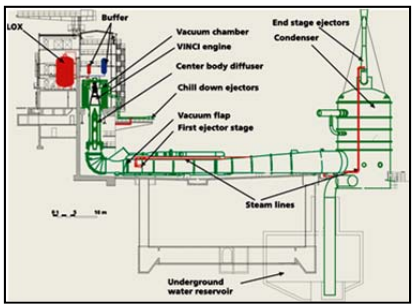
Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Handout

Development of the VINCI®
High Altitude Simulation Test Facility P4.1



General Lay Out P4.1


Test Bench P4.1


VINCI® engine

Introduction

From the very beginning in the 1960s, DLR Lampoldshausen has been involved in all European launcher programs and one of its special tasks has always been high altitude testing of rocket engines. The need to develop, qualify and accept propulsion systems under actual flight conditions in high altitude with fully expanded nozzle defines the essential operational criteria for the test facilities.

SNECMA is demonstrating a new Expander-Cycle-Technology with the rocket engine called VINCI® of 180 kN thrust. For the VINCI® engine tests the test bench P4.1 at the DLR test centre Lampoldshausen was adapted by a new altitude simulation.

Function

The task of altitude simulation consists of creating the test condition within a vacuum cell. This is primarily low ambient pressure of just few mbar. Special operational conditions are linked to the transients during Start-Up and Shut-Down of the engine with respect to the nozzle loads.

Maintenance of the vacuum with running engine is achieved by using the energy of the exhaust jet. The supersonic gas flow is decelerated and compressed by a diffuser. Additional extraction of the exhaust gas by steam jet ejectors and condensation maintains the necessary pressure conditions.

To provide the large quantities of steam, rocket steam generators with liquid Oxygen and Alcohol are used. The principle of rocket steam generators is to inject water into the hot gases of a rocket combustion chamber and to evaporate the water in a mixture chamber.

Test Conditions

The VINCI engine will be tested in 3 test configurations:
- The combustion chamber
- The combustion chamber with the fix nozzle
- The total engine including the extendible nozzle.

The P4.1 test conditions are:
- Vertical test position with maximum test time of 770 s.
- Ignition at pressure p < 60 mbar, corresponding to altitude > 25 km.
- Simulation of in-flight start up conditions
- Operational envelope in vacuum.
- Shut down considering the maximum nozzle loads.
- Ballistic phase and reignition in vacuum conditions.

Bench Development

To maintain the experience of the test facility engineering and to improve the altitude simulation technology the department of engineering was founded in 1996 within the institute of space propulsion.

Special developments were done for the P4.1 altitude simulation. Outstanding are the developments of the centre body diffuser, the ejectors and the rocket steam generators. For a maximum operational flexibility modular adapters are used for the different test configurations. The development of the altitude simulation was done in different phases:

Phase 1: Preliminary design with basic studies and general lay out.
Phase 2: Subscale testing and special developments.
Phase 3: Final design with detailed engineering.
Phase 4: Commissioning.
Phase 5: Final reception with VINCI®test.

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Handout

Centre Body Diffuser
Cold Gas Model

Diffuser Hot Gas Model

Centre Body Diffuser P4.1

Centre Body Diffuser
A centre body diffuser has a similar behaviour like a second throat diffuser. After starting of the supersonic flow the flow conditions are stable down to lower pressures ratios (Hysteresis). The second throat is realised by a ring channel around a centre body. The overall length of the diffuser is short because of the reduced hydraulically diameter of a ring channel.

CFD calculations and diffuser sub scale tests with cold and hot conditions were performed to verify the heat loads and functional behaviour of the centre body diffuser.

The cold testing is done with nitrogen. The simulation allows similar Mach numbers. The objectives were the verification of the basic design and the investigation of phenomena like Gimballing of the engine and transient studies.

The hot gas model was tested at the test bench P8 with a H2 / O2 combustion chamber and similar test conditions like VINCI (60 bar chamber pressure, mixture ratio of ROF = 6). The objectives were the verification of the modelling and design especially the verification of the heat loads and flow conditions like supersonic Start and Un-Start conditions.

Rocket Steam Generators
The main drivers to develop new rocket steam generators are the increased steam consumption of P4.1, cost reductions and environmental conditions.

The concept is based on a rocket combustion chamber operated by Ethyl alcohol and liquid Oxygen ignited by hydrogen oxygen pilot flame. Special investigations are done concerning injection and combustion of the propellants. Acoustic absorber baffles were integrated for stability of the combustion. The chamber itself is single walled and cooled by an inner water film.

The sonic cross section is not at the combustion chamber like rocket engines, it's inside the steam nozzle several meters away. This influences the ignition and start up of the combustion chamber. Therefore the steam generator is developed in two steps, the combustion chamber mode like a rocket engine and the steam generator mode with mixture chamber, steam lines and steam nozzle.

Several units of 4,5 kg/s steam up to 58 kg/s steam are developed and operational.

The steam generator plant of the P4.1 is equipped with 5 steam generators of total 240 kg/s steam generation equivalent to about 600 MW thermal powers. The maximum operational time is 1000 s.

Steam generator combustion chamber test

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