Deformation peculiarities of body of slag car pan

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Abstract
This paper is devoted to an analytical study of wall deformations of slag car pan during its operation. Distribution pattern of deformations in the pan body in the case of its manufacturing of standard material (steel 30) and with the usage of point alloying in the support ring area is determined.
Keywords: SLAG CAR, SLAG PAN, CONSTRUCTION, DEFORMATION, STRENGTH, ALLOYING, POINT ALLOYING

While operation pan of blast-furnace slag car is filed by smelted slag, temperature of which may achieve 1600°C. After the pan is filled by slag, there occurs intensive heat transfer across the pan section. This is explained by long duration of action and heat source strength. Pan body on different levels has non-uniform thickness. Under the influence of non-uniform heat transfer in the body there appear different in value and index stresses. Nonuniformity of heat transfer is known to be increased in the pieces, which are not symmetrical towards the center of their mass, in massive pieces and also in pieces of irregular shape. Pan of blast furnace slag car is such piece. In case when the values of internal stresses in the material are higher than the yield point, any steel piece starts deforming plastically, this causes imposed stresses and its deformation after cooling. Initial sizes of the construction may change. In case of great temperature differences, causing local heat stresses, exceeding material tensile strength, there appears a possibility of cracks formation.

This reduces significantly reliability of separate units and the whole construction. Within long-term usage, there may appear permanent strains in separate elements of slag pan, which influence its holding capacity. The most important task is not only decrease of the level of thermal stresses in the construction on the stages of production process but also its adjustment in terms of volume during operation. There are different ways for solution of this problem, for example by means of point alloying.

S.V. Timoshenko, M.I. Yankovskogo, A.S. Filippova paid great attention on the questions concerning thermal stresses. Analysis of researches of different authors [1-4] shows that in most cases durability of pieces may be decreased because of the influence of thermal stresses, which arise in cross section. This fact should be considered while designing, manufacturing and upgrading of metallurgical pieces and units of high-duty.

The aim of the article is to determine hazardous sections of pan body from the point of view of distraction and also to determine deformation value, which may arise while operating.

Reliability and endurance rate of machines or tools depend on the duration of preservation of main attributes by its separate components – units and pieces. In general, long-term preservation of original size, durability, surface quality, accuracy and class of fit, corrosive resistance, etc. refer to such attributes. Influence of the structure and partial operations of manufacturing process on the quality of pieces, especially on the condition of surface coating and piece material in whole, accumulated hidden energy, phase marginal stability, residual stresses is not clearly understood. Often during exploitation of pieces, the influence of technological heredity on the efficiency characteristics of pieces is so significant as to provide the necessary reliability targets of machine is impossible without regard to them.

One of the factors of technological heredity is formation of thermo stressed state under the influence of different sources of heat generation in the material of the product under examination. Sources may change the structure of material on various stages of casting formation, processing and further exploitation. For example, during formation of casting surface by means of grinding, sources are grinding area. Relatively short duration of influence of medium-powered heat flow, which is being generated in the area of cutting during machining process, will cause formation of thermal-stressed state only at small depth from the surface. Quite different situation is observed while piece operation.

During pan exploitation there occurs contact between rich slag and pan cold body, this causes temperature differential, which is one of the main factors influencing the pan durability. That is why calculation of strain-stress state (SSS) is reasonable first of all for the conditions of maximum load on the construction during operation, and one should start it with specification of temperature field of pan wall.

I.V. Raspopov [5], K.A. Pak and A.V. Chalenko [6] gave attention to this problem. Works on specification of outside surface temperatures of pan bodies were fulfilled by Theoretical and applied mechanics department of Priazovskyi State Technical University. Measurements were fulfilled with the help of optical pyrometer «Rautek» from any height of the pan; from begin of its filling with smelted slag and up to the reaching of maximum temperatures. Values received in the area of deformation development, namely in the area of support ring, are of great interest. Received experimental and comparative data of other researchers are led into the diagram shown in the figure 1.

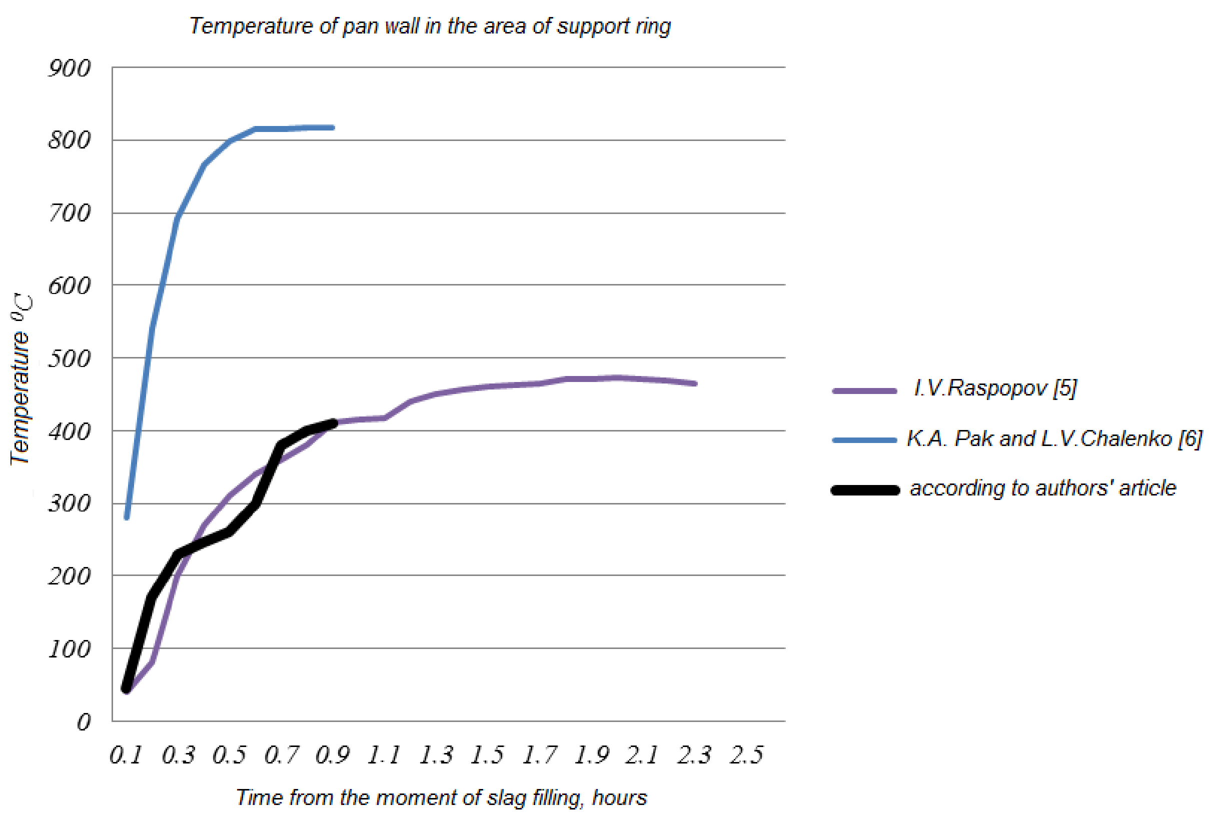

Figure 1 Temperature variation of pan wall during exploitation

According to the data obtained, maximum temperature of pan wall reaches 410°C, which is in keeping with data obtained by K.A. Pak and A.V. Chalenko. Received temperature values were used for modeling of thermal profile of pan body by means of finite-element method (FEM).

Modeling of temperature fields, which is being formed in the pieces while operation, was fulfilled in the calculation program ABAQUS. Abilities of static and dynamic strength analysis of ABAQUS program are used for determination of moving of stresses, deformations and forces, which arise in the construction or its components as a result of applied forces. The task was solved in static formulation, as inertial effect and energy scattering processes do not have great impact on the construction behavior. Such type of analysis is used by researches in many tasks and applications, for example, for calculation of temperature stresses or for determination of stress concentration in fillets of construction members.

While operation slag car pan takes up temperature loads, which are followed by significant heating of the body, which causes development of stresses and loads in it. In result of strain-stress computation of the pan with ordinal mechanical characteristics of the material (steel 30), there were stated that peak strain arise in the area of expected appearance of “tightening” defect, and namely in the area of pivoted tongue of slag car support ring. Maximum values of deformation for the first variant of calculation make 33 mm (fig.2). The figure reflects strain distribution in the area of pivoted tongue of slag car support ring. Herein deformations in other body areas of the zone of interest is far less (about 15 mm), which speaks for essential strain disparity in the pan body. Area with increased deformations is hazardous zone from the point of view of further destruction. For structural enhancement, it is necessary to enhance first of all this area, which is hazardous. This may be achieved by means of point alloying [7]. The method may be realized thanks to the application of flux-cored wires with ordered composition.

In case of additional alloying of pan body in the area of support ring maximum values of deformation in the area of appearance of “tightening” defect may reduce to 26 mm (fig.3). Mechanical characteristics of cast steel, received by experimental research, were used for design model. These results allow to suppose that additional alloying in the desired place of casting adjusts stress gradient in the field of elevated temperatures and simultaneously reduces maximum stress. The results obtained show that deformation range of variation in the pan body at local hardening makes 11-26mm.

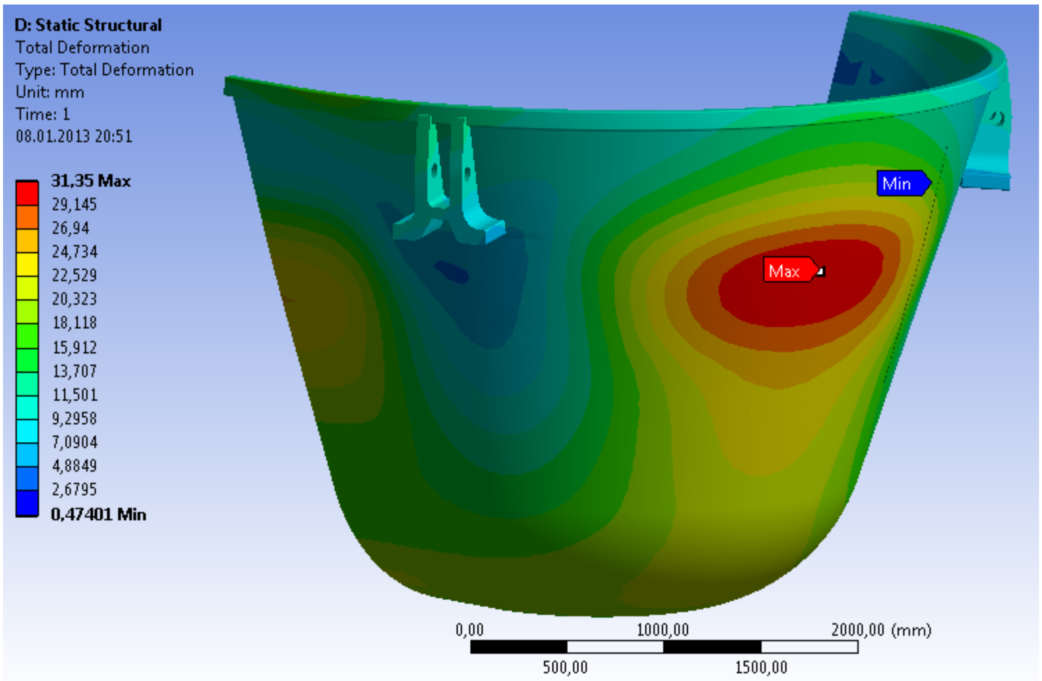

Figure 2 Deformations in the wall of pan (without extra alloying)

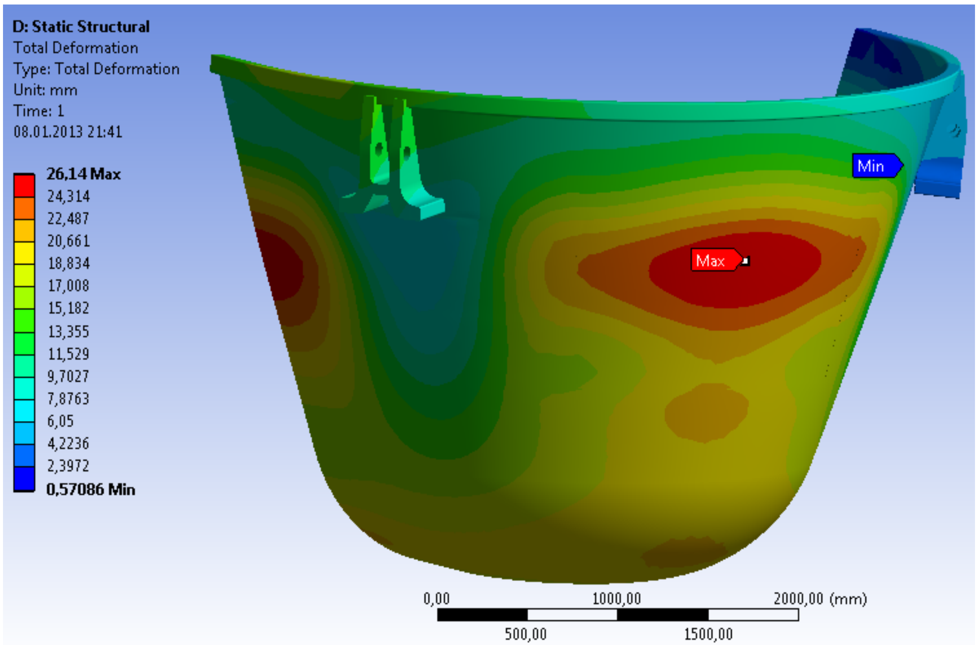

Figure 3 Deformation in the wall of pan with installed powder fillers

At the present time there carried out experimental work concerning optimization of manufacturing technique for pieces with hardening of the most loaded areas, the main aim of which is to increase their lifetime and also to minimize production costs.

Conclusions

Distribution pattern of deformations in the pan of slag car depends on its operation practice.
Maximum values of deformation are observed in the area of support ring. This area is hazardous from the point of view of loss of structural behavior by construction.

Alloying of the whole pan as casting – is irrational way for increase of its durability. In case of point alloying of steel body areas with minimal discharge of alloying elements, maximum values of deformation in the pan wall may be reduced in 1.5-1.6 times.

Results of comparative analysis of ordinal and point-alloyed model show that deformation in the body of additionally alloyed pan reduces significantly. This may provide increase of durability of the pan as the construction in conditions of high-temperature loading.

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