

OPTIMIZATION PROCESSABILITY OF SS316L USED NATURAL  
HYDROXYAPATITE FROM WASTE TILAPIA FISH BONES IN  
METAL INJECTION MOLDING

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For My loving husband, MR. MOHD RASHDAN, my sons, MUHAMMAD AMMAR NAUFAL & MUHAMMAD HARRAZ ADWAN, My late father, HJ. MUSTAFA BIN MOHAMED, My beloved mother, HJH. FATIMAH BINTI MOHD NOOR, my siblings, KHAIRUL RIJAL, ZARIR RAMIZ, LEILA SALWA, ZARITH SUFIAH, MOHD SOLEHIEN, MOHAMED NUR IMAN & BALQISH

Thank You for your endless support



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## ABSTRACT

Application of waste Tilapia Fish bones is introduced as a Natural Hydroxyapatite (NHAP) powder in metal injection moulding. Feedstock were prepared based on water atomized Stainless steel 316L (SS316L) and combination of NHAP powder bind with Low density Polyethylene (LDPE) and Palm stearin (PS). The results of rheological analysis show feedstocks with 63 and 64 wt.% of powder loading for both 90 wt.% SS316L and 10 wt.% NHAP and 85 wt.% SS316L and 15 wt.% NHAP composites shows a pseudoplastic behaviour. The screening of injection moulding and thermal debinding were conducted by using ANOVA. The significant parameters towards highest density and strength for injection moulding are injection temperature (A), mould temperature (B), injection pressure (C), and injection speed (D). Moreover, the significant parameters for thermal debinding were heating rate (A), temperature (B), dwell time (C), and cooling rate (D). The entire parameters have achieved the confident level above 90% using F-test and any interactions of A×B, A×C, and B×C were omitted since the results were insignificant. Taguchi method and Grey relational analysis was successfully employed for optimising the injection and debinding parameters. The optimisation of injection moulding process revealed the optimum condition for multiple response (density and strength) was injection temperature at 170 °C, mold temperature at 50 °C, 65 % of injection pressure and 60 % of injection speed. The optimisation of solvent debinding discovered the highest density and palm stearin loss. The optimum parameter for multiple condition was 8 hours of immersion time at 40 °C by using hexane in dilution of 15:1 solvent to feed ratio. The extraction process indicates that hexane solution was better compared to heptane and isooctane with respected higher percentages of palm stearin loss. The optimal condition of thermal debinding process was heating rate at 4 °C/min, temperature at 550 °C, 60 minutes of dwelling time and 4°C/min cooling rate and produced good quality brown parts. The final sintered part also shows good mechanical properties and microstructure of SS316L/NHAP parts.

## ABSTRAK

Penggunaan serbuk logam keluli tahan karat (SS316L) dengan kombinasi serbuk NHAP yang diuraikan daripada sisa tulang ikan Tilapia telah digunakan sebagai bahan suapan dalam proses penyuntikan pengacuanan logam. Nisbah campuran diantara SS316L dan NHAP ialah 85 wt. % SS316L dan 15 wt. % NHAP dan 90 wt.% SS316L dan 10 wt.%. Berdasarkan keputusan analisis reologi, bahan suapan dengan pembebanan serbuk 63 wt. % dan 64 wt. % menunjukkan sifat pseudoplastik. Eksperimen saringan untuk proses pengacuanan suntikan dan penyahikatan terma dilakukan dengan menggunakan kaedah ANOVA bagi mengenal pasti parameter yang signifikan. Keputusan ujian saringan bagi proses pengacuanan suntikan, menunjukkan suhu penyuntikan (A), suhu acuan (B), tekanan penyuntikan (C) dan kelajuan suntikan (D) merupakan parameter yang signifikan. Manakala bagi proses penyahikatan terma, parameter yang signifikan adalah kadar kenaikan suhu (A), suhu pemanasan (B), masa pemanasan (D), dan kadar penurunan suhu (D). Kesemua parameter yang terlibat melepasi aras 90 % aras keyakinan berdasarkan ujian  $-F$  dan sebarang interaksi antara  $A \times B$ ,  $A \times C$ , and  $B \times C$  diabaikan kerana tidak signifikan. Kaedah Taguchi dan Kaedah analisis *Grey* di gunakan untuk mengenal pasti parameter optimum bagi proses penyuntikan logam dan penyahikatan larutan dan terma. Parameter bagi menghasilkan ketumpatan dan kekuatan jasad hijau tertinggi bagi proses pengacuanan suntikan adalah 170 °C suhu suntikan, 50 °C suhu acuan, 65% tekanan suntikan dengan 60 % kelajuan suntikan Bagi proses pengoptimuman penyahikatan larutan, parameter yang optimum bagi ketumpatan dan pengekstrakan *Palm stearin* ialah penyahikatan selama 8 jam, suhu 40 °C pengekstrakan dalam larutan heksana dan nisbah pelarut terhadap berat sampel adalah 15:1. Seterusnya parameter yang optimum untuk proses penyahikatan terma adalah 4 °C/min kadar kenaikan suhu sehingga 550 °C selama 60 minit dan suhu penurunan ialah 4 °C/min dan menghasilkan jasad perang yang berkualiti. Jasad akhir sinter juga menunjukkan sifat mekanikal dan mikrostruktur SS316L/ NHAP yang baik.

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## LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of Variance
C	Carbon
°C	Degree Celsius
Ca	Calcium
CPVC	Critical Powder Volume Concentrations
CPVP	Critical Powder Volume Percentage
Cr	Chromium
Cu	Copper
DOE	Design of experiment
DSC	Differential scanning calorimetry
DTA	Differential Thermal Analysis
D <sub>10</sub>	Distribution at 10 %
D <sub>50</sub>	Distribution at 50 %
D <sub>90</sub>	Distribution at 90 %
EDX	Energy Disperse X-ray
EVA	Ethylene Vinyl Acetate
Fe	Iron
GRC	Grey Relational Coefficient
GRG	Grey Relational Grade
HAP	Hydroxyapatite
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
MIM	Metal injection molding
Mn	Manganese
Mo	Molybdenum
NHAP	Natural Hydroxyapatite
Ni	Nickel
O	Oxygen
P	Phosphorus
PE	Polyethylene
PEG	Polyethylene Glycol
PIM	Powder injection molding
PL	Powder Loading
PL	Polystyrene



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