

Experimental and numerical investigation on oxidation and reduction process of fuel-bound nitrogen species in swirl flame

Problems with maintaining a low emission fossil fuel combustion leads research activities into field of alternative synthetic energy sources, which are able to accumulate energy and could provide nearly zero greenhouse gases emission. Ammonia is flammable gas without carbon imprint, also well known as reducing agent in industry and relatively safe hydrogen carrier to storage and transportation. Mentioned properties fit into energy storage conception with ammonia as an accumulator of energy – medium produced with waste or unstable energy source, followed by combustion and heat release on demand, especially when lack of power in peak points is observed. Ammonia is effective reagent to NO mitigation technologies, but in unfavorable conditions could be a source of fuel nitrogen oxides, what makes the low emission synthetic gases combustion impossible. Preliminary investigations conducted by research group which applicant is a part of showed that there is connection between combustion process flow formation and nitric oxides emission during ammonia doped fuels firing.

Up to the date ammonia was combusted as a trace species, a contamination carried by synthetic or biogas, what is the reason that available information cover only fuels with up to 5% of NH₃ share. Conception of treating ammonia as energy storage material could change this situation and rise its content in the fuel even up to dozens of percents. Unfortunately, next issue is connected with combustion characteristics, significantly different from conventional gaseous fuels, like natural gas, what could be a compulsion to implement modifications into combustion systems design. Numerical simulation of flow and combustion process in combustion plants is one of the possible options in order to reduce prototyping and experimental works costs. Knowledge about fuel composition and flow formation influence on toxic compounds emission could make possible a proper design of combustion systems supplied with alternative fuels.

The objective of presented project is to conduct experimental and numerical research on oxidation and reduction of fuel-bound nitrogen species in swirl gaseous flames and to determine influence of initial process parameters and flow conditions on nitrogen oxides share in the reaction products.

Results of the investigation are essential to develop methods for low emission combustion process of non normative synthetic fuels with significant addition of ammonia as a hydrogen carrier or a problematic contamination. Flow and emission characteristics are necessary to compare numerical calculation results with experimental values and improve procedures for reacting flow modeling with internal flue gas recirculation in the swirl flow. In addition, properties of flammable mixtures, such as flammability limits, adiabatic flame temperature and laminar flame speed for wide range of synthetic fuels will be determined.

Results, both experimental and numerical, allow to determine dependencies between initial process state and emission process effect for non normative gaseous fuels. Knowledge about ammonia combustion principles enables conscious choice of fuel-bound nitrogen combustion systems design. Determination of those relations could provide proper direction of further research and eliminate ineffective solutions in the longer term. Numerical results will be supplemented with kinetic reaction pathways. Planned works will extend range of available kinetic reaction mechanisms for special fuels combustion, both reduced and detailed, verified in flow conditions. In addition, use of correlated parameters in a modified combustion model could improve effectiveness and reduce time of complex combustion systems simulations, what effects in a general improvement of prototyping process. Achieving of satisfactory emission level in combination with base or additional use of synthetic fuel will make possible to locally produce renewable energy with high energy effectiveness factor and increased use of primary energy in decentralized system, what is introduced with UE directives and incorporated in globally executed climatic policy.