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Professional Paper

SIMULATION OF THE IMPACT OF PREHEATING TEMPERATURE ON RAILWAY ALUMINOTHERMIC WELDING

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Abstract

For more than a century, railway rails have been joined using the aluminothermic welding process. The flexibility, compactness of the weld, and ease of execution are all advantages of this process. It is not necessary to use external energy to finish the operation. It is provided by the exothermic effect of the chemical reactions of the elements of the aluminothermic combination. The design of the mold with the pouring system, which should ensure even pouring of thermal steel, without turbulence, then even heat dissipation or cooling in order to obtain an appropriate micro and macro structure of steel, free of internal and external defects, is an important factor in producing a welded joint of the required quality. As a result, the design of the mold was continually developing, necessitating the adoption of expensive experimental approaches in industrial settings. To eliminate costly and time-consuming industrial experiments, software applications are being employed to imitate traditional casting methods that can be used in the casting of thermite steel during the fabrication of welded railway connections. This study presents a simulation of casting thermite steel in the mold cavity, i.e., in the weld joint, for the 49E1 rail using the NovaFlow & Solid CV software package

Keywords: aluminothermic welding, simulation modeling, Novacast, welded joint, preheating influence.

Introduction

Using Casting simulations for classic casting technologies is an innovative approach that basically simulates the filling of a mold with metal, as well as its hardening, and gives the possibility of simulating the production of castings. The simulation approach, in any event, saves manufacturing costs and optimizes the technical casting process (Delić et al., 2022). Most commercial casting procedures, as well as the termite steel casting method for aluminothermic rail welding (NovaCast, 2015), may be simulated. The simulation depicts the effects of various inflow routes and feeding systems. Defects in castings such as macro and micro inclusions owing to excessive turbulence, cold joints, shrinkage, and porosity may be prevented by improving the design of the input system and gas vents (Ravi, 2008; Ravi, 2010; Delić et al., 2018; Delić et al., 2019).

The simulation program's primary input data is a 3D CAD model for creating molds. The fundamental parameters of the aluminothermic process, such as thermite steel and mold properties, as well as heat transmission characteristics of the metal, sand mold, pouring temperature, and so on, are then entered into the software. Output data includes animated visualizations of mold filling, thermite steel solidification, and further cooling to room temperature. Total filling time, mold erosion, partial filling, and gas entrapment may all be predicted using mold filling simulation. The temperature and cooling rate in the casting solidification simulation are used to forecast the location of shrinkage porosity based on Niyama and other criteria. It is also possible to model further cooling to room temperature, which is important for forecasting microstructure, mechanical characteristics, residual stresses, and curl.

This study shows how to utilize casting simulation in aluminothermic welding to bypass the way of practical trial and error, particularly how different preheating times and temperature distribution influence casting. By optimizing the design of the ingate system, feeders, and ventilation, casting problems such as oxide inclusions caused by excessive turbulence, undercooling, shrinkage, and slag inclusions may be prevented.

Materials and Methods

The steel used for simulation is commercial railway steel R260 or EN 1.0623 and the type of rails are 49E1. The chemical composition is presented in Table 1, while some other thermal characteristics are presented in Table 2.

Table 1. Chemical composition of steel that is used as an input into NovaCast database

Element mass%								
C	Si	Mn	P	S	Cu	Sn	V	Al
0.54	0.35	1.07	0.025	0.20	0.11	0.001	0.11	0.31

Table 2. Thermal casting characteristics of the steel used according to the NovaCast database

Liquidus Temperature, °C	1478.6	Solidus Temperature, °C	1401.5	Eutectic Temperature, °C	1139.9
CLF up %	70.0	CLF down %	45.0	CLF press%	35.1
Qcr kJ/kg	172.6	Qet kJ/kg7	235.7		

Simulation set up.

The simulation is carried out using the software program NovaFlow& Solid CV (Novacast business, Sweden) (NovaCast, 2015). The finite volume method was utilized instead of the finite element method. The model is divided into small hexagons (cubes) and edge cells by altering the network parameters, resulting in a mathematical approximation that fully conforms to the original model. In such instance, the size of the cells is no longer as important, hence larger cells could be used (total number of cells 495261). The four perspectives of the model are presented in Figure 1.

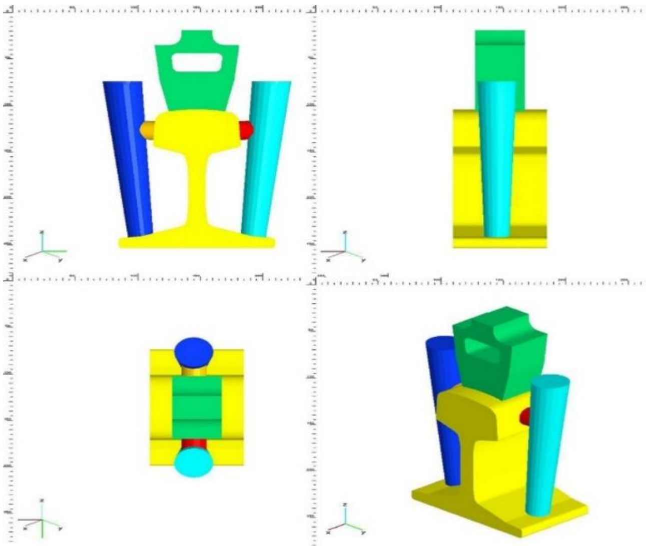


Figure 1. Casting model from the front, side, top, and angle perspective

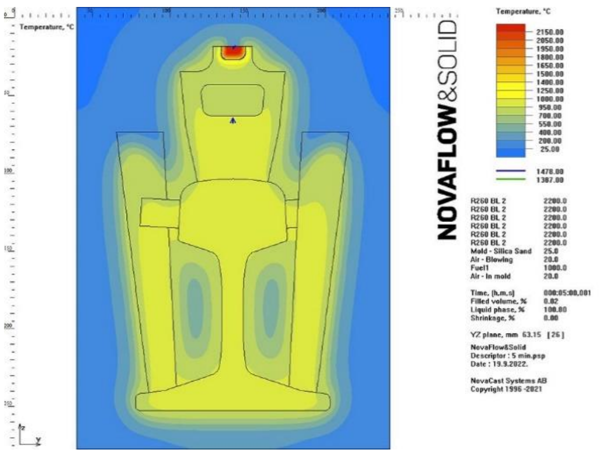
The model shown in Figure 1 consists of six elements: the rail canting (bright yellow), ingate system, and feeders (red, dark yellow, blue, and teal). The one and only gating point was placed at the center of the uppermost part of the ingate system. The molten metal flow was injected in a circle of 10 mm in diameter. Gravity casting was chosen for the filling parameters with a pressure height of 300 mm, making the flow 1.149 kg/s. The overall casting mass was calculated to be 5.370 kg and the casting temperature was set at 2200 °C. The shrinkage model was set at a high gravity influence, with a standard 83% gravity influence coefficient. In the solver setting option, conversion, gas at filling, bubble formation, and turbulence were all taken into account for quasi-equilibrium model calculation without segregation. In all simulations, the surface heat transfer model was taken into account.

Simulations were conducted with the preheating option turned on. Here the mold material (silica sand) is set to the room temperature of 25 °C while the cavity medium (air) is heated with a burner (1000 °C) from the right side of the flow divider for 4 different times (300 s, 420 s, 510 s, and 600 s). The shape of the burner area is circular, 30mm in diameter, and the flow was set at 0.1 L/s, while the initial temperature of the cavity medium was 20 °C and its flow was set at 0 L/s. These conditions were chosen in an attempt to more accurately represent realistic conditions and temperature distribution since the flow divider is not present during preheating.

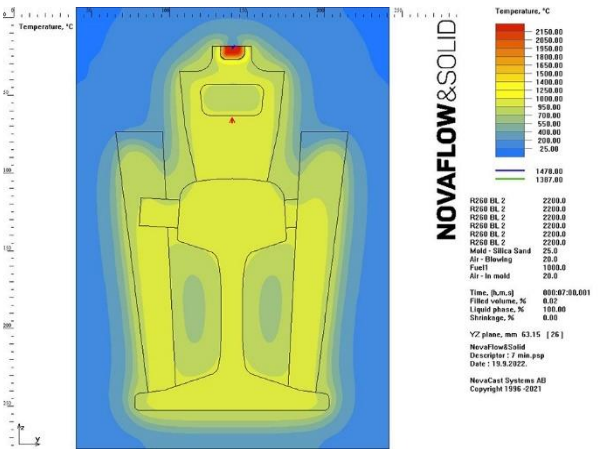
In the future, in order for the model to be closer to real conditions, two sets of solid steel rails will be added on each side of the casting mold. This way, the colling and heating temperature distribution will be improved. Furthermore, because the burner is typically located about 40 cm above ground, the temperature, diameter, and gas flow would be adjusted to accurately recreate these conditions.

Results and discussion

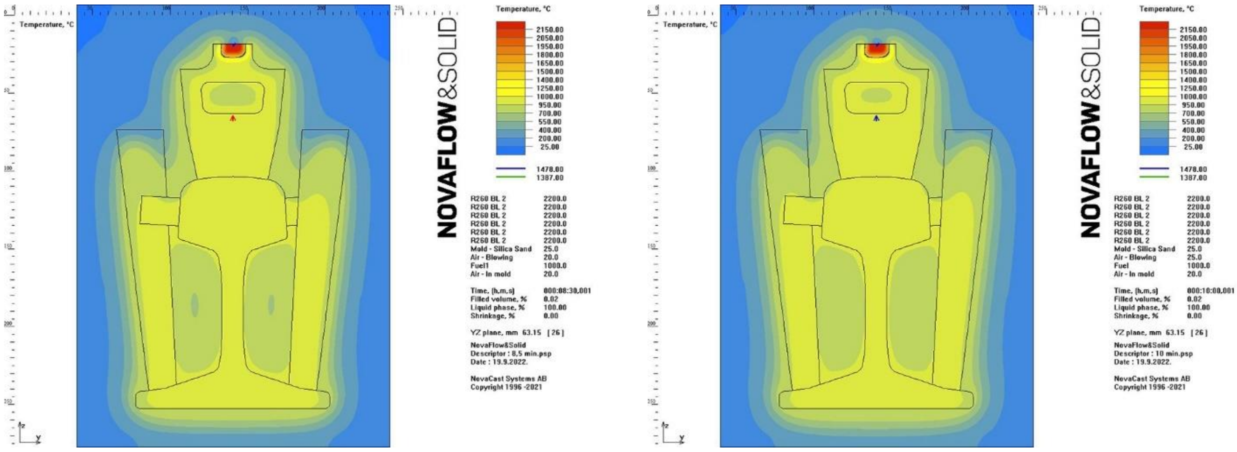
As it can be seen from Figure 2, the starting temperature distribution at the start of casting is heavily influenced by preheating time. This difference is still present at the end of casting (Figure 3), while it is negligible at the end of solidification (Figure 6).



(a)



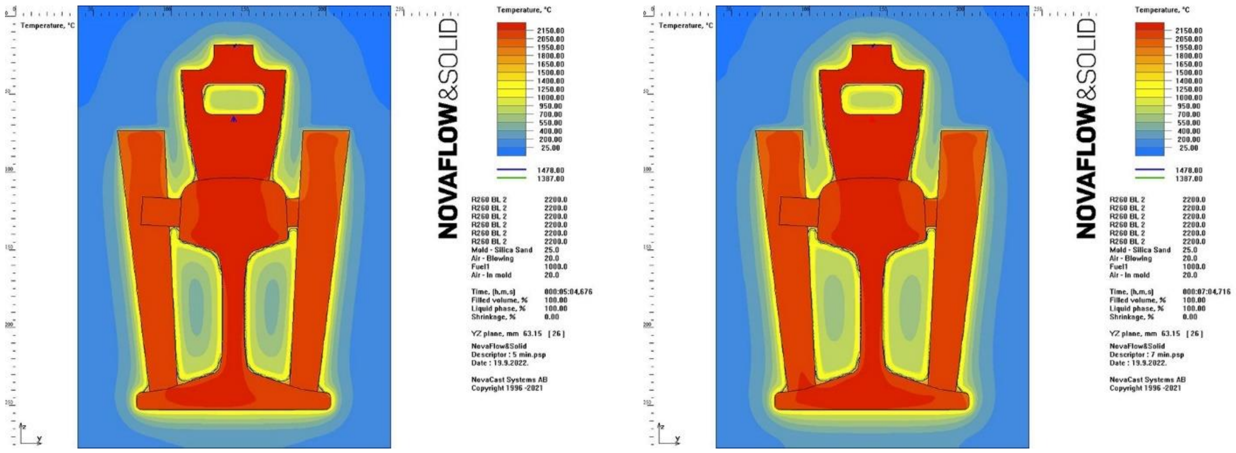
(b)



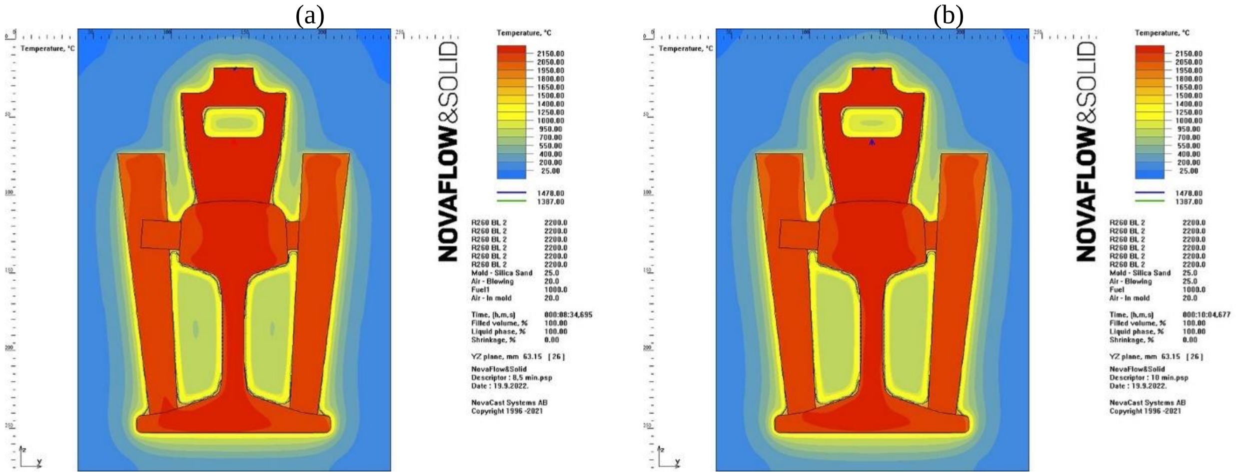
(c) (d)

Figure 2. Temperature distribution at the start of casing for diferent preheating times:
(a) 500 s; (b) 420 s; (c) 510 s ;(d) 600 s

The biggest differences in preheating times are evident in the sand mold heating that is between the rail canting and feeders. Clearly, at the lowest preheating time, the middle of that area is around 500 ºC and it rises with the increase of preheating time to 750 ºC. This same temperature distribution is maintained till the end of the casting shown in figure 3, with a maximum difference of a couple of degrees Celsius. It's also worth noting that the bottom edge of the rail has a cold spot.



(a) (b)



(c) (d)

Figure 3. Temperature distribution at the end of casing for different preheating times:
(a) 500 s; (b) 420 s; (c) 510 s ;(d) 600 s

Both Figures 2 and 3 show a cross-section of the casting model right in the middle of the x axis. However, in order to adequately show shrinkage (Figures 4) and local solidification time (Figure 5), the cross-section that divides the two feeders right in the middle is shown. The top arrows in figures 3 and 4 represent the gating point, while the bottom arrow represents the burner point, both of which are located in the center of the model. Since both figures 4 and 5 represent the end of solidification when the liquid phase reaches 0%, the same view point is kept for the temperature distribution at the end (Figure 6).

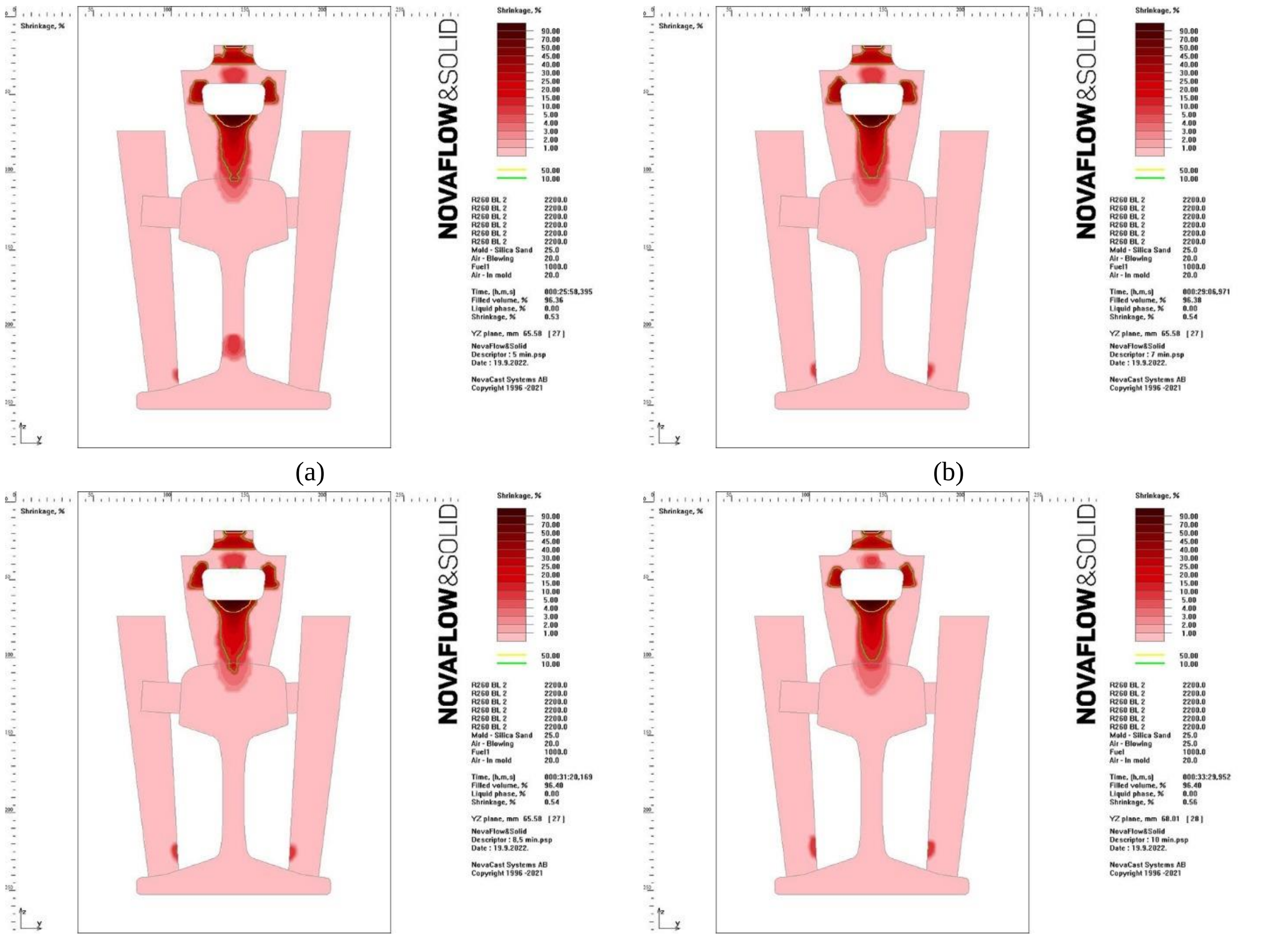
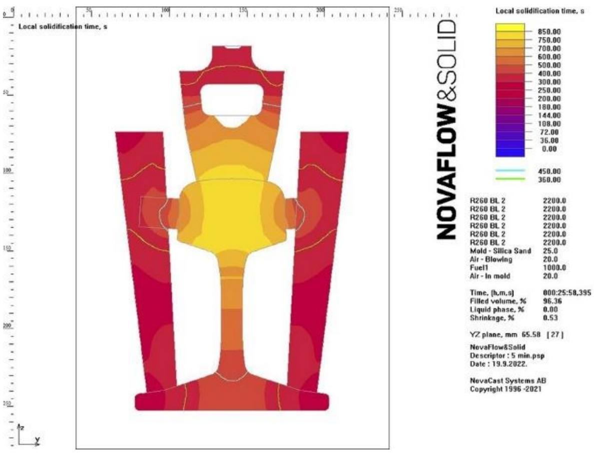
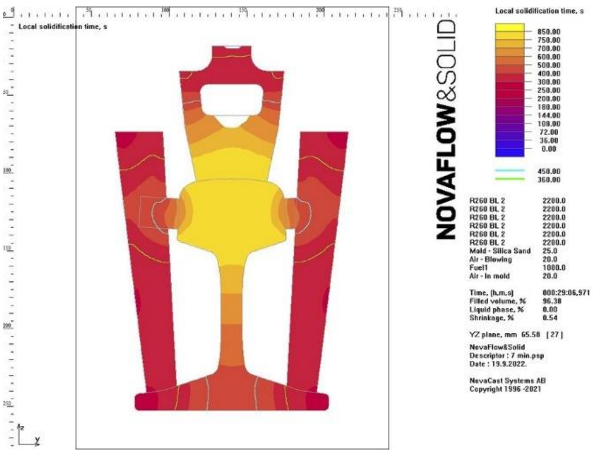


Figure 4. Shrinkage fields at the end of solidification for different preheating times:
(a) 500 s; (b) 420 s; (c) 510 s ;(d) 600 s

Shrinkage is considered one of the most important results from this simulation in regards to solidification. Most of the shrinkage is concentrated in the feeder that is also used as an ingate system. From figure 4 (a), it is clear that the preheating time of 5 min is inadequate since it causes shrinkage at the neck of the rail. This effect is absent from other preheating times, but at the bottom of the feeders it becomes more prevalent. The preheating time of 600 s is shown to be sufficient since it moves the feeder shrinkage away from the rail casting and the shrinkage in the ingate feeder above the rail head is minimized (Figure 4 (b)).



(a)



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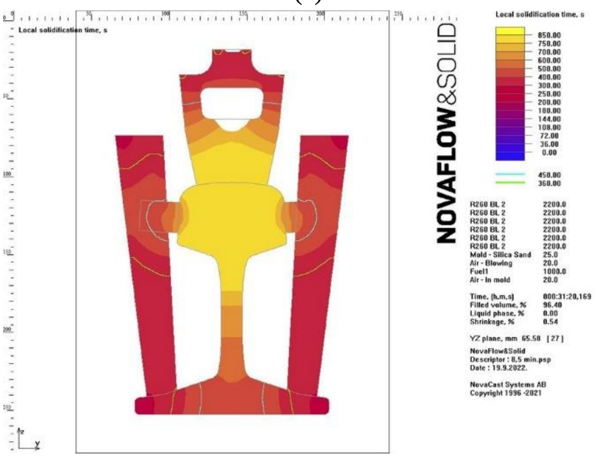
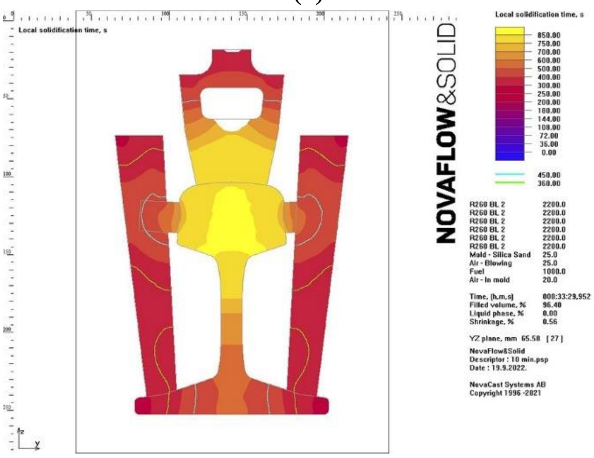


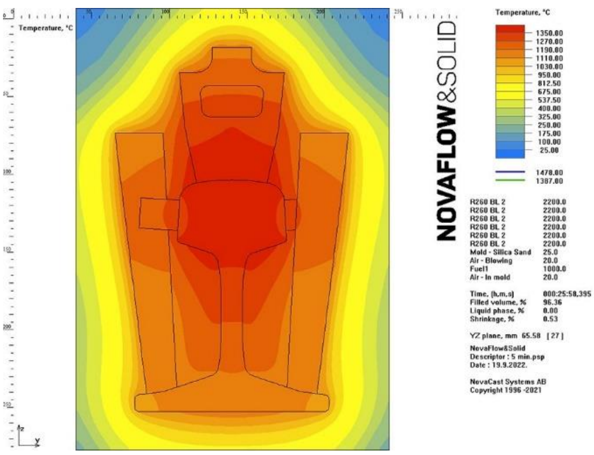
(c)



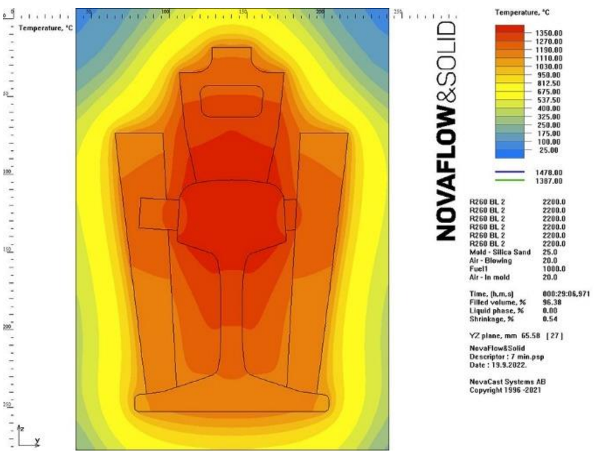
(d)

Figure 5. Local solidification times at the end of solidification for different preheating times: (a) 500 s; (b) 420 s; (c) 510 s ;(d) 600 s

If we observe the temperature distribution at the end of casting before solidification starts, we can see a direct correlation between figures 3 and 5. Local solidification time increases as preheating time increases. However, at the end of solidification, there is little difference in temperature distribution between preheating times as it can be observed in Figure 6. There is clear evidence of gas entrapment below the flow divider in both Figures 5 and 6, but this doesn't affect the quality of the rail casting since the ingate feeder will be removed.



(a)



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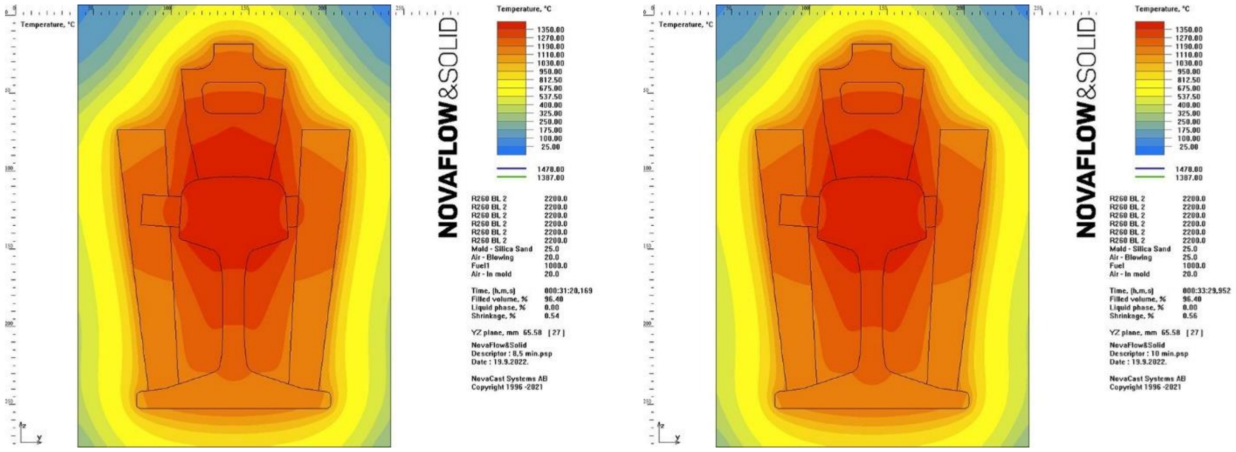

(c) (d)

Figure 6. Temperature distribution at the end of solidification for different preheating times:
(a) 500 s; (b) 420 s; (c) 510 s ; (d) 600 s

Conclusion

It was shown in this study that the software NovaFlow and Solid CV effectively simulate the aluminothermic process of railway rail welding and may considerably contribute to the optimization of the process's techno-economic parameters. The simulation showed that there is a considerable difference in shrinkage due to preheating temperature distribution. Preheating for 600 s showed the best results, which is similar to practical experience. It may also help to improve welded connection quality by anticipating defects in the seam and at the contact point of the extra and base material. Its suitability was shown by the manufacture of test welded joints that met the quality parameters defined by simulation in the program, in the particular example of welding the type 49E1 260 rails, avoiding the significant investment of producing a large number of test welded joints.

References

Delić, A. (2018). *Investigation of the relationship between the microstructure and properties of refractory austenitic steel HK30 modified with niobium in order to improve the properties at high temperatures* (Unpublished doctoral dissertation). University of Zenica, Faculty of Metallurgy and Technology, Zenica.

Delić, A., Oruč, M., Rimac, M., Gigović-Gekić, A. & Sunulahpašić, R. (2019). The influence of solution annealing on microstructure and mechanical properties heat-resistant cast Steel HK30 modified by Niobium. *Metallurgical and Materials Engineering*, *25*(3), 237–245. https://doi.org/10.30544/430

Delić, A., Manojlović, V., Sokić, M. & Gavrilovski, M. (2022). Optimization of mold design for aluminothermic welding of railway tracks by software simulation. *Tehnika*, *77*(3), 311–317. https://doi.org/10.5937/tehnika2203311D

Nova Cast Systems AB (2015). Nova Flow & Solid (6.0) [Computer software]. Nova Cast Systems AB.

Ravi, B. (2008). Casting simulation and optimization: benefits, bottlenecks and best practices. *Indian Foundry Journal*, *54*(1), 47. http://efoundry.iitb.ac.in/Academy/TechnicalPapers/2008/2008IFJ_CastingSimulation.pdf

Ravi, B. (2010). Casting simulation–best practices. *Transactions of 58th IFC, Ahmedabad*, 19–29. http://efoundry.iitb.ac.in/Academy/TechnicalPapers/2010/58thIFC-Ravi.pdf