Ref. Ares(2023)351947 - 17/01/2023

Fit4Micro

Deliverable 3.1

Operating parameters combustor

Funded by
the European Union

Document control sheet

Project	Fit4Micro
Grant Agreement n°	101083536
Coordinator	Michel Delanaye
Work Package n°	3
Work Package title	Flameless combustion for liquid fuels development and high temperature material assessment
Work Package leader	OWI
Deliverable	3.1
Title	Operating parameters combustor
Version	1
Lead Beneficiary	MITIS
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Reference period	First Period
Due date	31.12.2022
Submission date	
Dissemination level	Public

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This project has received funding from the European Union's Horizon Europe Research and Innovation Program under Grant Agreement n. 101083536.

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1. Introduction

Fit4Micro aims to develop a flexible hybrid energy system, able to provide renewable heating, cooling and power production for demand-driven domestic (multifamily) usage. The core of the micro-CHCP (Combined Heating, Cooling and Power) unit is a novel, high-efficiency micro gas turbine (mGT). By implementing an Intercooled Regenerative Reheat Gas Turbine Cycle (IRRGT) with a double shaft turbogenerator system and cycle humidification option, waste heat is recovered leading to increased electric efficiency while providing a flexible heat and power output. Flameless combustion further ensures minimum pollutant emissions and high fuel flexibility to allow the use of various liquid biofuels.

2. Fit4Micro system & individual components

The Fit4Micro MITIS system is based on the recuperated Brayton cycle and consists of an assembly of a compressor, combustion chamber, turbine, recuperator and generator. The IRRGT cycle is characterized by two stages of compression separated by intercooling and two stages of turbines with a reheat (second combustor) between the LP and HP stages (Figure 1). Combustors, designed to operate using renewable fuels and for two pressure levels, 3 bar (LP) and 5 – 6 bar (HP), will be developed.

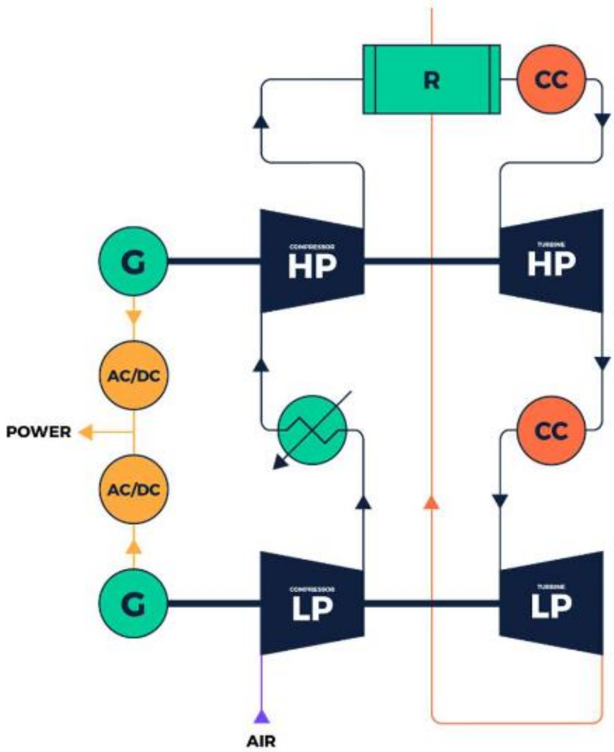

Figure 1: MITIS implementation of the IRRGT cycle

3. Objective of deliverable 3.1

In this deliverable 3.1., the operating specifications of the flameless combustors are set.

Fuel and air supply, operating pressure, relevant temperatures, and the fuel matrix for the development are fixed based on previous operation experience, system concept, fuel properties and micro-CHCP requirement.

The specifications include the base-case operating conditions and min/max values for adequate turn-down ratio. Impact of humidification on the combustion chamber inlet conditions is also studied and conditions for humidified cycle are also specified for combustor testing.

This deliverable 3.1 shows the starting point of combustors' parameter settings. These will be adapted according to optimization of the mGT including the combustion chamber. Changes in the parameters will be reported in future deliverables where working conditions and experiments will be explained, however will not be open to public due to their confidentiality.

4. Experimental set-up at OWI

Combustion tests will be carried out in the OWI test lab. First, the test rig for the combustor under pressurized gas atmospheres will be installed which includes the set-up of the fuel system, heating of inlet air (pre-heating), data acquisition and control system. Two combustion chambers are developed for the power 50 kW at 5.5 bar system pressure (High Pressure stage) and 30 kW at 3 bar system pressure (Low Pressure stage) respectively. They will be supplied by MITIS and sent to OWI. A flow diagram with the main hardware is shown in Figure 2. To plan the sizing of the equipment an energy balance was performed, from this it was found beneficial for the project workflow, that MITIS will supply OWI a heat exchanger to be employed in the experimental stand. The heat exchanger will see the following conditions during investigations: 5.5 Bar (both sides), 900°C maximum temperature. The heat exchanger will apply most of the heat applied for the air pre-heating, and will heat inlet air to around 680°C. The heat exchanger is still in the developmental state, and is currently in manufacturing, has thus not ran in long time operation testing. In case the heat exchanger cannot be applied to deliver the required amount of heat, mitigation strategy will be to perform a scale down of the experiments.

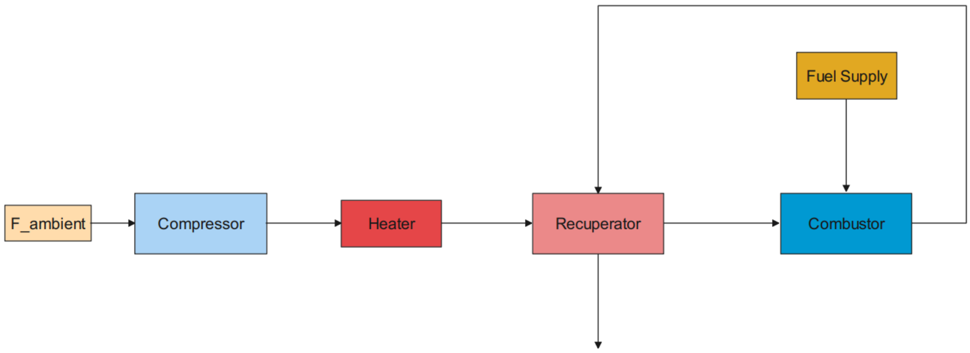

Figure 2: Flow diagram of main hardware components of the planned experimental test stand at OWI, at the outlet a valve will be placed for pressure regulation

5. Operating conditions and requirements of combustion chamber

For the testing the following operating conditions will be set:

- Fuel and air supply; From the energy requirement of 30 kW_{th} (LP) and 50kW_{th} (HP) the fuel supply was estimated, in the case of applying domestic heating oil as fuel 1.2 g/s (50kW_{th}) 0.7g/s (30 kW_{th}). Additionally, for introductory testing natural gas (NG) tests will be performed with conditions at 1 bar, 0.16 g/s NG (1 bar, HP combustion chamber, 8 kW_{th}) and 0.48 g/s NG (1 bar LP combustion chamber 25 kW_{th}). The air supply was estimated from the air-fuel ratio, or lambda number (λ), which is set to maximum λ =9, (and lower for startup). This gives a maximum air supply of 145 g/s.

The operating pressure and temperature were set based on system simulation and requirements of the mGT and other IRRGT components.

- Operating pressure; up to 5.5 bar in the HP and up to 2.5 bar in the LP combustion chamber.
- Operating temperatures: inlet temperature of air was set to the range of 650-790°C.

Both in the case of HP and LP combustion chambers, the gas supply will be air. Thus, the tests will be performed for LP and HP separately. Test will be performed firstly with NG, then domestic heating (or other HPO substitute as found suitable by project partner BTG), and finally tests will be performed with the HPO as developed within the framework of this project.

Humidification of the cycle can be performed by directly injecting water at the entry of the recuperator as shown in Figure 3. This will increase the water mass fraction to 5.9% in the incoming air to the combustion chamber and results in an increased electrical efficiency, approximately 4% compared to the dry case.

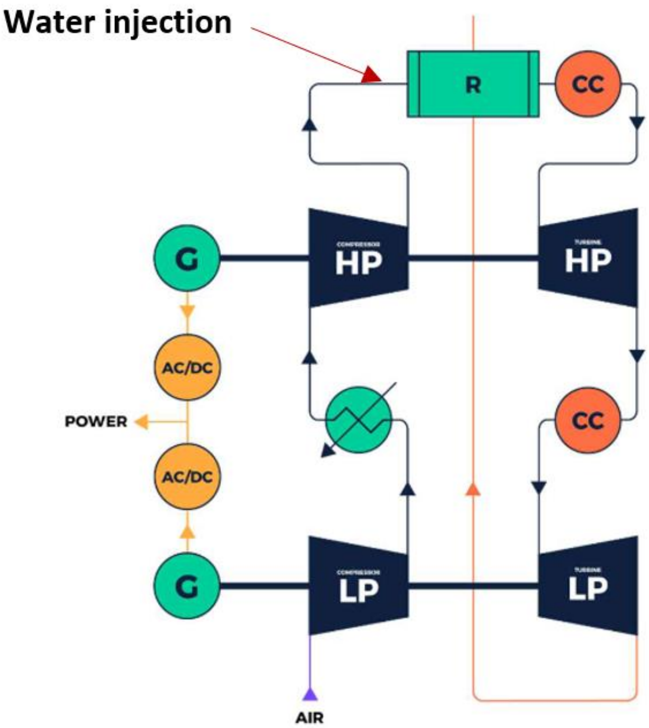

Figure 3: Schematic of the water injection at the recuperator for IRRGT cycle

Test conditions for the combustion chamber to emulate the humidified cycle are mentioned in the Table 1.

Table 1: Inlet conditions of combustion chamber for humidified cycle

Inlet Temperature	Water Mass Fraction	Electrical Efficiency Gain compared to dry case
660ºC	5.9%	4 %

As planned for the dry case, tests with both HP and LP combustors with water injection are also performed at nominal conditions to study the stability of combustion and its impact on emissions.