1 Introduction

Jet engines are developed based on computer models equipped with knowledge from best practices or from already-built engines. The process of jet engine development involves validation of the newly built models with measured test data. In order to get the required test data, certain measuring instruments are necessary. These instruments differ depending on the production standards of the development engines. The instruments are available for the research of the performance and detailed testing of the components of the jet engine throughout the development process. These instruments are needed primarily in production of the standard engines for regulation and condition monitoring. As a result, less instrumentation wires are attached to the components.

Any additional instrumentation on the engine is considered a foreign object in the system and has influence on flow patterns, heat transfer, vibration, pressure and etc. Additional effects, such as windage heating, need to be corrected in the models. The test data from certain parameters may not reflect the production standard correctly. For this reason, the influence of these parameters need to be taken into consideration, whenever the computer models are matched with the data. Any over- or underestimation of these effects in the models can lead to misjudgment of service life of the engine components. They require correction with every single input for a better quality of prediction of the standard engines. The inputs are derived from computational fluid dynamic (CFD) analyses.

The lifetime of high-pressure turbine (HPT) discs depend on the supplied cooling air and internal flow field. Differences in the flow field due to instrumentation wires can lead to metal temperature increase and misjudgment of the service life. The cooling air in a jet engine, redirected from the compressor stages causes windage in the secondary air system (SAS), since it flows through cavities. An overview of the airflow in a jet engine is shown in figure 1.1. The cooling air supply for the HPT is marked with red arrows in figure 1.1.

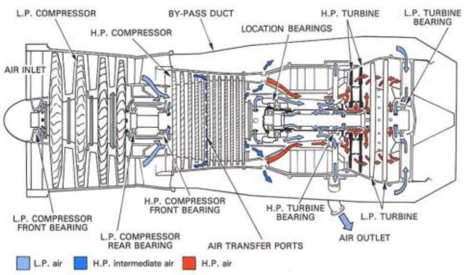

Abbildung 1.1: General airflow in jet engine [**?**]

Therefore, it is crucial to understand what impact these effects have on several components. For this thesis, a CFD analysis is done on the requested location. The investigated location is a rotor-stator cavity behind the rotor in a HPT stage and a stationary component. It shows an accumulation of cable routing through this cavity, as well as attachment to the walls. For an overview of the location, figure 1.2 shows a turbine layout with an exemplary rotor-stator cavity between a turbine disc and a stationary component, which is highlighted in red. Instrumentation wires attached to a turbine rotor surface can be observed on the right side.

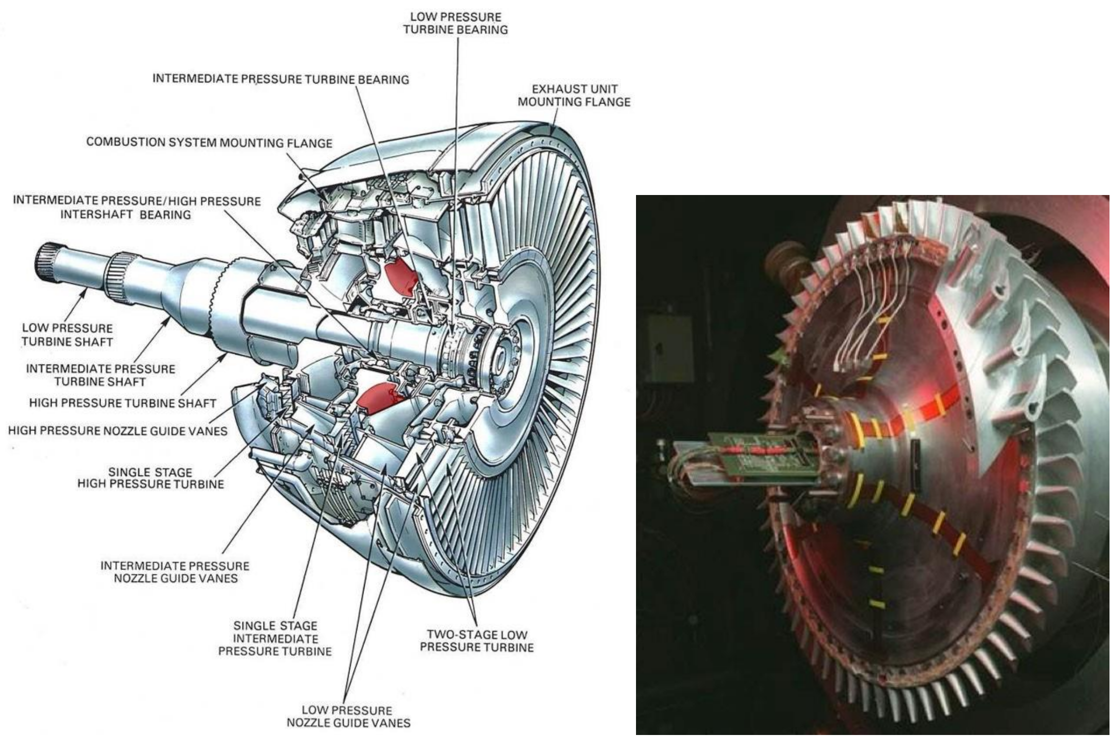

Figure 1.2: Turbine layout with highlighted rotor-stator cavity (left) [**?**]. Instrumentation on turbine rotor surface (right) [**?**].

Windage is a result of relative movement of a fluid and a surface with each other. Due to the friction forces, kinetic energy converts into thermal energy and additional heat is generated. Consequently, the cooling air is needed to cool down the hot components, such as the turbine blades, discs and vanes. Over time, the turbine entry temperature (TET) increases, resulting in enhanced efficiency of the engine performance. The higher temperatures challenge the supply of cooling air especially in the high-pressure turbine stages. The more accurate the windage prediction, the less cooling air is required, leading to a rise in efficiency.

This thesis focuses on the windage heating generated during the presence of instrumentation, as the cooling air passes over the rotor surfaces in the rotor-stator cavity, where it is encountered. Therefore, a comparison of a generic rotor-stator cavity with and

without instrumentation will be done. A detailed analysis of different parameter variations listed below is accomplished:

- spool speed
- inlet mass flow
- power conditions (idle, cruise, maximum take-off (MTO))
- amount of instrumentation attached on the wall
- layout of wires
- interaction of instrumentation wires
- inlet swirl number

A numerical investigation is performed with the CFD simulation software *Ansys Fluent*. As an introduction to this subject, a section of literature review of rotor- stator cavity analysis is done. Following this, theoretical background to this subject and fundamentals of fluid dynamics will be given and subsequently followed by chapters about the mesh generation and model setup. The analysis of the parameter variations and the numerical results will be presented afterwards. Finally, a conclusion of the work and overall outlook will be discussed.