euspen's 17th International Conference & Exhibition, Hannover, DE, May 2017

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Dimensional control in pre-sintered Zirconia machining for Double Pivot Micro Bearings of blood pumps

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Abstract

The use of pre-sintered zirconia in biomaterials due to their biocompatibility and resistance is common in dental implant industry. A similar technique is employed in cardiology, specifically in Ventricular Assist Device bearings. The device is an Implantable Centrifugal Blood Pump and it is under development in the Laboratory of Bioengineering and Biomaterials located in Federal Institute of Technology in Sao Paulo, Brazil. The pump has an impeller with magnetic coupling with brushless motor positioned outside the pump. This impeller is supported by a Double Pivot Micro Bearings in Zirconia. This study presents the technique employed in machining and sintering pieces, its dimensional control and results in pump performance. After micro-milling of pre-sintered zirconia green bodies, axis and pivots were sintered at 1600°C for 12 hours. Results for material contraction varied between 22 to 26%. Surface was finished with diamond grinding and checked in Scanning Electron Microscopy before pump bearings assembling. The dimensions were checked and implications in VAD assembly and friction due to the micrometric variations were analyzed. The blood pump performance was evaluated in final tests with the Double Micro Pivot Bearings. The proposed technique was considered satisfactory in all terms.

Green bodies machining, Bioceramics, Artificial Organs

1. Introduction

The use of ceramic bearings in blood pumps is consecrated in cardiology [1] and previously studied with a combination of ceramic and polymer pieces [2]. It is promising due to system simplicity and low energy consumption compared to electromagnetic suspension systems [3]. The mentioned combination is critical to dimensional control. This study demonstrates milling technique applied in pre-sintered zirconia micro pivots and precision analysis.

2. Materials and methods

The pre-sintered Tetragonal Zirconia Polycrystal (TZP) ($\mathrm{Zr}O_2(\,3\%Y_2O_3)$) is presented in compacted blocks with particle size of 0.5 µm. TZP green bodies were milled with micro-machining cutting tools, as seen on Figure 1 [4].

Figure 1. Micro-milling of pre-sintered zirconia block.

Zirconia was chosen as biomaterial for the micro bearings due to its excellent biocompatibility and results in dentistry [5].

The use of this ceramic compound facilitates the densification during sintering, resulting in final hardness of 1200HV.

Manufacturing techniques using CAD/CAM make process and part standardization easier [6]. The pivots were three-dimensional modeled using SolidWorks and machined with larger dimensions, predicting its size reductions after sintering.

As a first guest, all parts were machined 26% larger than the desired dimensions. The CNC Machining Center (HAASS Super mini Mill) used a 2mm spherical mill, Figure 2.

Figure 2. Pivot bearings during micro-milling of TZP green bodies.

After micro-milling, Figure 3, pieces were taken to oven for total sintering at 1600°C for 12 hours.

Figure 3. Pivot axes machined in zirconia after sintering.

All pieces were measured with electronic precision of ±0.5 µm before and after sintering in order to compare the reduction in size. The figure 4 shows bearings before the sintering.

Figure 4. Micro pivot bearings after finishing

Final pieces were analyzed with Profilometer (CCI-MP, Taylor Hobson, Leicester) and results analyzed with Talymap (Talymap Gold version 6.0, Taylor Hobson, Leicester). This software analyzes the influence of light intensity on topographic surface alteration.

3. Results

The nominal diameter dimensions are 2.0 mm for axis and 3.2 mm for bearings. Table 1 shows measured dimensions of 10 samples before and after sintering showing dimensional modifications.

Table 1. Measured dimensions [mm] in axis and bearing before and after sintering.

Dimensions	Pre-sintered		Sintered	
Items	**Axis**	**Bearing**	**Axis**	**Bearing**
1	2,520	4,030	1,920	3,127
2	2,525	4,031	1,918	3,129
3	2,525	4,030	1,912	3,125
4	2,520	4,031	1,912	3,127
5	2,521	4,030	1,916	3,127
6	2,527	4,031	1,914	3,128
7	2,530	4,029	1,918	3,125
8	2,525	4,029	1,917	3,127
9	2,526	4,031	1,915	3,126
10	2,525	4,030	1,915	3,124
Average	2,524	4,030	1,916	3,127
Contraction	26,22%	25,94%	-24,11%	-22,42%
Standard deviation	0,003	0,001	0,003	0,002

The samples were analyzed with profilometer to visualize the machining surface finishing as shown in Figure 5.

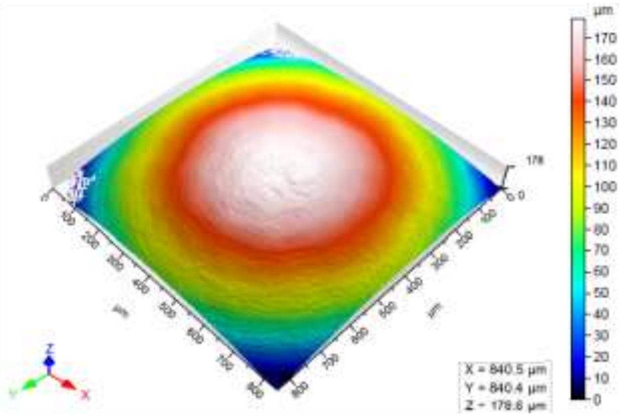

Figure 5. Three-dimensional profilometer analysis.

4. Conclusions

Dimensional variations in pieces that reached 1µm between samples could affect the titanium pump assembly and promote higher friction in bearings. Thus, it was mandatory to modify the assembly strategy. Micro welded housing that receives bearings is dimensioned to ready-made bearings. This can guarantee integral connection between the metal and the zirconia.

The zirconia surface analyzed by profilometer was considered satisfactory based on its regularity. There are no regions with lack or excess of material, Figure 5, as well as there is no significant roughness generated by micro machining.

The proposed technique was considered satisfactory in all terms. Future works will analyze friction and wear due to bearings operation and *in-situ* performance during hydrodynamic tests.

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