Study of a Semi-Closed OxyFuel Gas Turbine

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1. Introduction

CO₂ emissions from new natural gas fired plants are roughly half that of conventional coal-fired plants, which is the common argument used to focus on CO₂ Capture from coal fired plants only. Despite their lower GHG emissions, recent studies [1] indicate that increased natural gas use in lieu of coal for electricity generation will be insufficient to achieve the reduction in greenhouse gas emissions needed to stabilize climate change unless a portion of gas-fired plants are equipped with CO₂ capture and storage (CCS). According to the IEA Technology Roadmap [2], the total global installed CCS capacity will need to rise to over 1 100 GW by 2050, of which natural gas-fired CCS will account for around 30%. The OXYGT project develops a carbon capture technology for natural gas fired power plant based on the oxyfuel route. The work presented constitutes the first phase of the project and is based on optimization of two slightly different oxyfuel power plant concepts and developing a concept for a combustion system for a semi-closed oxyfuel combined cycle. The project is carried out in a partnership between a turbine manufacturer (Siemens), an engineering company (Nebb Engineering), a research institute (SINTEF), academic institution (Lund University), and the Norwegian funding organization Gassnova.

2. Oxyfuel gas turbine combustion system

In oxyfuel capture technologies, the oxygen is generated in an air separation unit (ASU), conventionally a cryogenic process. It means that the gas components are separated by condensation at low temperatures obtained in a refrigeration process. In a cycle perspective there might be possibilities to integrate the ASU process with the compression of CO₂ after the power plant. To reach the high pressures of the CO₂ (100-200 bar depending on...
storage conditions) and low temperatures that are required for final storage, the CO₂ will first be compressed to condensation pressure and then pumped to the final pressure.

Two oxyfuel cycle configurations have been investigated: an Oxyfuel Combined Cycle (OCC) and a High Moisture content Oxyfuel Cycle (HMOC). The pros and cons of both cycles are discussed and presented in [3]. The preferred design is the OCC cycle which is very similar to a re-circulated conventional combined cycle, with an efficiency of ca. 48 %. The future combustion development is mainly concentrated on this cycle.

The OXYGT combustion concept has first been evaluated by a simplified approach matching the laminar flame speed and the adiabatic flame temperature of the oxyfuel case with a relevant reference air case. A preliminary working fluid split between primary flame zone and dilution zone is thus determined and is used as design condition for the burner and combustor design phase. The volumetric flow of burnt mixture out of the primary zone is found to be approximately one third of that in the air case, whereas the total volumetric flow out of the combustor is less than approximately half of that of the air case.

Reactor network calculations have been done to evaluate temperatures and emissions. In this analysis it is found that the working fluid (WF) split should be around 0.6 through the burner and 0.4 for dilution. The flame zone temperature is below 1800 °C and the NOx concentration at the combustor outlet is only about 2 ppm. A higher WF share through the burner would reduce the flame zone temperature further, but the laminar flame speed will then be low and flame stability will be affected. CO burn-out is found to be very dependent on the O₂ excess. For example at an O₂ excess of 0.5% compared to the stoichiometric requirement, the exit CO is 400 ppmv, and requires an O₂ excess of 5.2% for the CO value to drop to 20 ppmv. Since all O₂ is produced at the ASU, this sensitivity has direct implication on cycle efficiency loss. It should be noted that in the oxyfuel case the exhaust is not emitted to air, but will go to storage or being used for EOR. Therefore the emission limits will have to be further defined for the targeted application. The values from the reactor network analysis falls generally well within the existing foreseen limits.

On the basis of the calculations, a schematic design of the OXYGT burner and combustor has been identified based on existing commercial technology. The burner is swirl stabilized by radial swirlers, fitted into a cylindrical combustion chamber (can or silo) with a smooth expansion between burner outlet and the flame tube. The combustor liner is to be cooled with the dilution portion of the working fluid by convection. This solution provides a baseline configuration on which several modifications will be tested both at atmospheric and pressurized conditions in a dedicated oxyfuel facility [4]. The results of the first experimental campaigns will be presented at the OCC3.

3. Acknowledgements

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4. References