

Reconditioning medical prostheses by welding

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Abstract. After the technological process of making, some of the medical prostheses may contain imperfections, which can lead to framing the product in the spoilage category. This paper treats the possibility of reconditioning by welding of the prosthesis made of titanium alloys. The paper presents the obtained results after the reconditioning by welding, using the GTAW process, of an intramedullary rod type prosthesis in which was found a crack after the non-destructive examination. The obtained result analysis, after the micrographic examination of the welded joint areas, highlighted that the process of reconditioning by welding can be applied successfully in such situations.

1. Introduction

The majority of the metallic materials used in present to fabricate prostheses and medical instruments are, in best case, inert towards the human bone tissue. These can become bioactive by controlling the morphology and chemical composition at the surface level. The type of material, process and fabrication standards, chemical composition, processing conditions and mechanical properties significantly influence the interaction between material and bone tissue.

The long-term stability of the implant is closely linked to its ability to integrate into adjacent bone tissue [1, 2].

Taking into account the excellent mechanical properties and their biocompatibility, titan alloys are best used in medical field. Lately, it is desired to improve the properties of the used materials, but also the development of new manufacturing technologies.

Titanium and its alloys are extensively used as biomaterials in bone surgery, generally thanks to good biocompatibility. Titanium and its alloys also have high mechanical properties (friction, torsion and pressure resistance), low density (half of the density of steel), are non toxic (stainless steel may cause a series of allergies), are not ferromagnetic (enables people with prosthetics to conduct investigations using magnetic resonance method) [3-7].

Prostheses and medical instruments can be achieved through two primary methods: casting and molding. Cast or molded blanks are then subjected to machining processes (milling, drilling, etc.) to fit the size and shape of each prosthetic case. In certain situations, after the technological processing of the prostheses, a series of dimension or shape nonconformities occurs which may classify the sample as waste? In this kind of situations, the material of the prosthesis must be remelted and undergone a new manufacturing process, which leads to increased costs associated with obtaining prostheses in the final form.

By using welding reconditioning technologies changes of the geometrical and shape configuration can be made for different type of prosthesis. Furthermore, the areas which contain crack or pore type



nonconformities can be removed and rendered. After processing the loaded areas and bringing them in conformity with technical specifications, defective parts can be recovered.

By the advantages offered by welding processes cost reduction can be achieved for prostheses manufacturing and long-term use of surgical instruments or aesthetic prosthetic.

After reconditioning and processing the samples will be undergone specific cleaning, decontamination and sterilization treatments specified in the quality standards on manipulation and use of medical instruments and equipment.

2. Experimental data

In order to analyse the welding reconditioning possibilities of prostheses or medical instruments made of titanium or its alloys it was considered the possibility of reconditioning a intramedullary rod type prosthesis in which was found a crack after the non-destructive testing of the product.

The material used for the prosthesis was titanium alloy type Ti-6Al-4V whose chemical composition is presented in table 1 and mechanical properties indicated in table 2, according to the ASTM standards F67 [8] and F136 [9].

For the welding reconditioning process the prosthesis was sectioned in order to totally remove the flaw (figure 1).



Figure 1. Prosthesis components after removing the flaw: a - superior part b - inferior part.

The filler material used to realize the welded joint by gas tungsten arc welding (GTAW) was ERTi-5 type twig. It may be considered in any biomedical application, particularly for implantable components, because of its biocompatibility, good fatigue strength, and low modulus. It could also be considered for any application where a combination of high strength, light weight, good corrosion resistance, and high toughness are required, especially at cryogenic temperatures. Some typical applications where this alloy has been used successfully include joint replacements, bone fixation devices, surgical clips, and cryogenic vessels [10].

The chemical composition and mechanical properties of the filler material are presented in table 1 and 2 [11].

Table 1. Chemical composition of the base and filler material.

Materials	Weight Percentage [%]							
	C	O	N	H	Fe	Al	V	Ti
Ti6Al4V	0.10	0.20	0.05	0.125	0.3	5.5-6.75	3.5-4.5	bal.
ERTi-5	0.05	0.12-0.20	0.03	0.015	0.22	5.5-6.75	3.5-4.5	bal.

Table 2. Mechanical properties of the base and filler material.

Materials	Tensile Strength [N/mm ²]	Yield Strength [N/mm ²]	Elongation [%]	Reduction of Area [%]
Ti6Al4V	950	880	14	25
ERTi-5	895	828	10	22

After preparing the joint between the two components of the prosthesis, in accordance with the specifications presented in figure 2, they were welded with GTAW.

In order to realize the welded joint, the surfaces were cleaned with oxides having 35% nitric - 5% hydrofluoric acid solutions at room temperature, then rinsed with water and air dried.

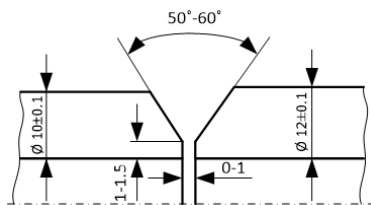


Figure 2. Single 'V' butt joint.

The welding parameters used in the experiments are indicated in table 1.

Table 3. The parameters used in the experiments.

No.crt.	Parameter	Value
1	Welding current [A]	40±5
2	Arc voltage [V]	12±2
3	Filler material diameter [mm]	2.00
4	Gas flow [l/min]	10
5	Travel speed [cm/min]	12
6	Type of gas protection	Argon

3. Results and discussions

The two components were welded providing inert protection at the root but also in the adjacent area of the seam. The prosthesis resulted through welding reconditioning is presented in figure 3.



Figure 3. The prosthesis obtained by welding reconditioning.

After the end of the welding processes, the samples were subjected to visual and penetrant testing. After analyzing the sample undergone the examination (figure 4), it can be seen that it shows no surface or surface related imperfections. Also, comparing the colour of the joint with the titanium weld colour quality inspection chart it can be observed that the welded joint can be accepted and that proper protection was assured during and after the welding process.

After non-destructive examinations the sample was undergone macrographic examination and hardness measurements in the characteristic areas of the welded joint. In order to perform the metallographic analysis the samples were cut using a special cutting system at low cutting speeds with continuous cooling so as to prevent the analysed zone from being affected by the heat. After the cutting process, the samples were cleaned from impurities and subject to a polishing process using metallographic paper with different granulations; finally, the samples were subject to polishing with abrasive diamond paste [12-14].

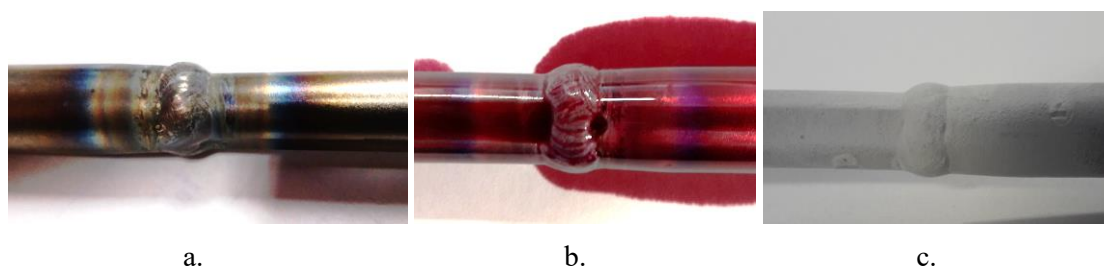


Figure 4. Penetrant testing: a- cleaning the surface, b-applying the penetrant, c- applying the developer.

After analysing the metallographic images it can be observed that in the central area there is an incomplete melted area. This nonconformity may be caused by inadequate processing of the joint or by the too low values of the welding current. Also, for increasing the penetration it is recommended to use a mix of argon and helium gas.



Figure 5. Welding seam macrography.

To analyse the quality of the welded joint the hardness was measured in the three characteristic zones (base material, heat affected zone, welded seam). The points layout is presented in figure 6. The hardness values obtained after measurements are presented in table 4.

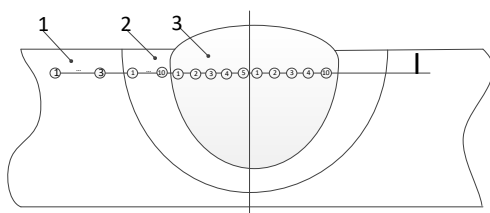


Figure 6. Localization of the measurement points for hardness: 1- base material (BM); 2 – heat affected zone (HAZ); 3 - welded seam (S); I –directions of measurement for hardness

Table 4. Obtained hardness values.

Measurement points	Hardness Value		
	S	HAZ	BM
1	404	359	361
2	390	350	356
3	380	357	347
4	384	364	328
5	401	359	325
6	395	370	332
7	393	358	330
8	386	377	325
9	383	367	341
10	401	380	351

Hardness values variation presented in table 4 are presented in the graphic from figure 7.

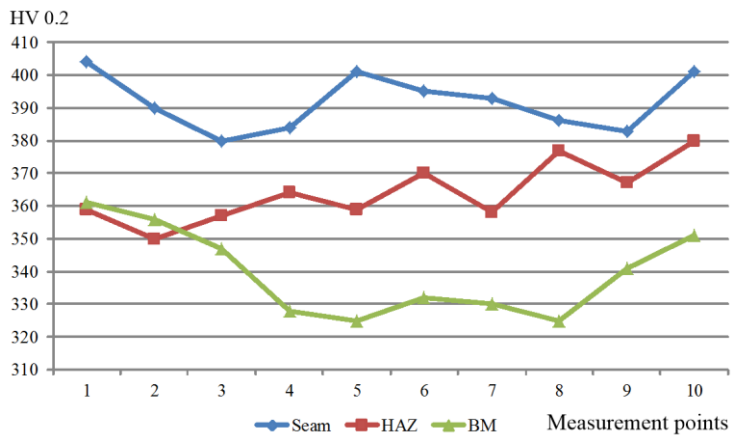


Figure 7. The variation of the hardness average values on the direction I, in the base material, in the HAZ and in the welded seam.

From the analysis of the values presented in table 4 and the graphic in figure 7 it can be observed that the values are increasing in the welded joint area and also in the heat affected zone. The increase of the hardness values is normal and it is the result of the α' appearance phase after structural transformation suffered by the material during the welding process.

Ti-6Al-4V alloy presents the best weldability of all $\alpha+\beta$ alloys thanks to the fact that the α' martensitic which is forming in this alloy is not as hard and fragile as the one in the alloys containing more stabilizing elements of β phase (ex. Ti-6Al-4V-2Sn) [15,16].

4. Conclusions

After analysing the results obtained by welding reconditioning of the titanium alloy prosthesis the following conclusions can be drawn:

- the welding processes can be successfully applied in titanium or titanium alloys prosthesis or medical instruments reconditioning;
- it is recommended to give special attention in choosing the appropriate geometrical configuration of the joint in order to ensure complete penetration of the welded seam.;
- in order to increase the penetration it is recommended to use a mix of argon and helium gas;
- in order to decrease the hardness in the BM or HAZ titanium alpha filler materials can be used, materials that provide lower hardness and mechanical properties in the characteristic areas of the welded joints.

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