ICTS 2008

11. mednarodno posvetovanje o prometni znanosti
11th International Conference on Transport Science

Prometna politika

Transport Policy

ZBORNIK REFERATOV

CONFERENCE PROCEEDINGS

28. - 29. maj 2008
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SLOVENSKO DRUŠTVO ZA ZNANOST V PROMETU

IN

FAKULTETA ZA POMORSTVO IN PROMET
UNIVERZE V LJUBLJANI

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ANALYSIS OF STRESSES IN WELDED RAILS UNDER THE ACTION OF DIFFERENT LOADINGS

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ABSTRACT

On railways of many countries of the world welded rails are used. Such technology becomes widespread on railways in countries of the former USSR. The length of welded rail threads here reaches 800 m. In the presence of a continental climate the differences of temperatures can reach 80 degrees. Hard loaded movement when static loading on an axis reaches 250 kN here is used. Bad condition of railways also has an influence on the increase of dynamic forces on the rails. Specified factors raise probability of a break of the rails. In the paper the attempt of the use of the finite element method for the analysis of the stresses in such rails under the influence of all complexes of external loadings is made. Thus the rail fastenings are modeled usage of the simplified scheme.

Key words: welded rails, finite element method, stress analysis

1 INTRODUCTION

Continuous welded rail (CWR) track is one of the most perspective directions of development of railway equipment. The terms «continuous welded, jointless or long-welded track» mismatches merits of the case a little. The joints are present in such track. But thus the length of the CWR between joints considerably exceeds the length of a separate rail. It is probably reach with the use of welding of separate rails in a CWR by means of various methods of welding. Advantage CWR tracks consists in reduction of dynamics of interaction in the system of a track - a rolling stock. The comfort of the passengers owing to decrease in vibrations, noise level thus improves. Such track can be intended for high-speed movement of the trains.

The idea of CWR has appeared in the 30s of the 20th century, however the beginning of wide use of CWR on railway transportation was in the 50s for Europe and in the 60s in the USSR [1]. Now on separate sites of the railway networks more than half of all tracks are long-welded.

Despite a widespread occurrence of the tracks of the specified type, essential exploration problems are inherent here. The considerable differences of temperatures reaching up to 80 degrees, and in separate regions and above, lead to occurrence of considerable thermal stresses. These stresses have cyclic character that is connected with change of temperature in a day cycle (up to 35º), and also depending on the change of weather conditions within a year, at maximum up to 108 - 112º. To the specified stresses the operational stresses connected with dynamic interaction between a track and a rolling stock is added. The specified factors promote occurrence in rails of fatigue cracks that can serve as a source of rail damages. Destructions of the track owing to loss of stability of a rail track are possible also.

Unfortunately, despite a widespread occurrence of the CWR tracks the technique of their calculation which was used until recently, was far from perfect. The wide usage of the finite element method (FEM), the software realizing FE analysis and increase of capacity of computer facilities allows to use this method also for research of a stressed state of CWR tracks ways under the action of various loadings. In works of the author [2, 3] various aspects of a problem with accent, first of all, on rolling stock elements were considered. In given paper attempt to use of FEM for research of stresses in welded rails taking into account various factors of force and temperature influence is made.

As object of researches rails R65 and rail fastenings KB65, which are widely used on railways of the former USSR countries, are chosen. Such interest of the author is connected not only with a wide usage of the specified designs, but also with unique problems where they are trying to solve now on Russian railways. For example, in article [4] it was noticed, that the problem of increase of speeds for movement of trains to 140 - 160 km/h on sites with operation of heavy trains is set. And it is with the use of CWR tracks which sites appear in the conditions of sharply continental climate.

It is necessary to notice, that considered paper has a methodological character, i.e. the developed technique can be used for the analysis of a stress state of welded rails in the tracks with other designs of rail fastenings.

2 GEOMETRICAL MODELLING

Let's consider a design of a rail fastening of type KB65, which is the basic for CWR tracks used on railways of the former USSR countries. The constructive sizes of separate parts of the given fastening are written in the instruction [5]. According to the given instruction in program AutoCAD the three-dimensional geometrical model of the given connection has been created (fig. 1). With a view of simplification of the drawing the parts of fastening of a tie plate to a tie, as well as a concrete tie, are not shown.

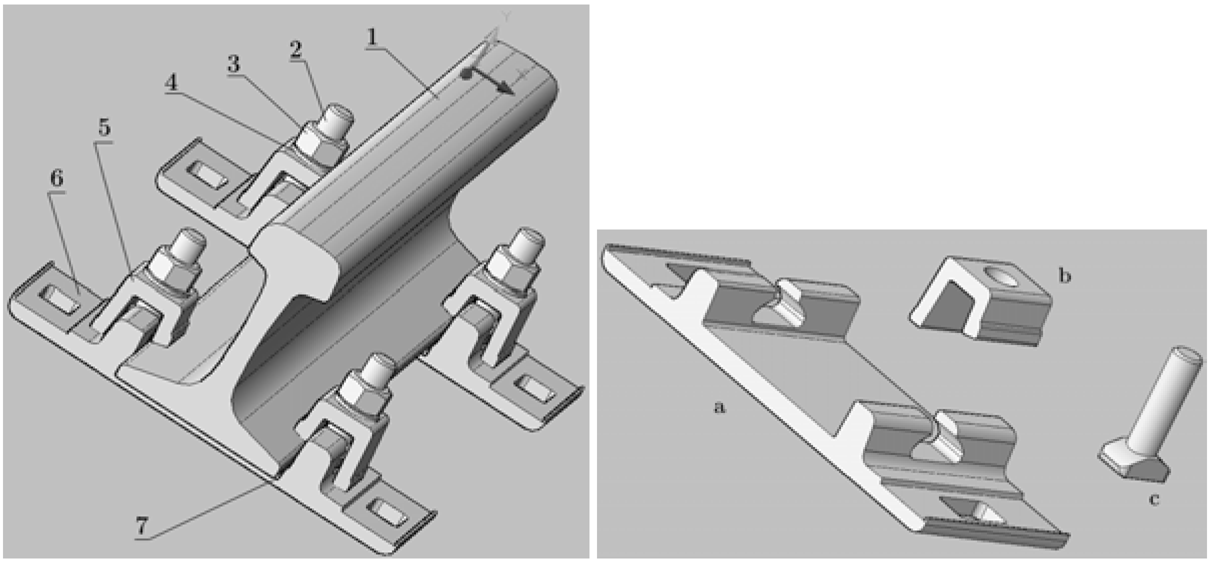


Figure 1: Three-dimensional geometrical model of rail fastening KB65 and its separate basic parts: a) tie plate; b) clip; c) T-head-bolt

The design of a rail fastening consists of the following elements. The tie plate 6 fastens to a concrete tie by means of two bolt connections consisting of T-head-bolts, nuts and spring washers (on fig. 1 are not shown). Between a tie and a tie plate the rubber pad (on fig. 1 it is not shown) also is located. The bedding point of the tie plate KB65 on a tie is carried out taken into account the rail cant 1:20, thus, the tie plate is mounted already with the set cant on which the rail also will be inclined.

The elastic pad 7 places above on a tie plate before rail mounting. Mounted rail R65 press to the elastic pad 7 and the tie plate 6 by means of metal clips 5. The pressing force acting on the clip 5 is set at a twisting bolted connection consisting from a T-head-bolt 2, a nut 3 and a spring washer 4. The tightening torque of nuts according to the instruction [5] is equal 150 Nm. During operation CWR tracks the reduction of nuts tightening and, accordingly, decrease of pressing force of a rail is inadmissible.

The basic geometrical sizes of the rail R65 which is used for CWR tracks in the former USSR countries are shown on fig. 2.

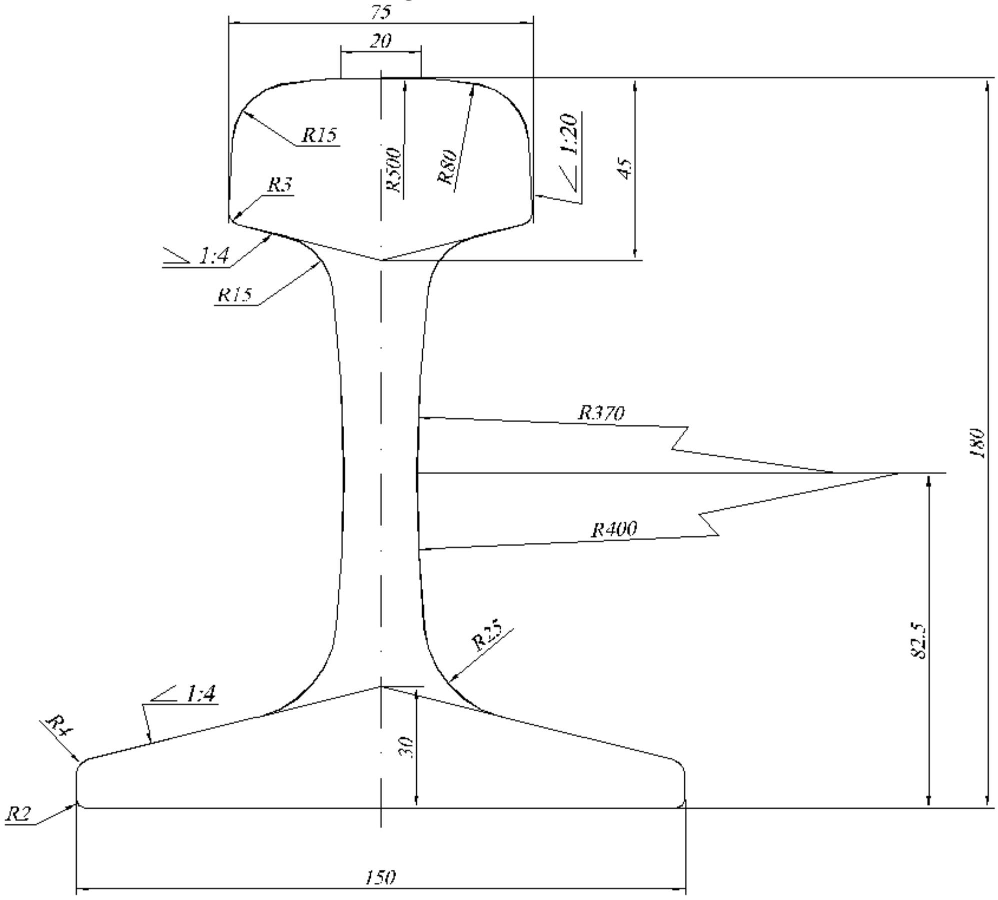
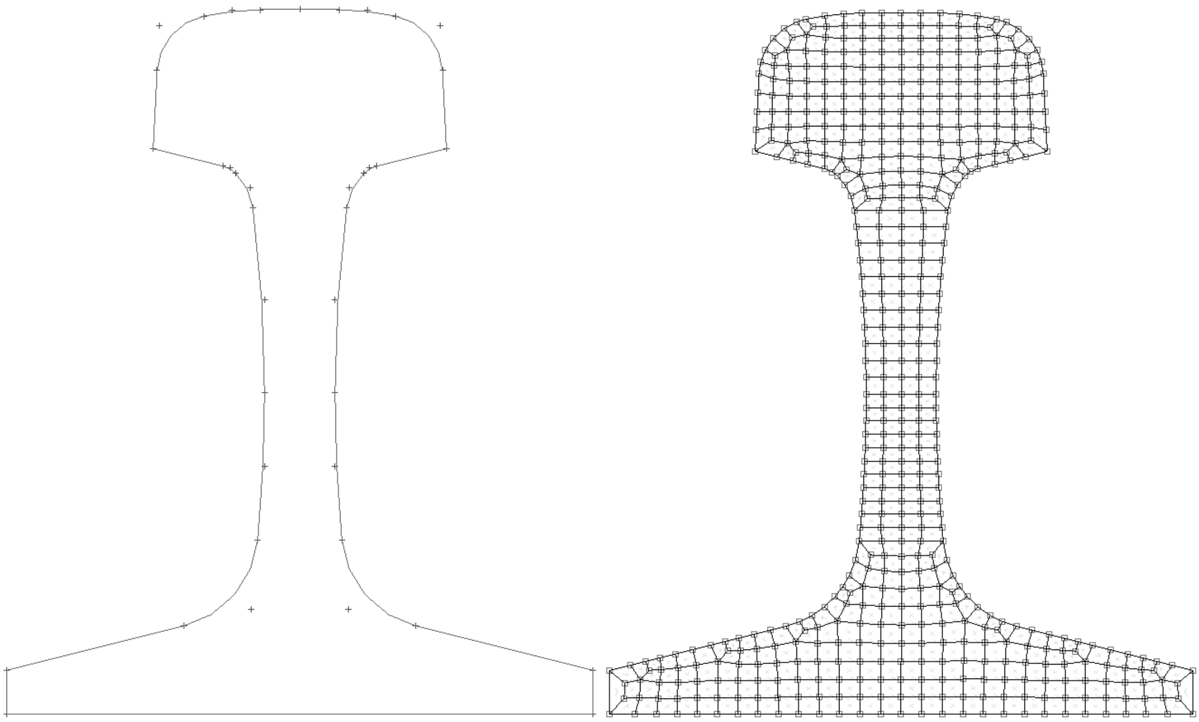


Figure 2: Design of the rail R65 in compliance with standard [6]

Rails mounted on concrete ties under the following scheme. On straight sites of a track (the radius more than 1200 m) 1840 ties lay on 1 km of a track. Thus the distance between axes of the next intermediate ties is 546 mm. For curve sites of a track without dependence from radius (<1200 m) 2000 ties lay on 1 km of a track. The distance between the next intermediate ties is 500 mm. The specified norms have been allowed at creation of the FE model.

3 CREATION OF FINITE - ELEMENT MESH

As basic FE tool of the analysis the program MSC.MARC 2007 R1 was used. The simplified contour of cross-section of the rail (fig. 2a) has been used for creation of flat FE mesh in the rail section. Thus fillet radiuses were not considered that the FE mesh with disproportionate small finite elements isn't created. Such approach has allowed creating flat FE mesh with approximately equal four-nodal elements (fig. 2b). Generation of a FE grid was carried out in a semi-automatic mode separately from the head, a web and a foot of the rail, and then pair nodes on the borders of the specified areas was merged.



a b

Figure 3: Contour of the cross-section of a rail with the characteristic points after import to program MSC.MARC (a); flat FE mesh (b)

Process of extrusion of a flat grid of finite elements with simultaneous formation of spatial 8-nodal elements was carried out in some stages. In particular, in the zone of the contact between the rail and the clip 6, the layers of elements with an identical thickness of 10 mm have been generated. The specified number of layers and their thickness are caused by clip geometry (fig. 1a). On other part of a rail between the next ties 40 equal layers of elements are generated. The thickness of each layer has been caused by requirements of an apportion of the ties, submitted above. After generation of elements for each considered zone pair of nodes in a joint zone merged, forming uniform FE mesh of a rail, which is shown on fig. 4.

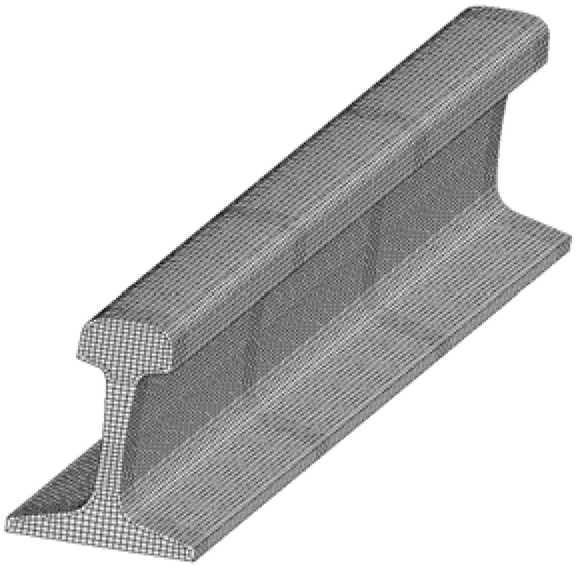


Figure 4: КЭ discretization of a considered rail

The final FE mesh of the rail has 76415 nodes and 64224 finite elements. It is supposed, that the considered part of a rail will rest on 4 in regular intervals laid ties to which the rail will be connected by means of the simplified model of rail fastening KB65. The setting of a material for considered FE mesh does not represent complexity as MSC.MARC has the library of materials which consider mechanical and thermal properties of materials including plastic properties, and also change of parameters during material heating.

4 CONTACT BODIES, INITIAL AND BOUNDARY CONDITIONS

Considerably big problems arise at attempt of the setting of boundary conditions for considered model. In program MSC.MARC can be set as directly boundary conditions, and the set of boundary conditions by means of such tool as contact bodies is possible. In real fastening КБ65 the rail contacts with a tie plate mediate through an elastic pad. The rail contacts with the clips directly. As model simplification it is offered not to consider elastic properties opposite bodies, replacing them with rigid bodies. Because of a problem, essential importance is friction at contact interaction, it is necessary to set friction ratio close to the real. In contact between the rail and the clip takes place contact interaction of steel parts. In a problem the sliding friction ratio equal 0,1 has been accepted. Business with contact interaction between a rail, an elastic lining and a lining is more difficult. Here contact between steel and rubber takes place. Nevertheless, here the possibility of the water penetration in a contact zone takes place at decreasing of a rail pressing. Therefore at modelling of the given contact there was a decision to set the friction ratio equal to 0,2.

To provide the set factors of a friction following contact bodies are set: a rail as an elastic body with the friction ratio 0,1; the clip is modelled by a rigid surface with the friction ratio 0,1; the tie plate / the pad as a rigid surface with the friction ratio 0,3. Such choice of the friction ratio is caused by that of contact of bodies with different friction ratios the program in contact establishes friction ratio average between corresponding parameters for interacted bodies. On fig. 5 the set contact bodies are shown.

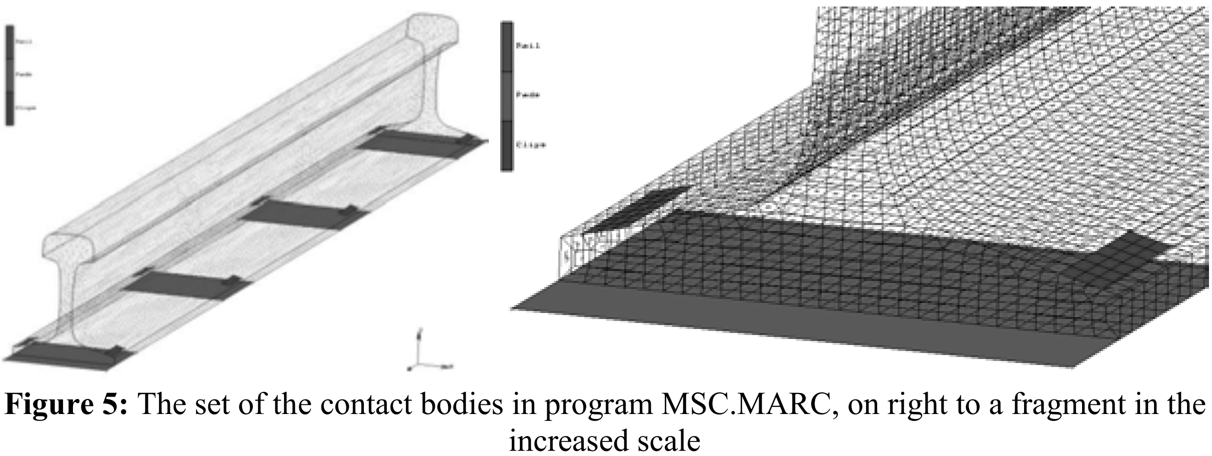


Figure 5: The set of the contact bodies in program MSC.MARC, on right to a fragment in the increased scale

At definition of contact bodies there is also a possibility of the set of their movement. In particular, it is set, that the surfaces modeling a tie plate is motionless and the surfaces modeling the clip move downwards on a size corresponding to a vertical moving of a contact zone of the clip that allows setting the landed force caused by the tightening torque on the clip nut.

As boundary conditions the various forces acting on a working surface of a rail head which modeled the contact interaction with a wheel were set also.

Separate question is temperature modes for a considered problem. The question first is what temperature should be observed at the mounting of a track and accordingly to be set as the initial condition for calculation. In the instruction [7] it is offered to make mounting of rails at optimum temperature for the given district. Thus the answer to what temperature is optimum, the instruction [8] can answer. For example, here it is noticed, that for the majority of areas of Central Russia such temperature is 30º +/-5ºC. For the northern areas this temperature is on 5 degrees lower. Hence, accepting as reference temperature 25ºC, it is possible to provide conformity to real conditions of exploration of railways in the majority of the former USSR countries. This temperature has been set as the initial condition for all nodes of considered model.

The second question is the problem of extreme heating or cooling of rails in operational conditions. Earlier it was specified, that for separate regions of Russia such spread makes nearly 110º. Therefore without noticeable error it is possible to accept in calculations, that in winter the rail can be cooled to-25 ºC, and in summer to heat up to 75ºC, that gives a temperature range of 100º. The specified parameters were set as temperature boundary conditions.

5 RESULTS OF CALCULATION

On fig. 6 the result of calculation for a case when the rail is fixed at nominal temperature of 25ºC and the result is the same temperature. Thus in the centre of a rail head the normal force equal to 125 kN acts from the wheel. Settlement position of a wheel concerning a rail is that the specified force acts on a rail being equally spaced between the next ties.

That displacements under the influence of the enclosed loadings were appreciable the nodal displacements are increased 30 times over. The level of stress state in the zones allocated in the drawings is approximately identical, i.e. exceeds of 800 MPa (the maximum value equal to 866 MPa). Taking into account that for a steel rail the plastic yield point is 794 MPa in the allocated most loaded zones there are already plastic deformations. Nevertheless, it is enough efforts acting from clips for keeping of rails in a stress state at the maximum heating or cooling. On fig. 7 and 8 the stress state in a considered rail are shown when to the loadings specified above the thermal influence caused by heating or cooling of rails is added.

Both on one, and on other figures it is visible, that owing to heating or cooling takes place considerable deplanation of the face sections. It occurs owing to the pressure of a rail foot in a rail fastening. Thus metal of the head of a rail is deformed rather freely. This fact should be considered at designing of joints between long-welded rails.

6 CONCLUSIONS

It is necessary to notice, that the developed solution technique of the stress and strain state for CWR track allows considering all major factors influencing on operational reliability of rails. The finite element method is an effective tool for modeling of rail fastening.

Further it is planned to consider the problems of fatigue failure of rails under the influence of cyclic loadings of various character.

Work is executed under the contract with the Latvian railway and the Riga technical university.

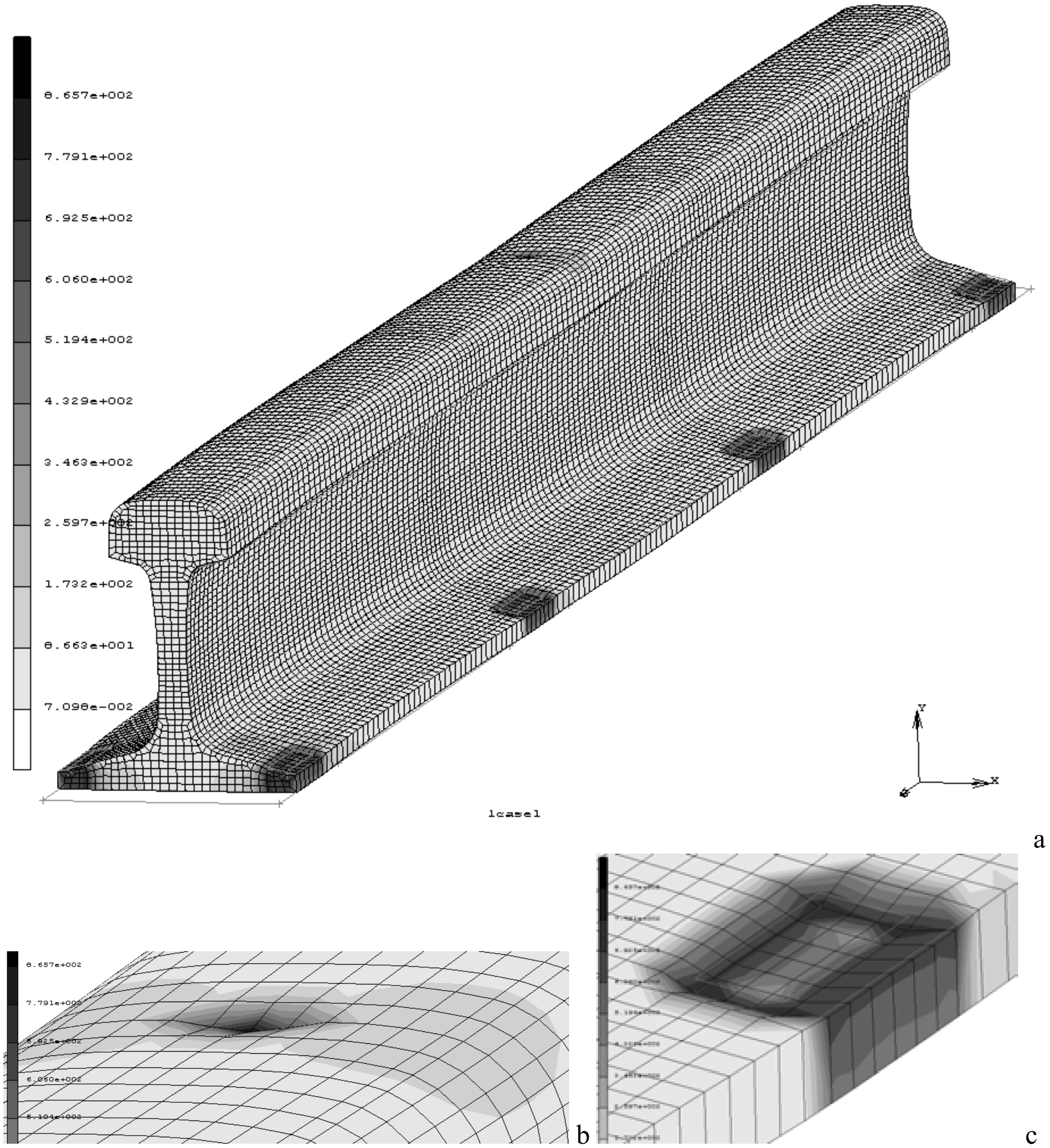


Figure 6: Distribution of equivalent von Mises stress under action of vertical contact force at normal temperature 25ºC (a); a contact zone (b) and a zone of fastening of a rail (c) are resulted in the increased scale

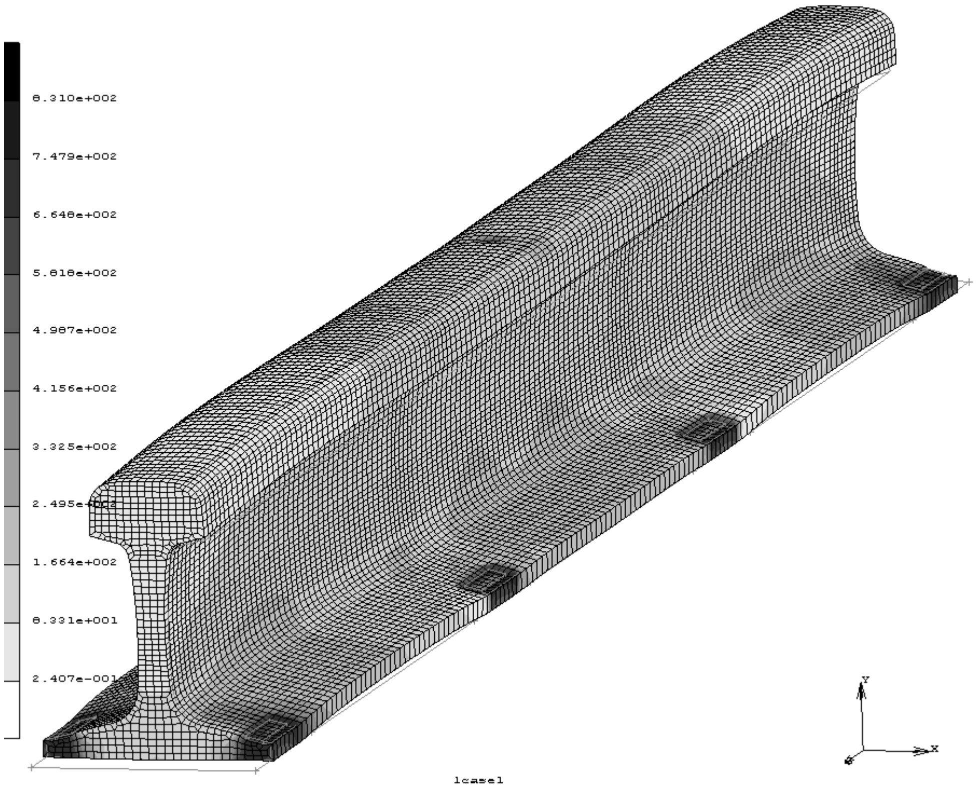


Figure 7: Rail deformation at heating to 75ºC (nodal displacement are increased 30 times)

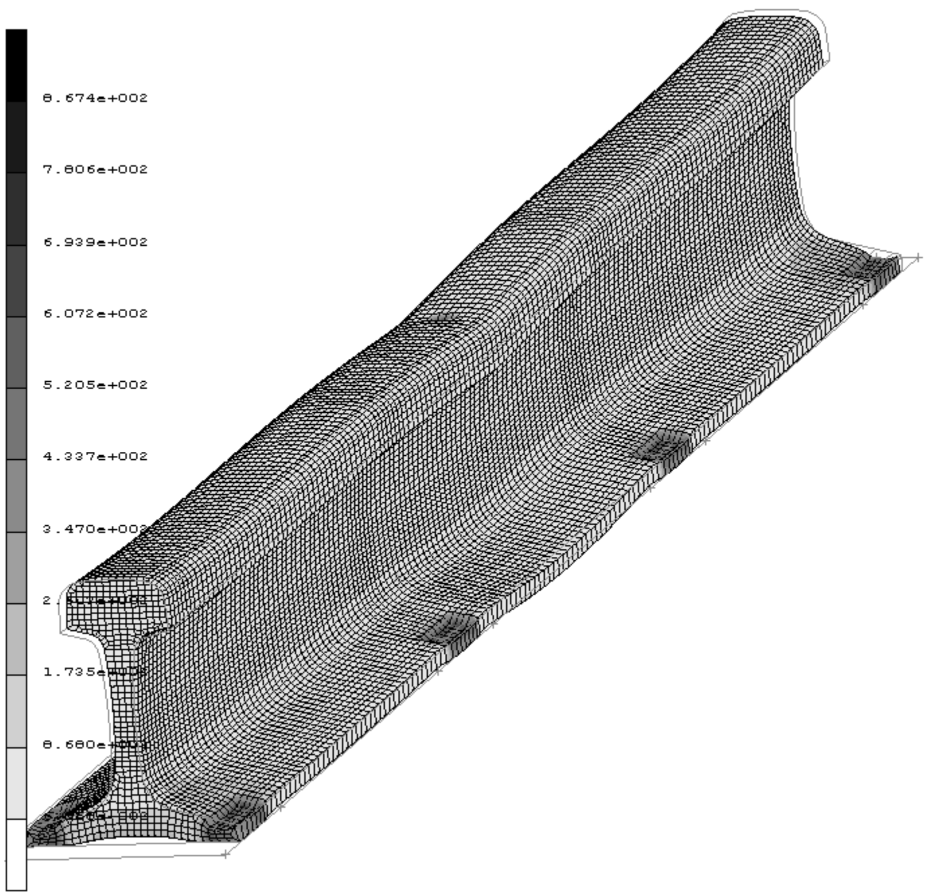


Figure 8: Rail deformation at cooling to -25 ºC (nodal displacement are increased 100 times)

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