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Method for Increasing the Density of a Printed Green Body Using Cold Isostatic Pressing (CIP)

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Introduction

Additive Manufacturing (AM) , which relies on the sintering of printed green bodies, enables geometries that are difficult or impossible to produce with conventional compaction-based methods. Despite this design freedom, they often suffer from lower density and increased porosity, which negatively affect the final mechanical properties after sintering. Cold Isostatic Pressing (CIP) is a known method for achieving uniform compaction, but its application to complex printed shapes poses significant challenges, such as sealing the part and avoiding structural collapse during compression. Tritone's MoldJet technology could potentially solve these problems. In their technology, metal or ceramic powders are printed within a wax mold that is also printed. The wax mold may serve as a sealant for the part to prevent oil from entering the printed part during CIP and provides mechanical support that prevents deformation or collapse under isotropic pressure. This project aimed to improve the density of printed green bodies while preserving their complex shapes through CIP and MoldJet technology.

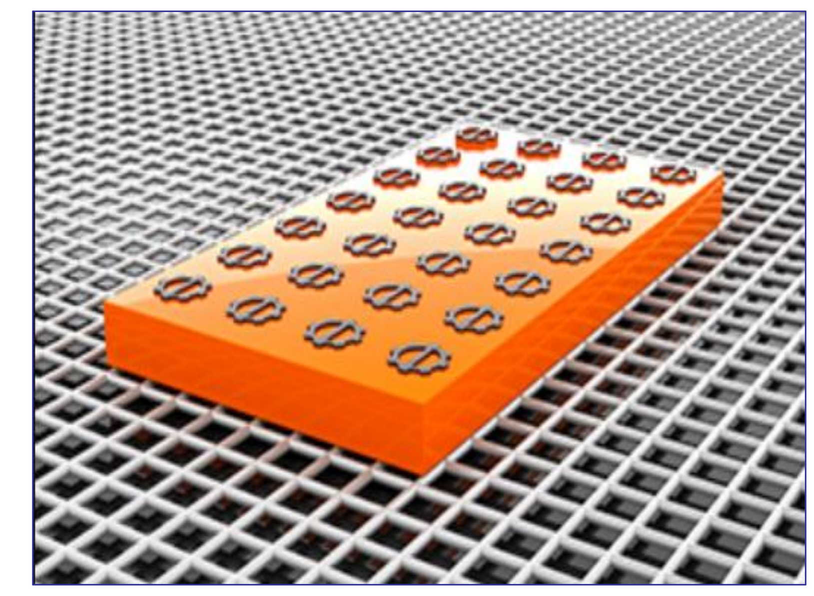

Fig 1: Sample preparation made by Tritone's MoldJet technology.

Preliminary Work

- The study began with CIP at 250 MPa of MoldJet-printed stainless steel green bodies featuring various geometries. Initial experiments conducted at RT resulted in moderate improvements in density, but the samples with complex shapes were cracked (Fig. 2).
- To overcome this limitation, the CIP system was modified with heating belts, insulation, and real-time thermal monitoring (Fig. 3), enabling controlled temperature-assisted pressing. Pressing at approximately 41 °C at the binder's glass transition temperature softened the binder, redistributing internal stresses more evenly during the compaction, significantly reducing the occurrence of cracks while maintaining shape integrity.

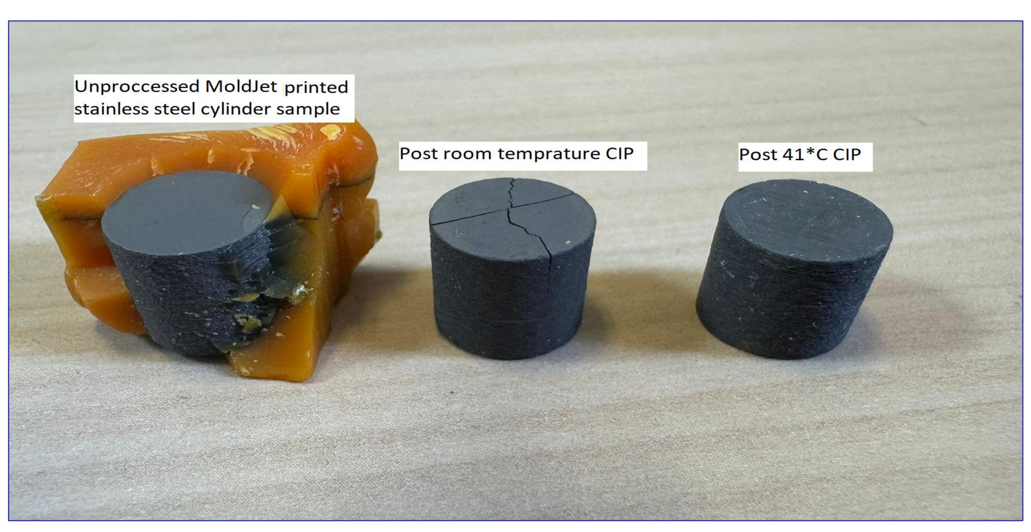

Fig 2: picture of an unprocessed MoldJet printed steel sample, post room temperature CIP and post Tg CIP sample.

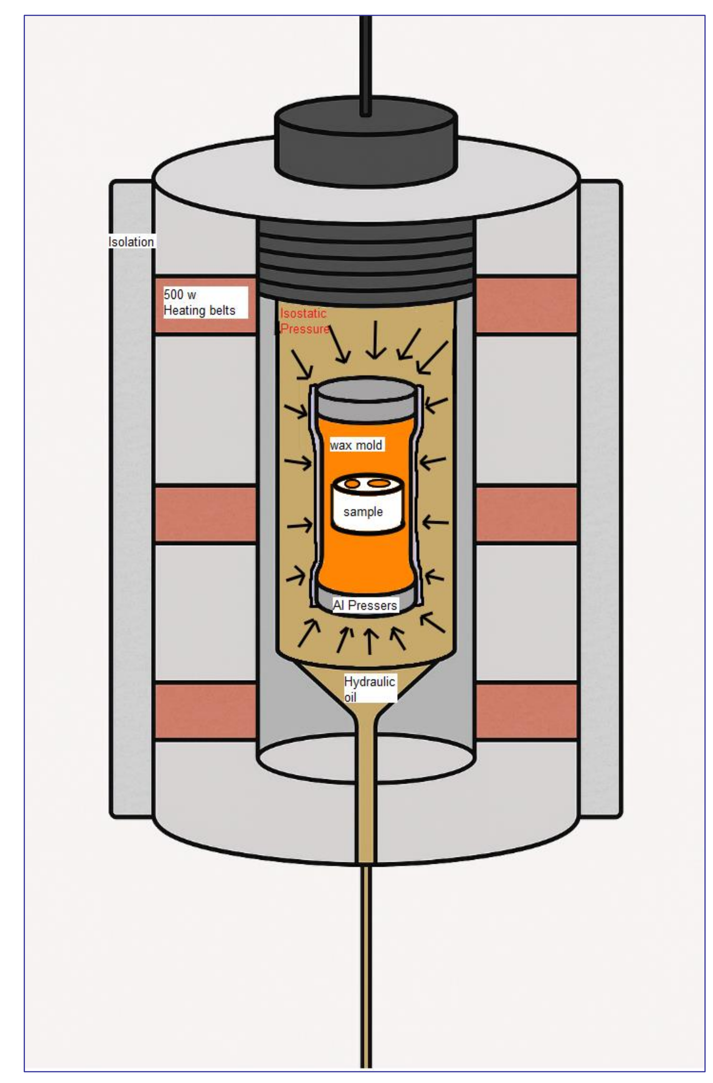

Fig 3: an illustration of the Upgraded oil based CIP system with heating capabilities and monitoring.

MoldJet 3D Printing Green Bodies

Enables sealed mold bound complex shapes ready for compaction

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Room Temperature CIP

cracks observed in complex geometries

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CIP Modification

Enabled temperature-controlled compaction

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Near Tg CIP

Compaction at the wax's glass transition temperature $(\sim 41^0 C)$

↓

Application

Modified treatment applied to ceramic YSZ samples and compared to conventionally pressed samples

Results

- Pressing at approximately 41 °C at the binder's glass transition temperature softened the binder redistributing internal stresses more evenly during the compaction, significantly reduced the occurrence of cracks while maintaining shape integrity.
- The use of modified CIP on initially stainless-steel samples with complex and simple geometries led to an average density increase of 12% (Fig. 2) and undamaged samples.

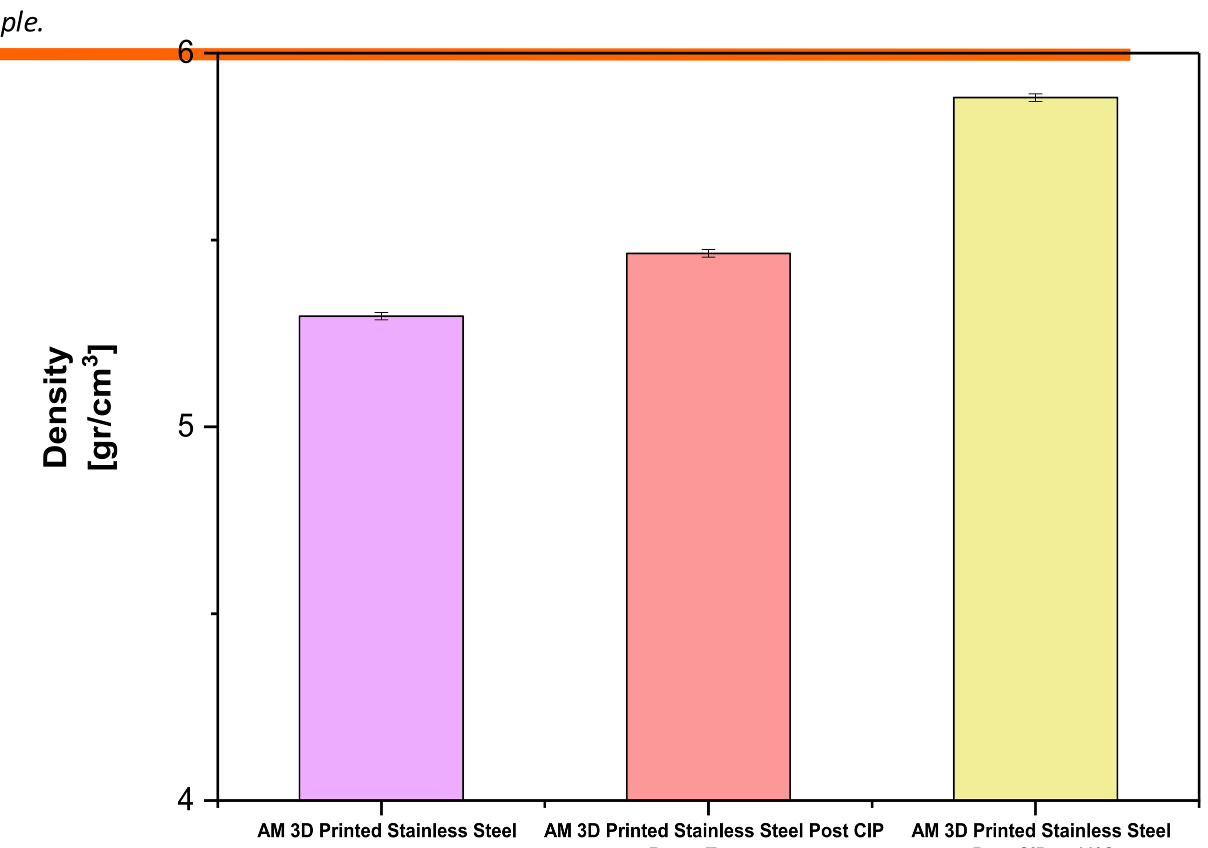

Fig 4: Steel density under no CIP, room-temp CIP, and ~41°C CIP

- More challenging cases involve brittle Yttria-Stabilized Zirconia (YSZ) ceramic samples. Using the same optimized conditions, the printed YSZ parts showed an approximate 23% improvement, with density increasing from 2.66 to 3.28 g/cm³ (Fig. 5) without experiencing breakage (Fig. 6). The maximum density achieved with this powder using uniaxial compaction was 3.48 g/cm³ (Fig. 5).

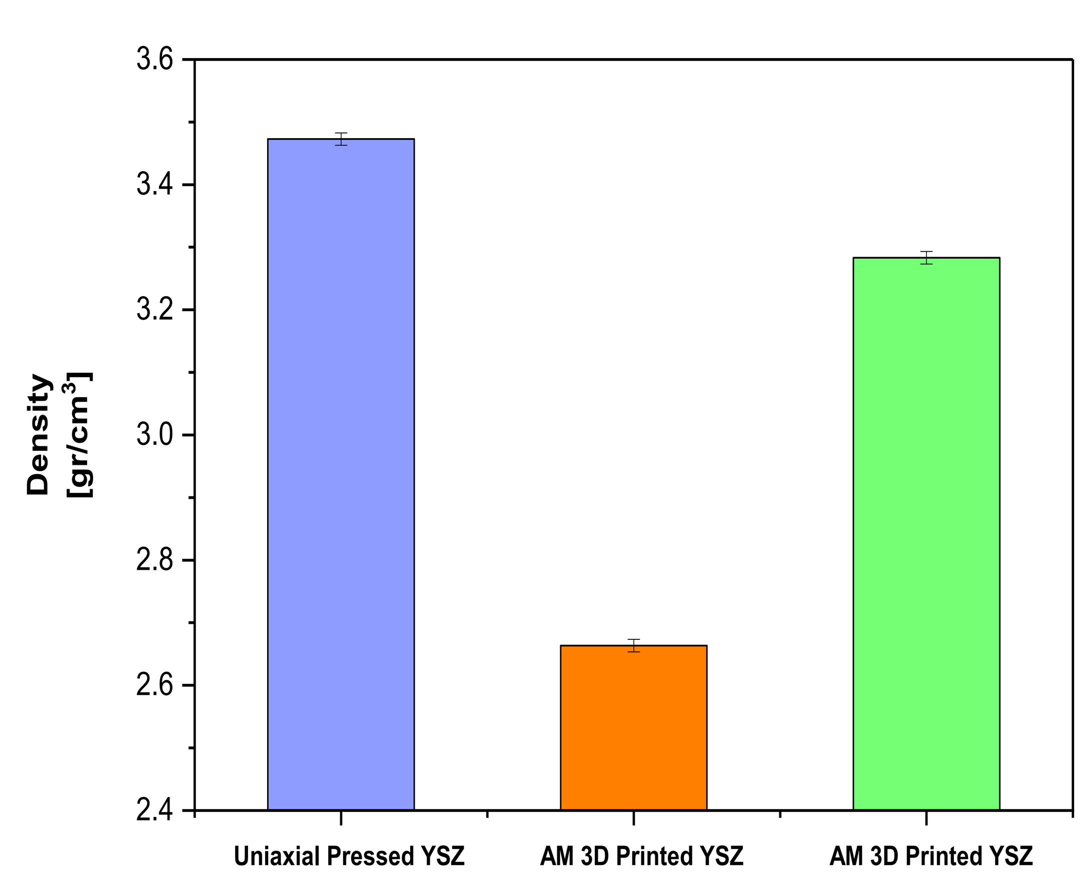

Fig 5: 3d printed YSZ samples compared to pressed samples of the same composite

Fig 6: Complex shape 3d printed YSZ samples post CIP at room temperature and 41°C and sintering

Summary

Cold Isostatic Pressing (CIP) increases density and reduces porosity in AM binder-bound green bodies. Conducting CIP at the wax binder's glass transition temperature (~41°C) minimizes internal stress and prevents fractures in complex geometries. This method boosts density by 12-25%, suggesting thermal-assisted CIP can enhance ceramic systems in additive manufacturing workflows.

Acknowledgments

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