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Flow field reconstruction of rocket engine turbine on sparse sensors

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Abstract

Flow field reconstruction from spatially sparse sensors provides a means to identify global flow behavior and analyze the propagation of dynamic flow phenomena. This approach is particularly valuable for applications with limited accessibility, a restricted number of sensors, and challenging operating conditions, such as turbomachinery instrumentation. Detecting early-stage flow separation in turbines enables intelligent control strategies to mitigate the growth of this phenomenon and minimize its adverse effects on performance.

This paper presents a method for reconstructing the flow field of a turbine-inlet manifold using an Autoencoder (AE) trained on computational fluid dynamic (CFD) simulation data. Figure 1 illustrates the extraction of a horizontal 2D flow field of interest from the toroidal manifold. Flow separation in the torus, visible in the upper-right region of the flow field, significantly affects the inflow into the downstream convergent-divergent stator channels, ultimately impacting the overall turbine performance.

The AE, trained on CFD data, is validated using experimental data. The described methodology is applied to the impulse turbine of a rocket-engine turbo pump. Identifying early-stage flow separation in the reconstructed flow field can enable intelligent data-driven turbine control, avoiding critical operational points, optimizing performance, and reducing lifetime degrading effects.

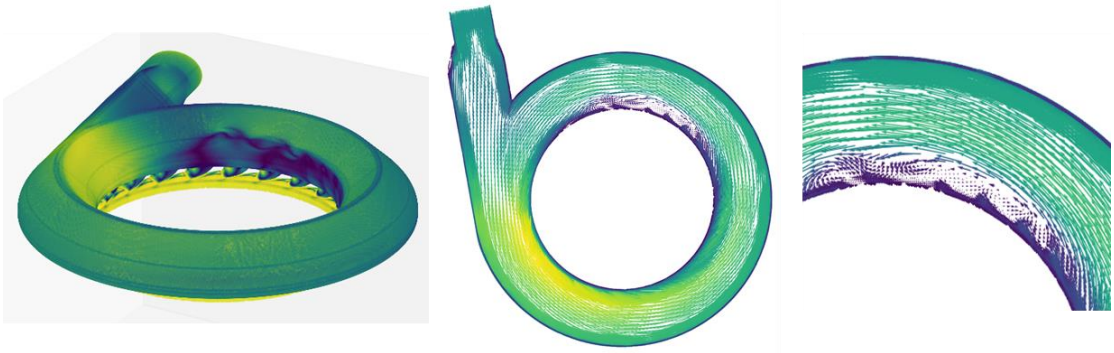

Figure 1 – turbine manifold, left: 3D velocity flow field, middle: 2D velocity arrows, right: zoom - flow separation

Keywords: flow field reconstruction, Autoencoder, flow separation, intelligent control, turbomachinery, turbine, sparse sensing, test, pressure, performance, rocket engine, manifold