FACULTY OF FOUNDRY ENGINEERING

XXXVIII INTERNATIONAL SCIENTIFIC CONFERENCE
FOUNDRYMAN' DAY 2014

Krakow, 27 – 28 Nov. 2014

QUALITATIVE ASSESSMENT OF THE DEFECTS IN METAL CASTING PROSTHETIC RESTORATIONS

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Keywords: Cobalt-based alloys, casting defects, dental prosthetics, 3D scaner

1. Introduction

Cobalt-based alloys are among the materials used for stomatological products. Next to a range of valuable utilitarian and technological properties of the Co-Cr-Mo/Co-Cr-Mo-W alloys, their flaw is a limited plasticity, which is seen as the main cause for the occurrence of defects (cracks) of the prosthetic elements [1]. Among the structural causes of cobalt casting alloys' fragility are such factors as microporosity of the cast, dendritic microsegregations, the presence of carbides in the alloy or the cast's tendency for a coarse-grained structure [2]. Metal prosthetic elements (crowns, brackets, frame prostheses, bridges, valves) based on the Co-Cr-Mo-W alloys can be produced by various methods, such as powder metallurgy, hot forging or lost wax (investment) casting [3-6]. Due to the small cross-sections of prosthetic restorations, and thus the necessity of high geometrical precision of the manufactured element, the most frequently used method in a prosthetics laboratory is the lost wax casting method, which assures the production of casts of the shape and anatomical parameters dedicated to the needs of the individual patient.

2. Experimental

Within the frames of this work, a macro- and microscopic analysis of ready prosthetic elements cast in a prosthetics laboratory by a dental technician was performed. Additionally, an analysis with the use of a 3D ATOS scanner by GOM was conducted.

The studies were performed on ready cast prosthetic elements (frame prostheses, clamps, substructures) made of a cobalt-based alloy, brand name Argeloy N.P. Special by Argen. The alloy's chemical composition (Table 1).

Table 1. The chemical composition of the investigated alloy Co-Cr-Mo, %mass

Cr	Co	Mo	Si	Mn	C
31,5	59,5	5,0	2,0	1,0	0,4

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3. Results and discussion

The macroscopic observation made it possible to reveal the casting defects on the examined prosthetic elements, such as blisters, misruns and cracks. The defects formed in the prosthetic metal elements are presented in Figures 1-3.

Fig. 1. Cast of a frame bracket prosthesis with a visible casting defect in the form of blisters

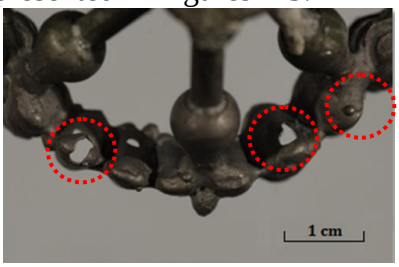


Fig. 2. Structure of a circular bridge with casting defects in the form of blisters and misruns in the upper and side part of the substructure

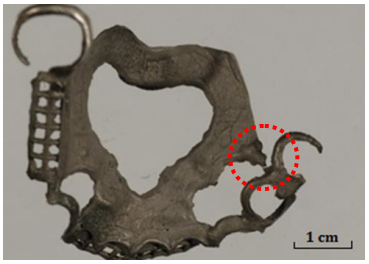


Fig. 3. Frame prosthesis with a visible cold fracture on the side of the bracket

The microscopic and SEM observations confirmed the presence of cast defects in the form of microshrinkages and pores occurring in the dendrite arms as well as microcracks running along the dendrite axis (Fig. 4-5).

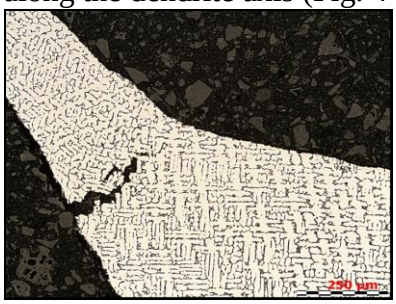
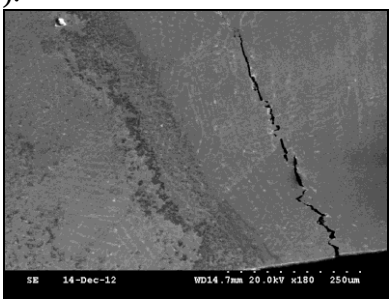


Fig. 4. Microstructure of the Co-Cr-Mo alloy with a visible casting defect – intercrystalline crack



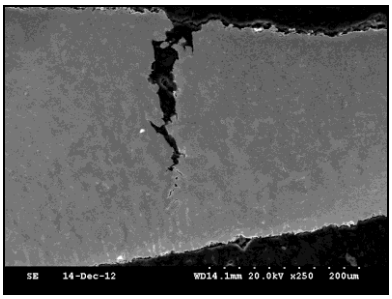


Fig. 5 Scanning images with visible casting defects in the form of microshrinkages and pores as well as cracks, with different magnifications

The GOM technology makes it possible to process the scanned element (detail) into a digital form. This allows for a detailed observation of the elements in the three-dimensional system, owing to which we can precisely analyze the measured element in space. The GOM Inspect program made it possible to perform a virtual visualization of the measured section of the examined frame prosthesis. The conducted examinations revealed casting defects in the form of a misrun of the material (Fig. 6-8).

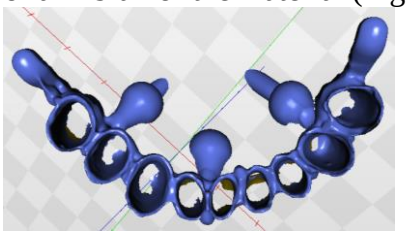


Fig. 6. Three-dimensional image of a circular bridge structure with a visible „series" of misruns revealed by means of a 3D ATOS scanner

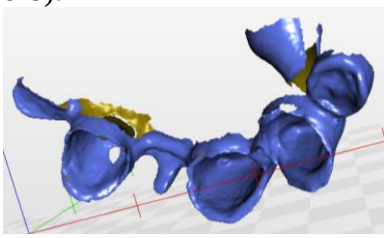


Fig. 7. 3D visualization with the use of a ATOS 3 scanner of a substructure with a casting defect (misrun)

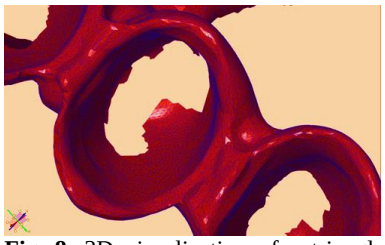


Fig. 8. 3D visualization of a triangle network showing the measured surface fragments of a circular bridge structure

4. Discussion of test results

One of the causes of the formation of shape defects is an improperly designed gating system. A frequent cause of the occurrence of casting defects is an inappropriate location of the ingates, which generates strong perpendicular strikes of the liquid metal at the walls of the mould. That is why, in the areas where there is a risk of a mould cavity deformation, the ingates should be situated at an angle in respect of the mould cavity.

An earlier solidification of the metal causes an incomplete fill-up of the mould, which results in the presence of defects such as a misrun of the material. The occurrence of a misrun is, to a large degree, caused by an insufficient castability of the metal. A defect of this type can also be caused by an insufficiently high temperature of the metal (which should be controlled throughout the whole technological process), a badly selected chemical composition or a thickness of the cast walls too low in respect of its height.

A cold or hot crack of the material is a result of a temperature difference in the cross section, which generates shrinkage stresses formed during the solidification process. The formation of this type of defects may also occur when the knock-out of the cast from the metal mould is too rapid or the content of gases in the metal which are formed in the alloy during its casting or during the mould filling process is too high. Too high an amount of non-metallic inclusions as well as their disadvantageous form also negatively affect the quality of the cast.

In the solidification process, the casting stresses present in the material generate not only external defects but also structural ones. An intercrystalline crack is the main defect of centrifugally cast materials. It is a fracture running between the grains of the alloy. Its main cause is an improper course of the metal's solidification process. Another internal defect which can be present in the cast is a blister. The main factor for the occurrence of blisters is the gas released from the moulding sand as well as the gas released from the metal during its solidification. In order to eliminate the causes of the defect, one should assure a proper degasification and purification of the metal

Acknowledgements

The work has been implemented within the framework of statutory research of AGH University of Science and Technology, contract No 11.11.110. 299 AGH

References

[1] Bojar Z., (1992), Analysis of the impact of the structure on the corrosion resistance and fracture mechanism of cobalt alloys type Vitalium, WAT Warszawa (in Polish).

[2] Beer K., Pałka K., Surowska B. & Walczak M., (2013), A Quality assessment of casting dental prosthesis elements. Maintenance and Reliability 15(3), 230-236.

[3] Marciniak J., (2008), Biomaterials in dentistry. Technical University of Silesia, Gliwice (in Polish).

[4] Augustyn-Pieniążek J., Łukaszczyk A. & Zapała R., (2013), Microstructure and corrosion resistance characteristics of Co-Cr-Mo alloys designed for prosthetic materials. Archives of Metallurgy and Materials 58, 1281-1285.

[5] Łukaszczyk A. & Augustyn-Pieniążek J., (in press March, 2015), Corrosion resistance of Co-Cr-Mo alloy used in dentistry. Archives of Metallurgy and Materials.

[6] Surowska B., (1997), Formation of chemical composition and structure of the alloy Co-Cr-Ni-Mo as biomaterials, Technical University of Lublin (in Polish).