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[Extended Abstract]

Design procedures of a turbo pump test bench

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Introduction

The turbopump is a substantial part of a liquid rocket engine and increases the pressure from low pressure in the tank to high pressure in the combustion chamber. The dimension and the performance of the turbopump depend on the engine cycle and the requirements in the combustion chamber. Thus, the turbopump is subject of fundamental investigations and optimizations within a joint research project in southern Germany.

In order to understand the flow phenoma in a turbo pump and refine the design process, a new turbo pump for liquid oxygen is under development in the framework of this research project at the Division Space Propulsion of the Technical University of Munich. This design is studied numerically and experimentally [1]. As the complexity of tests with cryogenic liquid oxygen is high, a test bench for water tests is of high interest. Besides research on flow phenomena, the focus of the test bench is on gaining validation data for the numerical investigations. To compare results yielded with water to liquid oxygen applications, scaling methods have to be applied [2]. In this paper, an overview of the experimental research facility at the Division Space Propulsion will be given together with the scaling methods for comparison of liquid oxygen and water. Together with the test bench, an EcosimPro model is established and continously updated in order to predict test results and to support the test bench dimensioning.

1. Test bench description

A schematic of the designed test bench is shown in figure 1. The setup will comprise a radial pump driven by an electric motor. This includes a combination of overhanging inducer and impeller together with diffuser and volute on the pump side. The bearing unit is located in-between the pump and the motor on the shaft. The pump housing allows for flexible accomodation of different pump components. The working fluid of the pump will be deionized water at different temperature and pressure levels.

The test setup will be equipped with dynamic and static sensor technology to obtain information on the pressure distribution inside the axial and radial stages of the pump. Further, different parameters of the pump housing will be monitored. This includes dynamic vibration sensors, gap monitoring

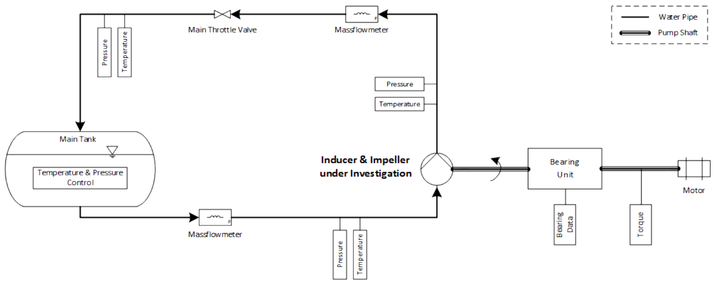

Figure 1. Schematic drawing of the designed water test bench.

devices and load sensors. The drive unit including bearings and the motor will be monitored to ensure safe operation of the pump setup. The dynamic sensor data, espcecially the dynamic acquisition of the pressure distribution in the pump will be used to investigate transient effects during the start-up and the shut-down of the pump system. The test bench infrastructure comprises a closed-loop water supply including throttling valves and massflow controls. Additionally, sensors for massflow, temperature and pressure as well as data acquisition devices are planned. The closed-loop water supply contains a pressure and temperature control system for the working fluid.

2. Content

The paper will contain detailed dimensioning analyses of the test bench infrastructure. This dimensioning is based on scaling approaches and analyses regarding the comparability of fluid dynamic properties, thermodynamic characteristics and the geometry of turbopumps under water-test conditions and real liquid oxygen conditions [2] [3]. A special focus will be on the reproduction of the caviational behavior of the oxygen pump and the reproduction of the thermal suppression head, which can be observed for pumps working with cryogenic liquids, on the test bench with water [4] [5]. Therefore, the paper will comprise an evaluation of scaling methods available in literature.

Further, the instrumentation of the test pump will be shown in detail.

The design process is accompanied by the implementation of all relevant components in the software tool EcosimPro. EcosimPro permits to evaluate the fluid- and thermodynamic parameters of the test bench via an analytical approach based on empirical correlations. First simulations of the expected transient behavior of the test bench infrastructure, especially regarding the thermal control of the system, will be presented. Furthermore, the process of continously updating the software model with yielded test results will be introduced. EcomsimPro is also used to create a model of the test pump itself. In addition to a generic pump model, which is based on the performance chart of the pump under investigation, a more detailed model is created. This detailed model allows for better prediction of the pump flow and is thought to incorporate models for the secondary flow system of the pump and detailed models for each of the pumps components.

References

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