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RAPID ITERATIVE DESIGN OF A COST-EFFECTIVE E-PUMP FOR A LIQUID-FUELLED REUSABLE SOUNDING ROCKET: A COMPREHENSIVE APPROACH TO IN-HOUSE DESIGN, MANUFACTURING AND TESTING.

Abstract

Turbopumps are usually the most complex subsystem within liquid-fuelled rocket engines, and therefore the most expensive and risky hardware to develop. This is especially true for student teams or startups, who lack previous technical knowledge or experience in the subject. Nonetheless, Delft Aerospace Rocket Engineering's (DARE) turbomachinery department has developed an electric pump, or e-pump, to be integrated in DARE's 10 kN ethanol and cryogenic oxygen-fueled engine: Firebolt. The e-pump has been designed from the ground up over two years and consists of a single-stage radial pump including a fully custom mechanical face sealing solution with ceramic contact rings, a 3D printed titanium closed impeller and volute, and custom machined bulkheads and shaft. An electric motor was chosen over a gas turbine to drive the pump primarily due to lower complexity and better packing efficiency paired with lower development costs and risks. The ethanol e-pump provides a pressure rise of 25 bar with a volumetric flow rate of 2.7 Liters per second, with a shaft rotational rate and power of 30,000 RPM and 10 kW respectively. The development of the e-pump centered around rapidly reaching the functional testing stage by producing a design that can be easily iterated upon. Furthermore, special emphasis was placed on ensuring compatibility of most key components across both the ethanol and LOX pumps. The electric power system was developed in-house, consisting of custom control and data collection electronics, and the adaptation and integration of an off-the-shelf electric motor, ESC, and battery pack. The e-pump was almost entirely custom machined by the team using the available university facilities, the only exceptions being the volute, the impeller, and the ceramic sealing rings. This proved to be a cost-effective approach and ensured close control over the entire manufacturing process. The test setup, together with the relevant safety and operational procedures are then devised to assess the system's performance. The testing campaign is carried out in close cooperation with TU Delft and governmental partners to guarantee access to the necessary advanced testing facilities. Future iterations of the e-pump will be improved upon, integrated with the Firebolt engine, and flight-tested aboard DARE's flagship Stratos V rocket.