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Extended experiment-simulation based assessment of a porous Ti alloy

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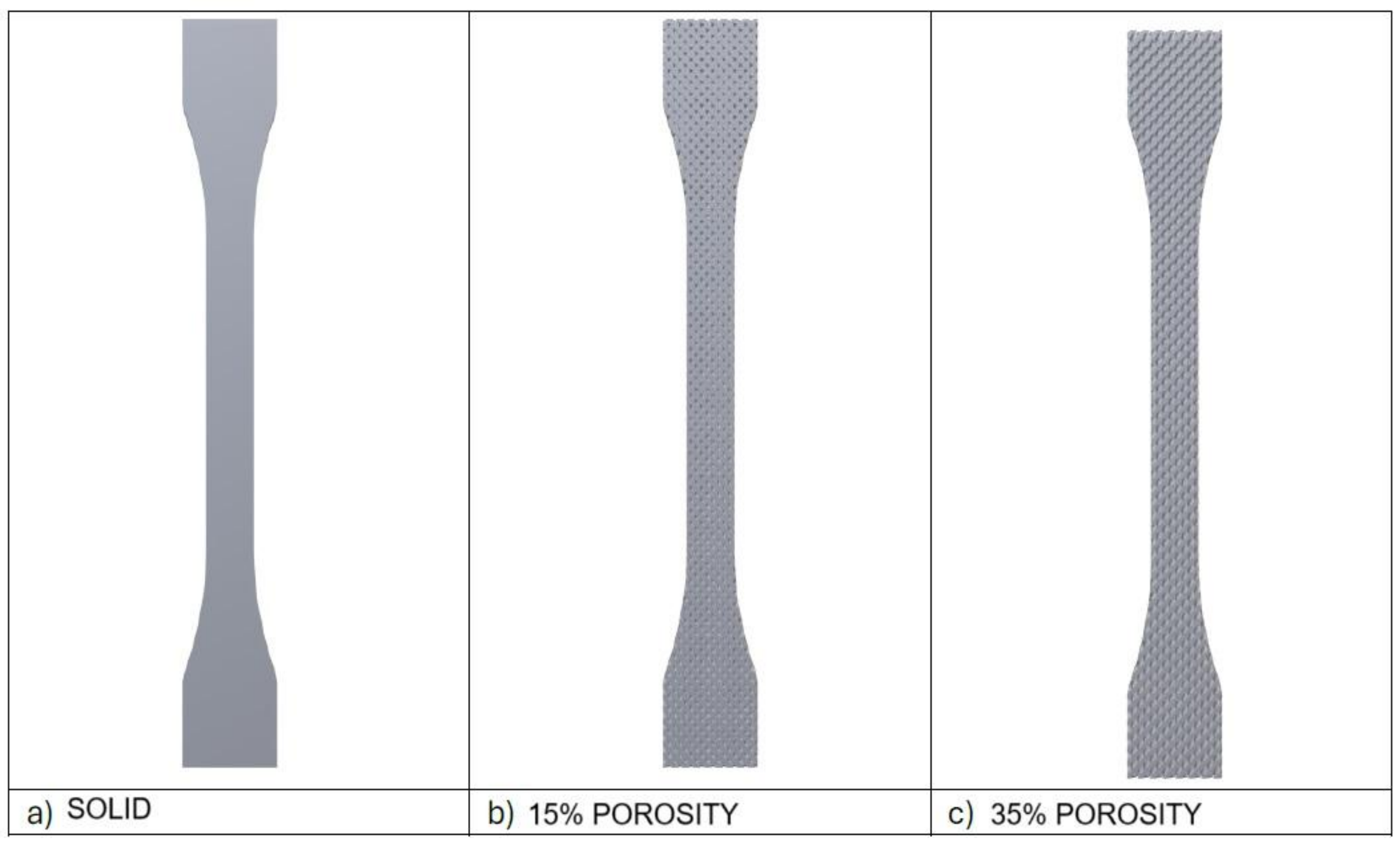
INTRODUCTION & AIM

With the recent advancements in implant technology, the need for novel biocompatible materials is higher than even. This is especially true for the hip joint, which is frequently injured with many patients disappointed from the surgery results. The aim of this work is to provide an extensive assessment of the properties of a porous 3D printed Direct Metal Laser Sintering (DMLS) Ti64 alloy. This study provides an extended experiment–simulation assessment of porous DMLS Ti64 paddle specimens across 0%, 15%, and 35% target porosity, quantifying porosity, density, strength, and Young's modulus, and augmenting tests with uncertainty-aware FE modeling using Sobol sampling to reflect realistic variability.

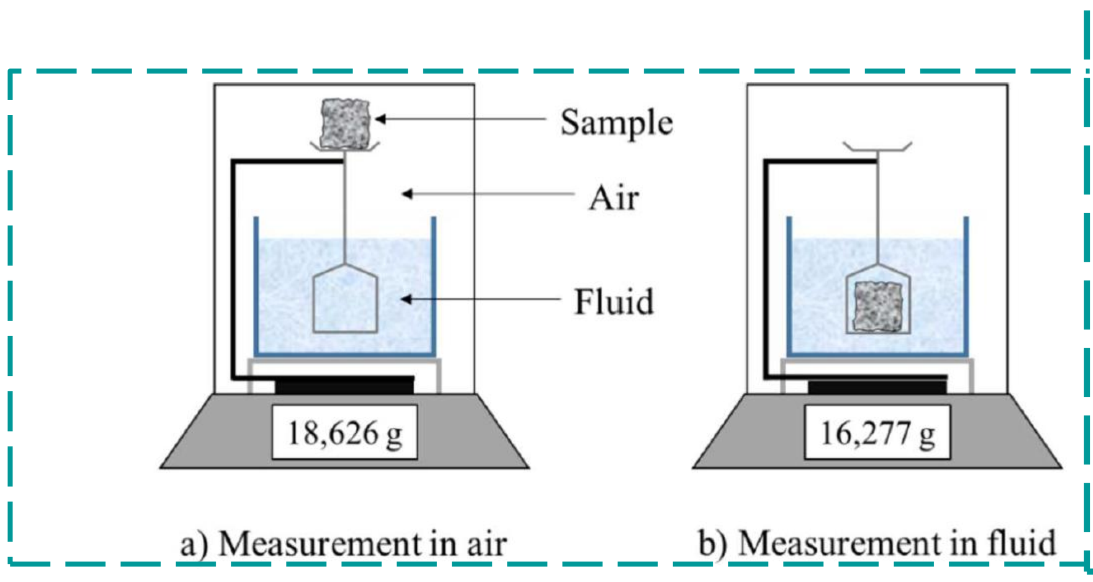
Table 1. Geometry and Porosity Levels of Ti-6Al-4V Tensile Specimens (Solid, 15%, 35%)

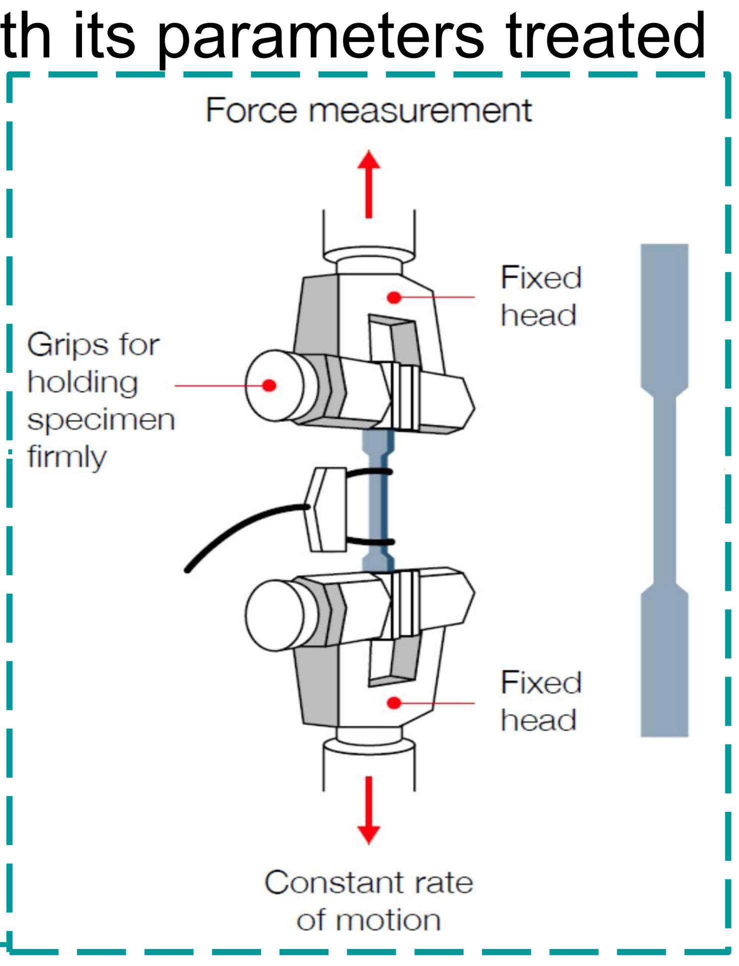


METHOD

The assessment was carried out in two parts – experiment and simulation. The experimental part consisted of Tensile Strength mechanical testing of samples with to compute the porosity, density and Young's modulus for two types of samples with varying levels of porosity (0%, 15% and 35%) and with 3 repetitions. Finite element modeling with parameter uncertainty was used to extend mechanical testing of the samples. The paddle sample FE model was solved 128 times based on a Sobol sequence with its parameters treated as random variables.

Figure 1. Archimedes Porosity and Uniaxial Tensile Test Setup for Ti-6Al-4V Specimens





RESULTS & DISCUSSION

The assessment was carried out in two parts – experiment and simulation. The experimental part consisted of Tensile Strength mechanical testing of samples with to compute the porosity, density and Young's modulus for two types of samples with varying levels of porosity (0%, 15% and 35%) and with 3 repetitions. Finite element modeling with parameter uncertainty was used to extend mechanical testing of the samples. The paddle sample FE model was solved 128 times based on a Sobol sequence with its parameters treated as random variables.

Table 2. Archimedes-Derived Porosity and Density of Ti-6Al-4V Specimens (Solid, 15%, 35%)

Sample No.	Mean measured porosity	± deviation POROSITY	Mean density	± deviation DENSITY
SOLID	1,920	1,321579272	4,163	0,099653678
15% POROSITY	8,633	0,484925178	3,521	0,160331978
35% POROSITY	27,335	4,925494086	2,723	0,034657996

Measured porosity increased from approximately 1.9% (solid) to ~8.6% (15%) and ~27.3% (35%), while density decreased from ~4.16 g/cm³ (solid) to ~3.52 g/cm³ (15%) and ~2.72 g/cm³ (35%), consistent with the expected density–porosity tradeoff in DMLS Ti lattices.

Table 2. Tensile Peak Load (Fmax) and Apparent Young's Modulus for Ti64 Porous Specimens

Sample No.	REPETITION	Fmax (N)	Mean ± deviation	E (MPa)	Mean ± deviation
SOLID	1	13306.517	13272.40 ± 24.18	160330.706	133423.38 ± 28826.74
	2	13254.802		136939.632	
	3	13255.885		102999.816	
15% POROSITY	1	9145.57	9055.95 ± 108.91	84161.8	94690.4 ± 21149.8
	2	9087.54		119038	
	3	8934.74		80871.3	
35% POROSITY	1	4571.83	4579.71 ± 22.23	54660.2	43389.0 ±1 8018.0
	2	4604.80		52898.3	
	3	4562.49		22608.5	

Peak tensile force Fmax decreased monotonically with porosity (≈13.27 kN solid, ≈9.06 kN at 15%, ≈4.58 kN at 35%), reflecting the known strength–porosity scaling observed in load-bearing lattices. Apparent Young's modulus declined with porosity (≈133 GPa mean solid with high scatter; ≈94.7 GPa at 15%; ≈43.4 GPa at 35%), aligning with Gibson–Ashby style trends where modulus reduction outpaces strength retention depending on lattice geometry and process quality.

CONCLUSION / FUTURE WORK

This study presents an extensive, two-step assessment of the Ti64 properties. Novel methods are applied both on the experimental side of the study, with tensile strength test and numerical part – with modeling under parameter uncertainty. The results showcase promising material properties of the Alloy for use in implant technology. Future studies will incorporate further experiments and extended modelling under more realistic implant loading conditions.

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