Nickel-free P558 stainless steel processed from metal powder – PHA biopolymer feedstocks

E Carreño-Morelli, M Zinn, M Rodriguez-Arbaizar, M Bassas

University of Applied Sciences and Arts Western Switzerland, 1950 Sion, Switzerland.

INTRODUCTION: Nickel-free stainless steels are used in prosthetics to avoid the harmful effect of nickel-ion release in the human body [1-2]. Metal powder injection moulding (MIM) allows net-shape processing of complex parts from metal-polymer feedstocks [3]. The feasibility of a novel binder formulation using biosourced polymer produced by bacterial fermentation [4] is explored.

METHODS: The starting powder (Fig. 1) was gas atomized P558 steel (PANACEA, Sandvik Osprey Ltd, UK, median particle size Dv50 = 6.05 µm). Polyhydroxalkanoate (PHA) binders from dried biomass (P. putida GPo1 and R. eutropha) were extracted with CH_2Cl_2 and polymer solutions were recovered using a pressure-filtration unit. Then, the extracted polymer was purified by precipitation in ice-cold MeOH. The selected binder was P(3HB-co-3HV) copolymer.

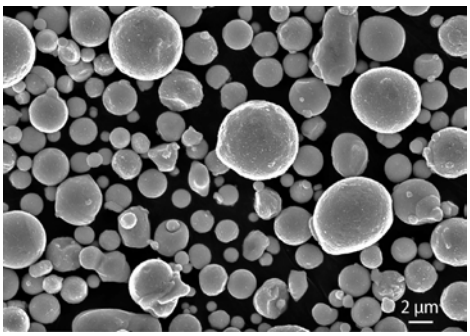

Fig. 1: P558 steel gas atomized powder

Feedstocks for MIM were prepared with a binder consisting of 45 wt% P(3HB-co-3HV), 45 wt% paraffin wax and 10 wt% stearic acid. The solids loading was 60 vol.%. Tensile test specimens were shaped using a Boy XS injection moulding machine with a mould thermalized at 40°C and a nozzle temperature of 120°C. Green parts were solvent debinded in heptane at 50°C for 20h, then thermal debinded at 500°C for 1h under argon. Steel parts were sintered at 1270°C for 3h under nitrogen in a Nabertherm VHT08-16MO furnace. Some samples were solution annealed at 1150°C 1h and water quenched. The density was measured by the Archimedes method. Tensile tests were performed according to DIN EN ISO 6892-1 method B in a Zwick 1445 machine.

RESULTS & DISCUSSION: Sintered P558 parts (Fig.2) exhibit a density of 7.45±0.05 g/cm^3 and a linear shrinkage of about 15%. The specimens are non-magnetic and the metallographic observation reveals a microstructure of twinned austenitic equiaxed grains with rounded porosity typical of MIM materials. Measured values for yield stress (YS), ultimate tensile strength (UTS) and elongation (A5) are summarized in Table 1 and compared with reference P558 commercial steel [1]. The carbon and nitrogen contents were measured by melt extraction with LECO devices as 0.15% and 0.90% respectively, with negligible increase between as sintered and annealed conditions. Both tensile strength and ductility are improved after solution annealing and quenching, which is due to the effective dissolution of Cr_2N precipitates present in the as-sintered material [5].

Fig. 2: Green (top) and sintered (bottom) parts.

Table 1: Mechanical properties of P558 steel

	YS [MPa]	UTS [MPa]	A5 [%]
MIM P558 as sintered	640	800	16
MIM 558 solution annealed	600	900	25
Böhler P558 solution annealed	≥ 520	≥ 850	≥ 45

CONCLUSIONS: Nickel-free austenitic stainless steel with good mechanical properties has been processed by MIM technology. The feasibility of using PHA natural polymers as a backbone binder constituent has been assessed.

REFERENCES: [1] G. Hochörtler, J. Bernauers, K. Kriszt (2000) *Material for Medical Engineering*, Ed. H. Stallforth and P. Revell, 210-215, [2] U.I. Thomann and P.J. Uggowitzer (2000), *Wear* **239**: 48-58, [3] E. Carreño-Morelli, *Medical Device Dev.* (2009), **2**:57-59, [4] M. Zinn, B. Witholt, T. Egli, *Adv. Drug Deliv. Rev.* (2001) **53**:5-21, [5] M. Sonderegger, *Proc. EuroPM2006*, **2**:31-36 (2006)

ACKNOWLEDGEMENTS: This project was funded by HES-SO EcoSwissMade BioMIM grant.