Abstract of the Doctoral Thesis

Currently, intensive development of Power-to-Gas (P2G) technology and gas microturbines can be seen. Potential integration of these two technologies can be assumed. In order to increase the efficiency of obtaining fuel with the P2G technology, one of the possibilities is to increase the participation of hydrogen in relation to methane participation in this fuel. Hydrogen is a fuel that has a higher laminar burning velocity and a higher adiabatic combustion temperature than methane. Gas microturbines are built in various combustion chamber technologies; chambers with diffusion, kinetic, and mixed combustion. Diffusion-type combustion chambers are very common in the past and present. They are characterised by high operational stability, simplicity of design and construction, high reliability and can be used for a variety of purposes; for these reasons, it was this type of combustion chamber that was chosen for this study, despite higher atmospheric emissions than for other types of combustors. Attempting to integrate both technologies and increase the efficiency of P2G technology, a potential need was assumed to power gas microturbines with methane fuel enriched in hydrogen. An increase in the laminar burning velocity and adiabatic combustion temperature may cause damage to the combustion chamber of the gas microturbine and may potentially contribute to an increase in the emission of nitrogen oxides.

On the basis of the literature review, it was concluded that a potential method for reducing the maximum combustion temperature and its gradient, reducing the laminar burning velocity and reducing the emission of nitrogen oxides may be the recirculation of exhaust gases to the zone of creating the fuel-air mixture and its combustion. The obtained effects, by lowering the values of the combustion parameters mentioned above, would allow a certain amount of hydrogen to be added to the methane fuel, thus returning to the nominal combustion and combustor work parameters. Furthermore, carbon monoxide oxidation was expected during flue gas recirculation, which could also provoke a reduction in the emission of this substance from the combustion chamber.

The exhaust gases recirculation was proposed to be achieved by the application of an autonomous internal exhaust gases recirculation system, based on a specially designed channels system located inside of the modified combustion chamber. Based on the design of the reference combustion chamber, (two) combustion chambers equipped with exhaust gases recirculation systems have been developed (SolidEdge). Numerical studies of the reference combustion chamber and two modified combustion chambers made it possible to verify the efficiency of the proposed exhaust gases recirculation system (Ansys Fluent, Ansys Chemkin and Microsoft Excel).

As a result of numerical research, it was found that there is indeed a possibility of creating a functional autonomous internal exhaust gases recirculation system for the combustion chamber of the studied gas microturbine. The maximum ratio of exhaust gases recirculation was 0.54% (mass percentage). In the next part of the investigation, it was shown that the recirculated exhaust gases do not allow the combustion process to be controlled in the desired way and that these exhaust gases do not affect the combustion process. The impact of the recirculated exhaust gases on combustion is imperceptible because the mass flow of the recirculated exhaust gases is too low.

Further analysis of the data obtained revealed the potential possibility of redesigning the combustion chamber liners permitting to limit the development of the combustion process in

the top part of the liner, making possible to protect this part of the combustor during the combustion of hydrogen enriched fuels. Redesigning the liners to burn fuels richer in hydrogen (changing the air flow passing through the liner) would make possible to limit the maximum combustion temperature and its gradient in the combustion volume. Achieving the not fully expected assessment of the proposed solution is nevertheless not a failure from a scientific point of view, as it has made possible to close a "door" in the World of Science, and it has made possible to see the potential for diffusion combustors adaptation to the combustion of fuels richer in hydrogen.

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