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ISSN 0543-5846
METABK 55(3) 433-436 (2016)
UDC – UDK 620.193:669.15:620.18:620.16=111

EFFECT OF HEAT LOAD ON STRUCTURAL CHANGES OF SELECTED CORROSIVE RESISTANT STEELS

Received – Primljeno: 2015-10-30
Accepted – Prihvaćeno: 2016-01-20
Preliminary Note – Prethodno priopćenje

Corrosion resistant steels are used for the production of parts exposed to corrosive environment and also to thermo-mechanical loads. Steel molds in the glass manufacture industry with their functional surfaces simultaneously exposed to the combined thermo-mechanical cyclical loads by liquid glass and corrosive effects of aggressive exhausts of preheating burners are fine examples. This paper is focused on the structural properties and stability of the selected steels under these demanding conditions. The experiment simulated heat load conditions. Two experimental corrosion and heat load resistant materials with high hardness were selected: austenitic steel Dominial-ZF2 ESU, 1.2782 and Toolox 33 and 44 martensitic steels (equivalent to W. Nr. 1.2311, 1.2312, 1.2738, and P20).

Key words: corrosion, resistant steel, microstructure stability, degradation

INTRODUCTION

Glass manufacture molds and preforms are construction parts used in the production of glass products. Their shape reflects the shape of a manufactured product and their functional surface is highly polished. They serve as a basis for pressing or moving the molten glass within short cycles. Hot molten glass drop falling on the metallic surface is mechanically processed and subsequently rapidly cooled. With regard to premature degradation of steel parts, the customers will be interested not only in material behavior just from the point of view of the mechanical properties but of the structural stability as well [1-3].

EXPERIMENTAL PROCEDURE

In order to predict structural changes in selected materials a simulation of the heat load conditions was performed on specially prepared tensile test rods subjected to cyclic heating. Surface roughness of the narrowed (central) region of all samples was identical because the high temperature exposition led to formation of oxide layer with varying coarseness covering the whole sample surface. Cyclical heating (at a temperature of 1 000 ° C) was conducted using a specially modified welding device allowing to concentrate the temperature into the smallest cross-section of the sample. After the heat load, the samples were rapidly cooled in flowing water of temperature of 18 °C (for 5 seconds). The whole process was repeated 80 times. Subsequently, the cycled test rods have been broken using a tensile testing machine. Structural stability observation was carried out on metallographically prepared sections (in the smallest cross-section) in a longitudinal section perpendicular to the fracture surface.

Microstructural responses of materials in proximity of the fracture surface

Although a continuous fractographical observation was being carried out throughout the whole experiment, only the relevant microstructures in longitudinal section perpendicular to the fracture surface were selected for the paper. Thermally unaffected microstructures (below the fracture surface) were compared with a microstructures of samples subjected to the highest thermal loads.

Dominial ZF 2 without the heat load:

This material commonly used for glass molds and preforms unaffected by thermal load showed sensitivity to the ongoing plastic deformation under the fracture surface. After the fracture, the material contained characteristic fine hardened bands and inhomogeneities originating from impurities missing due to the fracture. A detailed evaluation of the microstructure of hardened zones confirmed that the structure of the austenite is retained with the occurrence of twins and carbide phases (Figure 1a**)**. High amount of chromium based carbides arranged in bands or along the austenitic grain boundaries (Figure 1b) was observed in the plastically undeformed base material.

For all materials, the specific regions under the fracture surfaces were evaluated – microregions in close proximity of the tensile rod failure and areas of expected structural changes [4].

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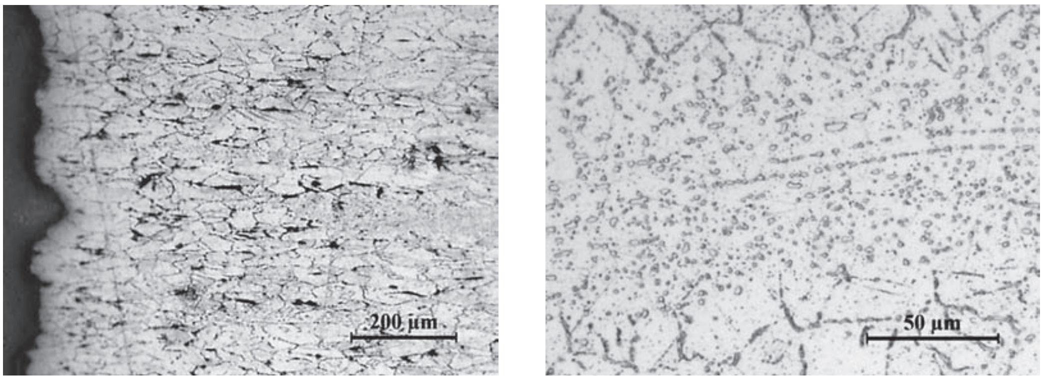
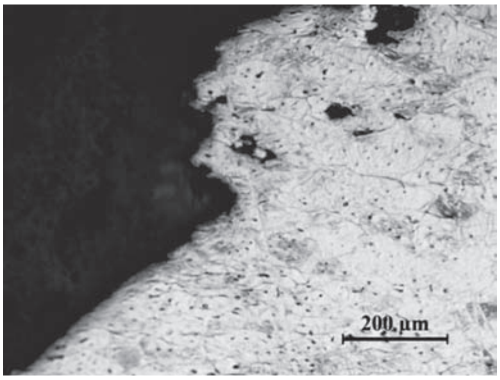


a) Microstructure next to the failure

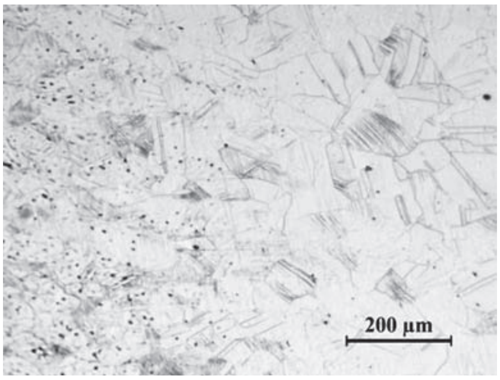
b) Microstructure, 3,5 mm from the failure

Figure 1 Dominial ZF 2, non-cycled sample

Heat loaded Dominial ZF 2 (80 cycles): During the course of the heat cycling, the microstructure was continuously changing due to the temperature and strain hardening manifested by formation of differently sized deformation bands with irregular distribution of carbide phases. After 80 heat cycles a relatively significant microstructural change was detected – occurrence of deformation bands in longer distance from the fracture surface [5]. The edge of the fracture surface was lined by inhomogeneities and cavities originating from missing inclusions (Figure 2a). Distinct interface was present between the hardened zone and the base material (Figure 2b). Redistribution of the carbides and highlighting of the slip lines in austenitic grains was observed in these locations.



a) Microstructure next to the failure



b) Microstructure of transition zone between plastically deformed and undeformed zone (app. 1,5 mm from the failure)

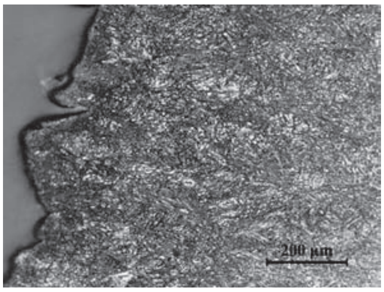
Figure 2 Dominial ZF 2, after 80 cycles

Toolox 33 without the heat load:

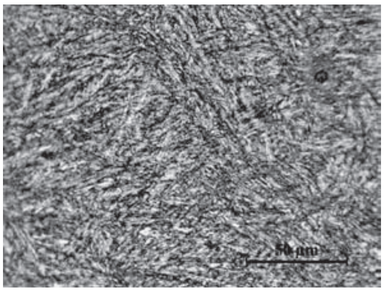
The material did not show any marks of strain hardening on the fracture surface edge (Figure 3a) as in case of Dominial ZF 2. The change consisted only in finer martensitic laths resembling lower bainite. Retained austenite was present between martensitic laths (Figure 3b) and in several cases was observed a relatively high amount of oxides and carbonitrides (confirmed by micropurity evaluation).

Toolox 33 after 80 cycles:

The microstructure after 80 heat cycles significantly changed in the proximity of the fracture (Figure 4). There appeared an area formed of distinctive white bands in close proximity of the fracture surface [3, 6]. In detail, the microstructure of this affected zone can be



a) Microstructure next to the failure



b) Microstructure, 1,5 mm from the failure

Figure 3 Toolox 33, non-cycled sample

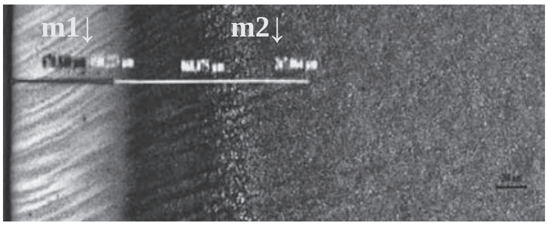


Figure 4 Toolox 33 – after 80 cycles

evaluated as incorrectly quenched and incompletely tempered martensitic structure. At the interface, there was decohesion of the prior austenitic grains (Figure 5a) confirmed by fractography evaluation. Microstructure of the transition zone (Figure 5b) can be described as low-tempered martensite (lower bainite).

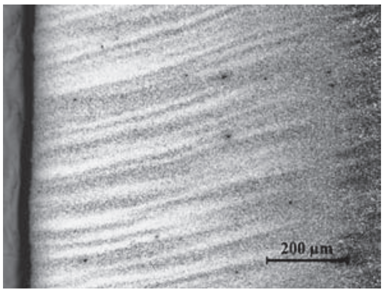
Toolox 44 without the heat load:

After etching, sorbitic structure with slight strain hardening effect due to the tensile testing was observed in the fracture area of the non-majority cycled Toolox 44 sample. The fracture area of the samples contained cracks. Their character is documented in Figure 6a. Inclusions of different sizes surrounded the cracks [7, 8]. Even the base structure can be characterized as sorbitic (Figure 6b), in which appeared cavities after missing impurities.

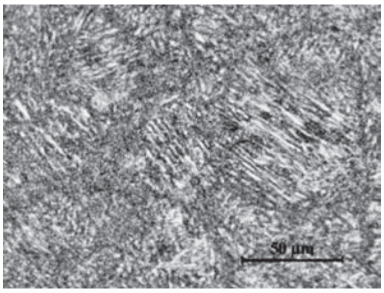
Heat loaded Toolox 44:

In the Toolox 44, microstructure alteration was observed already after several cycles of the heat load. Strain hardened band area consisted of bright and dark bands of fine sorbite (Figure 7 and 8a).

Material was typical by the fact that heat load was structurally reflected in uniformly alternating bands with their interfaces distinct only by their brightness [9]. Insignificantly altered base material consisted of lower bainite (Figure 8b).

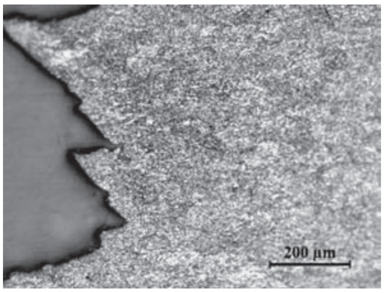


a) Microstructure next to the failure

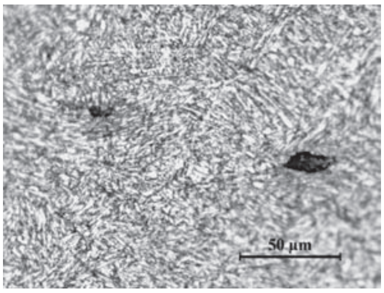


b) Microstructure, 3,5 mm from the failure

Figure 5 Toolox 33, after 80 cycles majority cycled Toolox 44 sample. The fracture



a) Microstructure next to the failure



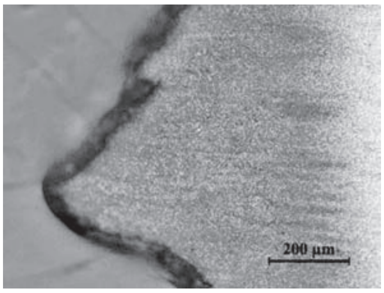
b) Microstructure, 3,5 mm from the failure

Figure 6 Toolox 44 – non-cycled sample

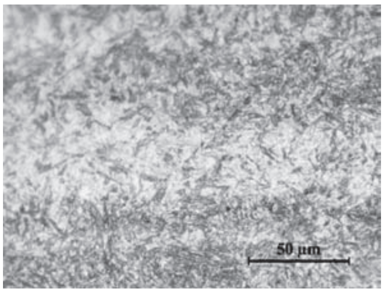
Figure 7 Toolox 44 – after heat cycling

CONCLUSION AND RECOMMENDATIONS

It is possible to state smaller or greater structure alteration was observed in all cases. Structure transformation in functional surfaces led to change in corrosion resistance. Mechanical–heat load cycles cause stress-



a) Microstructure next to the failure



b) Microstructure, 3,5 mm from the failure

Figure 8 Toolox 44 – after heat cycling strain states in micro volumes leading to the failure initiation. Degradation is superpositioned by the formation of various phases or deformation bands resulting in different thermal expansion in micro volumes and distinct surface wear (increased adhesion of the molten glass). Authors of the paper recommend neither of the tested materials for use in glass manufacture moulds and preforms.

Acknowledgement

This work was supported by the Ministry of Education, Youth and Sport of the Czech Republic, within the NPU1program, project No LO1207.

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Note: Translator responsible for English language is lector from University