Additive Manufacturing of Reconfigurable Modules for Space Robotics

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1. Introduction

Additive manufacturing offers the opportunity to utilize space resources to construct electromechanical systems. Lunar resources such as Iron, Aluminum and even Rare-Earth Elements can be extracted and used for developing the necessary components for Space Robotics.

This research demonstrates this concept through the development of a Reconfigurable Module (RM) that consists of a DC motor, Coupling Mechanism and Electronic Control Circuitry (ECC). These modules can act as the building blocks for complex robotic systems used in In-Situ Resource Utilization (ISRU) for power generation, resource mapping, and in-space manufacturing (ISM) [1].

The idea of using RM in this way opens a doorway for these robotics systems to become self-replicating [2], which can increase ISRU operations that can be performed over time.

2. Previous Work

From the three main components associated with the RM, [3] has shown that a DC motor can be created using additive manufacturing techniques such as Fused Deposition Modelling (FDM), Laser Powder Bed Fusion (LPBF), and Laminated Object Manufacturing (LOM). Both radial and axial motors were created using these techniques. However, [3] showed that the 3D printed radial flux DC motor (see Fig. 1) was the most practical option as it had the simplest and most compact design.

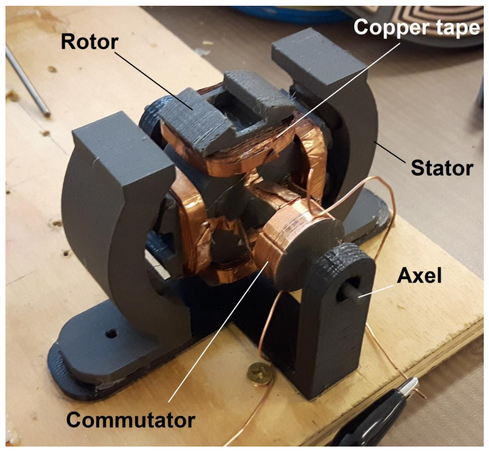

Fig. 1 Fully 3D Printed Radial Flux DC Motor [3]

3 Reconfigurable Modules

Fig. 2 3D Printed Reconfigurable Module

3.1 Motor

The DC motor in [3] was re-designed to improve the output torque. Several prototypes were designed and tested until a final design was selected. This motor featured a larger wire diameter in conjunction with a greater number of turns per slot, a more stable structure to reduce vibrations, and a higher metal content filament to maximize the generated magnetic fields. The final form of the DC motor (see Fig. 3) was printed via FDM, primarily using High Carbon Iron Filament.

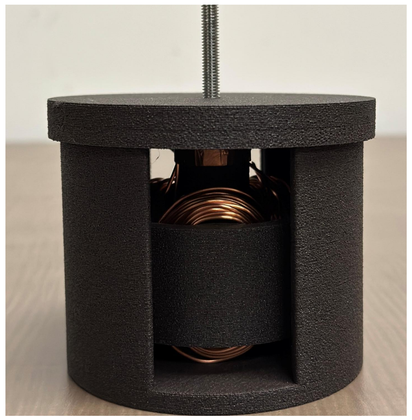

Fig. 3 3D Printed Brushed DC Motor for the RM

3.2 Coupling Mechanism

The DRAGON and ACOR connectors in [4, 5] inspired the design of the coupling mechanism. Both connectors feature a Shape Memory Alloy (SMA) actuator to facilitate the joining between two modules. Initial designs of the coupling mechanism featured the use of SMA wire wound through latches. However, after further iterations, the final design featured two latches connected by SMA springs. When the springs are actuated, the spring contracts and pulls the latches inward, releasing the connection (see Fig. 4).

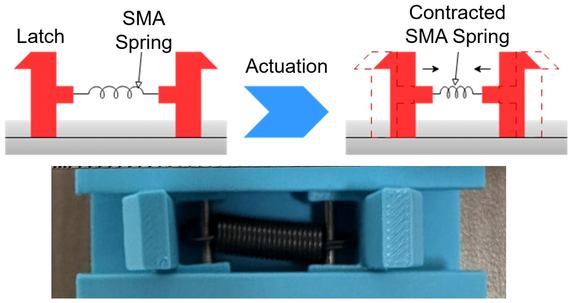

Fig. 4 RM Coupling Mechanism Working Principle

3.3 Electronic Control Circuitry

The ECC for the RM was designed using only basic electronic components, which minimized the complex processes required for ISM. The DC motor was controlled in open-loop configuration using a PWM generator (see Fig. 5(a)). An H-Bridge circuit (see Fig. 5(b)) was used to achieve forward and reverse motion. The coupling mechanism incorporated a resistive control strategy using an SR latch (see Fig. 5(c)). This allows the SMA to turn off once fully actuated.

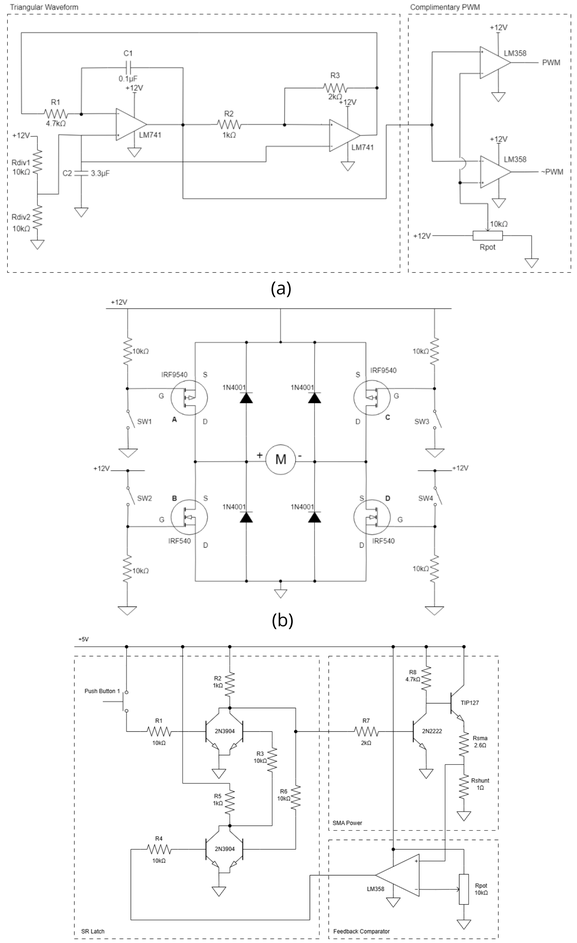

Fig. 5 Electrical Schematics of: (a) PWM Generator, (b) H-Bridge Circuit, (c) SMA Control Circuit

4. Conclusion and Future Work

This research has demonstrated that a DC motor and coupling mechanism can be developed using additive manufacturing methods. Using these components with an ECC allows them to form a functional RM that can be used as a basis for different space robotics systems.

Future work will investigate the completed RM further and the integration of different modules to allow complex robotic systems to be formed. The Cu wire can be replaced with Al wire extracted from Lunar Highland Simulant for the motor windings and 3D printed copper traces can be investigated for the ECC.

References

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