic) or steel coated with zinc or aluminium as well as made of aluminium, brass, copper or zinc, various welding technologies are used in industry. The longitudinal seam welding of tube can be done by the use of high-frequency (HF) resistance (conductive) heating or inductive heating.

The HF induction welding is effected by a ring shaped or profiled inductor, which includes the tube and induces a high frequency current into it. The current passing the strip edges heats the material with an increasing temperature towards the welding spot. The welding itself is now here effected without any additional material by pure pressure from upsetting rolls.

Welding processes and installations used nowadays are mainly based on practical experience and analytical calculations because suitable numerical simulation approaches are developed not enough.

High frequency induction tube welding is a very complex three-dimensional dynamic process, where the electromagnetic and thermal characteristics, like current density, induced power density and temperature are distributed not only in space but in time as well. The electromagnetic-thermal process parameters are depending on the geometry of the inductor, impeder and in particular on the tube (e.g. wall thickness, incoming angle etc.), the operation parameter, like total power, inductor current, frequency, welding feed etc. and finally also on the material data like electrical conductivity and other, which are temperature dependent or in case of magnetic permeability temperature and magnetic field strength dependent.

All of these influence factors and physical correlations have to be taken into account for the design and optimization of the HF induction tube welding process. Therefore a more profound detailed investigation of the induction tube welding process can be only done by numerical modelling. In order to simulate the three-dimensional (3D) “quasi” steady state and if necessary transient mode of an induction tube welding system, special numerical models are required. The models must simulate the heating process distributed in space and in time. That is why the models of induction tube welding must be based on special algorithm providing a time loop additionally to coupling between electromagnetic and thermal analysis.

The 3D transient numerical model of the induction tube welding process with continuous movement has been developed according to the created algorithm. For numerical simulation the continuously running physical welding process is replaced by big enough number of time steps. Electromagnetic and thermal analyses are carried out at each time step of simulation. The Joule heat distribution in the tube, calculated in the electromagnetic analysis, is used as an excitation for the thermal one at the running time step. Temperature dependent electro-physical material properties are corrected for electromagnetic analysis at the running time step according to temperature distribution in the tube after the previous time step. Thermal analysis includes simulation of thermal losses by convection and radiation from all open surfaces of the tube.