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**Reviewed Paper**

# Design of a Tool Changer For use in the Hybrid Manufacture of Advanced Ceramics

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## Abstract

Multi-material and hybrid methods have been proposed to improve the functional complexity of components fabricated using additive manufacturing. Hybrid ceramic AM integrates multiple processes such as paste extrusion, inter-layer drying and green machining into a single system, allowing for production of functional ceramics. Integration of these processes onto a print head reduces the build volume per axis stroke length, and working coordinate systems are used to avoid work piece collision. A tool changer mechanism has been developed that uses an electro-permanent magnet to collect and deposit the working tool. This is beneficial because the use of magnetism removes any moving parts that would be worn by ceramic particles. The electromagnet is 'energise to release', securing tools to the print head even in case of power failure. Incorporation of this device into AM processes creates new opportunities for multi-material and hybrid ceramic fabrication, such as LTCC embedded electronics for harsh environments.

## Design Reasoning

Hybrid ceramic AM integrates multiple processes such as paste extrusion, inter-layer drying and green machining into a single system, allowing for production of functional advanced ceramics. Integration of these processes onto a single print head reduces the build volume per axis stroke length, and working coordinate systems are used to avoid work piece collision.

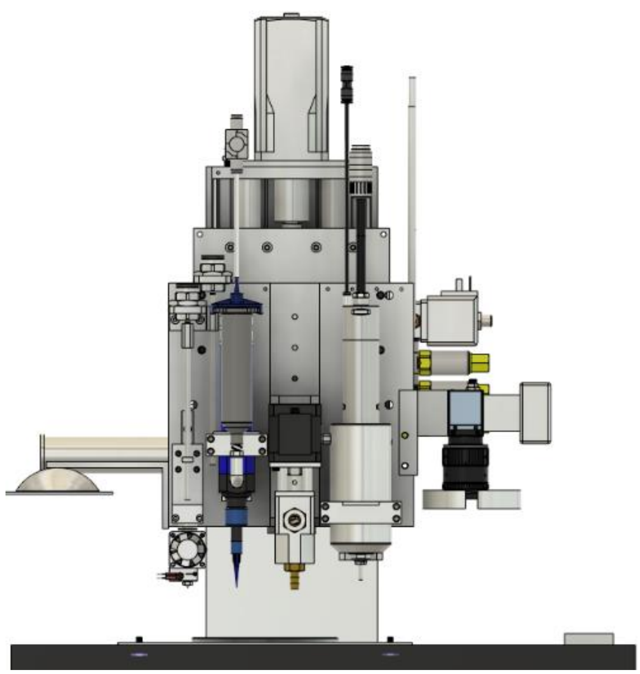

*Figure 1: Ceramic Hybrid AM Platform with processes integrated onto single print nozzle.*

A tool changer mechanism has been developed that uses an electro-permanent magnet to collect and deposit the working tool. Use of an electro-permanent magnet removes moving parts that would be worn by ceramic particles. Having the magnet be 'energise to release', means the tools are secured to the print head even in case of power failure, acting as an in-built safety mechanism.

**Tool Changer Design**

Design features two microswitch sensors to detect tool changer location relating to build plate & tools. Dowels fit in designated slots onto tool mounts to guarantee 'pick-up' precision. An aluminium block mount is used to secure microswitches & dowels, fits directly below gantry for compact design.

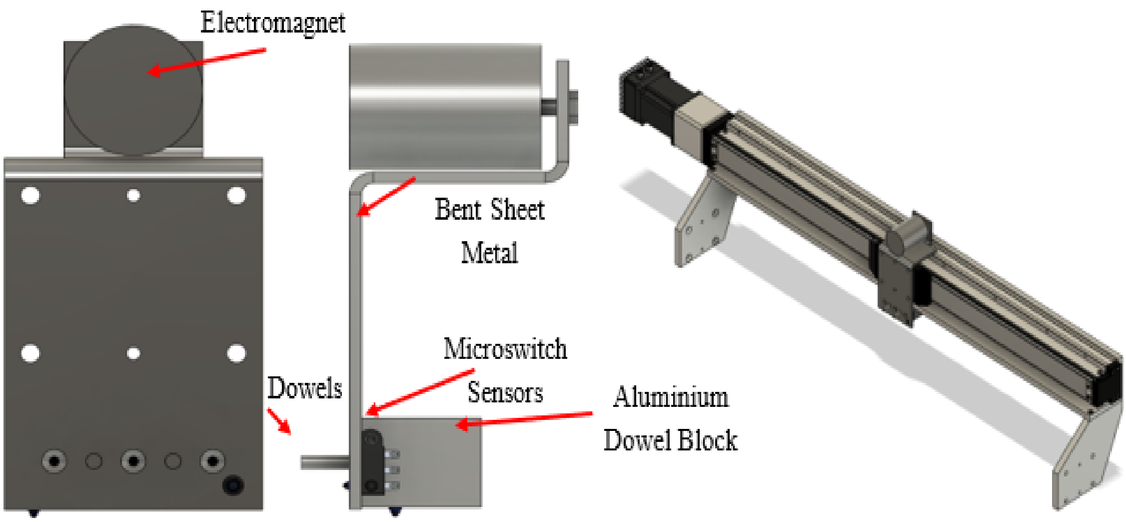


*Figure 2: CAD design of tool changer with integration onto gantry*

**Tool Mount Design**

A 3mm steel disc was positioned to align to electro-permanent magnet. The tool holder mount 'face' this disc is joined to is made from sheet metal. Dowel holes are aligned to the tool changer's dowel location. The tool parts are securely mounted to sheet metal. This produces a compact assembly for storage efficiency within a machine, and ease of removal for maintenance.

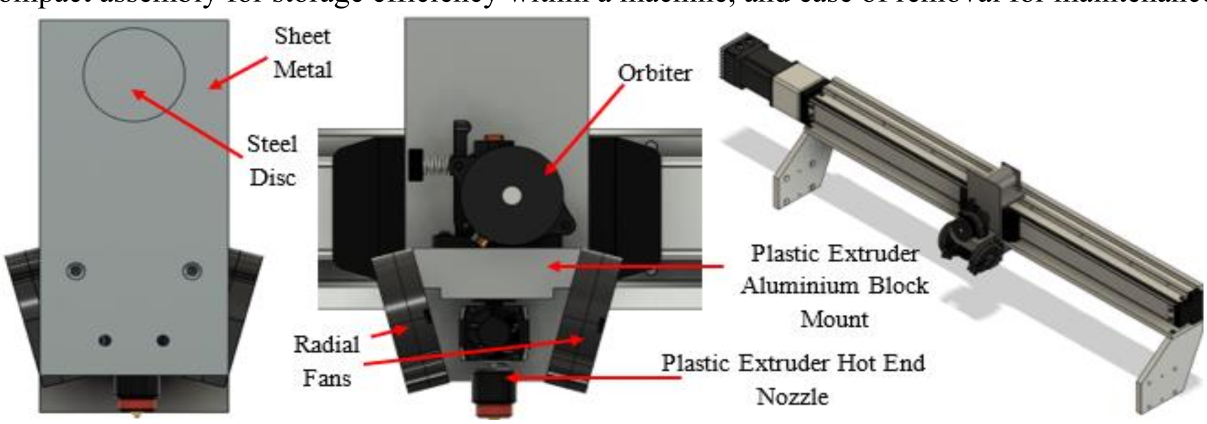


*Figure 3: CAD Design of process with integration onto tool changer head*

### Tool Changer Prototype

The produced prototype validates the tool changer design through compact design & testing. Precise dowel placement confirms that it is possible to accurately connect tools for use efficiently without error. Direct contact of magnet to tool results in a 250N holding force, exceeding the minimal factor of safety for practical and safe machine use.

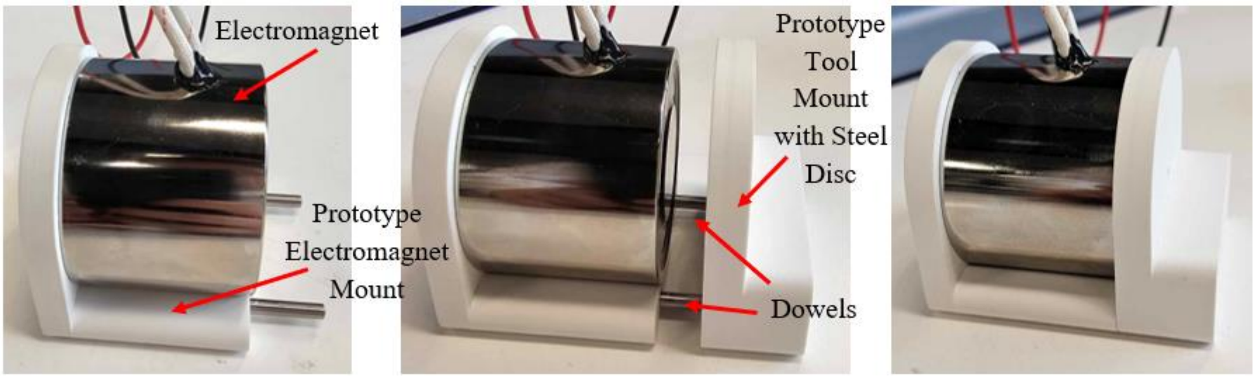

*Figure 4: Tool Changer Prototype with Tool Attachment*

### Conclusion

Incorporation of this device into AM processes creates new opportunities for multi-material and hybrid ceramic fabrication, such as LTCC embedded electronics for harsh environments. This is through improved process integration & increased versatility through seamless transition of optimal tools, enabling different fabrication processes in a single build cycle.