RECURSIVE SEQUENTIAL COMBUSTION: AN INNOVATIVE AND HIGH-PERFORMANCE COMBUSTION TECHNOLOGY, AIMED AT THE FUELS OF THE FUTURE

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The Recursive Sequential Combustion (RSC)

This new method invented by Combustion Bay One e.U. aims to produce robust lean combustion with excellent performance in terms of combustion efficiency, NOx and soot emissions. It addresses the fuels of the future, among others hydrogen.

The need for a better combustion

The challenge is to meet the Paris Agreement's goal of limiting greenhouse gas emissions so that the average temperature increase remains well below 2 degrees Celsius by the end of the century, and ideally below 1.5 degrees.

Industrialised countries have started their transition to a post-fossil fuel, carbon neutral economy. Many sectors that need heat and high temperatures rely on combustion and therefore need fuels. These include among others the energy sector, metallurgy, the concrete industry and aviation. The advantage of burning fuels is that it is an established, though improvable, technology that provides energy on demand in a well-controlled way. The fuels of the future will be carbon-free, such as hydrogen or synthetic hydrocarbons from a CO2 neutral or negative process balance.

Consumption of conventional resources is expected to plateau and begin to decline over the decade. While this change is urgent for environmental reasons, it must be borne in mind that fossil fuel resources are finite, that the long-forgotten concept of peak oil is another harsh reality, and that the legacy of natural resources for future generations is essential. This decrease will be linked to the effective transition mentioned above, combined with a better use of these "transitional fossil fuels", possibly blended with new fuels. In other words, the fuel of the future will be scarcer, and we must make the best use of it.

The challenge with synthetic fuels is to limit NOx and particulate emissions. The challenge with the use of pure hydrogen is to withstand the extreme heat generated by combustion, and to limit the thermal NOx emissions associated with these high temperatures.

The MOeBIUS project

MOeBIUS stands for Momentum-Enhanced Blend of the Reactants with Recirculated Burnt Gases. It is a novel concept for high-efficiency and low-emission combustion, developed and patented by CBOne with the support of the FFG in the frame of the Take-Off programme. It was inspired by the concepts of flue gas recirculation [1]-[2], the notion of flameless combustion [3], the notion of sequential combustion[4], and the novel approach on burner arrangements developed by [5]-[7].

The novelty of sequential recursive combustion is that the combustion chamber is arranged in a closed loop, where all burners are literally located one behind the other. They are supplied from the sides with premixed air and fuel. And while the burnt gases also exit from the sides, some of these gases meet and interact with the reactants in the next burner. Ultimately, the hot core generates a permanent hot gas circulation that sustains combustion, allowing robust, lean-burn operation showing a better flame stability near the lean blow out limit and a better combustion performance in terms of NOx and soot than on a conventional system operating at a similar equivalence ratio. As in a rotary system equipped with a flywheel, this amount of trapped and circulating burnt gas ensures high thermal conservation. The heat promotes complete oxidation of the particles, and the reburning effect helps to reduce NOx.

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Towards a safe and reliable combustion of hydrogen

A specific feature of RSC technology is the need for fine-tuning of the momentum flow of the combustion chamber inlets (high) and outlets (low), combined with an advanced flow design. Reactants are introduced at high velocity (up to Mach 0.3 - i.e. at the limit of incompressibility) to stabilise aerodynamically the flame along a vortex, at a safe distance from the walls.

This same characteristic is important for the use of hydrogen as a fuel, as it prevents the phenomenon of flashback. Due to the high reactivity of hydrogen, the premixed flame tends to return to the injection point inside the injector and settle there as a diffusion flame capable of irreparably damaging the combustor in a very short time. This flashback problem when using hydrogen or hydrogen-rich mixtures is the major concern of current combustor designers. We believe that the MOeBIUS paradigm can remedy this.

The motivations and principles of RSC will be explained, and two possible designs called the discrete sector and constant section concepts will be presented. At present, effective designs produce the desired circulation in both concepts. The audience will benefit from the latest progress made in the MOeBIUS project.

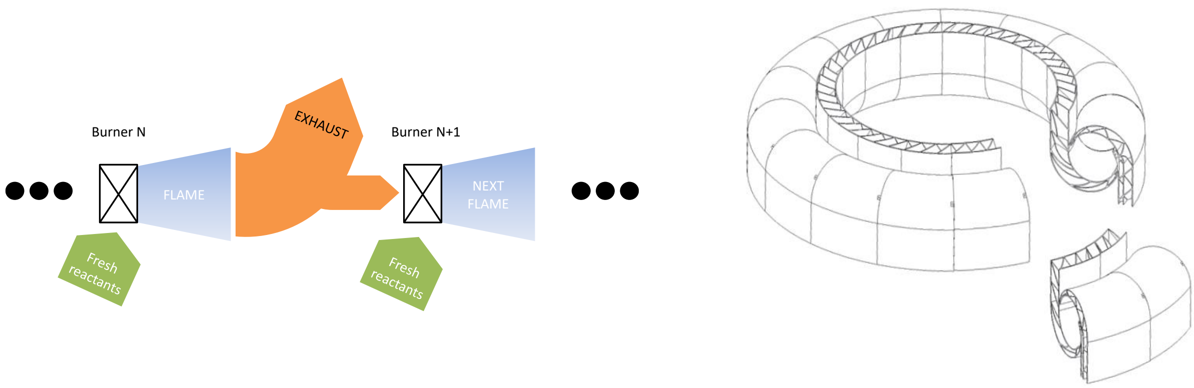

Figure 1: the recursive sequential combustor principle (left), and a RSC geometry with a constant section (right)

References

[1] Wilkes, C., and Gerhold, B., 1980. “NOx reduction from a gas turbine combustor using exhaust gas recirculation”. Am. Soc. Mech. Eng., CONF-8009102, 10. ASME Paper 80-JPGC/GT-5.
[2] Smoot, L., Hill, S., and Xu, H., 1998. “NOx control through reburning”. Progress in Energy and Combustion Science, 24(5), pp. 385–408.
[3] Kruse, S., Kerschgens, B., Berger, L., Varea, E., and Pitsch, H., 2015. “Experimental and numerical study of MILD combustion for gas turbine applications”. Applied Energy, 148, pp. 456 – 465.
[4] Pennell, D., Bothien, M., Ciani, A., Granet, V., Singla, G., Thorpe, S., Wickstroem, A., Oumejjoud, K., and Yaquinto, M., 2017. “An Introduction to the Ansaldo GT36 Constant Pressure Sequential Combustor”. In Turbo Expo: Power for Land, Sea, and Air, ASME, ed., Vol. 4B of Combustion, Fuels and Emissions. GT2017-64790.
[5] Ariatabar, B., Koch, R., Bauer, H.-J., and Negulescu, D.- A., 2016. “Short helical combustor: Concept study of an innovative gas turbine combustor with angular air supply”. Journal of Engineering for Gas Turbines and Power, 138(3), p. 031503.
[6] Savary, N., and Taliercio, G., 2016. “The SAFRAN helicopter engine spinning flame combustor concept to meet customer needs”. In 42nd European Rotorcraft Forum, Lille, France.
[7] Toqan, M., Gregory, B. A., Regele, J. D., and Yamane, R. S., 2015. Tangential and flameless annular combustor for use on gas turbine engines. Patent WO2015155452A1.
[8] Fabrice Giuliani. Patent AT523924B1: Recursive Sequential Combustion