Electric Resistance Welding Process in Tube Manufacturing: Comparison Between a Numerical Model and a Set of Plant Trials

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Abstract

In welded tube manufacturing, the electric resistance welding (EW) process begins with a coiled plate of steel with appropriate thickness and width to conform the produced tube. The strip is pulled through a series of rollers that gradually cold conform it into a tubular shape. The edges of the cylindrical plate come together forming a V. The strip edges are heated with a high frequency power source, both using contact electrodes or magnetic induction coils. The edges weld properly when they come into contact at a temperature slightly higher than the melting point.

Due to the many geometric variables involved and to the complexity of the related physical phenomena, it is very difficult to characterize the EW process. Nevertheless, the effect of the geometric variables on the process productivity and efficiency, and on the weld quality, is very important.

In the current plant operation, the values of these variables are determined by trial and error. To better understand the influence of these parameters and to contribute to their optimization, a numerical model which simulates the heating previous to the welding was developed using COMSOL Multiphysics® software. As a first approach, this model only solves the initial electromagnetic problem using the AC/DC Module, and neglecting the non-linear behavior of the steel.

With the idea of validating these simplified model, we performed a set of in-plant-trials. As it is not possible to modify the geometric variables in the actual process, where the strip enters the welder at high velocity, an alternative approach is used. In it, the heating is performed statically on a geometry that reproduces both the shape of the strip prior to welding and the obtained tubular shape, through a tube where a V-shaped section is cut. In each trial, the heating of the V edges is carried out using an induction coil meanwhile the temperature evolution of selected tube sections is registered using thermographs. Both the V angle and the V length (distance between the apex and the coil) are varied between trials, and for each geometric configuration a correspondent numeric simulation has been made. Considering the heating rate as a proxy of the trial process, its dependency with the selected variables is compared with the square of the surface current of the COMSOL model.

In general, taking into account the simplifying assumptions adopted and regardless the adjusting factor between the matching variables, the agreement between the measurements and the simulations is quite good. Particularly, main heating features are the following.
In the zone between the apex and the coil:
the heating rate is more efficient when the V is longer.
the heating rate is optimal when the V angle is between 4.1 and 4.6º.
the simulations show that the heating rate enlarges when approaching the coil, while the measurements present a behavior independent of the distance to the apex.
In the opposite zone to the coil:
the accomplished heating rate is lower, and diminishes with the distance to the apex both in the measurements and the simulations.
the dependency with the V angle is almost null.