Recent Combustion Strategies in Propulsion and Power Generation

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The effects of climate change and global warming are arising a new awareness on the impact of our daily life. Power generation for transportation and mobility as well as in industry is the main responsible for the greenhouse gas emissions. Indeed, currently, 80% of the energy is still produced by combustion of fossil fuels; thus, great efforts need to be spent to make combustion greener and safer than in the past. For this reason, a review of the most recent gas turbines combustion strategy with a focus on fuels, combustion techniques, and burners is presented here. A new generation of fuels for gas turbines are currently under investigation by the academic community, with a specific concern about production and storage. Among them, biofuels represent a trustworthy and valuable solution in the next decades during the transition to zero carbon fuels (e.g., hydrogen and ammonia). Promising combustion techniques explored in the past, and then abandoned due to their technological complexity, are now receiving renewed attention (e.g., MILD, PVC), thanks to their effectiveness in improving the efficiency and reducing emissions of standard gas turbine cycles. Finally, many advances are illustrated in terms of new burners, developed for both aviation and power generation. This overview points out promising solutions for the next generation combustion and opens the way to a fast transition toward zero emissions power generation.

Keywords: combustion ; hydrogen ; ammonia ; SAF ; MILD combustion ; RQL ; Lean Combustion ; Emulsion

1. Background

Every day, we are bombarded with news regarding the worrying evolution of the current global climate scenario. This frenzy by various stakeholders (mass media, politics, science) indicates a growing awareness of a really crucial issue that concerns all of us. “*2030 is now*” is the EU motto proposed by the European Economic and Social Committee on the Sustainable Development Goals to remind all of us that we need to work on all possible levels in order to achieve objectives that essentially depend on the way we start now to deal with them, even if they seem distant in time.

Among the different sectors, aviation and industry are considered “hard to abate” sectors characterized by high energy intensity and lack of scalable electrification solutions. According to the latest report published by the International Renewable Energy Agency (IRENA), aviation is one of the fastest-growing sources of greenhouse gas emissions. During the two last decades, CO_2 emissions related to the aviation sector have risen, reaching about 1 Gt in 2019, i.e., 2–3% of global emissions derived from fossil fuel combustion. In this analysis, IRENA forecasts that emissions will increase to 2.1 Gt/year by 2050 in the so-called Planned Energy Scenario, which is essentially an outlook based on the current strategic policies as proposed by governments [1].

According to the International Energy Agency (IEA), a strong effort is requested to increase aircraft efficiency by more than 3% per year until 2040 if we want to reach decarbonization targets [2]. In this scenario, one of the main key players is the International Civil Aviation Organization (ICAO), which adopted the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) in 2016. The plan is organized in three main steps: a preliminary step (from 2021 to 2023), a first step (from 2024 to 2026), and a second phase (from 2027 to 2035). Both the preliminary and the first steps are voluntary, while the second step will be obligatory for all Member States [3].

2. Purpose

In order to achieve higher sustainable levels, the aviation sector has to commit to deploy renewable and sustainable aviation fuels (SAFs), such as biofuels developed for jet aircraft. Biofuels for jet aircraft, known in the industry as biojet, are the most concrete solution for a significant emission reduction. Until today, the American Society of Testing and Materials (ASTM) has approved six biojet fuel production procedures, but among these, only one (i.e., the HEFA jet) is currently commercially available [4].

In industry, global energy-related CO_2 emissions have reached 31.5 Gt in the 2020, almost 8% lower than in 2019 following the energy demand reduction due to the COVID-19 pandemic [5][6]. Despite this decline, average annual CO_2 concentration showed the highest level in 2020 (412.5 parts per million). According to the latest Global Energy Review by IEA [7], global energy-related CO_2 emissions are projected to rebound in 2021 and grow by 4.8% as demand for coal, oil, and gas rebounds with the economy. In details, the power sector accounted for less than 50% of the drop in coal-related emissions in 2020, but it accounts for 80% of the rebound. CO_2 emissions related to natural gas combustion will reach a level of 7.35 Gt CO_2 in 2021.

Actually, these trends need to be changed as soon as possible. The first signal is given by renewables, which have shown good resilience despite the pandemic crisis. Regarding power generation for aviation and electricity production, a great effort needs to be addressed towards more research on fuels, combustion techniques and more efficient burners. For this reason, the present work aims to provide a survey on recent combustion strategies in gas turbines for aviation and power generation by focusing on specific aspects regarding nexgen fuels, burners and combustion techniques. The introduction provides a global overview of the current picture of both aviation and power generation sectors, the so-called "*hard to abate*" fields where a great effort is currently dedicated to decarbonization. Following the main intervention areas, the work initially gives an overview of new fuels (e.g., SAFs, hydrogen, ammonia and emulsions), which are supposed to gradually substitute the current ones; then a description of different combustion techniques is proposed in. Afterwards continues with recent proposals of burners, whose designs aim to obtain a more sustainable combustion.

References

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