Executive Summary

During the gait cycle of legged-robotics, leg-to-ground contact can generate large shock loads which cause gear failure in the gearbox component. Current solutions for gear protection with elastic and/or damping elements inserted into the direct load path can effectively shield the gears from impact but also create complications in controls and/or energy losses. Shear-thickening fluids (STF) show potential as a solution in isolating and redirecting impact loads away from the gears without introducing complications in controls. These fluids are non-Newtonian in that the viscosity increases with increasing shear rate. Through a rigorous concept selection process, two concept designs, the Viscous Coupling Unit (VCU) and Concentric Circles Unit (CCU) were chosen to be manufactured and tested. Both concepts seek to maximize the surface area of contact between the shearing surfaces and the STF in order to maximize the effect of the change in viscosity of the STF for effective torque transfer. Oobleck, a mixture consisting of cornstarch and water, was chosen as a suitable STF for our design due to the literature which has been found that characterizes the shear-thickening behavior of the fluid. These properties were used in determining the final dimensions and specifications of our prototype designs. The prototypes were manufactured with raw materials and equipment within a budget of $500.

Tests were performed by attaching each of our prototype units to a motor which was driven at different speeds at steady-state. From test data, the efficiency loss and stress mitigated from implementing our prototypes were calculated at different speeds in order to analyze the performance of our designs. The CCU was found to have a significantly higher performance than the VCU in terms of both efficiency loss and stress mitigation. At low speeds, representative of normal drivetrain operation, the prototypes do not induce large efficiency losses and do not show significant stress mitigation (4.88% efficiency loss and -0.45% of UTS mitigation at speeds of 130 – 190 RPM). At high speeds, representative of impact loading, the prototypes induce larger efficiency losses but mitigate a significant amount of stress (14% efficiency loss and 4.9% of the UTS mitigation at 270 – 330 RPM for CCU). Thus, our prototypes have shown that the concept of utilizing STF for impact bypass has potential. However, further testing with higher-quality equipment is required for more conclusive results regarding the steady-state behavior of our prototypes. Additionally, impact tests would have to be performed to determine whether the concept of utilizing shear-thickening fluids for shock bypass would be applicable to impacts.