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Evaluations of residual tension states in laser welded CoCrMo alloys

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Introduction

By applying finite element analysis we can make experiments regarding the efficiency of welded joints used for the repair of removable partial dentures components [1,3,4,5,6,7]. Welding procedure and appropriate equipment is determined by the components dimension, the quality of the alloys and the profile of dental prosthesis. Modifications that appear in welded structures can be investigated through non invasive tests, such as radiography or finite element analysis.

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Objectives

The study was focused on stress areas evaluation, induced in RPD laser welded frameworks, on the purpose of determining the durability of prosthesis rehabilitations.

Material and Methods

For testing, it was used a CoCrMo dental alloy type "C" (Vaskut Kohàszati Kft- Budapest, Hungary), which has the following chemical composition: Co% - 65%, Cr% - 29%, Mo% - 5% and the following mechanical parameters: Rm=760MPa, Rp0,2=560MPa, E=219000MPa. The welding equipment used for the tests was XXS Laser (Orotig, Verona, Italy). Three-dimensional cast plates were manufactured from this metal, in size of 7x7 mm and width of 1 mm, which were then meshed into solid elements (65960 elements, 294623 nodes).

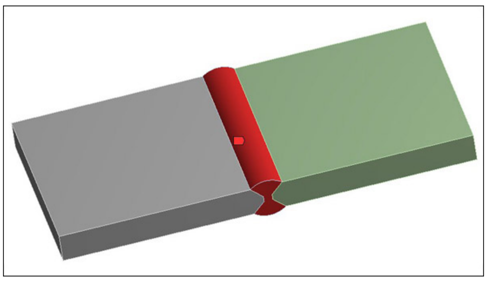


Fig. 1a: Models of welded joints: a. geometrical models

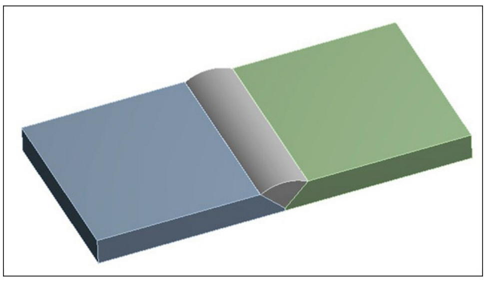


Fig. 1b: Models of welded joints: b. geometrical models

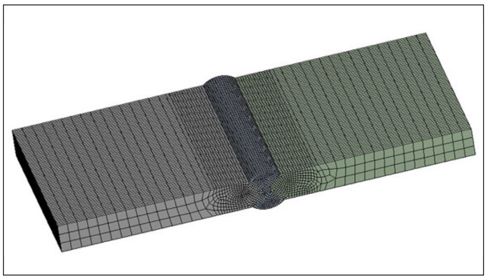


Fig. 1c: Models of welded joints: c. Meshed models

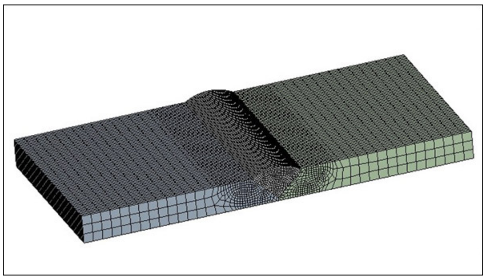


Fig. 1d: Models of welded joints: d. Meshed models

The welding method was in butt joint configuration with filling material on one or two surfaces.
There was made a static analysis of the tension state (resulted after welding) regarding temperature and heat flux distribution. This analysis serves to welding procedure simulation, in which temperature, heat flux distribution and static analysis of stress state, resulting from welding, were under constant observation.
The thermal parameters used for an estimation were: coefficient of linear expansion-β=3,36105 W/mm2°C, coefficient of heat conductivity-λ=6,0510-2W/mm°C; Specific heat-C=434 J/Kg°C.
In order to realize a thermal analysis with finite elements and reveal the welding residual stress, specific software (solid works 2007) was used.
The finite element analysis for residual tensions was realized in two stages:
1. a simulation of the welding process with emphasis on heat distribution and heat flux, in fact a thermal analysis
2. a static analysis of the tension state that occurs after the welding process.

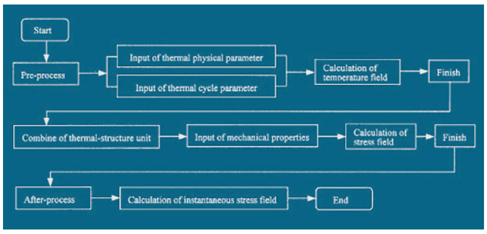


Fig. 2: Working diagram

Results

The study results reveal that around the fusion zone there is a stress gradient, and this is the one that forms cracks in the fusion zone in steel.
The thermal calculation applied in the rib is analyzed in connection with temperatures distribution during welding and cooling. This consists in temperature field's distribution on a period of 1-6s.
Analyzing the stress field of numerical simulated longitudinal section, the high values of stress from the heat affected zone and their orientation towards the welding exterior surface, where cracks usually appear, it can be observed the highest temperature is obtained in the first second.

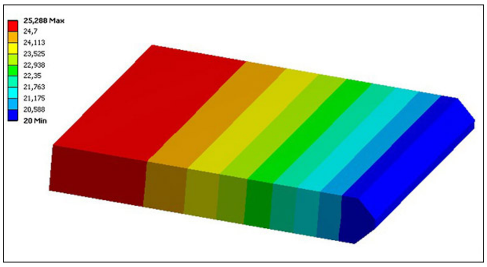


Fig. 3a: The weld simulation under the aspect of thermal distribution for: a. welds on two faces

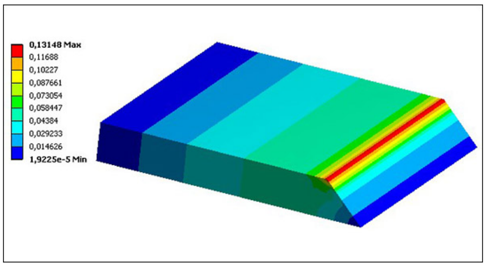
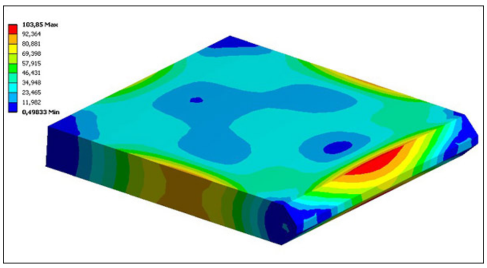


Fig. 3b: The weld simulation under the aspect of thermal distribution for: b. for welds in "V"

The results analysis consists in temperature distribution on a period of 1-6s (a,b), total heat flux distribution of the fusion zones (c,d) and equivalent tension at 1s (e) and 6s (f) after application of welding arch. Because of the symmetry, calculations were made only on one of the plates. For the other plate, the results are similar. The determination of tension states for this specific geometric pattern takes place when no exterior forces interfere .Therefore, the tension state will be influenced only by different variations in temperature.



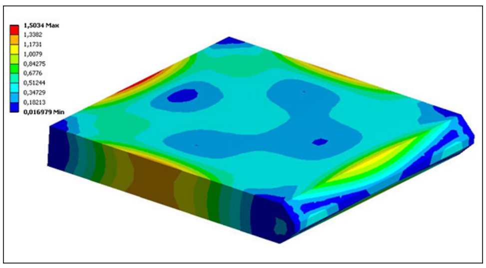
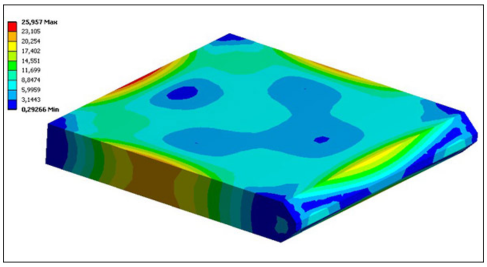


Fig. 4a: Stress distributions during 6 seconds: a. welding variant on two faces

Fig. 4b: Stress distributions during 6 seconds: b. welding variant on two faces



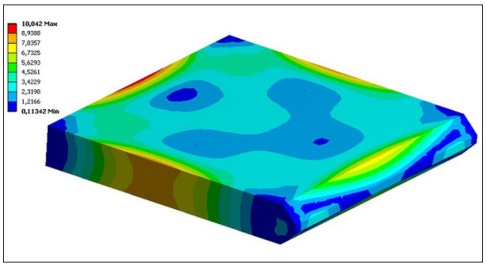
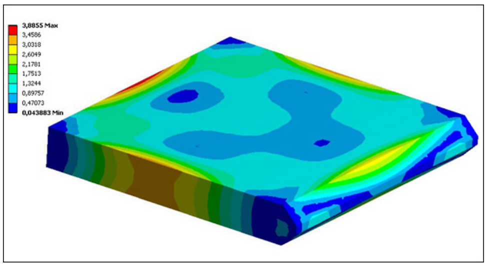


Fig. 4c: Stress distributions during 6 seconds: c. welding variant on two faces

Fig. 4d: Stress distributions during 6 seconds: d. welding variant on two faces



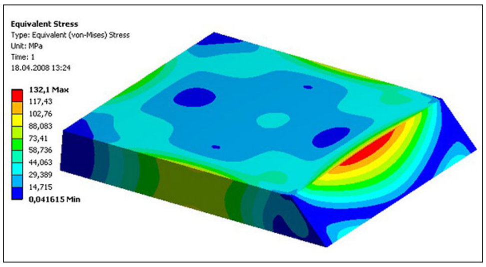
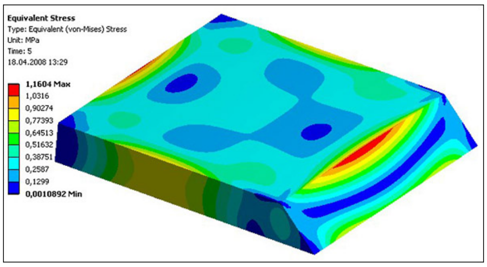


Fig. 4e: Stress distributions during 6 seconds: e. welding variant on two faces

Fig. 4f: Stress distributions during 6 seconds: f. variant of welding in "V"



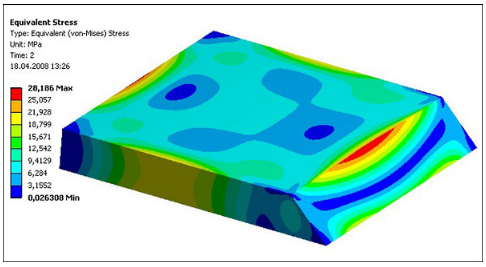
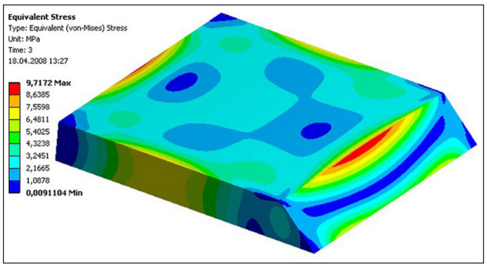


Fig. 4g: Stress distributions during 6 seconds: g. variant of welding in "V"

Fig. 4h: Stress distributions during 6 seconds: h. variant of welding in "V"



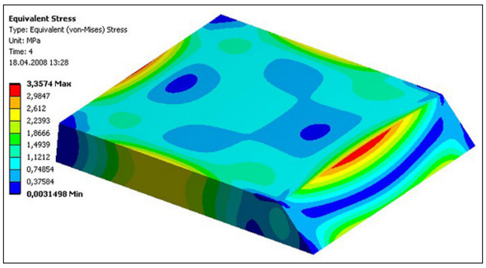


Fig. 4i: Stress distributions during 6 seconds: i. variant of welding in "V"

Fig. 4j: Stress distributions during 6 seconds: j. variant of welding in "V"

Longitudinal sections were executed on a both sides welded plate and on a "V"shaped welded plate, in order to follow the tension field. It can be noticed that tensions have greater values in the heated areas and these are oriented towards the external surfaces of the plates.

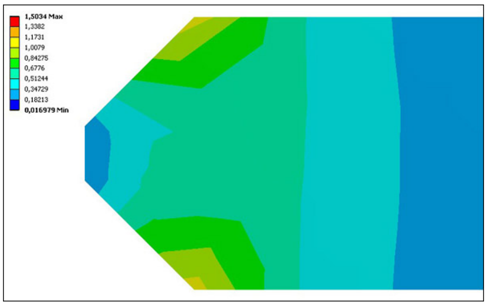


Fig. 5a: Presentation on the longitudinal section of the welded plates of the stress areas according to the welding type: a. Weld on two faces

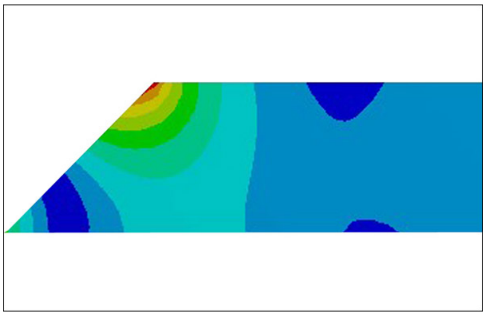
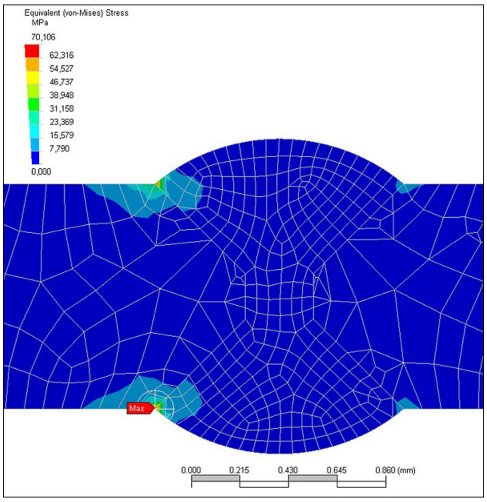


Fig. 5b: Presentation on the longitudinal section of the welded plates of the stress areas according to the welding type: b. Weld in "V"



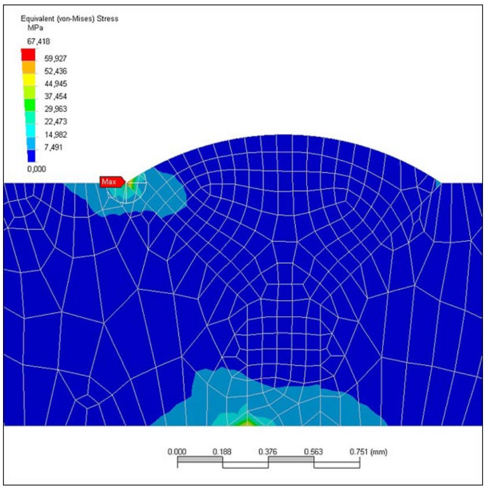


Fig. 6a: Equivalent von Mises stress for the two types of welded joints: a. on two faces

Fig. 6b: Equivalent von Mises stress for the two types of welded joints: b. in "V"

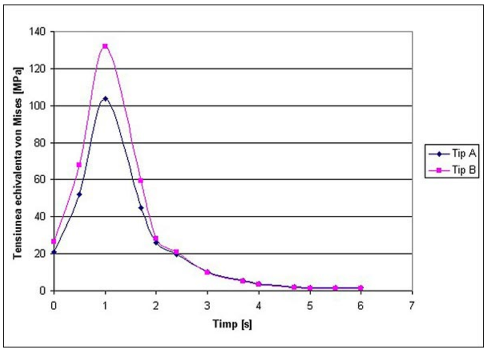


Fig. 6c: Equivalent von Mises stress for the two types of welded joints: c. the diagram equivalent stress/time for the two welding procedures

Conclusions

The welded area has the peak tensile residual stresses longitudinal to weld direction and perpendicular to welding arch. Study results reveal that around the fusion zone there is a stress gradient, and this is the one that forms cracks in the fusion zone in steel [5,7] Welding is a useful method in metallic prostheses repairs, and the decrease of alloys hardness is a priority. So, it is important to control welding heat input, in order to reduce welding stress and avoid cracks.

The residual stress will be used in determining the risk for bucking, fatigue, cold cracking or stress corrosion cracking. The finite elements method has no applicability for metallurgy [3].

Computational welding mechanics solve industrial problems [4]. This one establishes methods and models (through finite elements methods) that are usable for the control of welding processes or welding design.

In thermal simulation, there are certain limits [5,6,7]. Firstly, a high cooling rate is to be encountered. Secondly, the heat losses on the surface can be lower than that ones on the centerline of specimen, especially if the peak temperature is high and the thermal conductivity is low. Thirdly, the temperature gradient is much lower in the weld heat-affected zones, for instance near the fusion line of stainless steel.

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Abbreviations

RPD - Removable Partial Denture

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