Project Proposal

FEM Analysis for the Development of a Surrogate Model for Stress Prediction

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General Information

Type:	Semester Project (10 ECTS) or Master thesis (30 ECTS)
Laboratory:	Laboratory for Applied Mechanical Design (LAMD)
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Background

Optimizing individual components within a system composed of multiple subsystems rarely yields an optimal design for the system as a whole. Such strategies often lead to solutions that converge on a local minimum rather than achieving a global optimum. To overcome this limitation, an integrated design methodology is required, emphasizing the optimization of the entire system rather than its discrete components. The drawback of this approach lies in the substantial computational expense associated with integrated optimization. This process requires simulation and evaluation of the governing physics of all subsystems during each iteration of the optimization procedure. To mitigate these computational demands, surrogate models are frequently employed for the evaluation of subsystem physics, serving as efficient alternatives to more resource-intensive methods such as CFD or FEM.

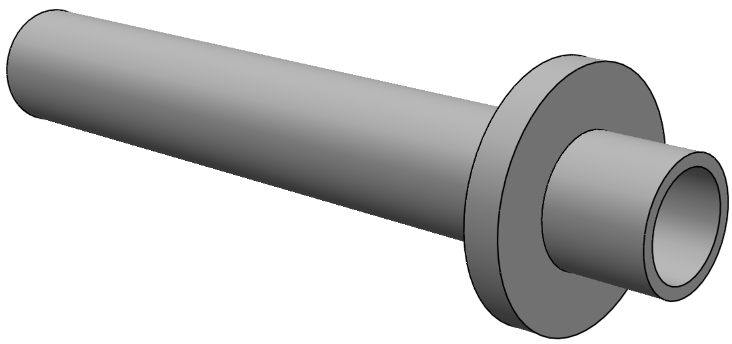

Figure 1: Classical mGT shaft geometry

A micro-gas turbine (mGT) supported by gas-lubricated bearings represents one of this complex system requiring an integrated design approach. Among its various subsystems, one particularly critical component is the shaft, which must be designed to be rigid, lightweight, and capable of withstanding the high centrifugal forces generated by the mGT rotation which ranges in the hundreds of thousands of revolutions per minute.

[1] For the semester project, attendance is required once per week, while for the master's thesis, attendance is required four times per week.

The classical shafts employed in these applications, shown in a 3D representation in Figure 1, can be seen as the combinations of multiple cylindrical sections, thereby reducing stress analysis to the solving of fundamental solid mechanics equations, for which analytical solutions exist. These solutions are conventionally employed to model both the stress distribution and the centrifugal expansion of the shaft. A novel concept of mGT currently under development requires modifications that disrupt the axial symmetry of the geometry, thereby precluding the application of analytical expressions for evaluating stress and centrifugal expansion. Consequently, the use of computationally expensive FEM simulations is necessary.

To reduce the computational expense of the integrated design optimization process, it is necessary to develop a surrogate model capable of accurately predicting the maximum von Mises stress for non axisymmetric shaft geometry.

Objective

A surrogate model capable of predicting the maximal von Mises stress as a function of the geometric characteristics of the non-axisymmetric shaft, the rotational speed, and the mechanical properties of the material.

Tasks

1. Set up and run FEM simulations to generate the data set.

2. Run the FEM simulations.

3. Perform a mesh convergency analysis.

4. Analyze the results of the simulations.

5. Develop a surrogate model for stress prediction.

NB: adjustments may be required according to progress, results, and project duration.

Prerequisite knowledge

1. Finite Elements Method
2. Abaqus / Ansys
3. MATLAB / Python