

# Laser Welded Ni-Cr Dental Alloys Inspection

Porojan S., Sandu L., and Topală F.

**Abstract**—Minor problems arising from optimizations by welding of fixed prostheses frameworks can be identified by macroscopic and microscopic visual inspection. The purpose of this study was to highlight the visible discontinuities present in the laser welds of dental Ni-Cr alloys. Ni-Cr base metal alloys designated for fixed prostheses manufacture were selected for the experiments. Using cast plates, preliminary tests were conducted by laser welding. Macroscopic visual inspection was done carefully to assess the defects of the welding rib. Electron microscopy images allowed visualization of small discontinuities, which escapes visual inspection. Making comparison to Ni-Cr alloys taken in the experiment and laser welded, after visual analysis, the best welds appear for Heraenium NA alloy.

**Keywords**—macroscopic visual inspection, electron microscopy images, Ni-Cr dental alloys, laser welding.

## I. INTRODUCTION

MINOR problems arising from optimizations by welding of fixed prostheses frameworks can be identified and corrected before the completion of the weld [1].

Macroscopic visual inspection is important to assess aspects of welding rib. To highlight the discontinuities which are not visible to the eye, optical or electronic microscopy may be used.

When assessing a weld it is important to note the type of discontinuity, its size and location. Each of these factors and all together are decision makers and, based on an established standard might transform a discontinuity in a defect.

Discontinuities are interruptions in the typical structure of a weld. They may be a lack of uniformity in the mechanical, metallurgical, or physical characteristics of the material or weld. All welds have discontinuities, but they are not necessarily defects.

A defect, according to AWS (American Welding Society), is a discontinuity or discontinuities, which by nature or accumulated effect (e.g. total porosity or multiple inclusions) renders a part or the whole product unable to meet minimum applicable acceptance standards. This term designates rejectability [1].

Discontinuities and defects have to be detected in order to determine the quality of the weld and related to the possible etiology.

Sandu L. is with the "V. Babeş" University of Medicine and Pharmacy Timișoara, Romania (e-mail: lilianasandu@gmail.com).

Topală F. is with the "V. Babeş" University of Medicine and Pharmacy Timișoara, Romania (e-mail: florin.topala@gmail.com).

Porojan S. is with the "V. Babeş" University of Medicine and Pharmacy Timișoara, Romania (e-mail: sorin\_poro@yahoo.com).

## II. OBJECTIVE

The purpose of this study was to highlight the visible discontinuities present in the laser welds of dental Ni-Cr alloys.

## III. MATERIALS AND METHODS

Three different Ni-Cr base metal alloys designated for fixed prostheses manufacture were selected for the experiments: Wiron 99: 22.5%Cr, 65% Ni, 9.5% Mo, <1% Si, <1% Fe, <1% Nb, <1% Ce, Wiroloy NB: 25% Cr, 67% Ni, 5% Mo, 1.5% Si, <1% Mn, <1% Nb, <1% C, <1% B (Bego, Bremen, Germany), Heraenium NA: 24% Cr, 59.3% Ni, 10% Mo, <2% Si, <2% Mn, <2% Fe, <2% Nb (Heraeus Kulzer GmbH, Hanau, Germany).

The filler materials were proper wires based on Ni-Cr with a diameter of 0.35 mm.

Experimental metallic plates (0.8 x 10 x 20 mm) were achieved by the classical melting-casting laboratory procedure and prepared for welding.

Using these plates, preliminary tests were conducted by laser welding in butt joint configuration, without filler material, bilaterally and with filler material, proper for the base metal, a Ni-Cr welding wire: 22.1% Cr, 63.8% Ni, 9.1% Mo, 1% Si, 1% Fe, 3% Nb (Bego, Bremen, Germany).

For laser welding the Nd:YAG laser device Trumpf HL 124P LCU (Trumpf GmbH, Ditzingen, Germania) was selected.

Macroscopic visual inspection was done carefully to assess the defects of the welding rib. Welding rib width, craters on the surface, continuity of the weld, visible cracks, penetration degree of the spot, and any surface inclusions were examined (Fig. 1-4). Some samples showed visible defects, but other seemed without any discontinuity and were completed with microscopy examinations.

For the experiments a scanning electron microscope (SEM) with integrated EDS system Inspect S + EDAX GENESIS XM 2i (FEI Company, Eindhoven, Netherland) was used.

Electron microscopy images allowed visualization of small discontinuities, which escapes visual inspection.

The examined samples revealed some small cracks in the welding rib, both longitudinal and transverse or oblique. Some start from the main longitudinal cracks, some from the middle spot, others are completely isolated.

Also details of the the weld surface, spots aspect, their overlapping and distribution of filler material could be detected by microscopic analysis (Fig. 5-8).

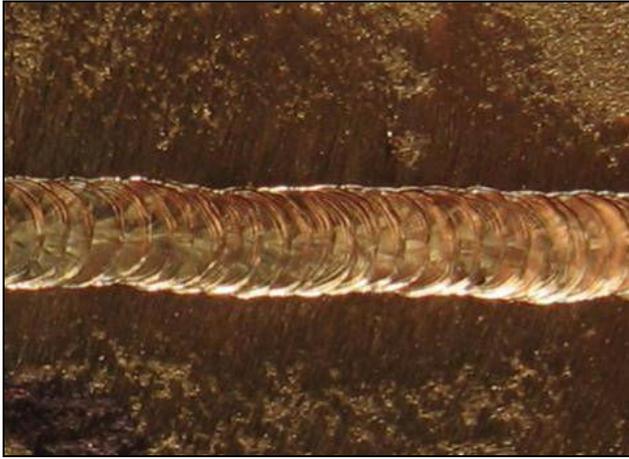


Fig. 1 Aspect of a welded Ni-Cr alloy sample (welding without filler): uniform overlapping of the spots, no visible defects



Fig. 4 Aspect of Ni-Cr alloy sample (welding with filler material): poor penetration on the opposite side

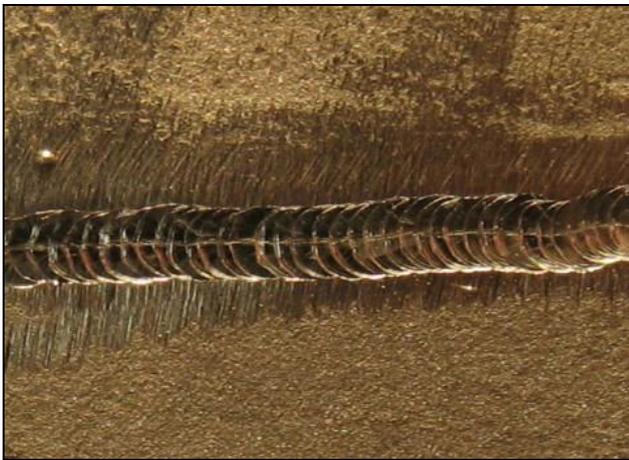


Fig. 2 Aspect of Ni-Cr alloy sample (welding without filler material): uniform width of the weld, continues crack along the joining line



Fig. 3 Aspect of Ni-Cr alloy sample (welding without filler material): good penetration on the opposite side

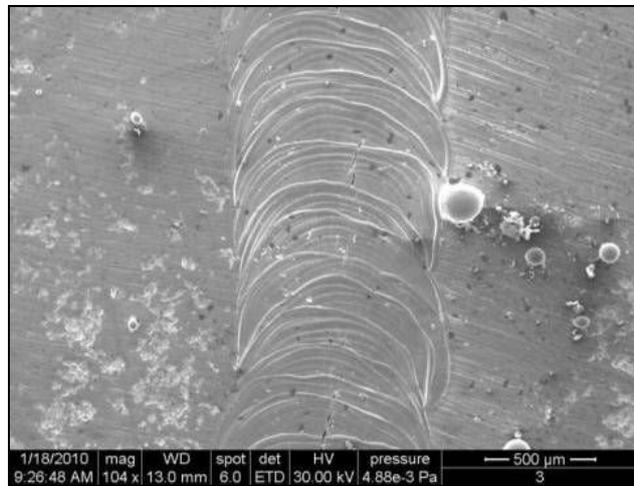


Fig. 5 Electron microscopic image of a Ni-Cr alloy welded joints without filler material: short longitudinal cracks on the welding rib (mag 104x)

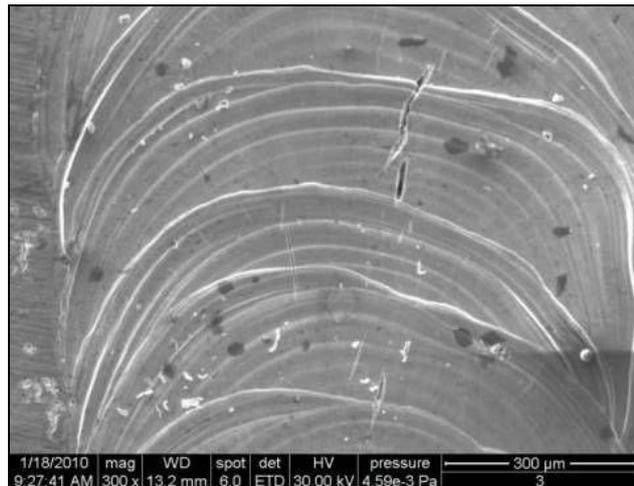


Fig. 6 Electron microscopic image of a Ni-Cr alloy welded joints without filler material: short longitudinal cracks on the welding rib (mag 300x)

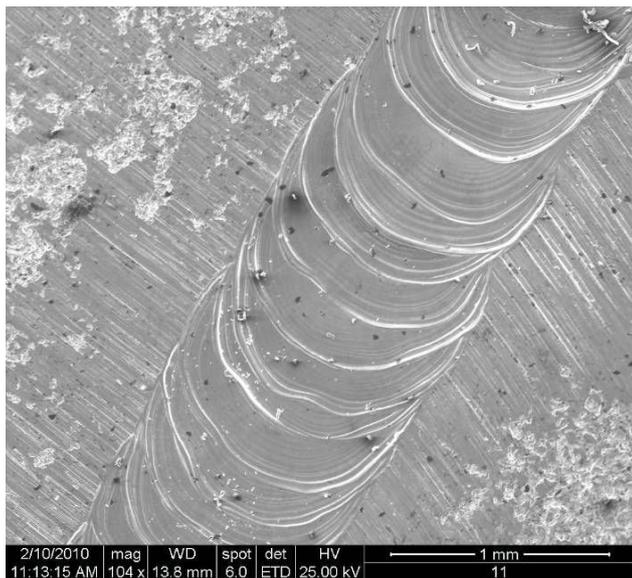


Fig. 7 Electronmicroscopic image of a Ni-Cr alloy welded joints without filler material: no visible defects on the welding rib (mag 104x)

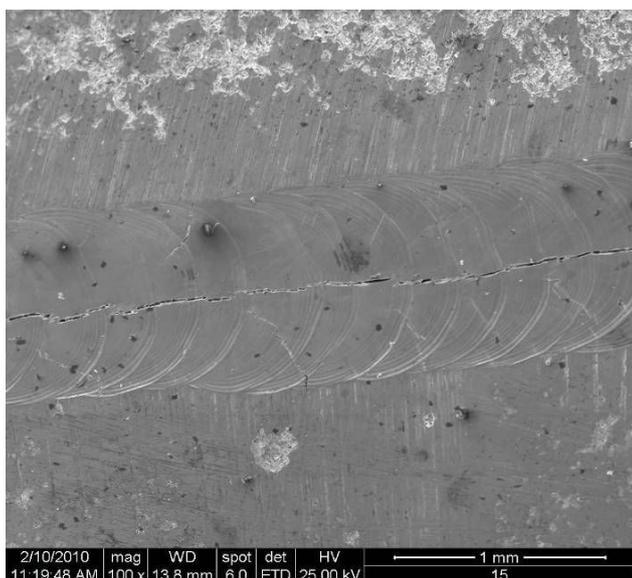


Fig. 8 Electronmicroscopic image of a Ni-Cr alloy welded joints without filler material: continuous longitudinal crack on the welding rib (mag 100x)

#### IV. RESULTS AND DISCUSSIONS

Making comparison to Ni-Cr alloys taken in the experiment and laser welded, after visual analysis, the best welds appear for Heraenium NA alloy, especially with no filler material, but also with filler material.

All samples show compact welding, without cracks, aspect proved by the tests. Welding with filler material is better for NB Wirloy than for Wiron 99. Penetration is higher. Welding without filler is similar for Wiron 99 and Wirloy NB. NA Heraenium alloy contains less Ni, and this improved

laser welding could be due to this fact.

In welding the first step is to establish the welding parameters, respectively the process parameters.

In practice metal frameworks have different thicknesses and this have to be also taken into account. Even if the weld penetration at higher power is also high, too strong power produces too much penetration that may induce formation of pores, which implicitly reduces weld strength. A very low penetration may not be able to determine enough strength. It is therefore important to determine the optimal parameters to achieve proper penetration. Welding on both sides could avoid these disadvantages [2].

Although each supplied welding device provides information on handling, personal experience of the operator is extremely important [3-5].

The key parameters involved in welds evaluating are smooth surface, full penetration, defects absence [6, 7].

Welding parameters could be in properly adjust the first stage corresponding to visual assessments [3, 4]. The spot diameter decrease increase the penetration because penetration per unit area is higher at a constant pulse energy [2].

Welding without filler material needs a space between the two components below 0.1 mm, a spots overlapping of 70% and welding on both sides [8].

The welding with filler material is prepared in the form of "X" and filler material is deposited from deep areas to the surface [9].

#### V. CONCLUSIONS

Laser welds of Ni-Cr alloys frameworks for optimizations are higher than those made by other welding processes.

In practice macroscopic visual analysis of weld quality is the only way to test from the experimental complex analysis methods. In the experimental tests it precedes other test methods.

Macroscopic examination allows assessment of the welding rib and the surface aspect. Microscopic analysis allows detecting small discontinuities, which are not visible to the naked eye and revealing details of location, trajectory, morphology and size.

Further studies could reveal the influence of these cracks on the strength of welds from practical point of view.

#### ACKNOWLEDGMENT

This work was supported by CNCISIS-UEFISCSU, project number PN II-RU TE\_217/2010.

#### REFERENCES

- [1] Jeffus, L. (2008). *Welding: Principles and applications*, 6<sup>th</sup> edition. Thomson Delmar Learning, ISBN 978-1-4180-5275-1, New York.
- [2] Baba, N, & Watanabe, I. (2005). Penetration depth into dental casting alloys by Nd:YAG laser, *J Biomed Mater Res B Appl Biomater*, 72(1):64-8, ISSN 1552-4973.
- [3] Bertrand, C. & Poulon-Quintin A. (2010). Proposals for Optimization of Laser Welding in Prosthetic Dentistry. *J Prosthodont*, 19(1):69-76, ISSN 0893-2174.

- [4] Watanabe, I.; Baba, N.; Chang, J. & Chiu, Y. (2006). Nd:YAG laser penetration into cast titanium and gold alloy with different surface preparations. *J Oral Rehabil*, 33:443-6, ISSN 0305-182X.
- [5] Sandu, L.; Porojan, S.; Topală, F.; Ciuluvică, R.; Stana, D. & Alexandrescu C. (2010). Digital evaluation of discontinuities on dental alloys microplasma welds. *Metalurgia International* vol . XV, Sp iss no. 9: 24-7, ISSN 1582-2214.
- [6] Baba, N.; Watanabe, I.; Liu, J. & Atsuta, M. (2004). Mechanical strength of laser-welded cobalt-chromium alloy. *J Biomed Mater Res B Appl Biomater*. May 15;69(2):121-4, ISSN 1552-4973.
- [7] Bertrand, C.; Le Petitcorps, Y.; Albingre, L. & Dupuis V. (2004). Optimization of operator and physical parameters for laser welding of dental materials, *Br Dent J*, 196(7):413-8, ISSN 0007-0610.
- [8] Neumann, M.O. & Lindigkeit J. (2005). Mechanische Festigkeit von geschweißten EMF-Legierungen, *Quintessenz Zahntech*, 31(9):966-73, ISSN 0340-4641.
- [9] Perret, O.; Bizonard, M.; Naudy, Ph.; Pascal, G.; Nore, D. & Horde, Y.(2001). Characterization of keyhole formed during pulsed Nd:YAG laser interaction with a Ti-6Al-4V metallic target, *J Appl Phys*, 90:27-30, ISBN 0021-8979.