Correlation of numerical simulation methods and failure criteria to experimental burst test

Karlo Kasljevic

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During lift off, the Prometheus rocket turbine components experience tremendous structural loads were failure could lead to catastrophic downfall. Therefore the components undergo several costly tests ensuring their reliability. To reduce development costs, simulations are performed to estimate the limitations of these components. The accuracy of these simulations are crucial and requires validation by correlating the results to real-life experimental testing.

Since the finite element method gained impetus we turn to numerical simulations to solve the governing differential equations of structural problems to reduces cost and development time.

The finite element method is today the most used method to solve engineering and mathematical problems in the fields such as structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential.

When the margins are small, and the stakes high, it is crucial to measure the disparity between simulated- and experimental results by correlating the results and evaluating their precision and accuracy.

Stationery the Prometheus turbine experiences tremendous structural, vibrational, and thermal loads, yet the turbine operates inside and during the liftoff of the launcher vehicle Ariane 6. With strict weight requirements, like all components of a launcher vehicle comes small safety margins, yet the failure of a rocket turbine will lead to catastrophic downfall.

The Ariane 6 Launcher vehicle is currently under development by ArianeGroup under the authority of the European Space Agency (ESA). It will be the newest addition to the Arianefamily as of 2020-2021. It is a medium- to heavy-lift launch vehicle able to carry a payload of up to 11500 kg to geostationary transfer orbit. In 2025 the next-generation Ariane 6 launcher vehicles will use the new Prometheus rocket engine.

In this thesis, the single-stage 3D printed Prometheus rocket turbine rotor is of primary focus. It is currently under development by *GKN Aerospace* and will be used in the next-generation Ariane 6 launcher vehicles to pump oxygen and methane into the rocket engine. The thesis analyses the structural load during overspeed burst.

GKN Aerospace provided experimental tensile test data of 3D printed Inconel 718 test specimen. The hardening phase was modeled by curve fitting the tensile test data using Hockett-Sherby hardening law. Both quasi-static elasto-plastic and linear-elastic simulations were performed using *Ansys Mechanical 19.1*. Later, several burst criteria were computed using the simulated results.

The elasto-plastic simulations were run by successively increasing the rotational velocity until convergence was lost due to excessive deformation. The linear-elastic simulations were run at experimental burst speed.

Comparing against the experimental overspeed burst test performed by *GKN Aerospace*, the elasto-plastic simulation yielded the most accurate burst speed estimation, with a difference of 0.2%. The most accurate burst margins calculated using linear elastic simulation results resulted in a difference of 1%.

Finally, Rice & Tracey failure criteria and the *Critical strain trough cross-section* criteria managed to pinpoint where the fracture would initiate, which correlated well with the experimental burst results.