ENGINEERING ANALYSIS OF THE CAUSES OF FRACTURES OF BOGIE'S SIDE FRAME

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ABSTRACT

The choice of such a subject, not an abstract field of engineering analysis is a confirmation of real possibilities of modern scientific and technical diagnostics. According to statistics in the last ten years there is a steady growth in fractures of bogie's side frames: in 2004 and 2005, such cases were absent, from 2006 to 2009 37 cases were recorded, and from 2010 to 2013 other 92 cases were recorded (Pic.1). The authors aimed at investigating causes of fractures, which arise in side frames of bogies. To do this, the authors use engineering methods, analysis and modeling.

The authors synthesize causal relationships of structural and technical defects, which relate to production and operation of a bogie's side frame. The results of analysis and modeling in ProCAST entitle readers to assess problem areas and to offer compensatory solutions.

Keywords: railway, car, bogie, side frame, technical parameters, fractures, faults, engineering analysis, modeling, problem solving.

Background. *According to statistics in the last ten years there is a steady growth in fractures of bogie's side frames: in 2004 and 2005, such cases were absent, from 2006 to 2009 37 cases were recorded, and from 2010 to 2013 other 92 cases were recorded (Pic.1).*

To obtain high-quality castings of a side frame of a bogie it is necessary in the process of its production to comply with a number of requirements concerning process parameters. This relates primarily to obtaining the desired chemical composition and temperature of the cast metal, the necessary compliance of casting molds, molding material strength and gas permeability, casting time and endurance of crystallizing casting, rational organization of heat removal and others. Each of these parameters is limited to a relatively narrow range of acceptable values, overrange beyond which leads to various defects and reduction of casting quality. Casting defects in casting mainly occur due to poor drainage of occurring gases, uneven cooling and crystallization of metal, insufficient strength of molding material and inelasticity of molding form. Blockages from washout of forms, gas pores, crystallization cracks are typical defects inherent in steel casting. Unidentified at factory inspection they are the main cause of failure of side frames during operation.

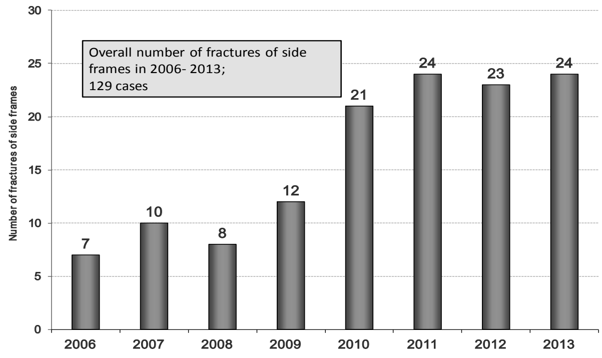
Objective. *The objective of the authors is to investigate causes of fractures, which arise in side frames of bogies.*

Methods. *The authors use engineering methods, analysis and modeling.*

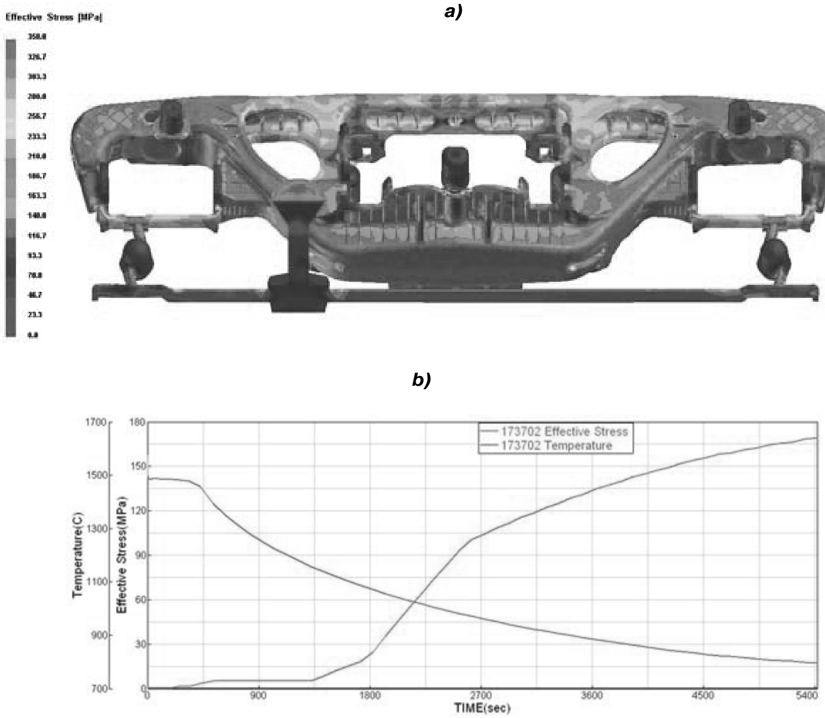
Results. *With the help of CAD ProCAST the authors analyze the simulation of thermal stresses and plastic deformations. By themselves, these stresses do not always pose danger of destruction, but contact with the mold, hindering linear shrinkage may cause cracks. In calculating the form was set as a rigid body for simulation of the most stringent conditions in the deformation of casting. Analysis of calculation results shows that at the time of knockout overall stress level in critical areas is much lower than tensile strength (Pic. 2). During cooling the zone R55 of pedestal jaw opening is deformed in the plastic region, but the level of residual plastic deformations is less than 2%. Since stress analysis was performed without regard to shrinkage defects resulting in the casting, according to the results we can conclude that cracks in the side frame are consequences of not only the accumulation of residual stresses, but of weakening the structure due to internal casting defects.*

Internal casting defects are detected in the simulation of casting and crystallization of a unit in serial technological process (Pic. 3). Let's consider the causes of shrinkage cavities in critical areas – R55 and R40. To do this, we examine geometry in the area of the inner radius R55 of pedestal jaw opening and the inner radius R40 of spring opening.

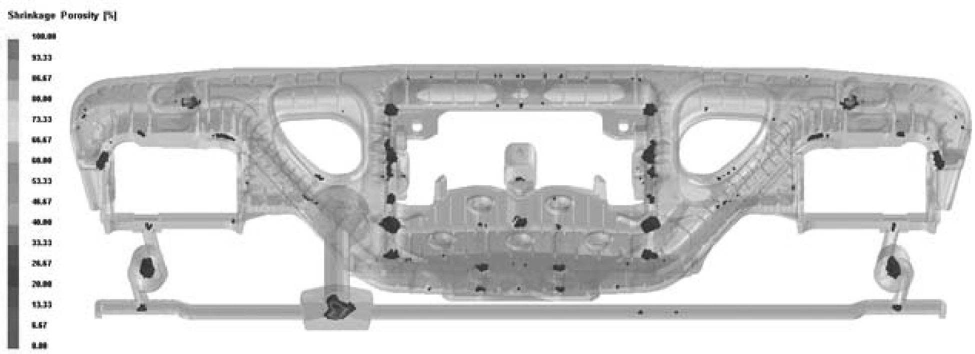
The wall thickness of pedestal jaw opening axle gradually increases toward the inner corner R55, so here during the solidification first heat node is formed (Pic. 4a), and then cavity. Since a frame has a box structure in the region R55 two such nodes are formed: one above and one below (the frame is



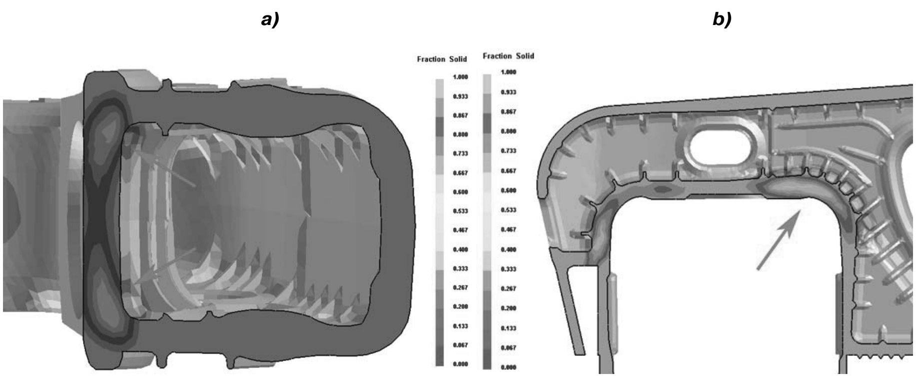
Pic. 1. Number of fractures of side frames of bogies in 2006–2013.



Pic. 2. Stresses in the casting before knockout of a form: a – stress field; b – change in temperature and stresses during the cooling in the inner radius (R55) of pedestal jaw opening.

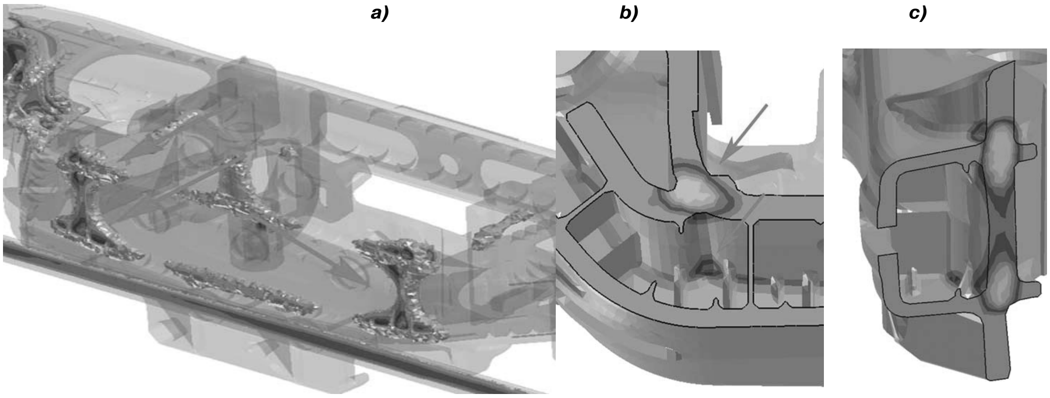


Pic. 3. Distribution of shrinkage cavities in the casting (pore volume of 20% or higher on a scale ProCAST).



Pic. 4. Geometry of pedestal jaw opening in the area of the inner radius R55 with fields of solid phase share: a – cut in a horizontal sectional plane; b – cut in a vertical sectional plane.

a) b) c)



Pic. 5. Geometry of spring opening in the area of radius R 40 with fields of a solid phase share: a – kind of thermal units; b – cut in a horizontal sectional plane; c – cut along a vertical axis.

casted in the «lying» position). Formation of two nodes is shown in Pic. 4b. Power supply of a top node is not a problem, over it or next to it it is possible to set a shrinkage head of appropriate sizes (standard or exothermic). It will provide the power supply to this node, and also to the central (reference) part of pedestal axle opening.

A similar situation can be observed in the spring opening. Connection zone of technological edges in the area R40 of the spring opening are also places of thermal units formation (Pic. 5). Complex geometry of spring opening, inner technological edge and extension of the zone in height make it practically impossible to organize necessary power supply of a problem wall without changing the geometry.

Solution can be found by setting supply shrinkage head above the upper thermal unit. This requires a change of the opening angle geometry to provide the flow of liquid melt into the wall. As in the case with pedestal axle opening, it may be required to use refrigerators, since the length of the wall and its contact with a cold mold cannot provide a continuous power supply of the lower thermal unit.

Conclusions. *Engineering analysis geometry and modeling in ProCAST allow us to conclude:*

- *thermal stresses and hindered contraction are not the main causes of the cracks in the responsible zone of the radius R55;*
- *causes of fractures of frames are hidden casting defects – shrinkage cavities serving as stress concentrators and weakening the cross-section of the frame;*
- *reason for the formation of shrinkage cavities is especially unfortunate (horizontal) in terms of the power supply the location of casting in the form; due to this orientation of the unit only the top half of the frame can be effectively supplied;*
- *supply of lower thermal units is unsatisfactory because of extended walls of equal thickness, on which these nodes are supplied;*
- *it is possible to address identified problems by the change in the geometry (e. g., creation of slopes in the walls) and by the creation of directional solidification character (bottom-up) in critical areas – by selection of the optimum size, position and type of shrinkage head on top of the frame and installation of refrigerators in the lower part.*

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