Influence of protective atmosphere on the mechanical properties of 420 Stainless Steel (AISI) processed by Selective Laser Melting (SLM)

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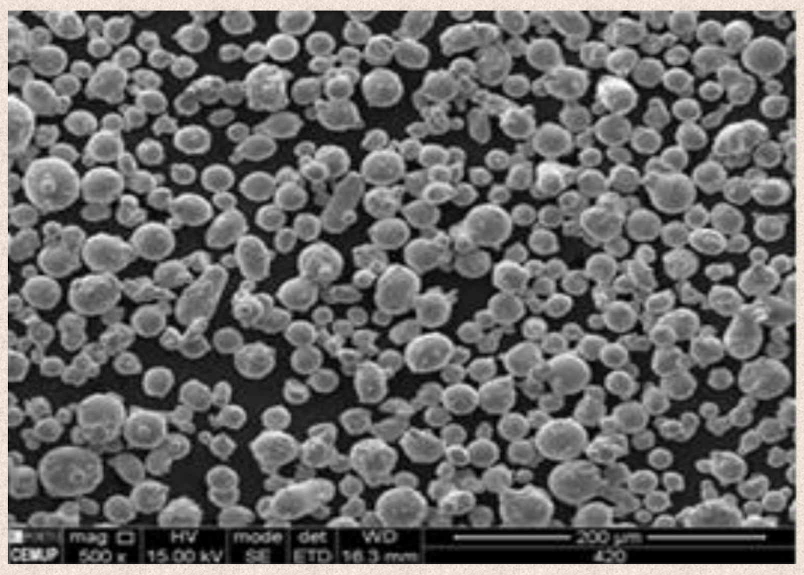
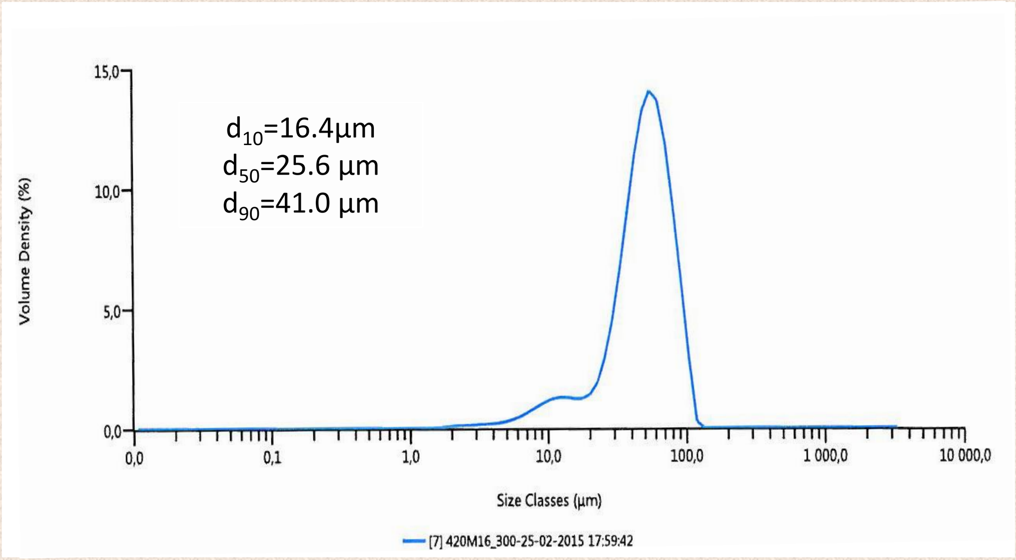
Introduction

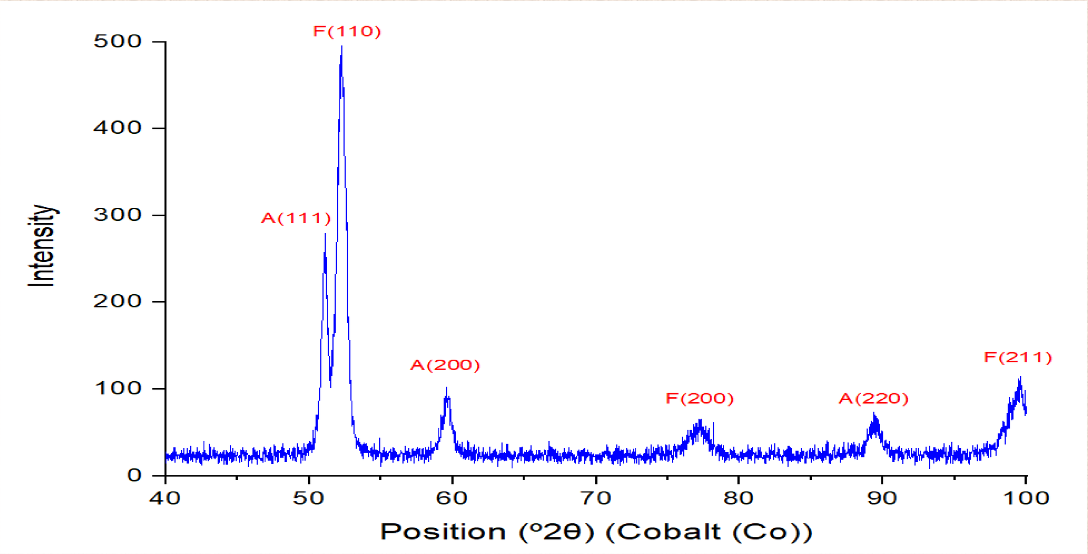
Martensitic Stainless Steel (SS) 420 (AISI) combines strength, hardness and high corrosion resistance. However, due to it's high carbon content, has been highly marginalized by SLM processing. Selective laser melted steel undergo a series of phase transformations and chemical modifications during processing, depending on the processing characteristics. Amidst them, gaseous atmosphere, for example, could have an essential role on the properties of the final parts. However, commercial SLM equipments work under two typical atmospheres - nitrogen or argon. On this study, it is highlighted the effect of the atmosphere in 420 SS processed under argon and nitrogen on mechanical properties (tensile strength, Young modulus and hardness).

Powder Characterization

420 Stainless Steel (AISI)







Methods

Processing: Selective Laser Melting

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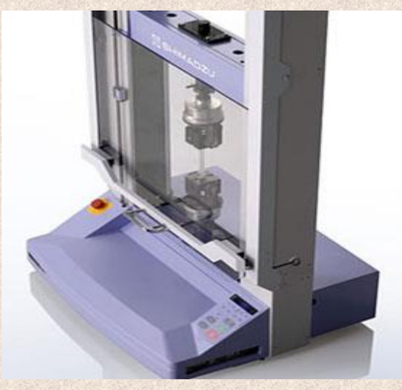
LASER type	Fiber (Ytterbium)
Potency (W)	400
Wavelength (nm)	1070
LASER diameter (µm)	87
LASER operation module	Continuous
Layer thickness (µm)	20-75
Minimum Wall size(µm)	140-160
Gas	Ar / N_2
O_2 (%)	< 0.2
Maximum scanning speed	10 m/s

Characterization: Tensile Tests



adaptado de: www.shimadzu.com

Equipment type	SHIMADZU Autograph
Cell (kN)	100
Norm	ISSO 6892
Strain Gauge	SHIMADZU MFA 25
Max rectangular section	50*14 mm

Characterization: Hardness/Young Modulus

adaptado de: www.apexauctions.co.uk

Equipment type	Fischerscope H100
Indenter type	Vickers (Diamond)
Load range	0.4-1000 mN
Load resolution	0.04 mN
Distance resolution	100 pm

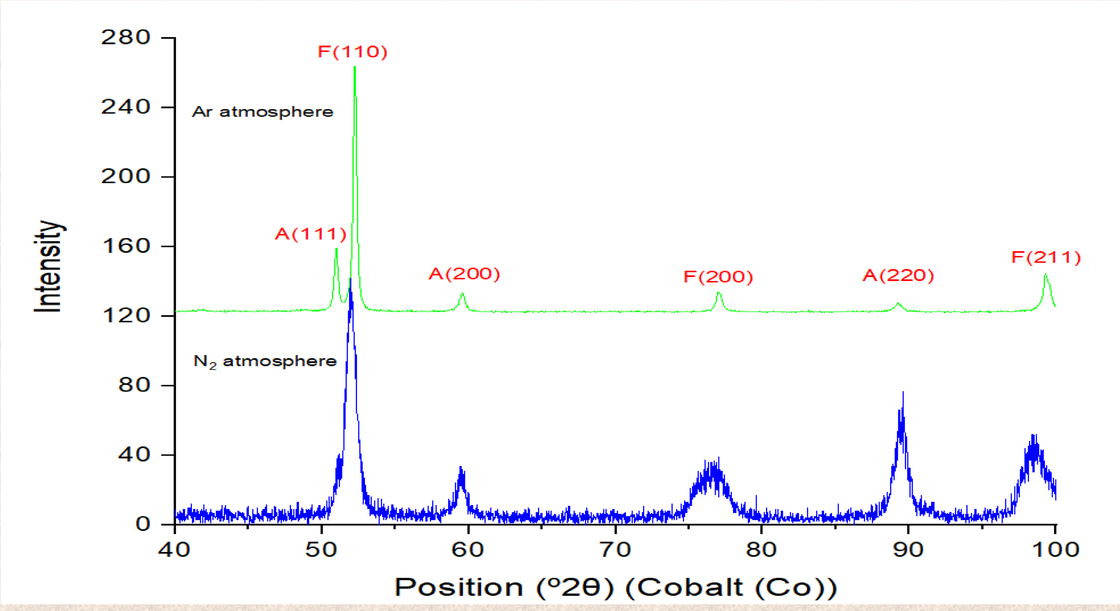
Characterization: X-Ray Diffraction

adaptado de: scientificservices.eu

Anode type	Cobalt (Co)
Wavelenght	0.154 nm
Goniometer	PW 3020/00
Max. potency	2,2 kW
Max .Voltage	60 kV

Results

X-Ray Diffraction Comparison



Test Specimens Characterization

Stress at break (MPa) [Strain (%)]	
Ar atmosphere	805±36 [7±1]
N_2 atmosphere	814±74 [9±1]
Bulk	1550-1890 [5-11]

Hardness (HV) – 1000 mN	
Ar atmosphere	759±35
N_2 atmosphere	644±24
Bulk	540-590

Young Modulus (GPa)	
Ar atmosphere	159±26
N_2 atmosphere	148±9
Bulk	195-205

Conclusions

Results ultimately show that there is a difference in the final structure of the parts built under a argon atmosphere and a nitrogen atmosphere. Although the presence of austenite may be expected, caused by the large presence of carbon, excessive austenite in parts processed under nitrogen, combined with a shift in austenite orientation (from (111) to (220)) are a sign that major structure changes occur under this atmosphere.

Tensile test specimens show that:

-The major driving force for stress at break is the presence of porosity;
-Young Modulus is highly affected by porosity present, as shown by Mackenzie, and must be taken in consideration in additive manufacturing (1973);
-As expected, the presence of austenite leads to a lower hardness in parts processed under nitrogen atmosphere.

Acknowledgements

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