Mechanical Properties and Microstructural Characterization of Cobalt-Chromium (CoCr) Sintered Obtained by Casting and...

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Mechanical Properties and Microstructural Characterization of Cobalt-Chromium (CoCr) Sintered Obtained by Casting and Selective Laser Sintering (SLS)

PTECH 2015

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Abstract

The aim of this study is the consolidation of Cobalt-Chromium (CoCr) alloy powder, using the additive rapid prototyping technique by selective laser sintering (SLS) and the conventional technique casting. The research of this study have been applied for this biomaterial to the development of prosthesis and dental implants. The gas atomized powder was analyzed by their physical and chemical properties. The mechanical properties as uniaxial tensile, three point bending and micro hardness were evaluated of standard samples manufactured by SLS and casting technique. The microstructural characterization were examined using optical microscope (OM) and SEM-EDS. The micrographs revealed a characteristic morphology of layer used in the SLS technique and the dendrites in the casting technique.

Materials and Methods

The Cobalt-Chromium (Co-Cr) alloy was been used in this study. The chemical composition of the gas atomized powder was evalueted by X-ray fluorescence (see Table 1). The flow chart of the process of this study is showed in Figure 1.

Table 1 – Chemical compositions of the gas atomized Co-Cr alloy powder.

Alloy	Content of elements [%]						
	Co	Cr	W	Nb	V	Mo	Fe
	62,0 ± 1,0	25,0 ± 1,0	6,0 ± 1,0	< 0,2	< 0,2	7 ± 1,0	0,2 ± 0,1

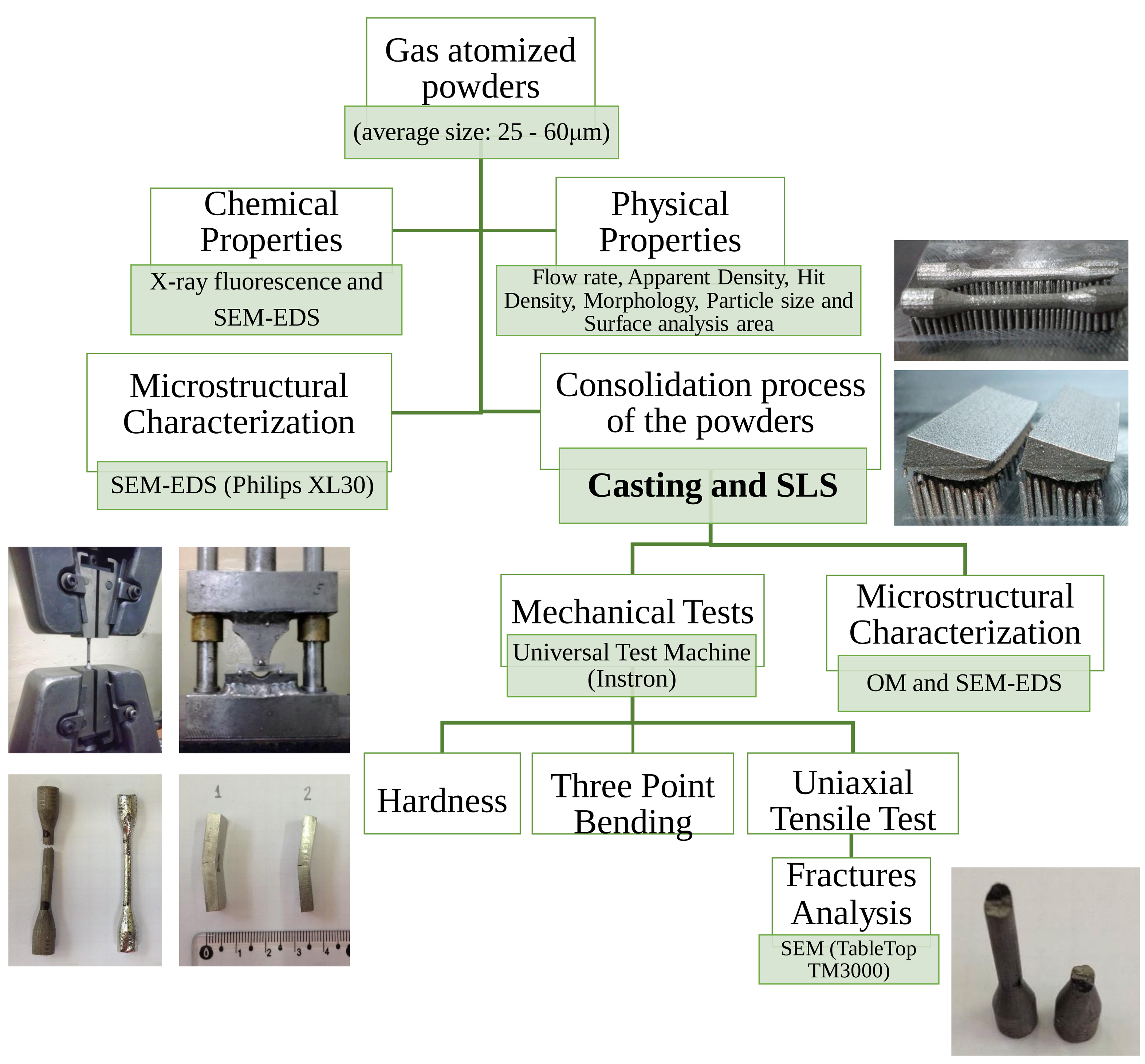

Figure 1 – Flow chart of the process of this study and images of tests and specimens.

Results

The results of all physical properties are showed at the table 2.

Table 2 – Physical properties of Co-Cr powders.

Properties		Powder	Standard
Granulometric Distribution [µm]	diameter of 10%	26,10	
	diameter of 50%	39,52	
	diameter of 90%	64,05	
	medium diameter	42,74	
Flow Time [s/50g]		20,598	MPIF 03
Apparent Density [g/cm³]		4,63	MPIF 04
Tap Density [g/cm³]		5,17	MPIF 46
Specific Surface Area [m²/g]	One Point	1,799	
	3 Points	2,644	

The analysis in MEV shows that the powders are spherical and presented satellites. The analysis with EDS in some particles indicate a possible oxidation in the powder surface (see figure 2).

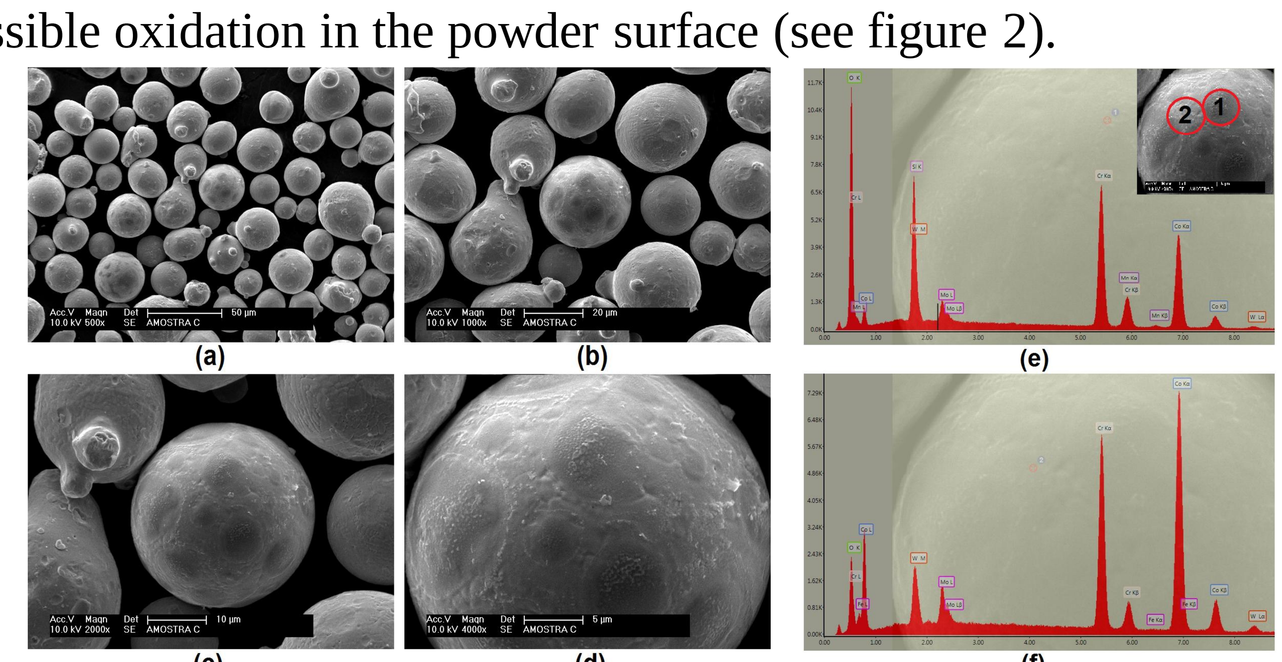

Figure 2 – a) SEM micrographs of atomized powder in the magnification 500x, b) magnification 1000x, c) magnification 2000x, d) magnification 4000x, e) spectroscopy of powder - area 1 and f) spectroscopy of powder – area 2.

Mechanical curves of uniaxial stress and three point bending are presented at Figure 3. For more explanations about the mechanical properties values are apresented the Table 3 with the tests results of standard samples.

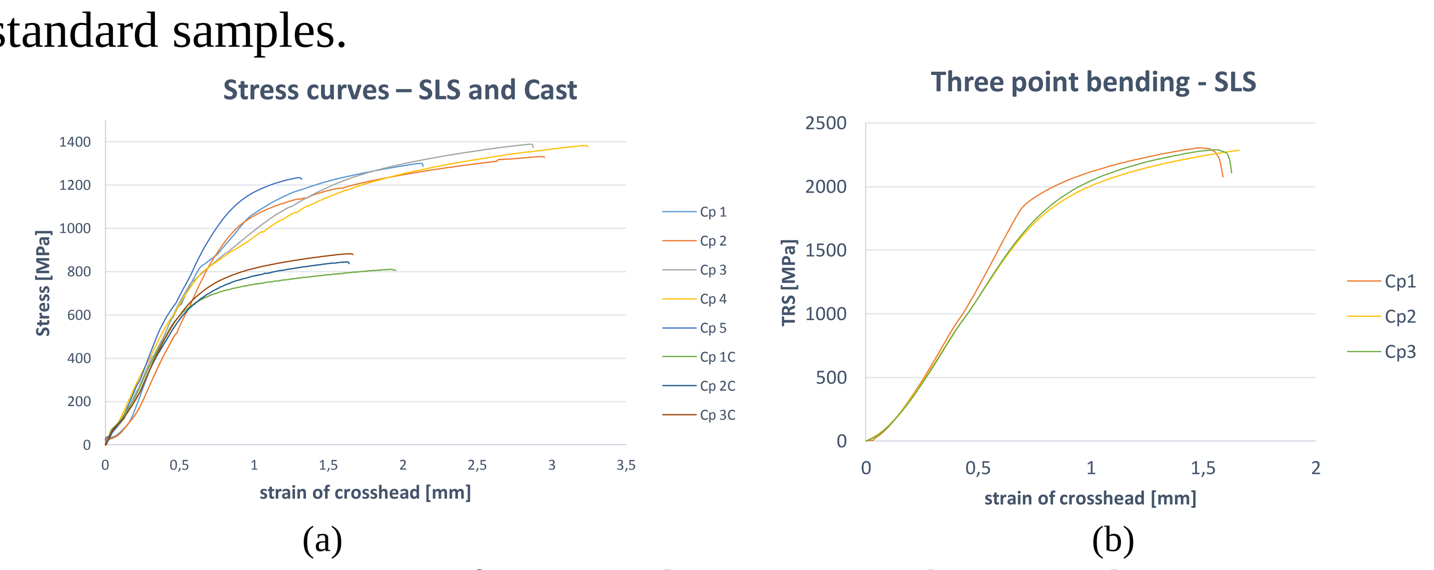

Figure 3 – a) stress curves of SLS samples (Cp1 – 5) and Cast samples (Cp 1C – 3C) and b) three point bending curves of SLS samples.

Table 3 – Mechanical properties of the specimens manufactured by casting and SLS process (medium values and desviations).

Mechanical Properties		Consolidation Process		Standard
		Cast	SLS	
Yield Stress (Rp 0,2%)	[MPa]	516,4 ± 27,34	788,4 ± 158,12	ISO 22674: 06
Rupture Stress	[MPa]	715,0 ± 94,27	1312,4 ± 67,67	
Max. Stress	[MPa]	740,6 ± 80,68	1327,4 ± 63,40	
Elongation	[%]	5,58 ± 3,17	7,68 ± 0,80	
Transverse Rupture Stress	[MPa]	-	1790,0 ± 91,94	ASTM B528:12
Micro Hardness	[HV]	381,50 ± 12,63	551,55 ± 20,03	ISO 14577-1

The microstructure of the specimens were evaluated by OM and SEM with EDS as showed in Figure 4. The fractures of the specimens are possible analyses in the Figure 5.

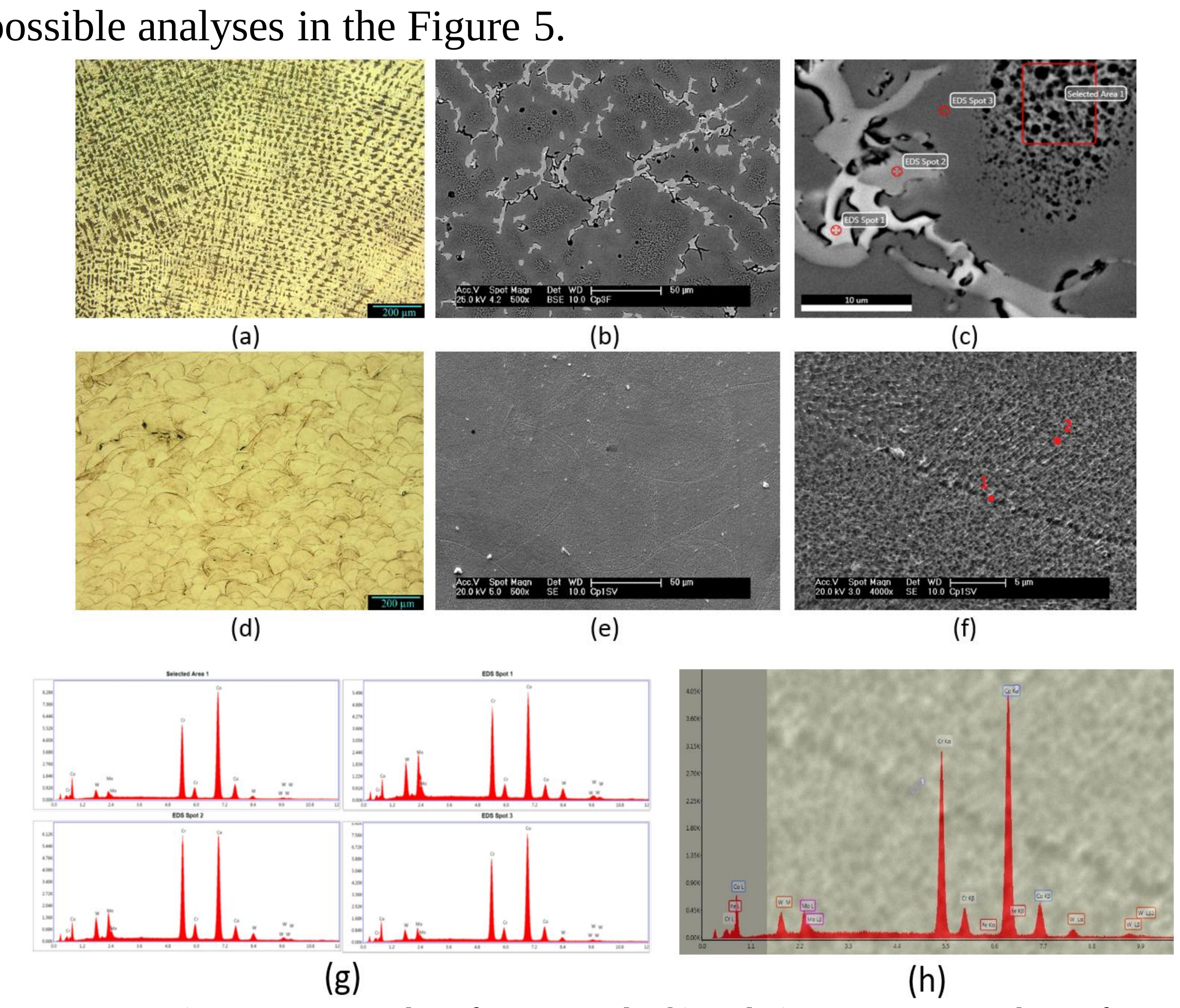

Figure 4 – a) OM micrography of cast sample, b) and c) SEM micrographies of cast sample and spots/area of EDS analyses, d) OM micrography of SLS sample, e) and f) SEM micrographies of SLS sample and spots of EDS analyses, g) and h) EDS spectroscopies of samples respectively cast and SLS samples.

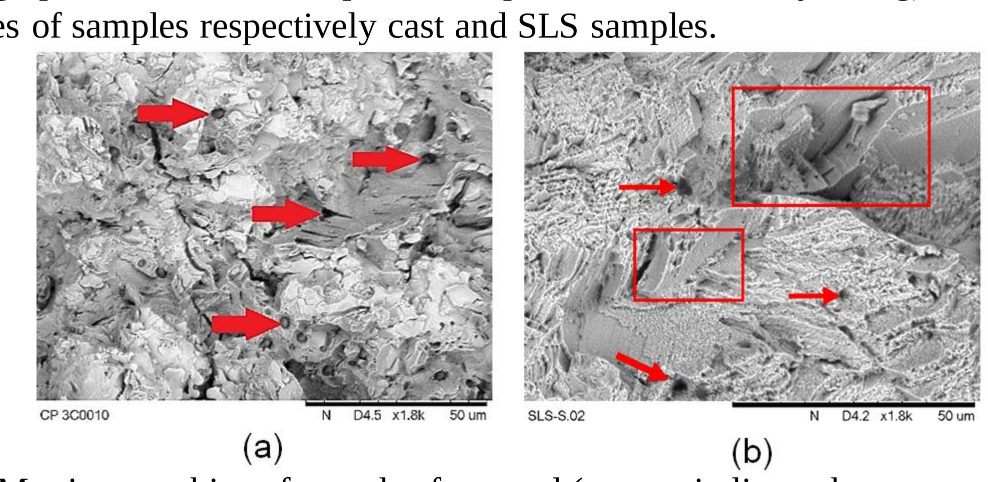

Figure 5 - SEM micrographies of samples fractured (arrows indicate the pores and the rectangles indicate the quasi-cleavage fracture). a) cast sample and b) SLS sample.

Conclusions

1. The mechanical properties as yield stress, rupture stress, maximum stress, elongation and hardness in the SLS technique are better than casting technique.

2. The microstructure in the samples represent the characteristics phases in the manufacturing processes. The casting specimens are characterized by the dendritic phases and the SLS specimens are characterized by the solidification morphologies of the laser beam melting.

3. The fracture analysis by SEM shows that the microstructure presents more pores in the casting technique than the SLS technique. The SLS fracture represents a ductile fracture, showing the presence of dimples. This is one of the evidences in the low values at the results of uniaxial tensile tests in the casting samples.

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