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Casting of Magnesium Foam for Bone Regrowth

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Introduction

- An artificial porous foam scaffold structure allows bone cells to grow on all surfaces of the scaffold
- Increased foam porosity correlates with increased surface area
- Foam strength must mimic that of bone to ensure proper strength of regrown bone tissue (approximately 150MPa)
- A magnesium foam scaffold slowly degrades by corrosion in the human body due to the environment
- Prior foam creation methods include sintering, laser printing, and titanium wire space holders, all of which are expensive, time consuming, or use harsh chemicals
- This work: Refinement of a low-cost casting technique to enable synthesis of magnesium alloy (AZ91E) foams and simulated compression tests of Mg foam
- Novelty of this work: Precise control of final foam structure, no harsh chemicals necessary, increased and controllable porosity, reusable furnace equipment

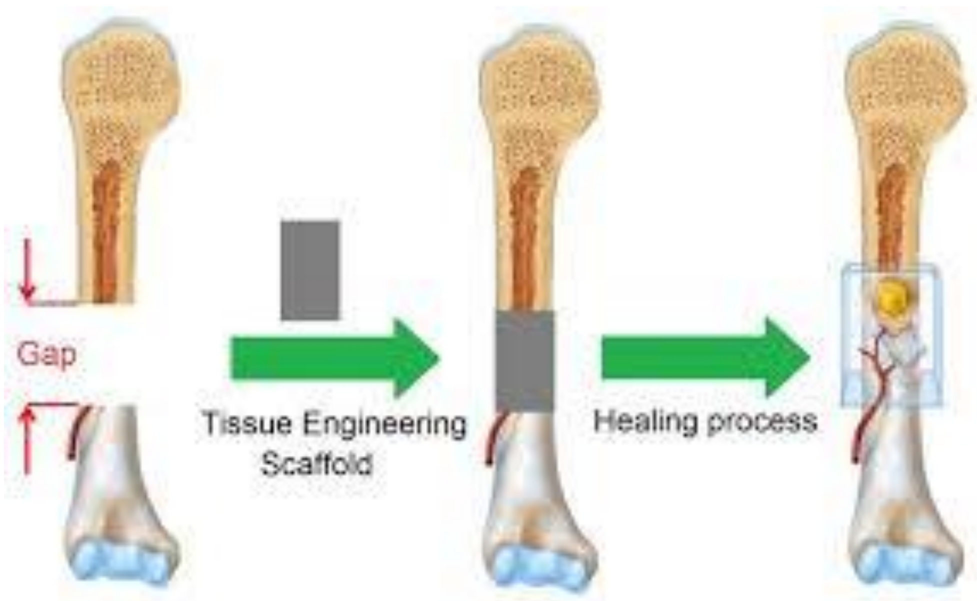

Figure 1: Foam bone replacement aiding in growth

Objectives

- Design a 3D porous foam structure model using a CAD program with controllable porosity
- Optimize ceramic mold shape
- Optimize casting variables
- Characterization of foam structure
- Compression strength of foam to determine physical characteristics

Method

- Using CAD software, create and update foam structure models with porosities of 42.2% - 56.9%
- Foam dimensions: 13mm x 13mm x 16mm
- Porosity calculations (where V_V is void volume and V_T is total solid shape volume)

$$\text{Porosity} = \frac{V_V}{V_T} \times 100\%$$

Equation 1: Porosity Calculation

- Design mold shape using CAD software to allow for reuse of furnace equipment
- Create molds of designed foam structure by proprietary investment casting process
- Introduce Mg melt to the mold under vacuum conditions using a proprietary technique

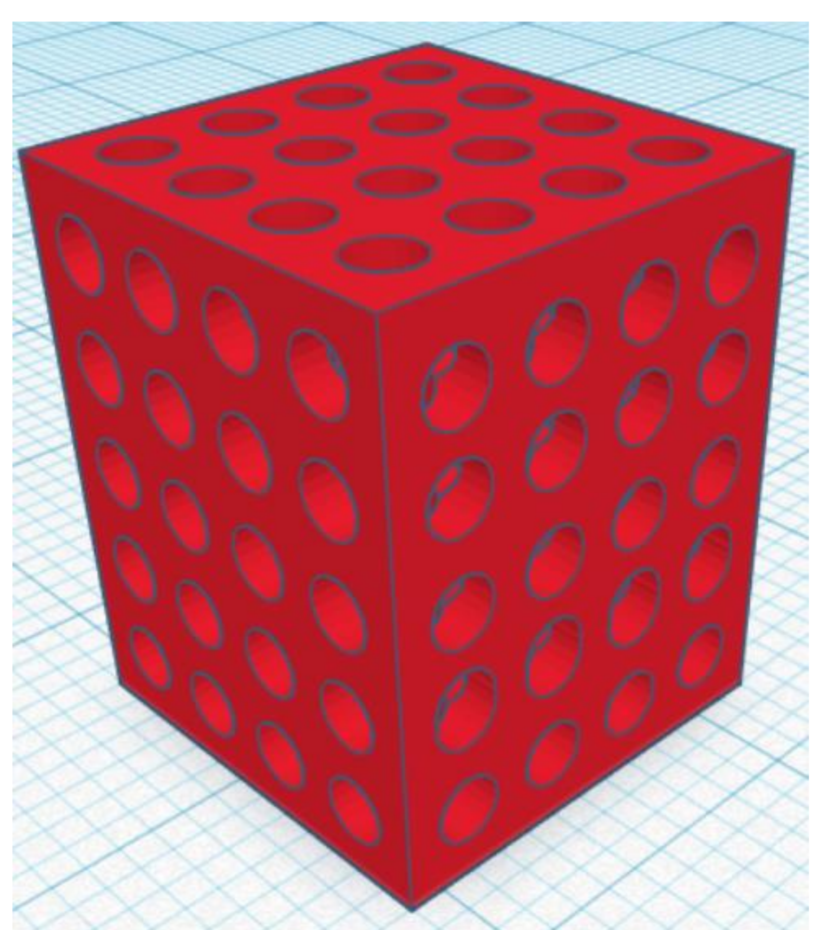

Figure 2: Foam CAD model (56.9% porosity)

- Use finite element analysis (via ANSYS Workbench) to simulate area compression tests (150MPa in 10s) of the designed Mg foam structures under foam ideal conditions

Results

- Design of foam structure with controllable porosity
- Cracked molds remain usable due to precise dimensions in pressure infiltration equipment design
- Creation of magnesium foam without harsh chemicals

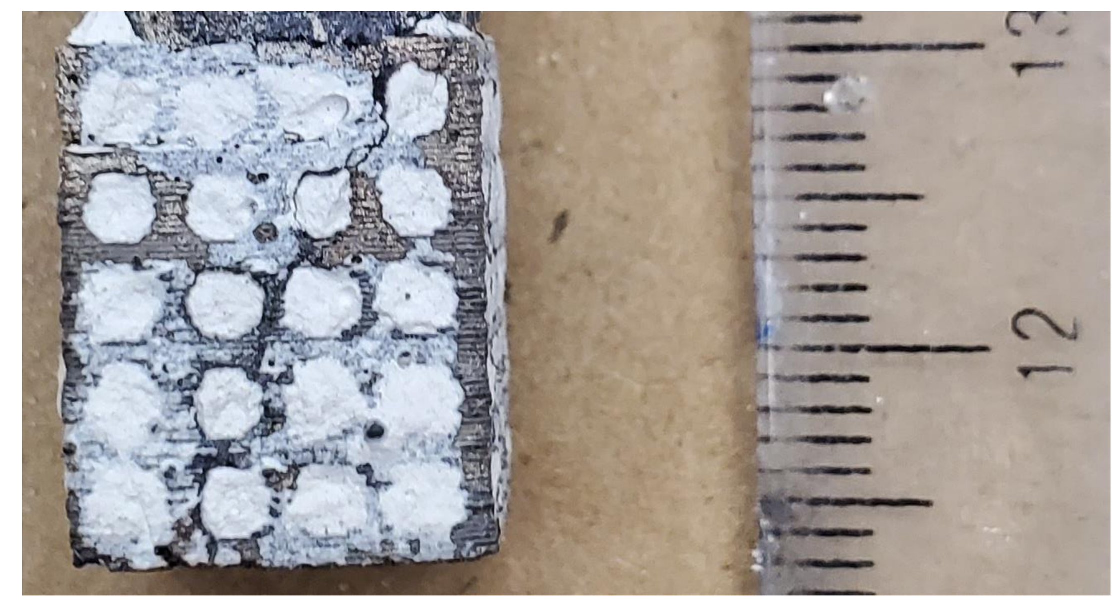

Figure 3: As-cast Mg foam with excess ceramic material

- Simulated compression tests produced results of maximum deformation 0.23mm at 150MPa load

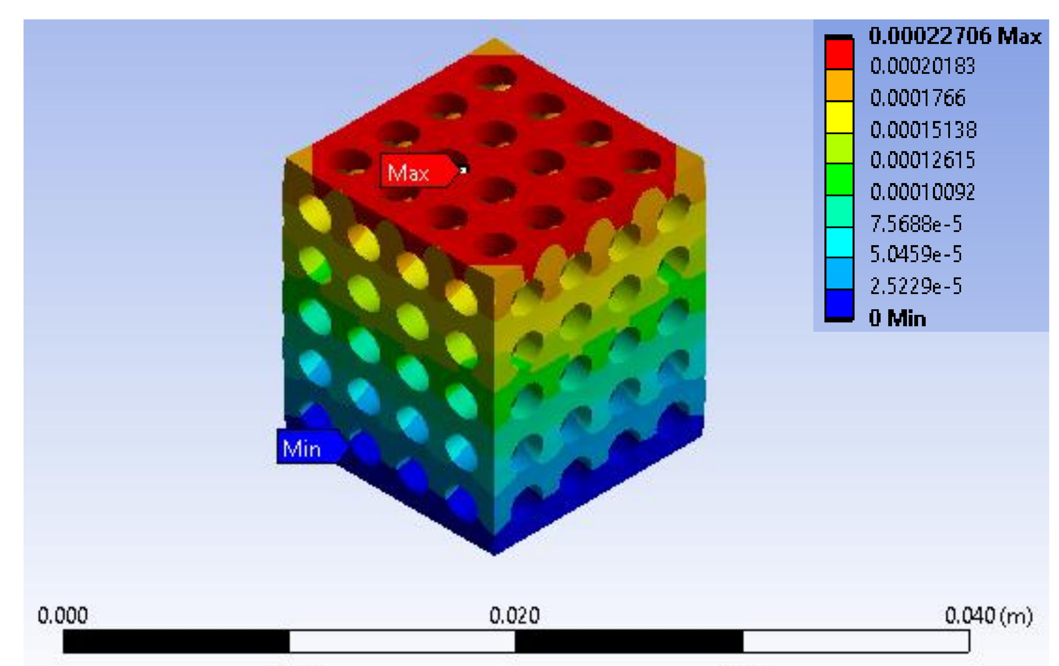

Figure 4: Simulated compression test of Mg foam, deformation (mm)

- Circular pore shapes reduce areas of stress concentration, decreasing risk of foam failure

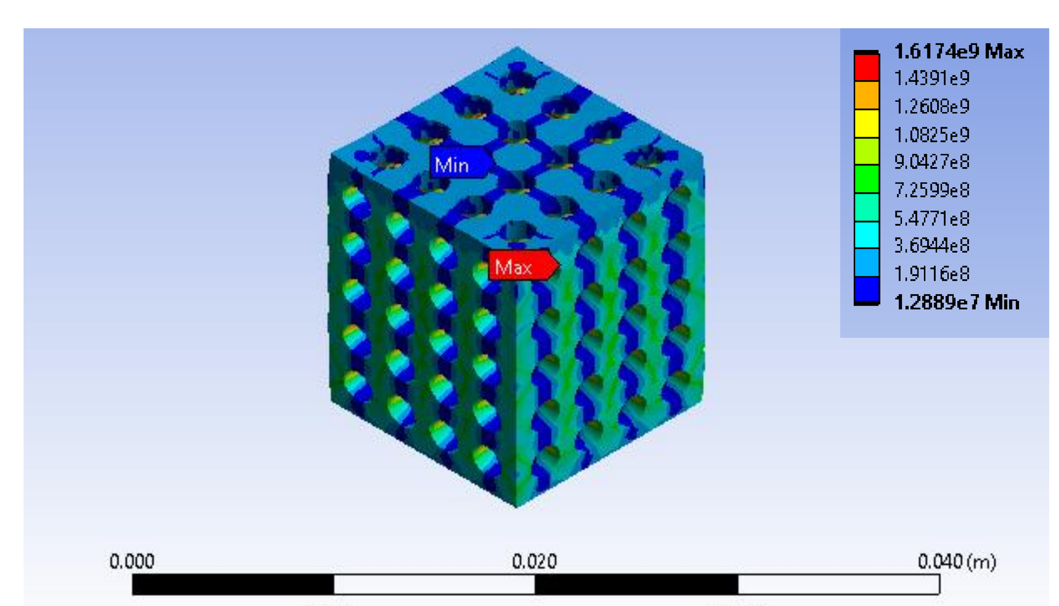

Figure 5: Simulated compression test of Mg foam, stress (Pa)

Conclusions

- Foam designs with controllable porosities up to 56.9%
- Mold shape optimized enabling furnace equipment reuse
- Successful investment casting and melt introduction to mold to create Mg foam
- Simulated compression test show the Mg foam mimics bone tissue properties
- Minimal deformation occurs of the loaded foam (necessary to maintain bone regrowth)

Future Work

- Fully remove excess mold material
- Strength vs porosity compression tests of Mg foam
- Optical and SEM micrography of foam structure
- Bone cell growth on Mg foam
- Different alloy compositions

Literature Reviewed

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