Temperature field evolution during flash-butt welding of railway rails

L. Weingrill, J. Krutzler and N. Enzinger

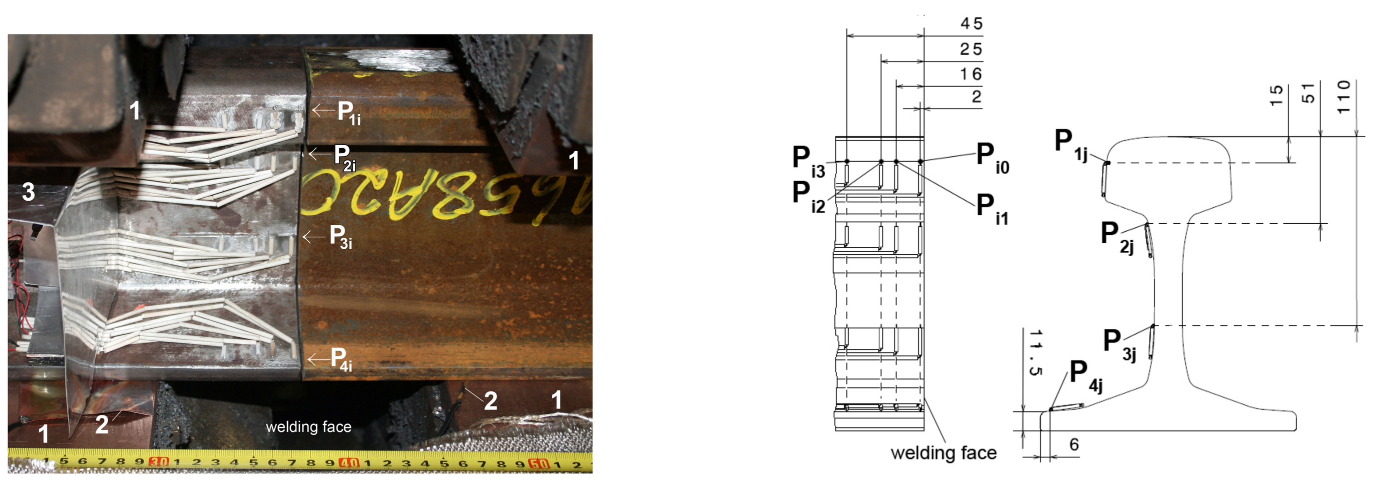
Institute of Materials Science and Welding, Graz University of Technology. Austria

INTRODUCTION & OUTLINE

Flash Butt Welding (FBW) is today the most commonly used joining process for railway rails. Rail steel properties have been improved over the last decades towards higher strength and better resistance against wear and rolling contact fatigue (RCF) [1, 2]. Welding can essentially deteriorate properties of the rails in the heat affected zone (HAZ) and thus contribute to undesirable reduced life-time of railtracks [3]. Temperature evolution T(t) has a major impact on the properties of rail weld joints, as it drives the phase changes in the weld metal and HAZ. This work seeks to deepen process knowledge for FBW of rails with a focus on the temperature evolution in the proximity of the weld joint. The goal is to support optimization of welding parameters.

WORK CONTENT & RESULTS

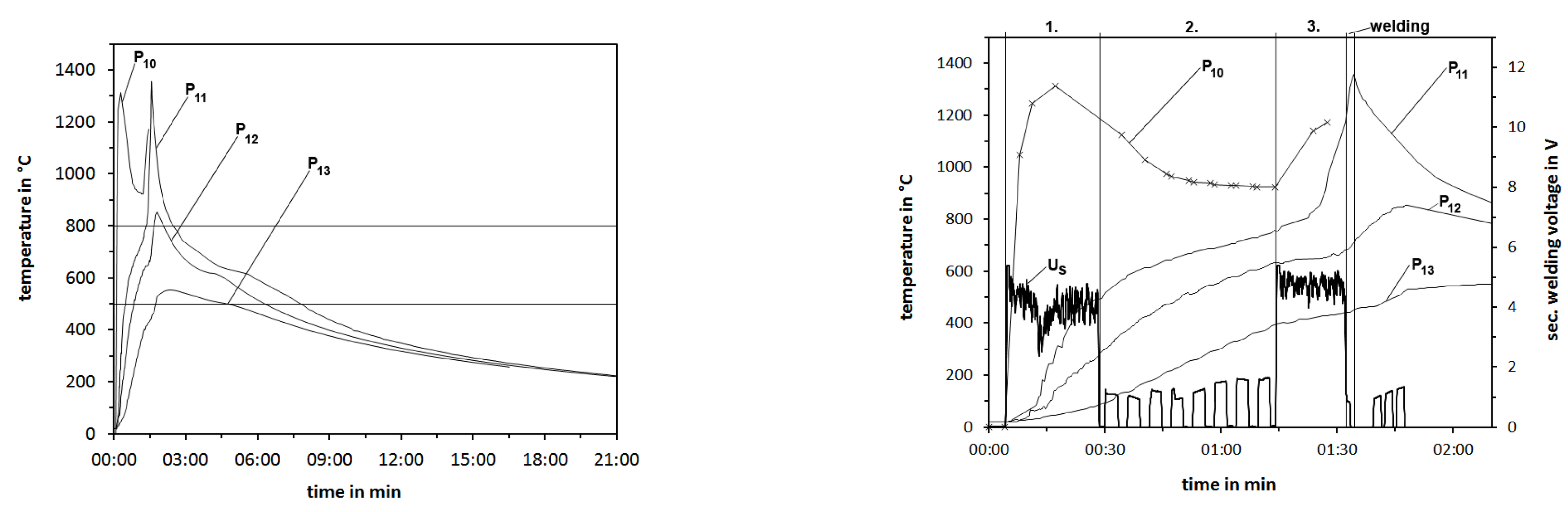
Experimental. Instrumented samples of 60E1 R260 rails – acc. to [4] – were used for the experiments on a stationary FBW welding machine at standard parameters and under industrial conditions. T(t)-curves were captured by the use of thermocouples on the surface of the rail. The secondary welding voltage U_S was simultaneously measured.



(a) (b)

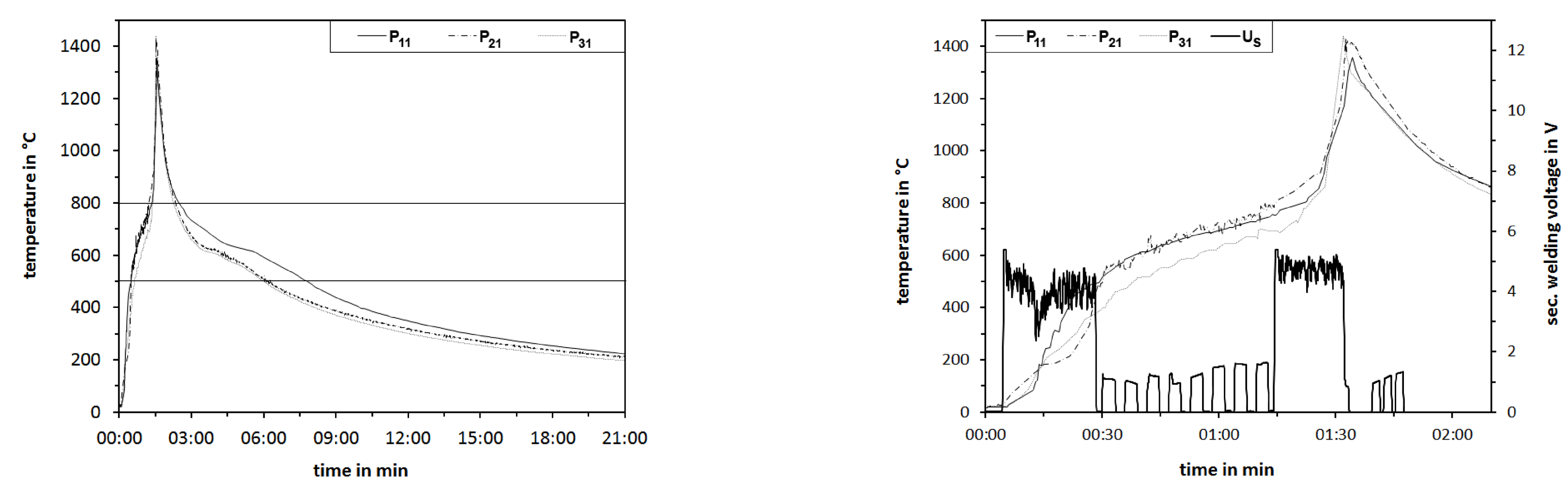
Figure 1: (a)... instrumented rails. (b)... measuring positions and labelling.
1... welding electrodes 2... U_S-measuring 3... protection cover thermocouples.

T(t)-curves in *figure* 2 depict the temperature evolution at the rail head. By overlaying U_S(t) in *figure* 2 (b) the characteristic temperature evolution for the three stages of the heating phase – *1. plane flashing*, *2. pre-heating*, *3. flashing* – can be identified. In *figure* 3 the temperature evolution closest to the welding face is depicted. Differences in the heating phase and faster cooling rates, as well as higher T_{max} at the web of the rail can be derived.



(a) (b)

Figure 2: T(t)-curves at the rail head. (a)... entire welding sequence.
(b)... heating-phase in detail. U_S... secondary welding voltage.



(a) (b)

Figure 3: T(t)-curves closest to the welding face. (a)... entire welding sequence.
(b)... heating-phase in detail. U_S... secondary welding voltage.

Numerical. The FEM-model from SYSWELD is depicted in *figure* 4. A 3D-electrokinetic-thermally strong coupled calculation is used for the simulation. The transition resistance between the welding faces and material properties of R350HT rail steel are implemented as $f(T)$. A simplified U_S(t) at one pair of electrodes is applied, while the voltage at the other pair of electrodes is held constant zero. Phase changes are calculated based on an implemented CCT-diagram of the R350HT rail steel. Numerical results are compared to experimentally retrieved T(t)-curves in *figure* 5.

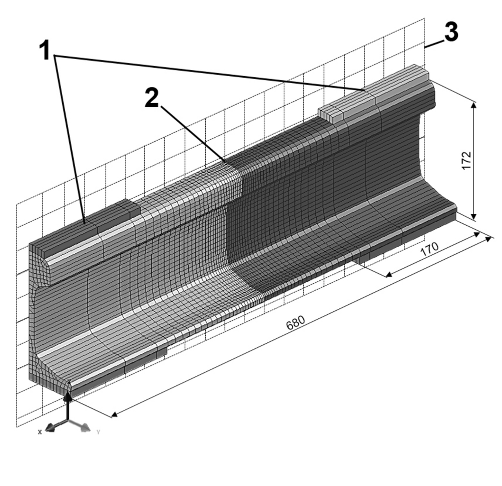


Figure 4: SYSWELD FEM-Model.

1... welding electrodes
2... welding face transition resistance R_T
3... symmetry plane

T(t)-curves in figure 5 are taken from the FEM-model at the same upright postion at the rail head (P_{1i}). Distances from the welding face thereby are: 11mm, 16mm, 30mm and 47mm.

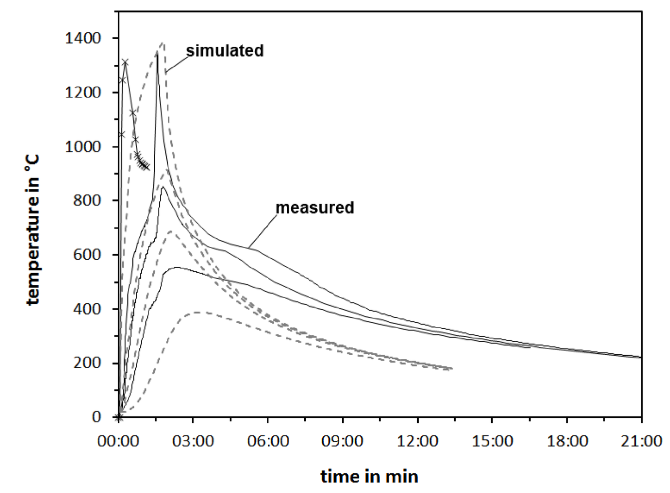


Figure 5: Experimental vs. numerical T(t)-curves at rail head.

CONCLUSIONS

The temperature evolution and related U_S(t) at each stage of the heating phase are understood as a result of complex thermo-physical interactions due to the rails' specific geometry and varying contact conditions at the welding face in the heating phase and during welding.
Experimental and numerical results were within the same range. However, the accuracy of the simulation results was not good enough to depict the intended aspects. Planned optimizations of the simulation include: optimization of the model for R_T(T) and the cooling parameters, implementation of a coupled mechanical FE-calculation to depict the upsetting. Furthermore an enhanced metallurgical model – with focus on the pearlitic transformation– is being implemented.

ACKNOWLEDGMENT & REFERENCES

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