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# Repair Welding of the Massive Cast

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## Abstract

The rebuilding technologies are used to develop surface of ladle. Among many welding methods currently used to obtain surface layer without defects one of the most effective way of rebuilding is using metal arc welding. This additional material gives more possibilities to make expected quality of rebuild surface.

Chemical composition, property and economic factors allow to use metal wire. Because of these reasons, solid wire gives opportunity to be widely used as material to rebuild or repair the surface in different sectors of industry.

The paper shows a few ways to rebuild the surface in the massive cast with the use of metal active gas welding for repair. The work presents studies of defect in the massive cast. It contains the pictures of microstructures and defects. The method of removing defects and the results of checking by visual and penetrant testing methods are shown. The paper describes the methodology of repair the ladle with metal active gas welding, preheating process and standards nondestructive testing method.

**Keywords:** Cast defect, Rebuilding, Quality, MAG, Welding

## 1. Introduction

Massive casting ladles are an integral part of the equipment of large foundries. Many factors, from the design phase to the use phase can influence the quality of ladles. Each stage of casting production is essential. The design phase is expected to provide technological, geometrical and metallurgical solution. The production phase is supported to minimise technical difficulties, whereas the usage phase provides durability. Despite the improvement of foundry technology, casting defects which disqualify components for direct use still occur.

The aim of this study is to present the practical technology used to remove casting defects detected in the massive elements. The methodology can also be used for regeneration of castings have worked a certain number of hours and require major repair or were accidentally damaged. The paper presents ways to remove casting defects and the treatment for repairing massive elements. It discusses the issue of heating before welding and the possibility of heat treatment after welding.

The work is dedicated to practical issues of repairing massive castings weighing more than 10Mg. The first step to begin welding work is preparation for the non-destructive testing and preparation of the documentation of defects. The next step is the selection of proper welding technology with the use of solid wire and the proper welding technique. Then, defects are removed with selected method. After that, surface is checked by NDT (Non Destructive Testing) and if is flawless, the process of preheating is conducted. When the preheating temperature reaches the expected level the welding process begins. [1-10]

## 2. Materials

Ladle is manufactured with the use of cast steel. Cast steel is characterized by high shrink casting. Low-carbon steel (<0.2% C) is characterized by highly alloyed poor castability. In the structure of obtained castings defects such as flaw in casting, cracks, blisters, may be found.

The increase of carbon content in steel is improved fluidity, so that the medium and high carbon steel casting does not cause great difficulties, and the structure is obtained without casting defects.

The mechanical properties of cast steel, is mainly dependent upon the carbon content, a relatively low yield caused by steel structure is dendritic, it involves the segregation of C, P. The disadvantage of cast steel, which affects the mechanical properties is the strong influence of the wall thickness of the casting on solidification speed. The mechanical properties of the steel such as homogenisation, normalizing, annealing, and quenching and tempering are improved by heat treatment.[1-6]

### 3. Repair technology

To repair the ladle weighing more than 10 Mg and of chemical composition (C=0.2%, Si=0.29%, Mn=0.93%, P=0.01%, S=0.013%, Cr=0.1%, Ni=0.09%, Mo=0.025%, Al=0.04%, Cu=0.1%) and MAG welding wire EMK-6 (C=0.08%, Si=0.85%, Mn=1.4%; P=0.009%, S=0.017%, Cr=0.04%) with the mechanical properties  $R_e > 420$  MPa,  $A_5 > 20\%$ ,  $KV > 47J$ , type of electrode: G 42 4 M21 G3Si1 according to standard EN ISO 14341-A, diameter 1.2mm, shielding gas: Ar/CO<sub>2</sub> (82/18), flow 15 l/min were used.

Before the process of repair, volumetric - ultrasonic testing was conducted to determine the position of casting defects and the depth of their occurrence. Next, a manual processing gouging (Fig. 1) and grinding (Fig. 2) or machining milling (Fig. 3) depending on the depth of the casting defect was performed. After cleaning the visual inspection and penetration tests (Fig. 4) of the repair surface were performed. [11-17]

Then, after removing all defects the repair process began. Due to its weight and thickness the element was heated in an oven to a temperature of 200°C and then spot welding was blanketed with insulating mats and was secured before cooling of the element (Fig. 5) by using the powerful gas burner.

For welding the current setting in the range of 270-290 and the voltage in the range 30-32V by the welding speed 20-30 cm/min, was used. Repair was made in the flat position (PA).

### 4. Casting defects

Casting defects resulting from the casting process are divided into five groups: [6]

- shape defects - misrun, mechanical failure, pushing, trapping, breach dimensional adjustment, distortion.
- surface defects of the cast - including: roughness, contamination, pitting, blisters, scabs, folds, slightly melt, dent, raids, etc.
- breaks of continuity - cracking, tearing, nonwelds.
- internal defects - bubble, bladder, systolic cavity, cinder, segregation, etc. These kinds of defects inside the cast are determined by using ultrasonic and X-rays testing.
- material defects - It is stated on the basis of chemical analysis, metallographic tests, strength, etc.

The reasons for the occurrence of casting defects are: inadequate design of the casting, faulty design or execution model, improper molding material, inappropriate forms of execution, improper preparation of the alloy, wrong selection of the casting mold, improperly implemented spiking, cleaning and finishing the casting.

The repair of defective castings mainly concerns defects of shape, space and continuity. The most important ways to fix defective castings for this case are:

- removal of surface defects by manual gouging (Fig. 1) or grinding (Fig. 2) or by mechanical means - grinding, shearing, milling (Fig. 3)



Fig. 1. Removing the defect by manual gouging



Fig. 2. Cleaning the surface by manual grinding



Fig. 3. Preparing the surface by mechanical milling



Fig. 4. The view of the surface checked by penetrant testing (PT)



Fig. 5. Gas burner to preheating

- welding - repair of cracks (Fig. 4), misruns, bubbles, etc.
- overmolding - supplementing the damaged part of the cast or misrun (Fig. 6)



Fig. 6. Rebuilding the surface of ladle



Fig. 7. Rebuilding of the surface of ladle by sequential welding

- heat treatment of the casting - getting a proper structure and properties of the casting. Figure 8 shows irregular structures by the high speed of cooling, and figure 9 shows structure in the middle part of ladle wall (100mm).

There are also cases of repairing by: obstruction, cements, impregnation of castings, metallization and soldering.

Surface research by: visual, penetrant and magnetic particle test and checked by volumetric test such as: ultrasonic and radiographic test are used most commonly to determine the quality of ladle.

Table 1 provides a summary of non-destructive testing standards that could be used for castings research.

Table 1.

List of standards NDT

Test method	Testing standard	Acceptance criteria
Visual testing	---	EN 1370-2012, Founding - Examination Of Surface Condition
Penetration testing	ISO 3452-1:2013 Non-destructive testing. Penetrant testing. Part 1: General principles	EN 1371-1:2012-01, Founding - Liquid penetrant testing - Part 1: Sand, gravity die and low pressure die castings. Part 2: Founding. Liquid penetrant inspection. Investment castings
Magnetic particle testing	ISO 9934-1:2016 Non-destructive testing. Magnetic particle testing. Part 1: General principles	EN 1369:2012 Founding. Magnetic particle testing
Ultrasonic testing	ISO 16810:2014 Non-destructive testing. Ultrasonic testing. General principles	EN 12680-1:2003 Founding. Ultrasonic examination. Steel castings for general purposes
Radiographic testing	ISO 5579:2013 Preview Non-destructive testing. Radiographic testing of metallic materials using film and X- or gamma rays. Basic rules ISO 19232-1:2013 Preview Non-destructive testing. Image quality of radiographs. Part 1: Determination of the image quality value using wire-type image quality indicators	EN 12681:2003 Founding. Radiographic examination

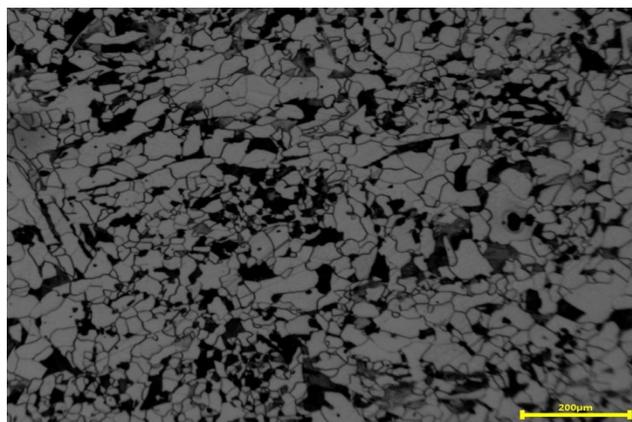


Fig. 8. Irregular structures of the ladle

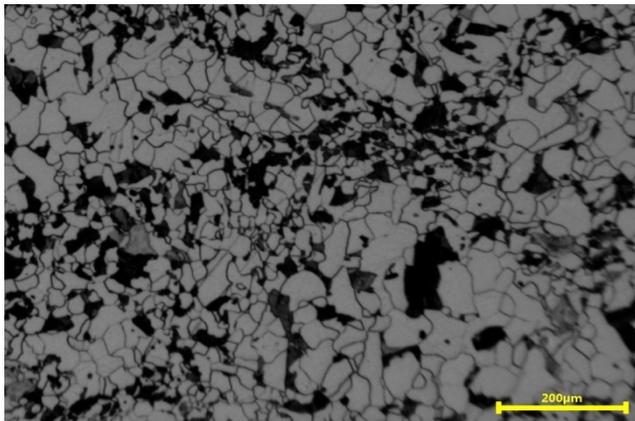


Fig. 9. Structures in the middle of the surface layer

## 5. Conclusions

In the case of repair of massive castings, it is important to use appropriate treatment process before, during and after the welding. The use of pre-heating allows safe and efficient repairs. The control of interpass temperature (up to 300°C) and preheat temperature (up to 200°C) gives the expected quality effects. A crucial factor is the way of identification casting defects prior to the repair process. For this purpose, methods such as: research studies of surface, visual, penetrant and magnetic powder, ultrasonic and radiographic testing can be used. Due to the large volume of the cavities attention should be pay to:

- the sequence of welding parameters,
- the geometry of the beads,
- minimizing the factors related to the heterogeneity of the chemical elements
- segregation in the cast by application of a buffer layer,
- the stress generated in the weld which can cause incompatibility in the repair process.

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