Design of an Implantable Stepper Motor

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Introduction

The field of motor miniaturization has seen significant progress in recent years, leading to revolutionary advancements in active implants. These cutting-edge technologies hold immense potential for enhancing the quality of patient's life by enabling invivo actuation. However, deploying motors within the human body poses unique challenges, requiring strict adherence to factors such as sterility, bio-compatibility, and reliability. This study aims to explore the essential design guidelines for motors in active implants, addressing the intricate demands of the human body and contributing to the development of safer and more effective medical devices.

Materials and Methods

Various tests and evaluations were carried out on critical functions, including the thermal resilience of the magnet, mechanical resistance of the shaft, adhesive application methods, sealing, coating encapsulation resistance and insulation. The feasibility of sensorless control was also investigated.

Fig. 1 Motor prototype without casing

The magnet resilience test involved subjecting an unsaturated N50SH grade magnet to 0, 1 and 100 autoclave cycles (137°C steam). The shaft resistance test involved a torsion to break the smallest diameter. Two adhesive application methods were compared: pre-positioning and capillary filling. The aim was to identify the most effective and robust bonding technique for motor component assembly. The sealing evaluation used moisture indicator cards to assess vapour infiltration during autoclave cycles. A major focus of the study was coating encapsulation. As motors require ferromagnetic materials that can be susceptible to corrosion, assessing the materials' resistance was critical to avoid adverse reactions or immune responses in the body. Corrosion has been assessed by submerging parts in a saline solution. The coating encapsulation also serve as electrical insulation of electronic components which has been tested by measuring the insulation resistance under 500V. Finally, the feasibility study for sensorless control involved simulating and filtering the coil current response to a high frequency injection (HFI) signal

Results

The unsaturated magnet lost <2.5% of his strength after 100 cycles, suggesting that when saturated the N50SH grade can withstand autoclave. The torque required to rupture the shaft reached 170 [mNm] i.e. 40 times the motor torque. Regarding adhesive application, capillary filling resulted in consistent adhesive application whereas pre-positioning left air bubbles inside the cavity. The moisture card did not survived the test but adaptation using pressure gauge has been suggested. The undamaged coating encapsulation reduces the corrosion of parts but does not suppress it completely. However, minor coating damage resulted in localized corrosion and coating detachment from substrate

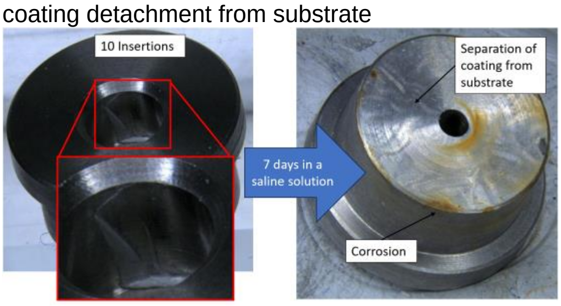

Fig. 2 Parylene-ceramic multi-layer coating damage caused by 10 pin insertion resulting in part corrosion and coating loosening after 7 days in a saline solution.

In addition, to little resistance, the coating did not fully insulated flexible printed circuits (FPCs). Finally, sensorless control feasibility study found that brushless direct current (BLDC) motor is better suited for HFI rotor position detection.

Discussion

These results mainly indicates that the parylene-ceramic multi-layer is too fragile for mechanical parts and not a sufficient barrier regarding corrosion in a saline environment. Alternatives coating such as titanium nitride might be evaluated. Further investigation regarding the protection of the electronic might include epoxy over molding to protect the coating and improve the barrier.