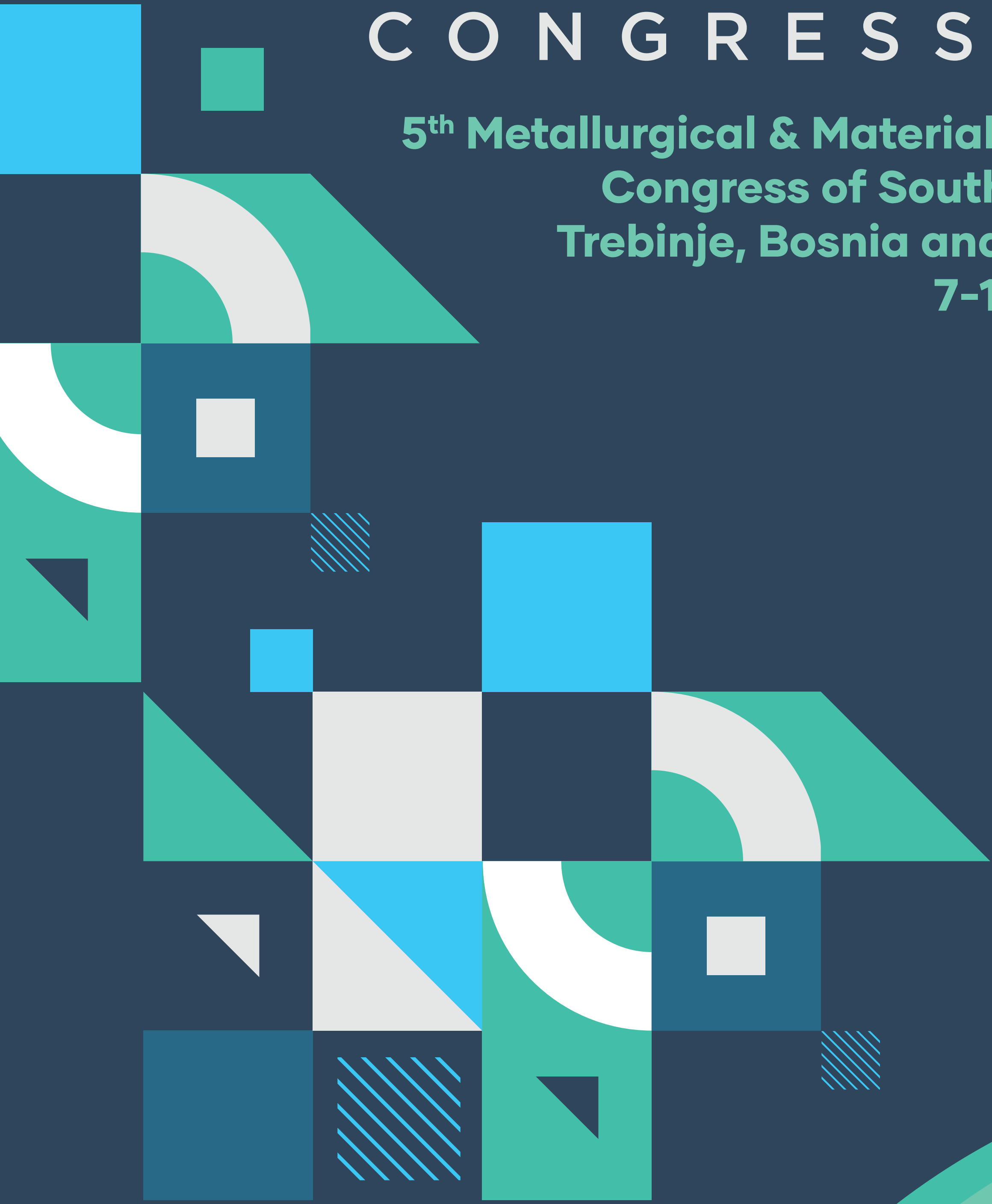
MME SEE
CONGRESS 2023

5th Metallurgical & Materials Engineering
Congress of South-East Europe
Trebinje, Bosnia and Herzegovina
7-10th June 2023



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PROCEEDINGS

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The Faculty of Metallurgy at the University of Zagreb in Sisak, Croatia;
The Faculty of Natural Sciences and Engineering at the University of Ljubljana, Slovenia;
The Faculty of metallurgy and technology at the University of Podgorica, Montenegro.

CONGRESS PROCEEDINGS - MME SEE 2023
5th Metallurgical & Materials Engineering Congress of South-East Europe

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PREFACE

On behalf of the Scientific and Organizing Committee, it is a great honor and pleasure to wish all the participants a warm welcome to the Fifth Metallurgical & Materials Engineering Congress of South-East Europe (MME SEE 2023) which is being held in Trebinje, Bosnia and Hercegovina, 07 - 10 June 2023.

The MME SEE 2023 is a biannual meeting of scientists, professionals, and specialists working in the fields of metallurgical and materials engineering. The aim of the Congress is to present current research results related to processing/structure/property relationships, advances in processing, characterization, and applications of modern materials. Congress encompasses a wide range of related topics and presents the current views from both academia and industry: Future of metals/materials industry in South-East European countries; Raw materials; New industrial achievements, developments and trends in metals/materials; Ferrous and nonferrous metals production; Metal forming, casting, refractories and powder metallurgy; New and advanced ceramics, polymers, and composites; Characterization and structure of materials; Recycling and waste minimization; Corrosion, coating, and protection of materials; Process control and modeling; Nanotechnology; Sustainable development; Welding; Environmental protection; Education; Accreditation & certification.

The editors hope that Congress will stimulate new ideas and improve knowledge in the field of metallurgical and materials engineering. The Congress has been organized by the Association of Metallurgical Engineers of Serbia, with the co-organization of the Institute for Technology of Nuclear and Other Mineral Raw Materials, Belgrade, Serbia, Faculty of Technology and Metallurgy, University of Belgrade, Serbia, Faculty of Technology, University of Banja Luka, Bosnia and Herzegovina; the Faculty of Metallurgy, University of Zagreb, Sisak, Croatia; the Faculty of Natural Sciences and Engineering, University of Ljubljana, Slovenia; and the Faculty of Metallurgy and technology, University of Podgorica, Montenegro.

Financial support from the Ministry of Science, Technological Development and Innovation of the Republic of Serbia to researchers from Serbia for attending the congress is gratefully acknowledged. The support of the sponsors and their willingness to cooperate have been of great importance for the success of MME SEE 2023. The Organizing Committee would like to extend their appreciation and gratitude to all sponsors and friends of the conference for their donations and support.

We would like to thank all the authors who have contributed to this book of abstracts and also the members of the scientific and organizing committees, reviewers, speakers, chairpersons, and all the conference participants for their support of MME SEE 2023. Sincere thanks to all the people who have contributed to the successful organization of MME SEE 2023.

On behalf of the 5th MME SEE Scientific and Organizing Committee

Miroslav Sokić, PhD

INFLUENCE OF MOLD PREHEATING ON RAILWAY ALUMINOTHERMIC WELDING CASTING SIMULATION

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Railway rails have been linked using the aluminothermic welding process for over a century. This method has several advantages, including flexibility, compactness of the weld, and ease of execution. It is not necessary to employ outside energy to complete the procedure. It is provided by the exothermic effect of the chemical reactions of the aluminothermic combination's elements. 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 the required quality welded joint. As a result, the mold's design was constantly evolving, necessitating the use of costly experimental procedures in industrial settings. In this iteration of the model the casting cavity was improved by adding hoes in the sand and putting rails on both sides in order to more aqurately simuate heat transfer. Software programs are being used to simulate conventional casting procedures that can be used in the casting of thermite steel during the fabrication of welded railway connections in order to prevent costly and time-consuming industrial experimentation. The NovaFlow & Solid CV software package was used to simulate casting thermite steel in the mold cavity, i.e. in the weld joint, for the 49E1 rail.

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

Introduction

Casting simulations for traditional casting technologies are a new approach that replicates the filling of a mold with metal, as well as its hardening, and allows for the simulation of casting manufacturing. In any case, the simulation approach reduces manufacturing costs and optimizes the technical casting process [1]. Most commercial casting techniques can be mimicked, including the tremite steel casting method for aluminothermic rail welding [2]. The simulation illustrates the consequences of several inflow routes and feeding systems. Defects in castings caused by high turbulence, cold joints, shrinkage, and porosity can be avoided by enhancing the design of the input system and gas vents [3-6].

The major input data for the simulation program is a 3D CAD model for producing molds. The casting cavity was modified in this version of the model by adding hoes in the sand and rails on both sides to more closely approximate heat flow. The program then enters 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.

Animated representations of mold filling, thermite steel solidification, and further cooling to room temperature are included in the output data. Mold filling simulation can forecast total filling time, mold degradation, partial filling, and gas entrapment. Based on Niyama and other criteria, the temperature and cooling rate in the casting solidification simulation are utilized to anticipate the position of shrinkage porosity. Further cooling to room temperature can also be modeled, which is useful for anticipating microstructure, mechanical properties, residual stresses, and curl.

This study demonstrates how to use casting simulation in aluminothermic welding to avoid practical trial and error, specifically how varied preheating durations and temperature distribution affect casting. Casting difficulties such as oxide inclusions generated by excessive turbulence, undercooling, shrinkage, and slag inclusions can be avoided by improving the design of the ingate system, feeders, and ventilation.

Materials and methods

The steel used for simulation is comercial 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 characteristic are presented in Table 2.

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

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

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

Material parameter	
Liquidus Temperature [^{o}C]	1.478.628
Euthectic temperature [^{o}C]	1.139.902
Solidus Temperature [^{o}C]	1.401.497
CLF up [%]	70.000
CLF down [%])	45.000
CLF press[%]	35.100
Q_{cr} [kJ/kg]	172.600
Q_{et} [kJ/kg]	235.711

Simulation set up

The simulation is carried out using the software program Nova Flow&Solid CV (Novacast business, Sweden) [2]. 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 (cell size 3,120, total cell count 498792.

However when building the mesh the **Mould thickness** option was adjusted so the calculating box would start at the edge of the mould rails and bottom of sand mould. This way more realistic cooling could be achieved. **Boundary condition** options were left as default (normal conditions), but that is something we will consider in future upgrades to the model. The sand mould as a whole and in two cross sections can be seen in Figure 1, while the entire model is presented in Figure 2.

As shown in Figures 2 and 3 the model consists of six elements: the rail casting (red), ingate system (blue), and feeders (green), sand mould (yellow) and rail track (grey). The one and only gating point was placed at the centre of the uppermost part of the ingate system, at the center of the blue square in Figure 2. 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 6.328 kg and the casting temperature was set at 2200 ^{o}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.

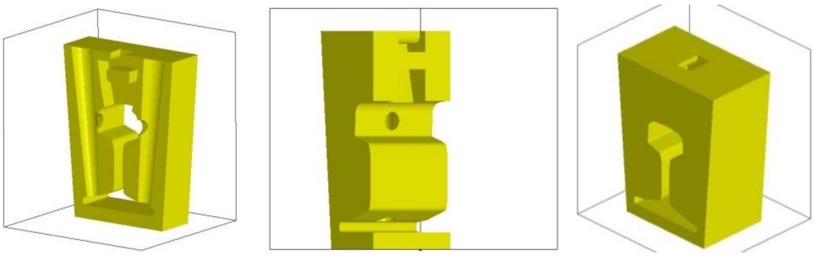

Figure 1 Sand mould used for casting in two cross-sections and as a while

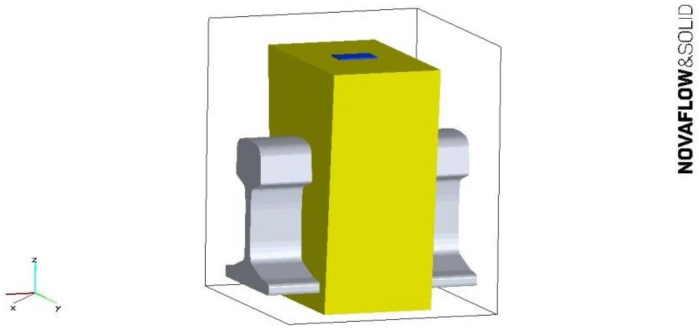

Figure 2 Whole casting model from an angle perspective

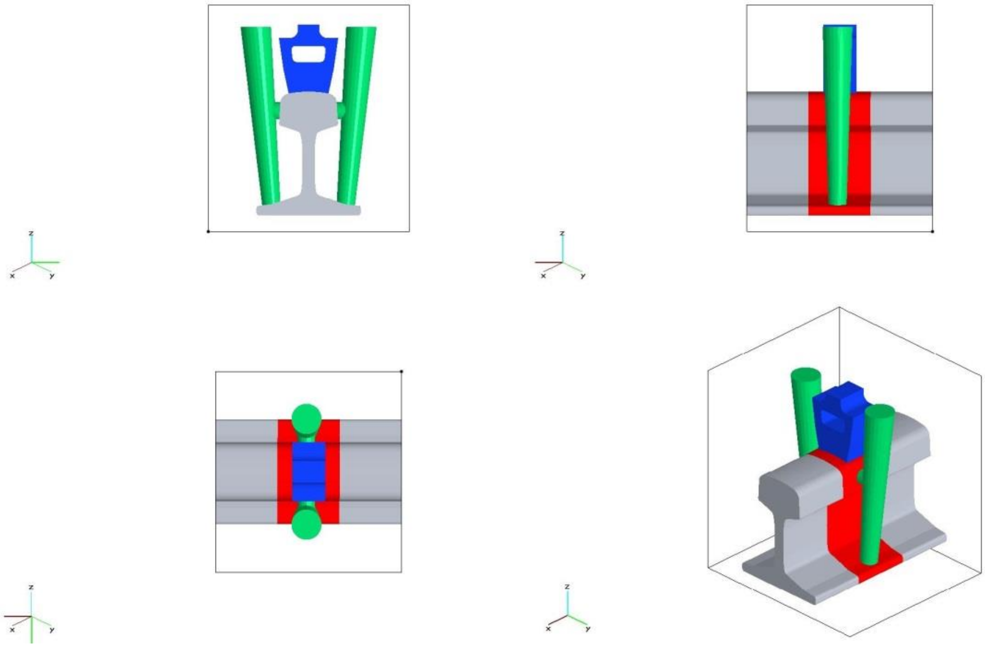

Figure 3 Metal casting without the sand mould, from the front, side, top, and angle perspective

Simulations were conducted with the preheating option turned on. Here the mould material (silica sand) is set to the room temperature of 20 ^{o}C while the cavity medium (air) is heated with a burner (1000 ^{o}C) from the right side of the flow divider for 600 s. The shape of the burner area is circular, 30 mm in diameter, and the flow was set at 0.1 L/s, while the initial temperature of the cavity medium was 20 ^{o}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, the two sets of solid steel rails that are added on each side of the casting mould will be altered as heating media under the mould material category. This way, the cooling and heating temperature distribution will be improved. Finally when the cooling conditions are satisfactorily simulated to reflect real-world conditions we will apply stress and strain modelling to the weld.

Results and discussion

After the model was improved by adding rails to the side the asymmetry of the design (Figure 3) made an visible impact then it comes two the temperature distribution. The is mostly visible during preheating (Figure 4) when the rail closer to the feeders is more heated then the other, since the gas doesn’t flow evenly through the model. This change is then carried over to the casting stage (Figures 5 to 7) of the simulation since it takes 5.537s to fill the model to 100%.

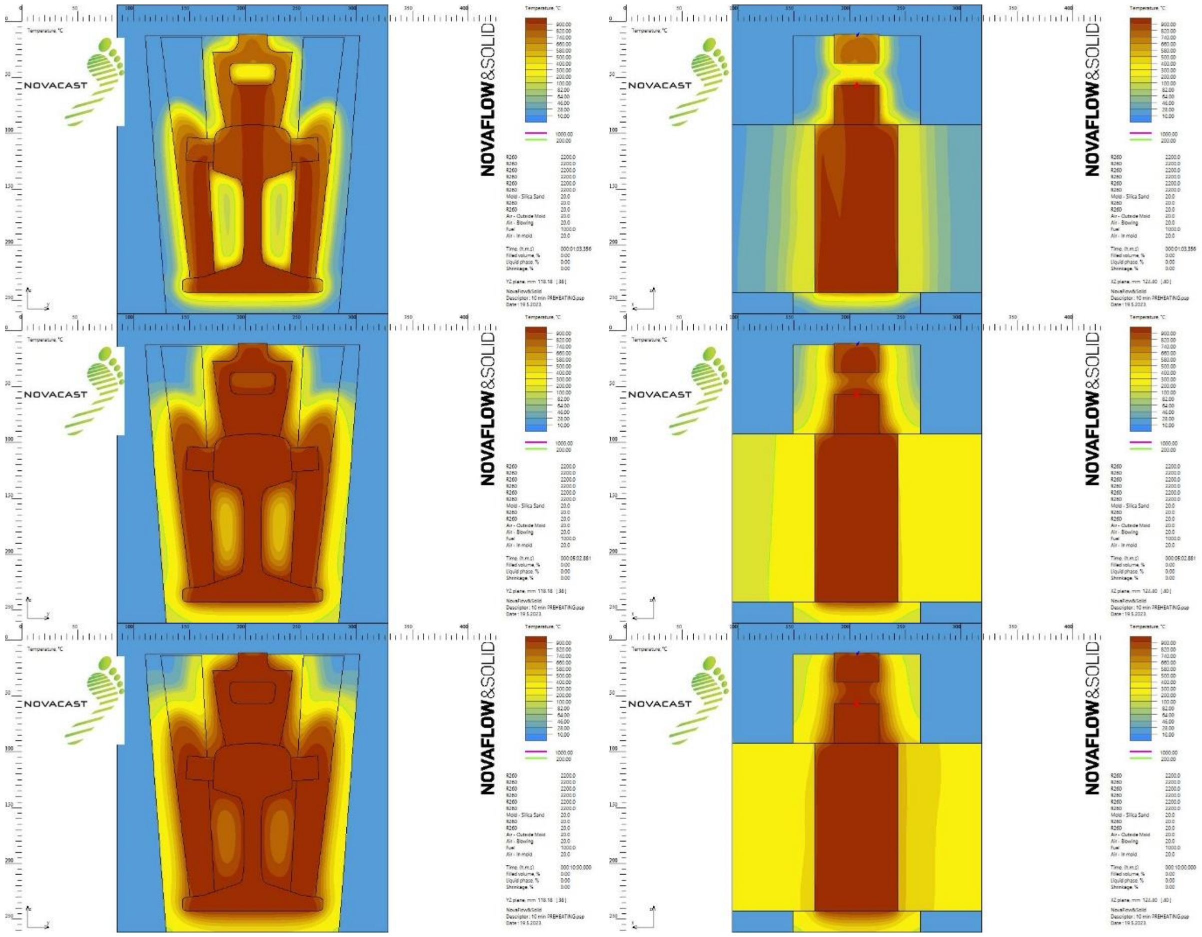

Figure 4 Temperature distribution during prehearing after 60s, 300s and 600s (x and y cross-section)

In Figure 5 we can see how this effect of preheating influenced the temperature distribution when the model is filled to 50%. As it can be seen from Figures 6 and 7 the effect of filling the mould from 30% to 90% has little influence on the temperature distribution of the rails either.

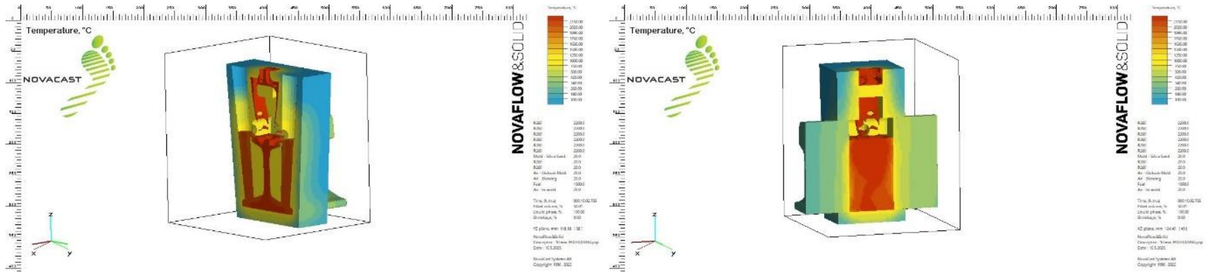

Figure 5 Temperature distribution at 50% filled volume 3D preheated model (x and y cross-section)

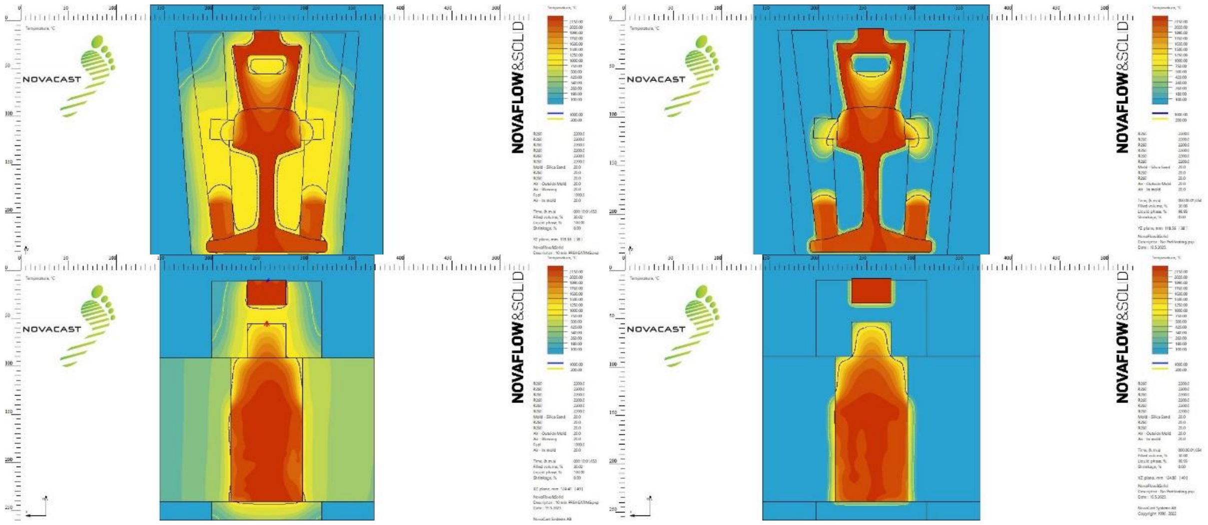

Figure 6 Temperature distribution at 30% filled volume:
preheated model – left; non preheated model – right (x and y cross-section)

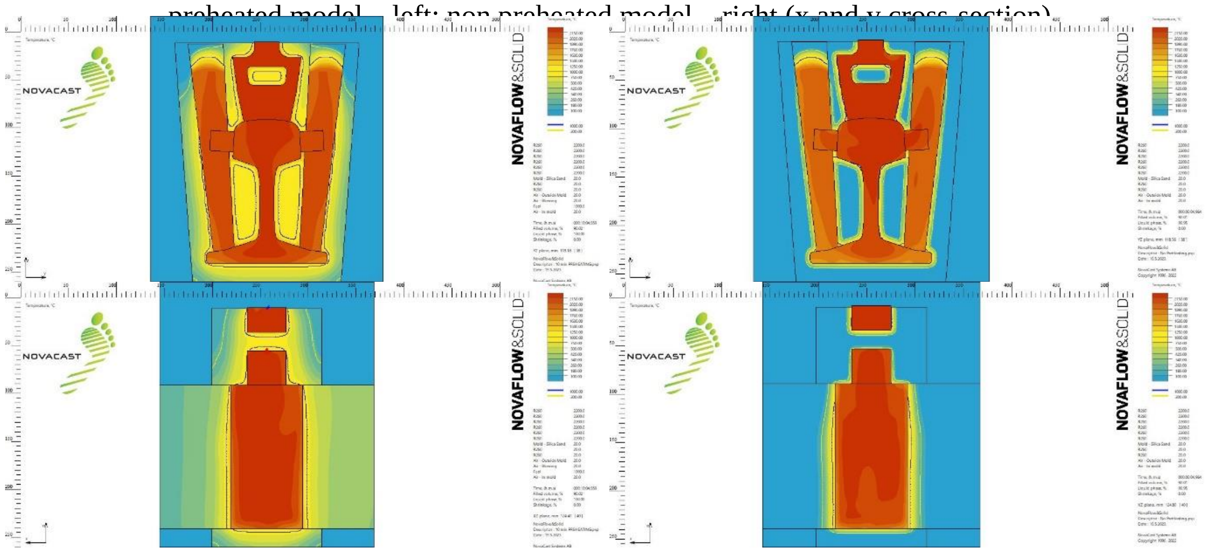

Figure 7 Temperature distribution at 90% filled volume:
preheated model – left; non preheated model – right (x and y cross-section)

As it can be clearly seen from Figure 8 the shrinkage is more pronounced in the non preheated model when it comes to the crucial neck of the cast rail. However due to the asymmetry the highest shrinkage isn't at the center of the model but at the canter cross-section of the feeders as it can be seen in Figure 9.

The main difference between the models is that when the model isn't preheated the shrinkage reaches values over 50% (yellow line) in the ingate system of over 10 % (green line) in the neck of the cast rail. When this is coupled with the solidification time shown in Figure 10 we can form a cleared picture of how preheating is important for the process of aluminothermic welding. There is about a 50s difference in local solidification times around the shrinkage area in the center of the rail neck between the models.

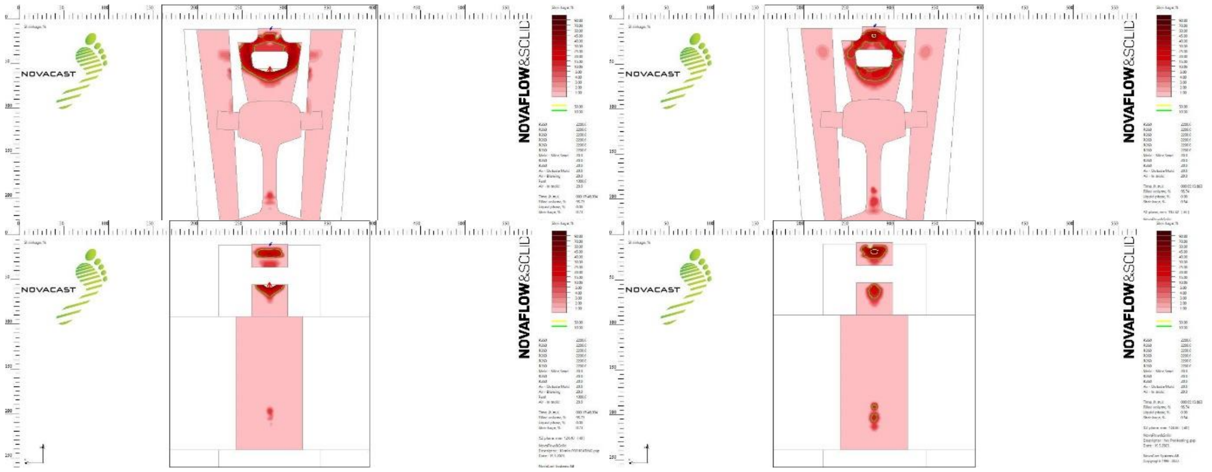

Figure 8 2D shrinkage after solidification at the center of the models: preheated – left; non preheated – right (x and y cross-section)

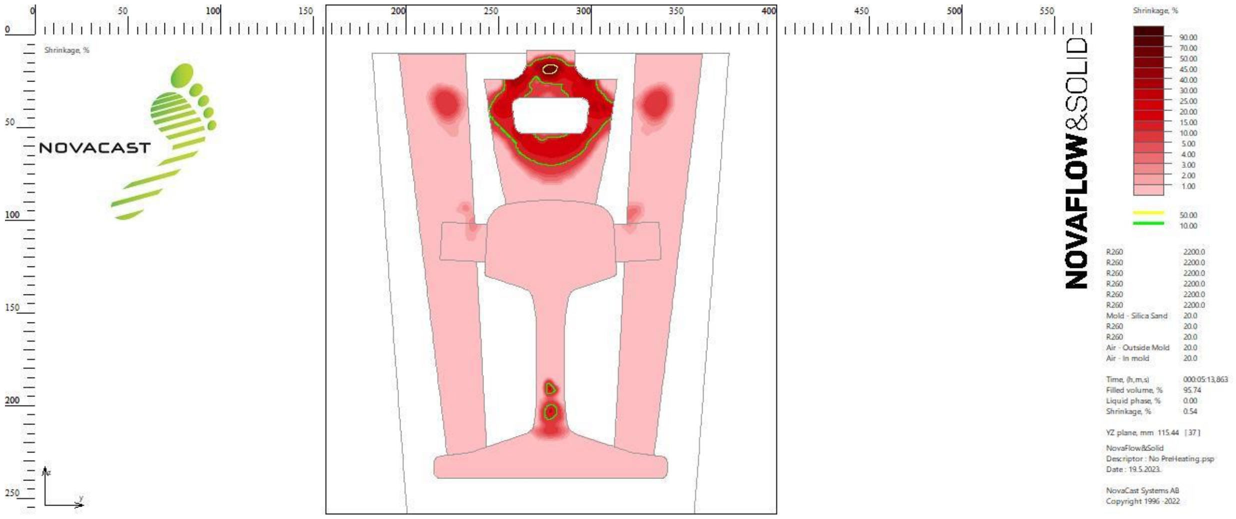

Figure 9 2D shrinkage after solidification at the center of feeders for the non preheated mode

Because the burner is typically located about 40 cm above ground, before changing the feeder positions in future iterations of the model to accurately recreate these conditions we would move the heat source to the appropriate place or adjust the temperature, diameter, and gas accordingly at the current position. Furthermore a new part of the model could be added to represent the divider that would be switched between air and silica sand material at the end of prehearing using the **replace material** function during the simulation setup phase of modelling.

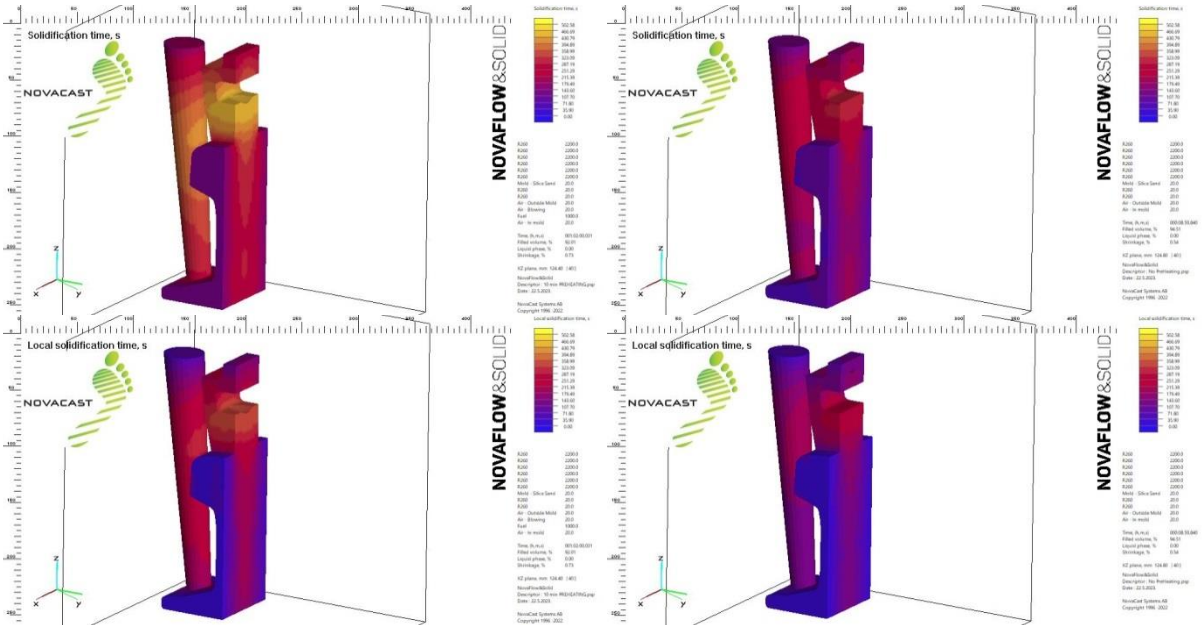

Figure 10 Solidification time and Local solidification time distribution for the metal casting: preheated model – left; non preheated model

Conclusion

This research shown that the aluminothermic process of rail welding can be successfully simulated using the software packages NovaFlow and Solid CV, which might make a significant contribution to the optimization of the process's techno-economic parameters. The distribution of preheating temperatures has been shown to make a significant impact in shrinkage in the simulation. The greatest results were obtained with a preheating time of 600s, which is consistent with actual experience. Predicting flaws in the seam and at the contact site of the additional and base material might also assist enhance the quality of welded connections. In the case of welding the type 49E1 260 rail, its applicability was demonstrated by the production of test welded joints that matched the quality requirements set by simulation in the program.

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