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# Welding Applying for Increasing the Service Life of Cast Components of Metallurgical Equipment

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**Abstract**

Cast connection joints used in metallurgy do not have enough resistance to high temperatures. Service life of such products can be increased by minor structure improvement with the use of welding technologies. In this article the possibility of large-scale product strengthening through welding is presented on the example of a slag pot carrier. The improvement of the pot will allow 3-5 times decreasing of the pot body deformation.

**Keywords:** Cast details; Welding; Metallurgy equipment; High temperatures; Service life increasing

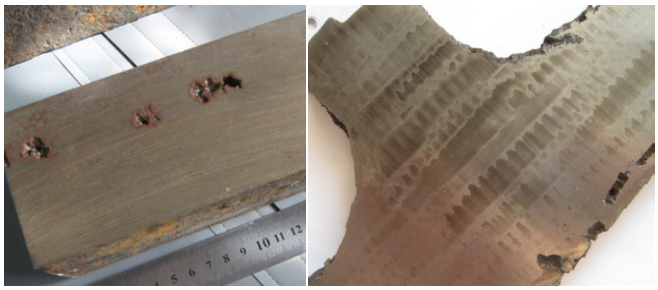
## Introduction

A great number of small and large cast steel products are always used in the steel industry, where metal-consuming equipment has a major volume weight. The reason of such wide use is a relatively low prime cost of steel and iron casting. But on the other hand, such products are not durable enough due to large amount of manufacture defects, which are commonly not seen at the phase of acceptance. The durability of products can be significantly increased and the price of maintenance can be substantially reduced, if a minor improvement of the structure is made using welding and manufacturing of welded cast products. The production and use prospectively of such products are the result of the unique union of different materials' properties which are combined in one product. Such combination hardly can be obtained for the one material. This approach is rather prospective for any large manufacturing plant, because the use of compound products sometimes allows several times increasing of service life.

## Analysis of the Possibility of Welding use for Strengthening of Cast Products

For the current phase of technology development, the modeling of the product behavior under nominal loads and under highest possible workloads is the most important stage of any product producing and improvement. It is true for metallurgy and for any other branch of industry. Each product should be used under certain conditions. Computer modeling is a convenient and cost-effective way to determine required conditions for equipment work due to the large amount of possible structure solutions for any kind of equipment.

In fact, modeling is the first step of creating or improving structures including welded cast structures. Specifying structure characteristics is the most important part of the modeling process. The generally accepted way of modeling is when any product is considered as homogenous body with evenly distributed characteristics, for instance mechanic and thermo-physical properties. Such assumption is applied for lots of materials, but it causes noticeable errors for castings, especially for big sized ones. It stems from the inhomogeneity of cast structure and characteristics and from the large number of micro- and macro-defects in them. For example, in 50-60 or more mm thick carbon steel castings besides macro-defects (Figure 1a) there is inhomogeneous chemical composition which causes noticeable heterogeneity of structure and cross-section characteristics. It appears in higher resistance to cutting of its' different sections (Figure 1b).



a) b)

**Figure 1:** Structure defects in carbon steel castings 30 l, 35 l (30 L, 35 L) (a – macrostructure defects, b) cross-section chemical heterogeneity).

In addition, chemical inhomogeneity can cause the dozens of per cent difference in mechanical characteristics of one product [1]. In most cases, structure inhomogeneity occurs under certain manufacture conditions and depends on accidental technological factors, which are difficult to predict. That is why on the first stage of modeling structure components are considered as homogenous bodies with typical characteristics [2]. Despite such an assumption, there is a possibility to make comparative calculations in order to choose the best structure solution.

The pot of a slag carrier made of cast carbon steel can be a good example of a product improvement with the use of welding. Uneven heating of the pot during the operation causes appearance of after-strains and cracks in the body of the pot. Welding of additional elements (stiffeners) with target rigidity is a reasonable way to reinforce the pot body. Calculations show that additional 30 mm thick stiffeners should be welded to the pot body in order to increase its' stiffness. The reliable welding junction in welded cast structure can increase the lifespan of the pot and ensure fail-safety of operation of the slag pot carrier,

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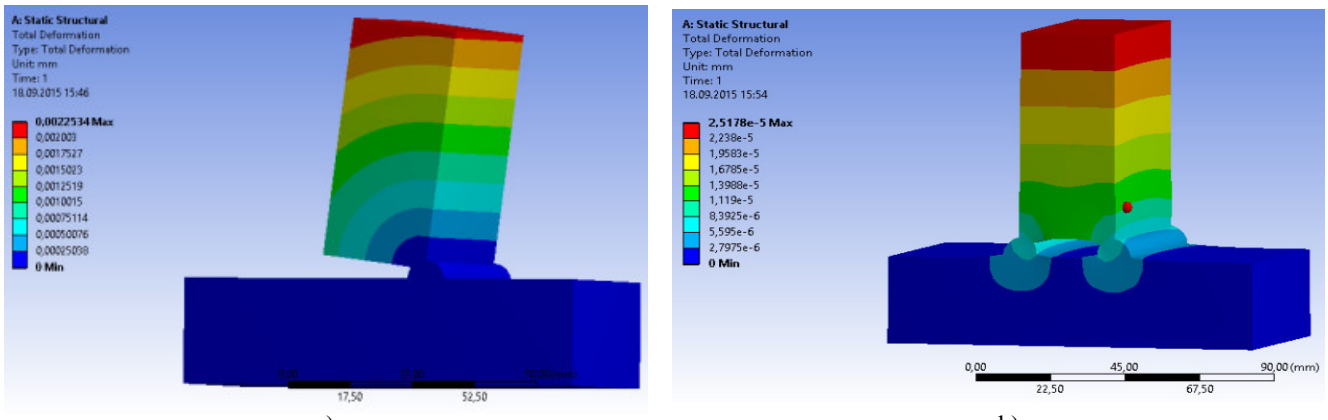


a) b)

**Figure 2:** Modeling of deformation in junctions with one-sided (a) and double-sided (b) seams.

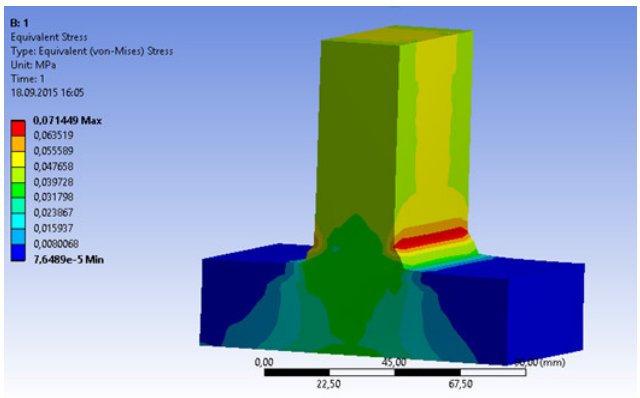


**Figure 3:** Stresses modeling in welded seams T8 and T10 with fool penetration of rib cross-section.

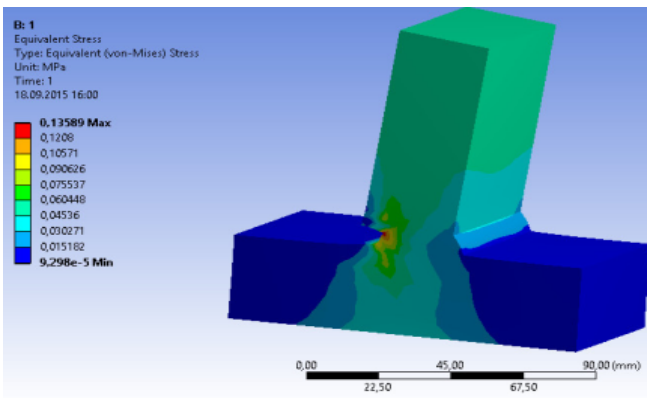


**Figure 4:** Stresses modeling in welded seam T9.

which cares liquid slag with temperature of 1500°C to 1600°C. In the Russian State, Standard GOST 5264 several types of T-bar junctions are considered: with bevel on the edge T8, T9, T10 and without bevel on the edge T1, T2, T3, T4, T5. According to the requirements of GOST 5264, the maximum thickness for welded ridges of T-bar junctions for joints with one bevel for one edge (T8, T9) is 26 mm. This requirement is due to much of built up metal, which is not economically reasonable. That is why when it comes to developing technology of 30 mm thick ribs welding to the pot, primarily T1, T2, T3, T4, T5 and T10 joints should be considered. In theory, any of weld joints above can be applied. Welding technology developing should be based on reasonable selection of joint type and welding materials. One of the most important performance indicators for any structure is the level of tensions inside of it.

## Estimation of Deflected Mode of the Structure

The comparative modeling of the certain part of the structure (the junction of the pot and the stiffener) was accomplished in order to estimate the deflected mode of the welded structure. The modeling was executed for different types of welded joints with similar basic parameters assigned (thickness of the components, loads, materials and mechanical properties of the components). This enables to predict different types of deformation, estimate the possibility of crack occurring and recommend the most acceptable welding technology option. The calculation of deflected mode was estimated with the use of finite element method (FEM) for 3-dimention models prepared with applying of frame design principles [3,4]. Comparative analysis has showed that welded joints with symmetrical arrangement of seams are the most appropriate because the symmetrical seams provide the lowest permanent deformation value in loaded condition. A welded T-bar joint modeling has showed that similar loads for different types of the seam can cause several times different deformation values (Figure 2). This should be taken into account while common using of the product.

The value of permanent deformation of welded joint has an essential meaning for the pot structure, because a big deflection of the pot wall (more than 100 mm) causes aggravating of slag cakes removing and enables the slag sticking in the pot while discharging. The service life of the pot and drive gears decreases significantly due to applying of the impact method of slag odds removing.

Tensions in welded joint of the structure correlate with deformations occurred. The purpose of designing is to create a joint, which, other things being equal, provides minimal tension and deformation volumes and prolongs the service life of the product. Seams T8 and T10 guarantee minimal tensions under commensurate loads due to complete penetration of metal in the junction of the stiffener and the pot body. The acceptable stress distribution in the major metal is obtained (in the pot body) (Figure 3) without peak values occurring in welded joints of other types (Figure 4).

Thickness of the welded rib is limited by Russian State Standard (GOST). For the seam T8 it must be no more than 26 mm, which makes the seam T10 more appropriate. At the same time calculations show

that gaps in welded seam enlarge maximal tensions in metal. Such enlarging depends on a size of defect and can reach decades of per cent according to calculations made in the modeling process.

Laboratory tests showed reducing of the major metal penetration and occurring of local defects like lack of penetration while welding T10 seams with bevels on two edges made due to GOST requires (Figure 5). Taking into account these outcomes the most rational and advanced seam is T1, which is easier to be provided with required quality and with full penetration while welding in any position. The pot size is nearly 3.5 meters high (Figure 6).

## Study on Metal Properties

The second stage of welded cast design of the pot of the slag carrier comprised studying of metal characteristics. It allows taking errors of preparatory calculations into account. The preparatory calculations didn't consider defects of casting technique of the pot manufacturing. Structure analysis of metal samples chosen from various sections of the pot moldings has showed that in the zone of additional stiffeners welding defects of shrinkage are hardly possible. It is so due to the ferrostatic pressure of liquid metal which is in the casting chamber on the stage of casting. At the same time the cast metal structure includes considerable amount of non-metals (Figure 7), causing mechanical, especially plastic properties of the structure decrease. Low plastic properties of metal under complex loading cause premature crack occurring and developing. This leads to the shortening of durability of the cast welded junction.

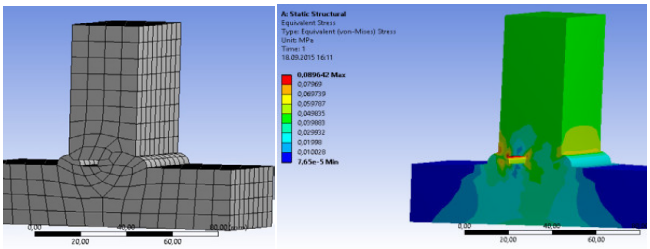

**Figure 5:** Modeling of the welded junction with defect. Stress distribution in the junction (seams T8 and T10).

**Figure 6:** Cast pot in the repair department, stage of welding additional stiffeners.

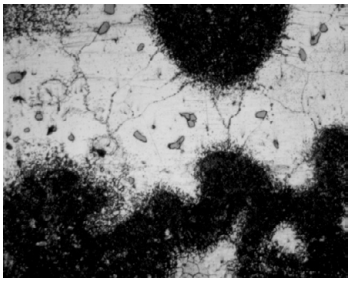

**Figure 7:** Cast structure of the pot metal, steel 30 l (30 L) × 350.

| Electrode type | Ultimate tensile strength (MPa) | Yield point (MPa) | Relative elongation (%) | Toughness (MJ/m²) |
|---|---|---|---|---|
| УОНИ 13/45 (UONI 13/45) | 460 | 350 | 22 | 1.47 |
| УОНИ 13/55 (UONI 13/55) | 490 | 400 | 20 | 1.27 |
| УОНИИ 13/55 (UONII 13/55) | 540 | 410 | 29 | 2.60 |

**Table 1:** Mechanical properties of the metal of the seam at a temperature of +20°C.

In fact, the theoretical analytic model of welded cast junction demands adaptation to real casting conditions with heterogenic properties, otherwise brittle gaps in the composite joint will occur leading to premature destruction of the welded junction. To provide homogenous properties of castings with defects is a complicated problem, which yet can be partly solved due to special manufacturing methods (metal modifying, ultrasonic machining of metal melts, [5–7], special intermediate layer in the welded junction). The last of the methods above is the most cost-effective due to low material accounting in the demanded place of stiffeners installation. Welding-up of intermediate layer on the major layer of cast metal can be executed with the use of electrode classifications УОНИ 13/45 (UONI 13/45), УОНИ 13/55 (UONI 13/55). High mechanical properties of welded-up metal (Table 1) allow welding of a seam providing force transmission from stiffeners onto the pot body without crack occurring. Herewith the absence of brittle gaps in the welded junction guarantees the sustainable running of the product.

## Results and Discussion

The results obtained by modeling of welded cast junctions were used in manufacturing of the pilot output lot of slag pot carriers with pots reinforced by welded stiffeners. Analysis of slag pot carriers' work has performed that welded junctions have no cracks. It also was found out that in operation of the pot additional stiffeners effectively resist body wall deformation. Applying of pot with welded cast structure enables 3-5 times decrease of permanent plastic flow.

Analysis of different joints behavior in metallurgy equipment allows considering that stages of components improving and of new welded cast joints constructing mentioned above are obligate for the process of any composite steel structure manufacturing and can be used in modifying of joints in metallurgy equipment according to specific features of its' operating mode.

## Conclusion

Welding is one of the most effective and workable ways to strengthen joints of equipment used in metallurgy. Stiffing of the slug carrier pot with welded components enables to decrease deformations of its' body from 3 to 5 times.

Studying on major metal properties in the place of additional component connection is obligate for providing high property of the welded junction in the welded cast structure. Taking measures for the metal structure improving in the seam and the weld-affected zone is also obligate.

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