CONTROL of pollutants and emissions has become a major factor in the design of modern combustion systems. The “Liquid Hydrogen Fueled Aircraft - System Analysis” project funded in 2000 by the European Commission can be seen as such an initiative. Within the framework of this project, the Aachen University of Applied Sciences developed experimentally the “Micromix” hydrogen combustion principle and implemented it successfully in the Honeywell APU GTCP 36-300 gas turbine engine. Lowering the reaction temperature, eliminating hot spots from the reaction zone and keeping the time available for the formation of NO\textsubscript{x} to a minimum are the prime drivers towards NO\textsubscript{x} reduction. The “Micromix” hydrogen combustion principle meets those requirements by minimizing the flame temperature working at small equivalence ratios, improving the mixing by means of Jets In Cross-Flow and reducing the residence time in adopting a combustor geometry that provides a very large number of very small diffusion flames. In terms of pollutant emissions, compared to the unconverted APU, an essential reduction in emitted NO\textsubscript{x} was observed, stressing the potential of this innovative burning principle.

The objective of this thesis is to investigate the “Micromix” hydrogen combustion principle with the ultimate goal of an improved prediction during the design process. Due to the complex interrelation of chemical kinetics and flow dynamics, the “Micromixing” was analyzed first. Stereoscopic Particle Image Velocimetry was used to provide insight into the mixing process. A “simplified” set-up, that allowed to investigate the flow characteristics in great detail while retaining the same local characteristics of its “real” counterparts, was considered. The driving vortical structures were identified. To further investigate the physics involved and to extend the experimental results, numerical computations were carried out on the same “simplified” set-up as on a literature test case. In general, a number of physical issues were clarified. In particular, the interaction between the different vortical structures was looked into, and a kinematically consistent vortex model is proposed. After demonstrating the development of the mixing, the “cold flow” study was extended to a single injector. The double backward-facing step injector geometry was addressed experimentally and numerically. At design geometry, the flow appeared to behave single backward-facing like, with respect to the first gradation. In terms of varying step configurations, the flow was seen to be dependent on the periodic perturbation arising from the graded series of backward-facing steps. During the second part of the investigation, the “hot flow” was analyzed. Considering combustor similar operating conditions, a test burner was experimented on an atmospheric test rig. NO\textsubscript{x} emissions were traced by exhaust gas analysis for different working conditions. Particular flame patterns, such as a regular attached flame as well as lifted flames were observed. In parallel with the experimental work, numerical computations on a pair of opposite injectors, permitted to classify the combustion regime and the main factors involved in the NO\textsubscript{x} formation. Accordingly, NO\textsubscript{x} emission enhancing design changes are proposed. Finally, the demanding computational effort, worthy of acceptance for academic purposes, is found not agreeable as future design tool and improvements to speed up the design process are projected.