A NEW TEST RIG FOR LASER OPTICAL INVESTIGATIONS OF LEAN JET ENGINE BURNERS

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Abstract

The combustor enables the optical investigation of unscaled large burners for lean combustion in aeroengines. The maximum operating condition is 2.3 kg/s air mass flow through the combustor liner at 900K preheat and 20 bar inlet pressure, which exceeds to the author's knowledge the capabilities of pre-existing optically accessible single sector combustor rigs. The combustor volume and cooling are as close as possible to the engine condition. Various optical techniques will help to understand the physics leading to the emission behaviour measured in conventional rigs. Real time logging of emissions, temperatures, pressures and videos of the flame enables the exact relation of laser based measurements to operating conditions of the combustor and operating modes of the burner. The rig is currently used in national and European research projects to understand the behaviour of the burners throughout their operating range helping to find the optimum design to satisfy the conflicting demands imposed on the key element of lean combustion in aeroengines.

1 Introduction

Environmental aspects of aviation have received the attention of the general public because of its ever rising share of the overall traffic and its singular situation to depose its emissions into the upper atmosphere. Apart from carbon dioxide, Nitrogen oxide (NOx) has been shown to play a role in atmospheric chemistry such that there are even debates of imposing special taxes on those emissions. New emission legislation limits for NOx with CAEP/6 are effective since January 2008 and further restrictions are expected within future CAEP initiatives. Further to the stringent regulations of the CAEP process, the airplane manufacturers are responsive to that situation by imposing challenging demands on the NOx emissions of the engines on their future airplanes. Hence it seems attractive to reduce the environmental footprint of airplanes significantly by changing the combustor of the engine. The highest reduction potential has been identified for lean combustion, which should be capable to reach the -80% NOx goal of ACARE.

However, lean-burn in its principles implicates inherent challenges with respect to weak extinction stability due to fuel air premixing prior combustion and drives the development of viable solutions in respect to operability, altitude relight and combustion efficiency at fuel staging points. Lean-burn combustors require fuel staging to obtain full combustor operability and to enable typical aero-engine turn-down ratios while burning lean at high

power conditions. In order to derive detailed design rules for low emission combustion the application of non-intrusive measurement techniques is a very important step within the development process. Conventional tests giving information at the combustor exhaust tell if a design was successful but they do not tell why. The effort of building optical accessible combustors and probing the flame with laser optical techniques is a promising approach to help answering that question.
In the past a single sector test rig (“SSC”) with optical access from DLR was frequently used by Rolls-Royce Deutschland to investigate and rank new fuel injector configurations upfront of full-annular combustor and engine testing. In general and depending on the targeted engine cycle the effective flow area of lean injectors can increase significantly compared to conventional rich burn fuel injectors to operate at fuel lean conditions. In order to avoid fuel injector scaling to a rig dependent injector size it was necessary to upgrade also the existing combustion test rig with optical access at DLR to allow testing of fuel injectors with increased flow areas. To overcome the existing constraints of the available SSC rig the new test rig BOSS was designed and build within a close collaboration between DLR and Rolls-Royce Deutschland. The expected key features of the new BOSS rig are: 1) capability to investigate advanced lean fuel injectors with increased effective areas, 2) generation of a more representative combustor environment regarding lean burn combustor volume, shape and air flow distribution and 3) increased operating conditions regarding combustor pressure and inlet temperature. With the capability to investigate and demonstrate scaling laws for fuel injectors of different size the new test rig can reduce known uncertainties when transferring results from single sector to full annular geometries.
This paper gives a detailed overview on the setup of the new test rig itself, its features, abilities and advantages. The available measurement techniques, as well as the supporting infrastructure are described, to illustrate the overall capabilities of the BOSS rig.

2 Big Optical Single Sector (BOSS)

The BOSS is an optically accessible test rig for the investigation of a single sector of a jet engine combustor. Burners up to a diameter of 80mm and an effective area of 1400mm² can be employed. BOSS has been designed for a maximum combustor pressure of 20bar (p_{4max}), maximum air preheating temperatures of 900K (T_{3max}) and combustion temperatures up to 2400K (T_{4local}), which equates to an air fuel ratio (AFR) of about 20 considering pressure, preheating temperature and kerosene as fuel.
Considering the abovementioned maximum operating conditions, for a burner of 1400mm² effective area and a burner pressure drop of about 4.5%, a main air mass (m_{Main}) flow of approximately 1.7kg/s is required. Additionally 0.6kg/s of preheated window cooling air (m_{Window}) and 1.3kg/s of cold liner cooling air (m_{Liner}) would be supplied under such circumstances.
A summary of the specifications of the rig is given in Table 1.

Table 1: Maximum operating conditions

p_{3max}	**20bar**
T_{3max}	**900K**
T_{4local}	**2400K**
AFR	**>20**
m_{Main} **(20bar, 900K)**	**1.7kg/s**
m_{Window} **(20bar, 900K)**	**0.6kg/s**
m_{Liner} **(20bar)**	**1.3kg/s**

(The nomenclature is widely used within the gas turbine community. The indices 3 and 4 describe positions upstream respective in the combustor.)

2.1 Setup

The BOSS is assembled from five major components (compare Fig. 1). In order of air flow direction they are termed diffusor (1), plenum (2), combustion chamber (3) and exhaust pipes (4, 5). The task of the diffusor is to slow down the preheated air that can be supplied with a maximum preheat temperature of 900K. The plenum accommodates the fuel

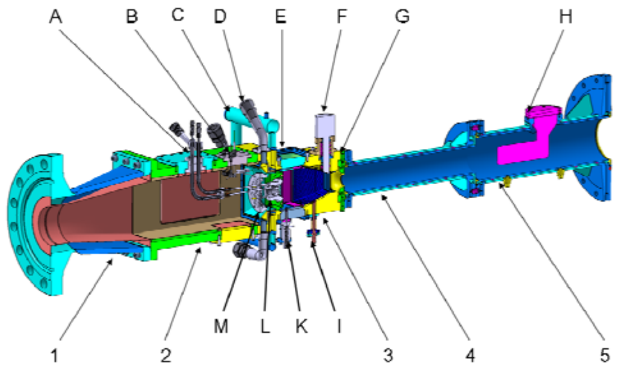

Fig. 1: Half section of BOSS

supply (A), consisting of two independent lines for pilot fuel and main fuel, as well as some pressure and temperature probes (B), and provides access to the candidate burner (L) that is mounted to the baffle (M) by spacer bolts (S), customized for each burner.

Burner and baffle are located in the pressure casing (R) of the combustion chamber (compare Fig. 2). The baffle is connected to the cooling casing (N) which houses the burner. The combustion takes place inside the liner (P) which is held in position in the pressure casing by a transition piece (O). By fitting the cooling casing into the liner and connecting it to the pressure casing, the combustor upstream end is defined by the burner and the face plate, which forms the downstream end of the cooling casing. Through four openings (C) that are located at all four sides of the pressure casing liner cooling is supplied to the gap in between the liner and the pressure casing. Four additional bores (D) are used to supply pre heated window cooling air. The cooling layout of the test rig will be described in more detail in chapter 2.3. Three pressure resistant windows (E) are embedded in the pressure casing. The forth side is equipped with a similar sized metal dummy which carries the ignition unit (K). The ignition unit uses a hydrogen torch flame to ignite the fuel that is supplied through the burner and is transported to the liner wall by outer recirculation. The hydrogen flame is ignited by a spark using a car ignition coil to create the spark in between the hydrogen supplying tube as the electrode and the metal dummy which is grounded. A small pressure window (U) allows optical access to the outside of the liner. Two dynamic and one static pressure sensors (I) are used to collect data from the inside of the combustor at different axial positions (compare chapter 4.3). One additional access (F) is available that is used for flame observation using an endoscope camera system (compare chapter 4.1). The downstream end of the combustion chamber is defined by a changeable static nozzle (G). Two different nozzles with 1256mm² and 2375mm² can be used, depending on volume flow and required combustor exit velocity. The static nozzles are water cooled, as well as the exhaust pipes and the gas probe (H). The liner (P) is square shaped with a side length of 140mm at its upstream end and about 250mm long. The axial cross section profile of the liner was kept close to real engine combustor layouts. Some concessions had to be made due to the necessity of a symmetric flow field and the task to perform optical measurements. Fig. 3 shows the single parts of the liner and illustrates the setup.

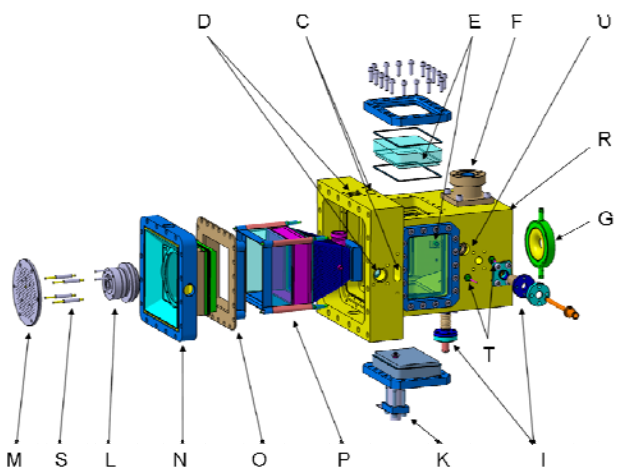

Fig. 2: Combustion chamber

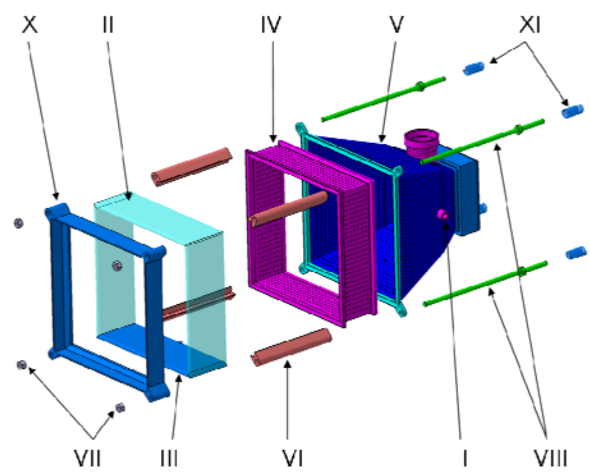

Fig. 3: Combustion chamber

The three liner windows (II), the similar sized ignition dummy (III) and the flame tube segment (IV) are held in position by a cage that is formed from the upstream liner part (X), the conical liner section (V) and spacers (VI) at all four corners. Each liner window is 140mm wide, 50mm long and 5mm thick. Upstream and downstream edges of the windows are semi-circular contoured with a radius of 2.5mm. The windows are held in position by the identically shaped metal counter parts of the liner. To avoid direct contact between metal and glass 0.5-1.0mm thick graphite seals are used (not shown in Fig. 3). The cage is pressed together by four nuts (VII) tightening the bolts (VIII). The spacers define the distance between the conical liner section and the upstream liner part and therefore make sure that the axial pressure on the windows is limited. The position of the liner in the pressure casing is defined by the downstream ends of the four bolts. They fit into four holes in the pressure casing and guide the entire liner section. Axial positioning of the liner is supported by four springs (XI) that are placed on the downstream ends of the spacers.

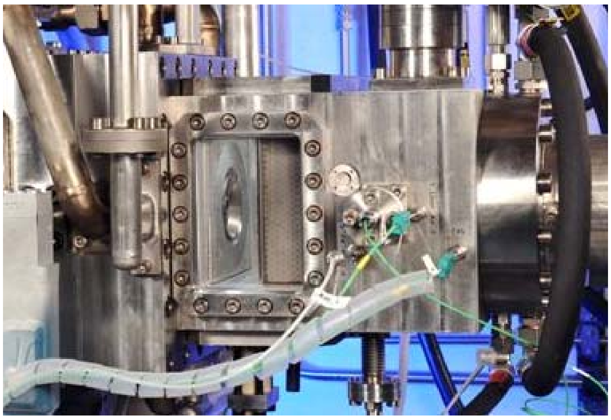

Fig. 4: View through the window

2.2 Optical Access

Optical access to the flame is possible from three sides over the full width of the combustion chamber. At the forth side of the combustor the ignition unit is located.

The current liner setup provides optical access for the first 45mm downstream the burner. A second liner setup that will provide access for the area in between 45mm and 90mm downstream the burner is planed but not yet available. The windows in the pressure casing are made big enough to support both possible liner setups. Again graphite seals are used at both sides of the windows to prevent direct contact of glass and steel (see Fig. 1).

Another possibility to access the inside of the combustor is a bore at one side in the middle of the conical section of the liner. It can be used for installing an endoscope camera (compare chapter 4.1) which allows to take head-on videos or photographs of the flame and faceplate, looking upstream (see (F) in Fig. 1 and Fig. 2).

Additionally a small round window ((U) in Fig.1) is providing access to one specific position at the outside of the liner that is considered to be the hottest point of the conical liner section. It allows measuring the outside wall temperature of the liner by using a pyrometer which allows controlling the amount of cooling that is necessary to prevent damage by overheating the highly sophisticated, welded conical liner section. The position of that window was chosen considering the results of a three dimensional CFD/FEM cooling analysis.

All windows used in the BOSS test rig are made from fused silica glass of a quality similar to SQ1.

2.3 Cooling Design

Two separately controllable cooling lines are available. One is supplying preheated air for the cooling of the liner windows, the other one supplies cold air for the cooling of the liner. Fig. 5 shows the cooling setup.

2.3.1 Window Cooling

To protect the liner windows from the hot combustion gases and also to avoid fuel being sprayed on the windows, preheated air is supplied as a film to all four sides at the inside of the liner. The thickness of the film is 1mm. Mass flow and temperature of the air can be controlled independently. Therefore the influence of the cooling air on combustion is limited and can also be studied. Depending on the circumstances, the window cooling air mass flow ranges between 10% and 30% of the main air mass flow. The temperature can be varied from ambient temperature to 900K.

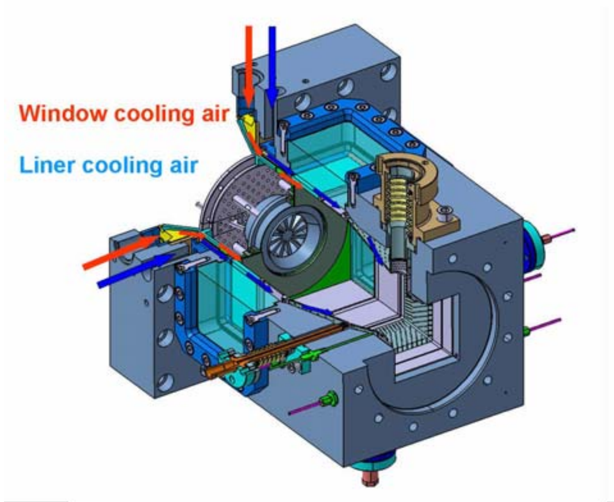

Fig. 5: Cooling setup

2.3.2 Liner Cooling

To prevent overheating the liner is cooled with cold air. The cooling air first flows over the outside of the liner and cools the surface by convection. At the same time the air builds an insulation layer between the liner and the pressure casing and thereby prevents the pressure casing from heating up. Downstream of the windows the effusion cooled part of the liner starts. During the passage of the air through the effusion cooling holes convective cooling takes place. Finally the air is forming a insulation layer at the inside of the liner, which reduces the thermal input to the liner. Several probes (T) (see Fig. 1) allow to measure pressure and temperature of the air in the gap between liner and pressure casing.

To optimize the efficiency of the effusion cooling considering the lifetime of the liner as well as the cooling air consumption of the BOSS, a combined CFD/FEM analysis was performed in three steps. In the first step the effusion hole distribution was optimized using CFD in a stripe model of the conical liner section. Eight setups where examined using different axial and tangential distances (10-15mm, 4-6mm) between individual holes, as well as different hole diameters (0.5-1.0mm). At the same time the conical structure without the effusion holes was checked for its stability by FEM. The necessary wall temperature distribution was derived from the first CFD results. The results of the FEM analysis have been used to reevaluate the manufacturing design of the conical liner section as well as the acceptable maximum wall temperatures for the CFD analysis. In a third step a quarter model of the entire liner including the finally chosen effusion hole layout was checked by a combined CFD/FEM analysis. The results showed that at maxim operating conditions of the test rig, a local temperature of 900K would not harm the liner.

2.3.3 Water cooled parts

Water cooling takes place in all parts of the test rig that are located downstream of the combustor. This includes the static nozzle, and the two exhaust pipes. Additionally both fuel supply lines are water cooled. By changing the amount of supplied cooling water, the fuel temperature can be controlled.

3 HBK1 Test Facility

The HBK1 test facility consists of the test cell of about 55 m² ground area, the control room, the silencer building, the multi-purpose room for minor repair and a small spare-part storage. The BOSS test rig and most of the supporting infrastructure is located in the test cell. The electrical equipment as well as the power supply and the process control units are accommodated in a neighbouring building.

The supporting infrastructure consists of several systems for media supply, the water injection system, the air heaters and an adjustable throttle.

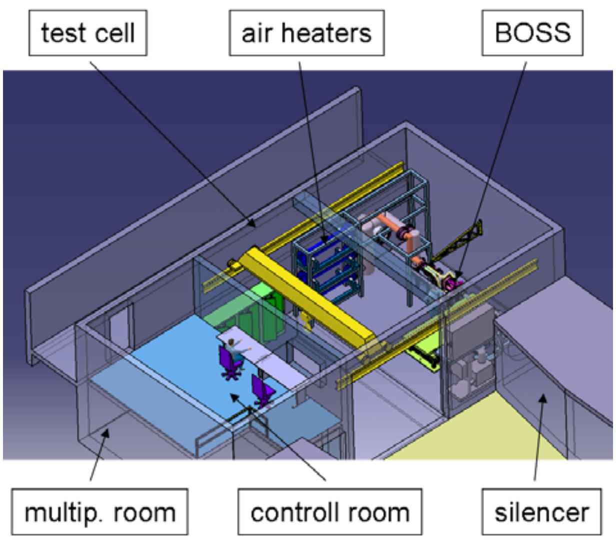

Fig. 6: HBK1

3.1 Air Heaters

The HBK1 employs three air heaters, each with 540 kW electrical power. Each of them can be individually controlled. They allow a maximum air temperature of about 900K in the test rig. Two of them supply the combustion air to the test rig, the third provides preheated window cooling air. To reduce temperature losses all pipe work in between the air heaters and the test rig is insulated.

3.2 Water Injection

The HBK1 test facility comprises a water injection that feeds up to 2.0 kg/s of cooling water into the exhaust gas. It is integrated in the downstream end of second exhaust pipe of BOSS (see Fig. 7).
The purpose of the system is to reduce exhaust gas temperature and therefore the exit velocity of the gas and the noise generated. The system is self controlled by a Siemens S7 programmable logic controller (PLC). It protects itself by shutting down the HBK1 fuel supply in cases of emergency or at runaway operation. The water is injected through eight nozzles that are placed in two rings of four nozzles each at the upstream end of the 1.7m long water injection pipe. The pipe itself is double walled and water cooled.
The SCHLICK hollow cone nozzles have different diameters between 1.6mm and 4.2mm. The eight nozzles are grouped to five individually controllable units. Three of the units use two nozzles, the other two units have one nozzle each. Each of the units has a Swagelok three way valve and a Flowserve control valve. The three way valves allow cooling the nozzles with air when no water is injected. The control valves control the amount of water that is injected through the single units. The water for all units is supplied by a SPECK 52/120-120 piston pump.
The water injection system can be manually controlled or used in automatic mode. In automatic mode the operator sets a maximum exhaust gas temperature. The system compares the preset temperature with the temperature that is measured at the downstream end of the water injection pipe. The water injection controls the amount of injected water accordingly.

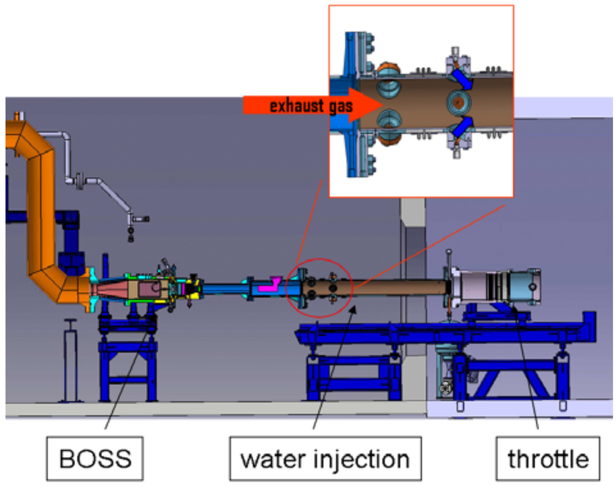

Fig. 7: Water injection and throttle at HBK1

3.3 Adjustable Throttle

To achieve the required operating pressure conditions inside the test rig, a hydraulically controlled throttle is employed. The capability of this device of varying the exit's cross-section allows independent control of pressure and mass flow through the test rig to cover a wide range of operating conditions for air flow rates, pressures and particularly high exhaust temperatures, and so substantially contributes to the reduction of test costs. The throttle is located in the silencer building. Its upstream end is connected to the water injection pipe.

3.4 Media Supply

3.4.1 Air Supply

Compressed air is available at two different pressure levels in the HBK1: 8bar for valve control and other auxiliary purposes, and up to 58bar bar for the actual test bed operation. Both air supply systems are fed independently by the compressor station at the DLR Cologne site.

3.4.2 Fuel Supply

Kerosene (Jet A-1) can be supplied through two individually controllable fuel lines to the test rig with a maximum pressure of 150bar. The maximum mass flow ratio of each line is about 120g/s. Both fuel lines can be flushed with nitrogen to avoid buildup of residual kerosene reservoirs in the pipes.

3.4.3 Cooling Water Supply

For cooling purposes deionised water is supplied by four individually controlled centrifugal pumps with a maximum pressure of about 13bar.

3.4.4 Other Fluid Supply

The HBK1 is connected to a gas container storage, which allows supplying small amounts of any available gas. For example, nitrogen (N_2) is currently supplied to the test rig at pressures just above operating conditions for scavenging the candidate burner during the test and particularly immediately after shut-off/extinction. This prevents kerosene coking inside the injector feed lines exposed to the high-temperature air flow, and inside the injector.

Also hydrogen (H_2) is supplied to the test rig. It is fed to the ignition unit which ignites the kerosene combustion by creating a hydrogen torch flame.

3.4 Electrical Installation

The available electrical installation is connected to the site's 6 kV feed-in bus. At the moment, the overall current transformer output for HBK1 amounts to 3200 A at 400 V.

3.5 Process Control Equipment

The process control of the facility equipment is managed by a Simatic S7-400 PLC automation system. The process operating interface is based upon Factory Link visualisation software exchanging the current information with the PLC environment using a real-time data bank. Decentralised architecture of the PLC modules makes provision for better operability during the test, uncomplicated replacement in case of repair, comfortable handling in cramped space conditions and additional flexibility for further installations.

4 Measurement Equipment

4.1 Optical Measurement Techniques

The design of a setup for optical, in particular laser-based measurements in a high pressure rig faces several specific challenges beyond application in laboratory setups. The equipment and the optical alignment has to withstand the harsh environmental conditions in the test cell, like vibrations, high noise levels, and temperature fluctuations, the latter resulting from the ejector effect of the silencer system. Since safety requirements preclude entering the test cell during operation of the rig, remote control is required for the test equipment and some aligning parameters that need re-adjustment during a test day. Because operating costs of the test bed are high, it is desirable to optimize the efficiency of optical measurements by combining as many techniques as possible in one setup, optimize measurement procedures and reduce dead times for adjustments during operating as much as possible.

The simplest way to obtain optical information on flame structure and its dependence on operating parameters is to use visual observation by photography or video. Two video systems are used to allow continuous monitoring of the flame. One system uses a PTZ network surveillance camera (PTZ 213, AXIS Communications) which observes the flame through one of the side windows. A second camera (uEye GigE SE, Imaging Development Systems) is connected to the exit port of a water-cooled boroscope which is mounted in an access port in the converging part of the liner, and enables viewing upstream inside the combustor towards the burner faceplate. Its field of view can be seen in Figure 8, which shows the burner exit and the surrounding effusion cooled heat shield.

In addition, a high speed camera system (APX-RS, Photron) with framing rates from 3 up to 250 kHz has been used to track the temporal evolution of the spray, by using the bright soot luminosity downstream as a light source for illumination of the spray.

The more sophisticated measurement techniques fall into two categories. One group comprises point measurement techniques, like LDA (Laser Doppler Anemometry) and PDA (Phase Doppler Anemometry) for measurements of the flow field and analysis of the fuel spray in terms of droplet velocities and sizes. For these methods, off-the-shelf hardware is available, but

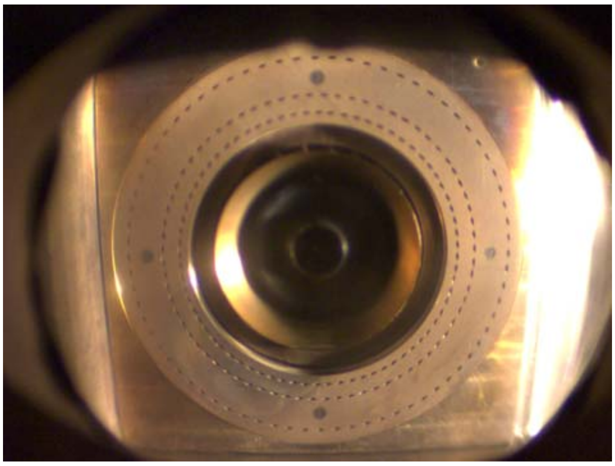

Fig. 8: Field of view of combustor probe camera

they have not been applied in the BOSS rig so far. An example of their application at comparable operating conditions in a similar but smaller rig is given in [2]. CARS (Coherent Anti-Stokes Raman Scattering) spectroscopy is another point measurement technique used for temperature measurements, which is planned to be applied in the future, but has not yet been implemented.

The second group comprises planar measurement methods. These are chemi-luminescence of the OH or CH radicals for visualization of reaction zones and their fluctuations, planar Mie scattering on fuel droplets for visualization of the liquid phase, planar laser-induced fluorescence (PLIF) on kerosene for measurement of distributions of both phases of the fuel, and PLIF on OH radicals. Apart from information on reaction zones and mixing, the latter can be used to obtain planar temperature data under favourable conditions. These techniques and the basic arrangement for their combined application are described in [1]. Here, only the modifications pertinent to the application in the BOSS environment are discussed. The hardware for these techniques is combined in one single setup which is mounted on a breadboard with an additional aluminium profile frame which supports cameras, filters and steering optics. A photograph of the setup is shown in Figure 9. The breadboard carries a pulsed Nd:YAG laser pumping a frequency-doubled dye laser. The frequency-doubled radiation of the YAG laser at 532 nm is used as a light source for Mie scattering. The tuneable UV radiation of the dye laser near 285 nm excites fluorescence of the OH radical and/or kerosene (depending on the selected wavelength). The laser beams are shaped into light sheets and guided into the combustor in a co-planar arrangement in a plane orthogonal to the burner faceplate through one of the side windows. Fluorescence, chemiluminescence and Mie scattering are observed through the top window by two image-intensified CCD cameras (FlameStar, LaVision). In the case of planar Mie scattering, the light sheet can be rotated by 90°, thus travelling parallel to the burner faceplate; in this orientation, the scattered light is recorded by the liner probe camera. This allows to record distributions of liquid fuels in planes at different distances from the burner exit.

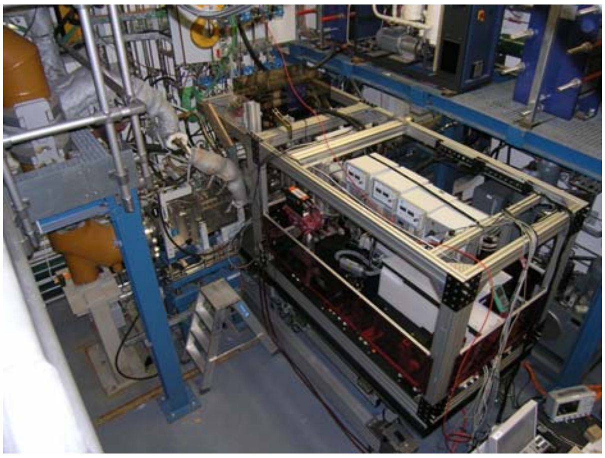

Fig. 9: Container with planar measurement techniques hardware at the test section

The breadboard with the entire optical setup is placed on a three-axes traversing stage (Bosch-Rexroth) which allows remote controlled positioning of the measurement plane with respect to the combustor with an accuracy of 0.1 mm. To facilitate quick access to the rig for assembly and disassembly, the traversing stage is equipped with pneumatically extending wheels. If maintenance of the rig or the test section is required, the gear is lowered, and the traversing stage can be removed. The position control software contains a measurement system based on optical pattern recognition, which measures the shift of the test section due to thermal expansion of the rig, and corrects the position of the traversing stage accordingly.

The exchange of measurement hardware is easily accomplished by lifting the breadboard with the entire planar test equipment off the traversing stage, and replacing it with hardware for point measurement techniques or, in the simplest case, a high speed camera system.

The planar measurements describe above generate time-averaged data, temporal fluctuations and instantaneous distributions; they are performed for a multitude of operating conditions and allow, along with emissions data, assessment of the burner performance throughout its operation envelope.

It is also planned to perform planar gas velocity measurements by applying Particle Image Velocimetry (PIV). A high pressure particle seeder will be fitted to the combustor for that purpose. The technique provides the capability to map the entire burner near field in one measurement. It's higher productivity compared to the pointwise LDA technique should thus enable to understand the influence of different operating conditions on the burner induced flow field. An example of the application in the smaller pressurized combustor is given in [3].

4.2 Emission Analysis

For emission analysis a state of the art analyzing system is available. It consists of a Maihak S710 Unor (CO, CO2), a Maihak S710 Oxigor (O2), a Testa FID 123 (UHC) and a Spectra Physics CLD (NO, NO2, NOx).

The gas is collected by a water cooled emission rake. To avoid condensation of the water which is part of the exhaust gas, the cooling water is preheated to a temperature of 433K. The rake uses five small tubes at different radial position to insure a homogenous composition of the collected gas. Alternatively a blank can be used instead of the rake to collect the exhaust gas.

The exhaust gases are delivered to the analyzing system by an electrical heated tube. Two valves are installed between the rake and the tube. One is a three way valve which allows flushing the rake in reverse flow with N_2 to avoid contamination of the analyzing system, for example with liquid fuel during ignition. The other one is a bypass valve which reduces the pressure in the tube to slight overpressure condition. Another such valve is placed at the other end of the tube. It reduces the exhaust gas pressure before the gas enters the gas analyzers. This valve can be manually controlled for achieving a feed pressure of about 1.25bar.

4.3 Acoustical Measurements

For acoustical measurements KISTLER Typ 7001 pressure transducers can by applied at two different axial positions of the combustor (compare (I) at Fig. 2 and Fig. 3). The integration of another sensor upstream of the combustor is planned but not yet implemented. With the available equipment a basic analysis of pressure fluctuations and the detection of combustion instabilities is possible. To be able to investigate the influence of pressure fluctuations on the combustion, as well as for the possibility to compare the sensitivity of different burners with respect to pressure fluctuations against each other, it is planned to replace the first exhaust pipe by a device that is able to create pressure fluctuations of variable amplitude for excitation frequencies between 50Hz and 1000Hz. Also it is planned to enable the BOSS test rig for measurements of flame and burner transfer functions by placing a hotwire probe directly upstream the burner and applying LDA and OH*- chemiluminescence.

4.4 Data Acquisition System

To continuously monitor and log the measured data for further evaluation a sophisticated data acquisition system is available. The custom-tailored LabVIEW-based application provides accurate monitoring and recording of the conventional data from measurement data scanners and from a central PLC-data concentrator at 1 Hertz rate. The modular system layout meets requirements for independent operation of each single component and allows quick replacement for maintenance and repair. The main components in operation are:

- *Pressure Scanners (Pressure Systems)*
- *Multipurpose DAQ System (Delphin)*
- *OPC server*
- *Exhaust Analysis System (see 4.2)*

4.4.1 Pressure Scanners

The applied pressure measuring scanners integrated in a convenient rackmounted housing consist of three 16-channel piezoresistive sensors with varying pressure ranges enabling to acquire the necessary data from the rig. The measured data in engineering units is output through an Ethernet interface which supports the TCP protocol.

4.4.2 Multipurpose Measurement System

The TopMessage-modules are equipped for measuring campaign-specific temperatures and analogue values.
The physical measurement values are stored in the devices already scaled and linearized. The communication with the data acquisition system occurs via an implemented Ethernet interface.

4.4.3 Process Operating Values via OPC

To collect the data from the PLC network, the data acquisition system is connected to a central data concentrator by an OPC interface, which transfers the necessary process information for further processing, recording and evaluation.

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