Evaluation of Mechanical Properties and Microstructural Characterization of ASTM F75 Co-Cr Alloy Obtained by Selective Laser Sintering (SLS) and Casting Techniques

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Abstract

Advances in processes using the powder metallurgy techniques are making this technology competitive compared to the other traditional manufacturing processes, especially in medicine area. The additive rapid prototyping technique – selective laser sintering (SLS) was applied in a biomaterial of CoCrMoFe alloy (ASTM F75), to study the mechanical properties and microstructural characterization in comparison between the conventional technique – casting. The gas atomized powder was investigated by their physical and chemical properties. Specimens of standard samples were manufactured using these techniques to evaluate the mechanical properties and microstructural characterization.

Materials and Methods

The CoCrMoFe (ASTM F75) alloy was been used in this study. The chemical composition of the gas atomized powder were 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	Mo	Fe
Powder	63,858 ± 0,067	28,965 ± 0,042	7,019 ± 0,013	0,159 ± 0,008

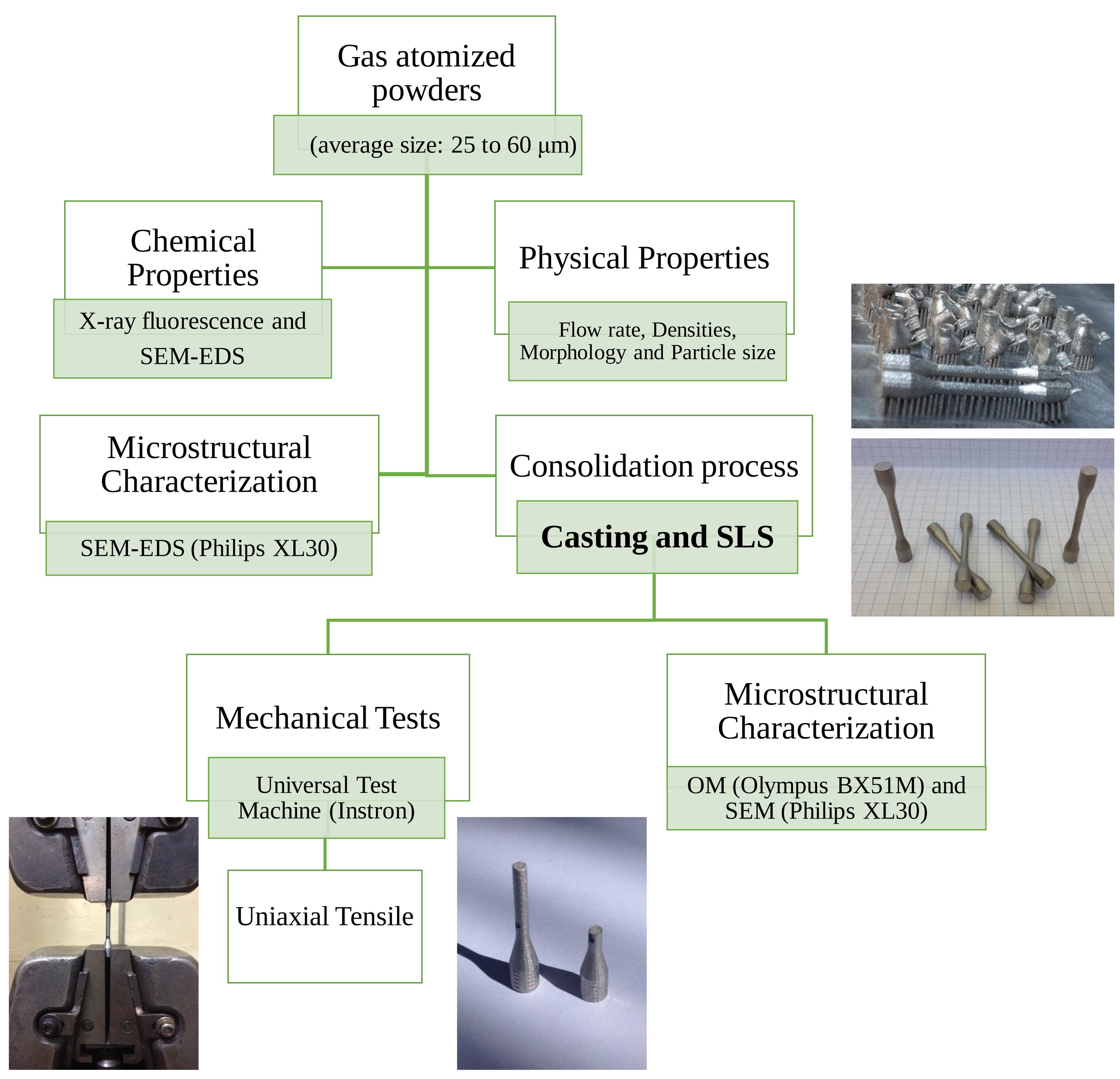

Figure 1 – Flow chart of the process of this study and images of tests and specimens.

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%	20,88	
	diameter of 50%	31,11	
	diameter of 90%	46,10	
	medium diameter	32,36	
Flow Time [s/50g]		15,88	MPIF 03
Apparent Density [g/cm³]		4,51	MPIF 04
Tap Density [g/cm³]		5,28	MPIF 46
Relative Density [g/cm³]		8,60	
Picnometry Density [g/cm³]		8,30	

The powder as recieved and the cross-sectioned powder etched were analysed in MEV. The spherical powders presented satellites and the cross-sectioned powder shows a dendritic characteristic morphology of gas atomization.

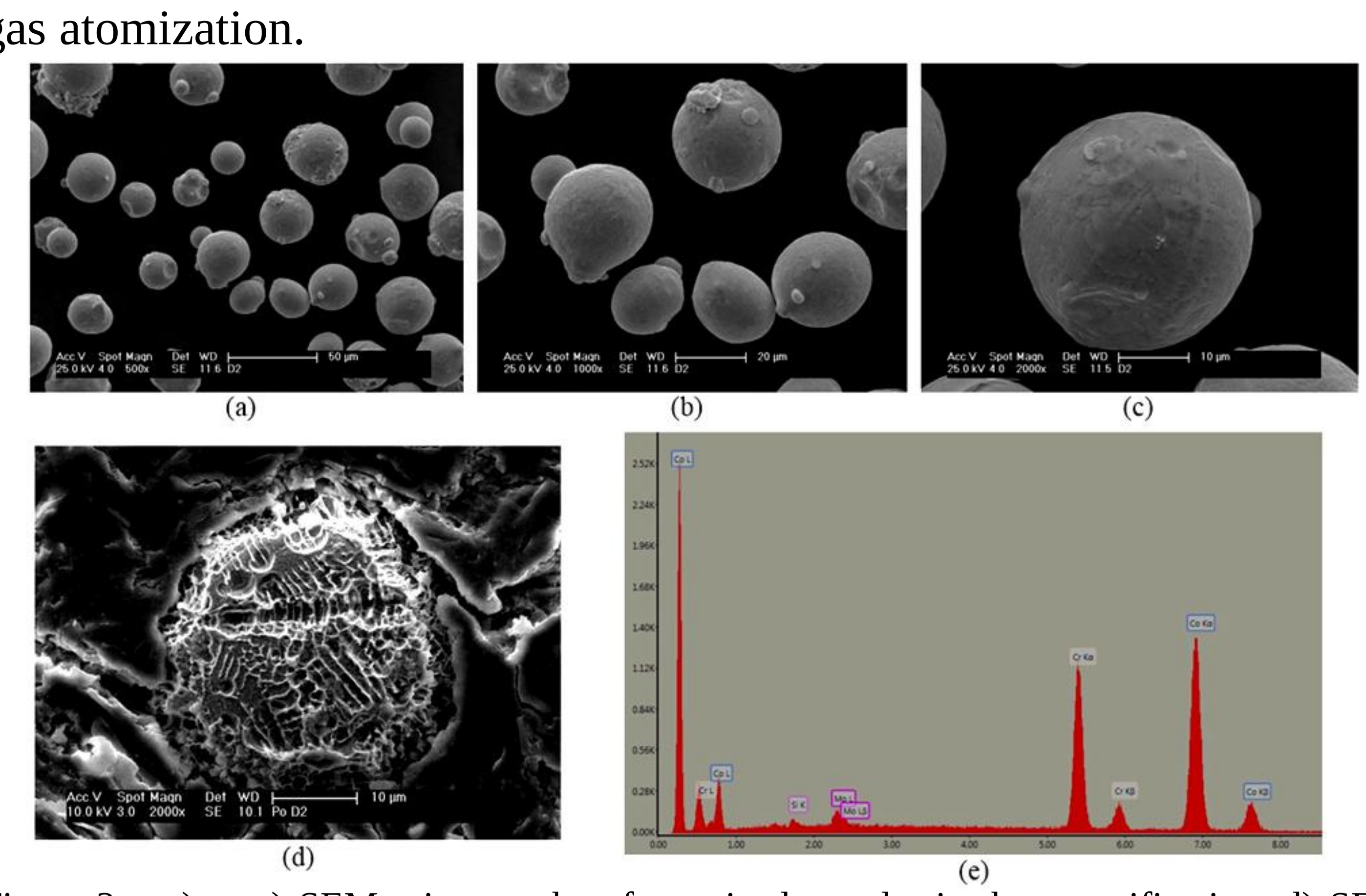

Figure 2 – a) to c) SEM micrographs of atomized powder in the magnification, d) SEM micrograph of cross-sectioned powder etched and e) EDS of powder gas atomized.

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

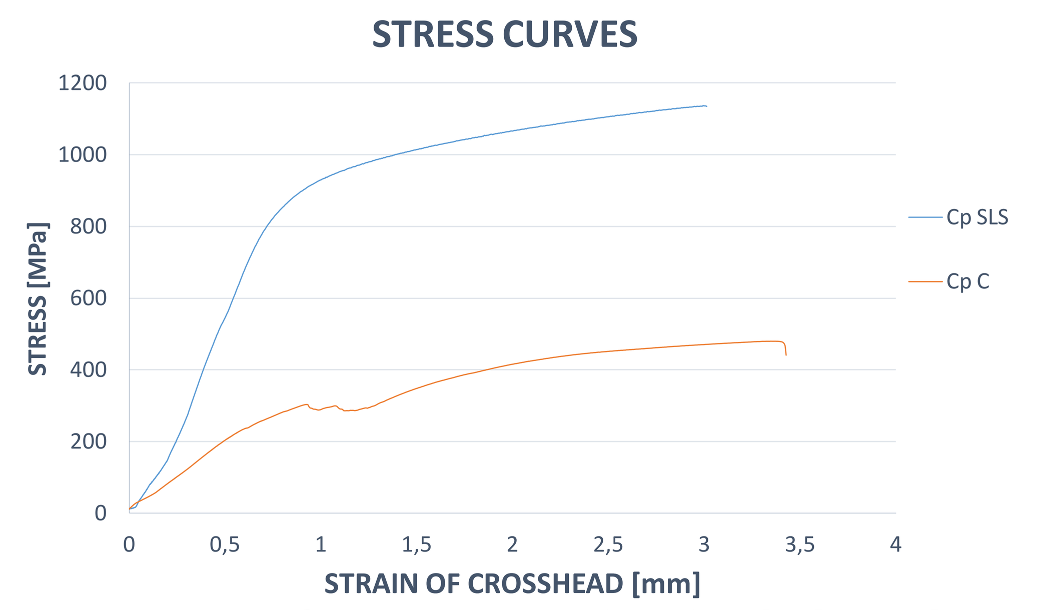

Figure 3 – Stress curves of specimens – cast (Cp C) and selective laser sintering (Cp SLS).

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

Mechanical Properties	Consolidation technique		Standard
	Cast	Selective Laser Sintering (SLS)	
Yield Stress (Rp 0,2%) [MPa]	229 ± 18,50	760 ± 15,04	ISO 22674: 06
Rupture Stress [MPa]	411,54 ± 5,00	1127,82 ± 2,00	
Max. Stress [MPa]	479,79 ± 5,00	1136,31 ± 2,00	
Elongation [%]	8,37 ± 4,45	13,73 ± 5,32	
Micro Hardness [HV]	365,74 ± 16,15	420,62 ± 21,16	ISO 14577-1

The microstructure of the specimens were evaluated by OM and the fractures analyzed by SEM as showed in Figure 4 and Figure 5.

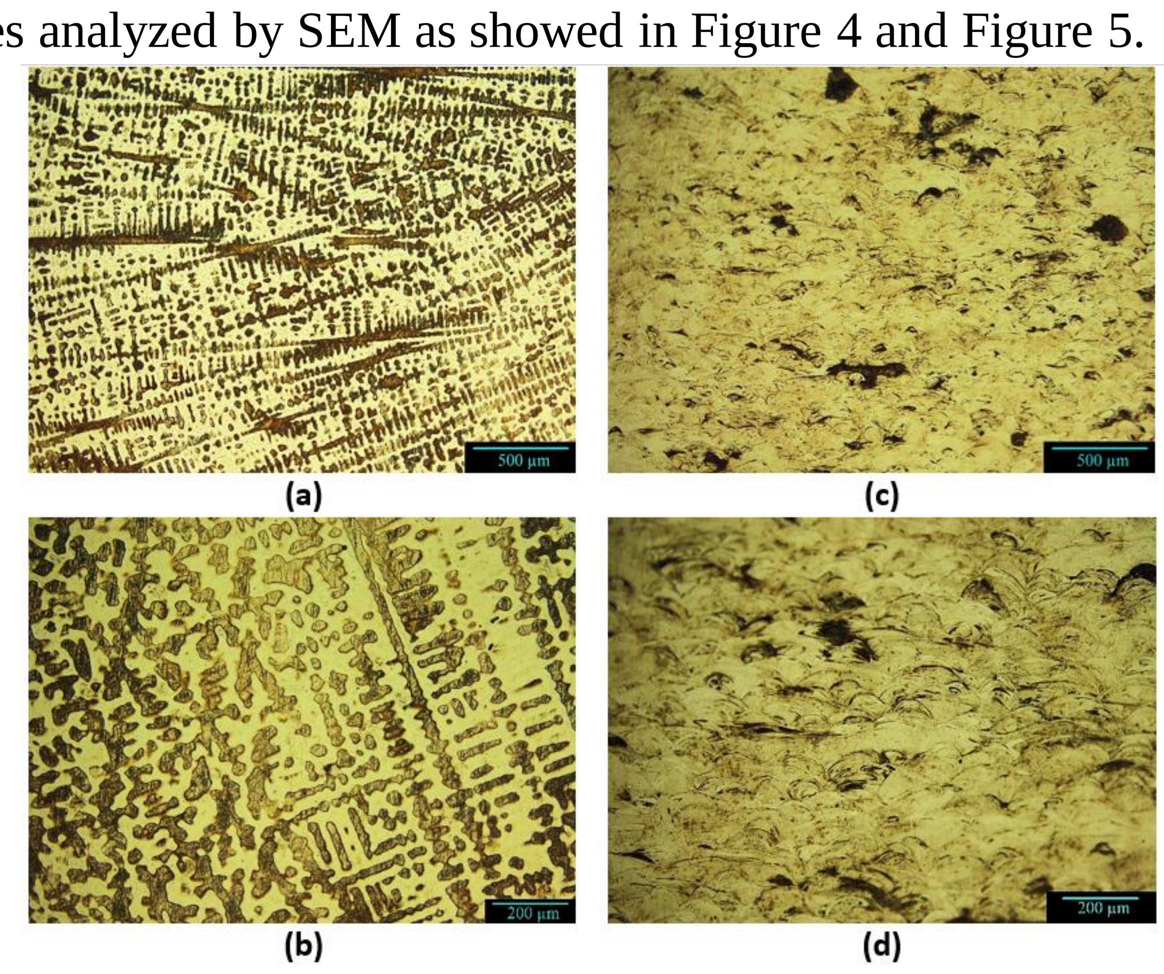

Figure 4 – OM micrographies of CoCr specimens. a) and b) cast sample, c) and d) SLS sample.

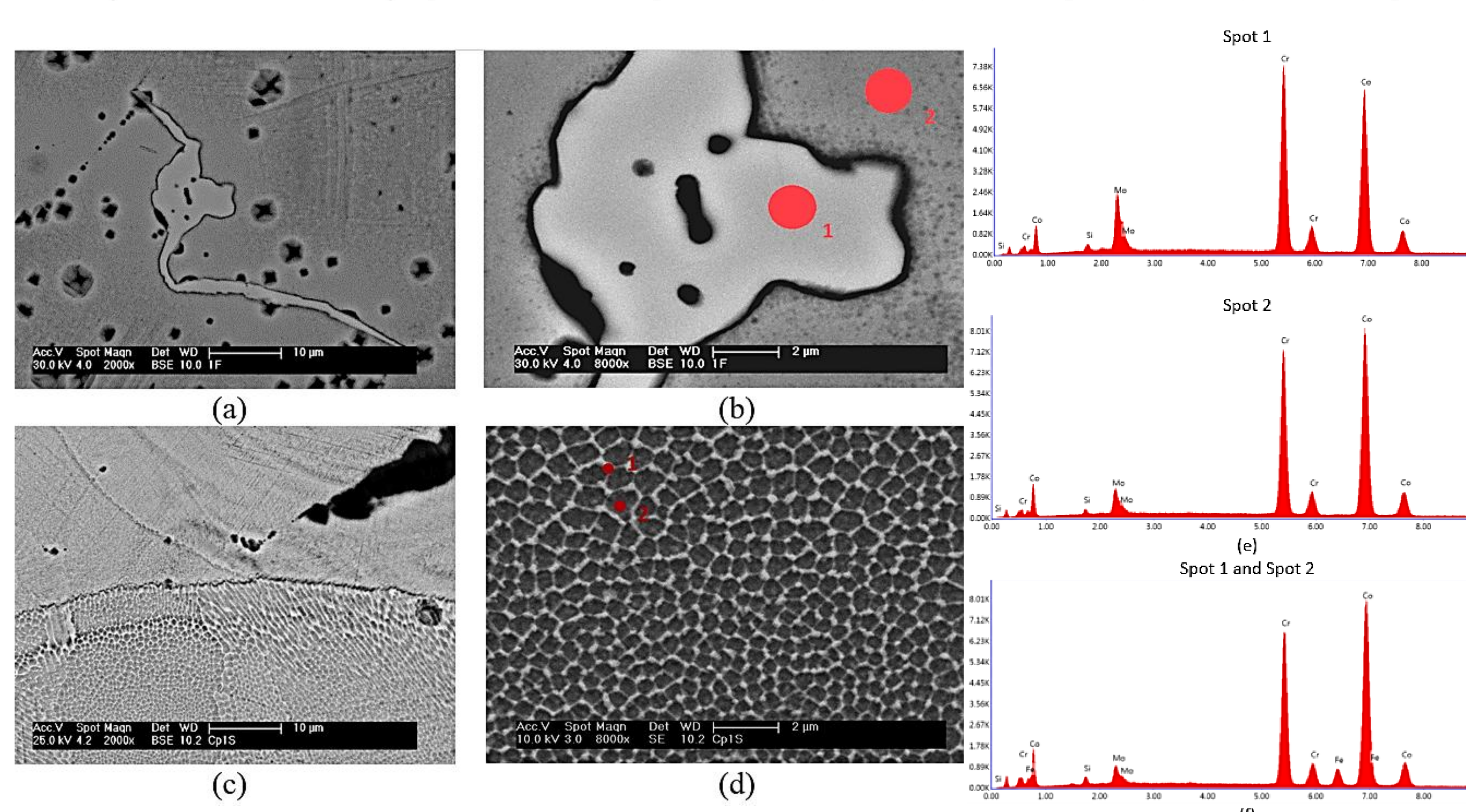

Figure 5 – SEM micrographs of CoCr specimens, a) and b) cast sample, c) and d) SLS sample, e) EDS spectroscopy of cast sample and f) EDS spectroscopy of SLS sample.

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. 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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