Formation of NO_x in oxy-fuel combustion in a bubbling fluidized bed

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MOTIVATION AND SCOPE OF THE THESIS

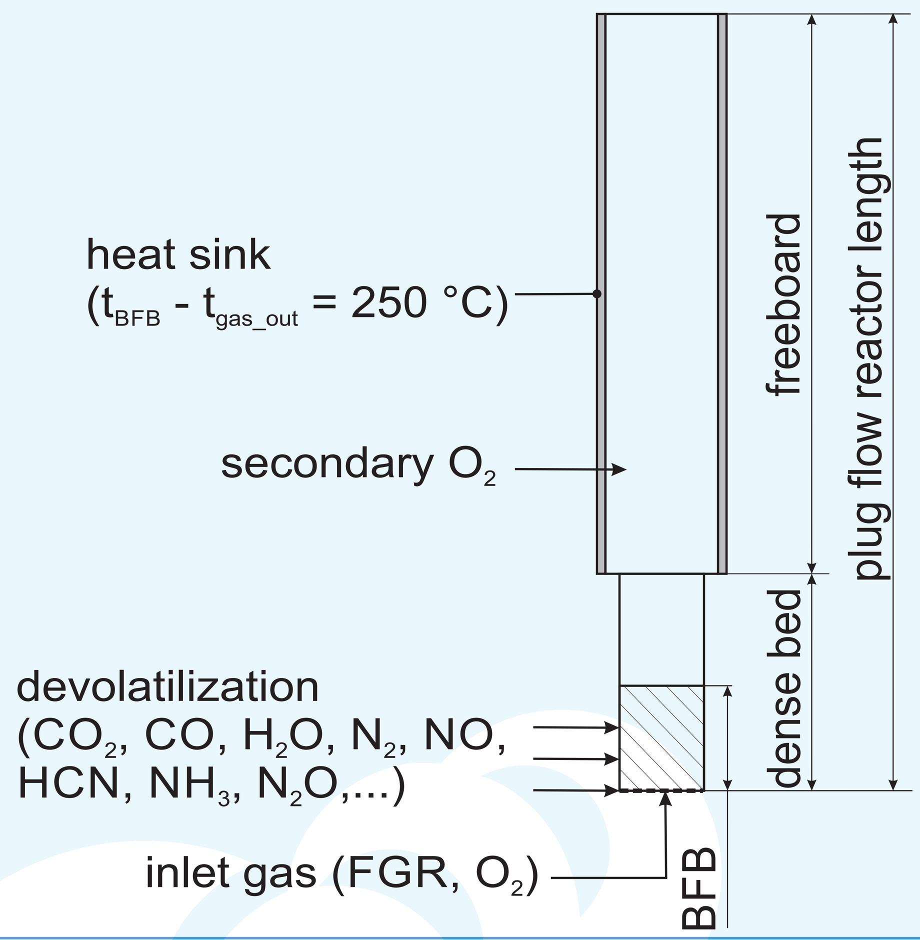
- this thesis is focused on the formation of nitrogen oxides (NO_x) in the oxy-fuel combustion in a bubbling fluidized bed (BFB)
- oxy-fuel combustion is a promissing technology for CO_2 capture, particularly for facilities with bubbling fluidized beds
- share of NO_x in the CO_2 stream should be lower than 100 ppmv due to health and safety reasons and because of corrosion risks
- study of NO_x formation in the oxy-fuel combustion in BFBs with real flue gas recirculation (FGR) is missing in the current state of the art

GOALS AND NOVELTY OF THE THESIS

- design of the numerical model of the formation of NO_x in a BFB combustor operating under oxy-fuel conditions using chemical kinetics
- numerical simulation of the formation of NO_x in a BFB combustor operating under oxy-fuel conditions
- design and construction of an 30 kW_{th} lab-sclae BFB combustor for oxy-fuel combustion of various fuels with real wet FGR
- experimental verification of the formation of NO_x in the 30 kW_{th} BFB facility and experimental validation of the numerical model

NUMERICAL MODELING

- a 1-D mathematical model of the BFB combustor was proposed using a plug flow reactor (PFR) concept with calculation of chemical kinetics
- physical and operating parameters of the PFR were set according to corresponding parameters of the experimental facility
- four different kinetic mechanisms were applied within the model and compared, mechanism published by Hashemi et al. was used for further detail analysis



EXPERIMENTAL FACILITY

- 30 kWth BFB facility was developed combusting multiple fues in air- and oxy-combustion regime with real wet FGR
- composition of flue gas was continuously analyzed (CO_2, O_2, CO, SO_2, NO_x)

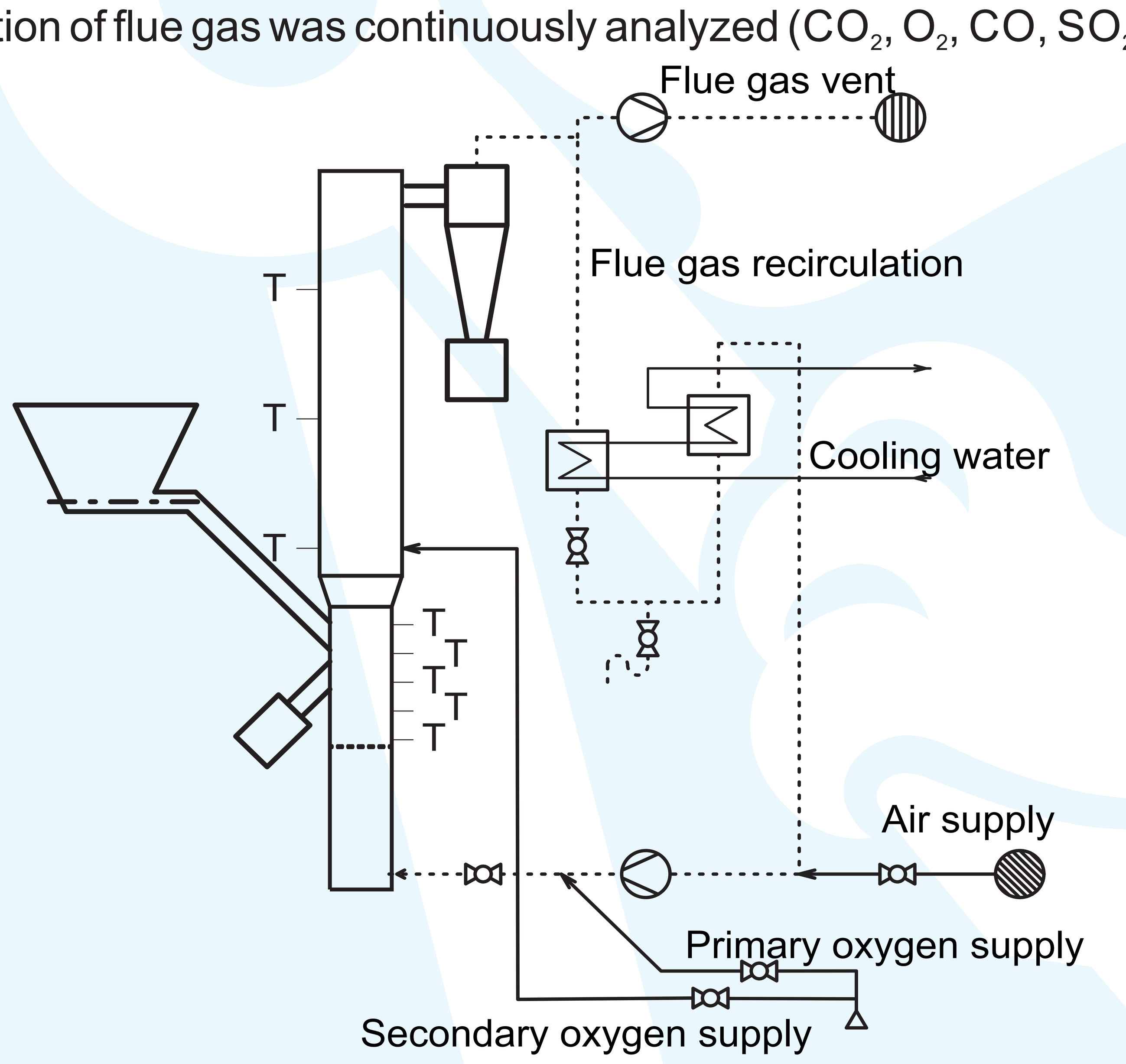


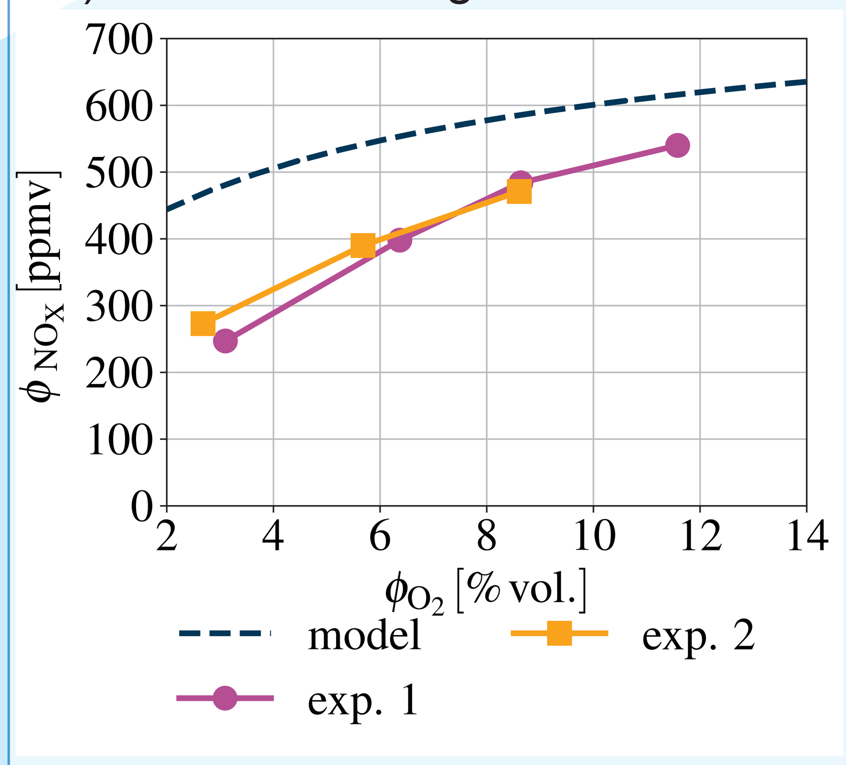
Table 1: Composition of fuels used within the study.

	As recieved			Dry ash free			
	LHV	Water	Ash	C	H	N	S
	[MJ/kg]	[wt. %]	[wt. %]	[wt. %]	[wt. %]	[wt. %]	[wt. %]
lignite	17.6	21.1	9.9	72.3	6.3	1.1	1.3
wood	16.4	7.8	1.5	51.0	6.9	0.3	0.003

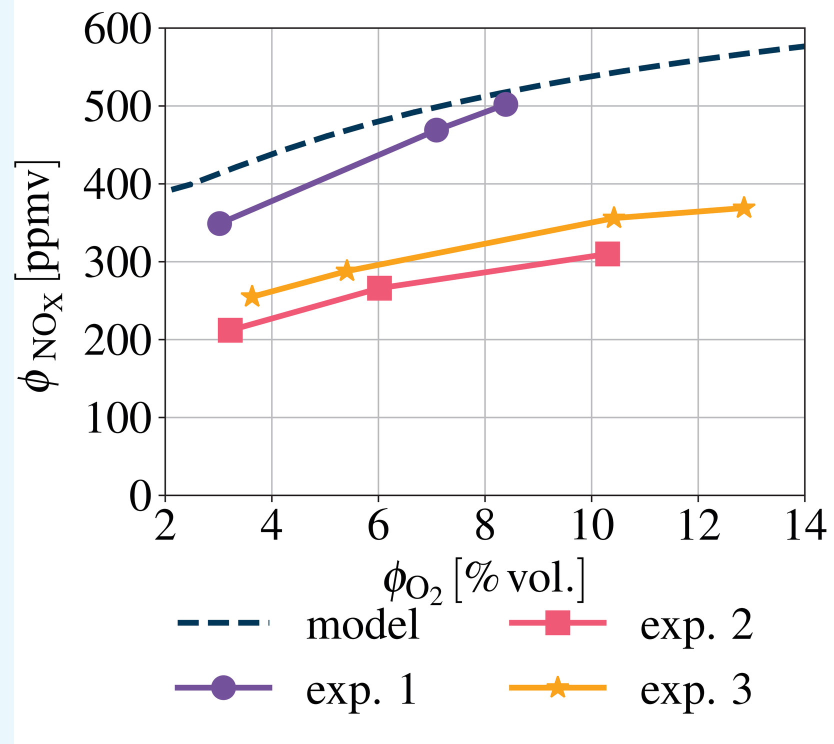
RESULTS

- **effect of oxygen stoichiometry:**

a) combustion of lignite

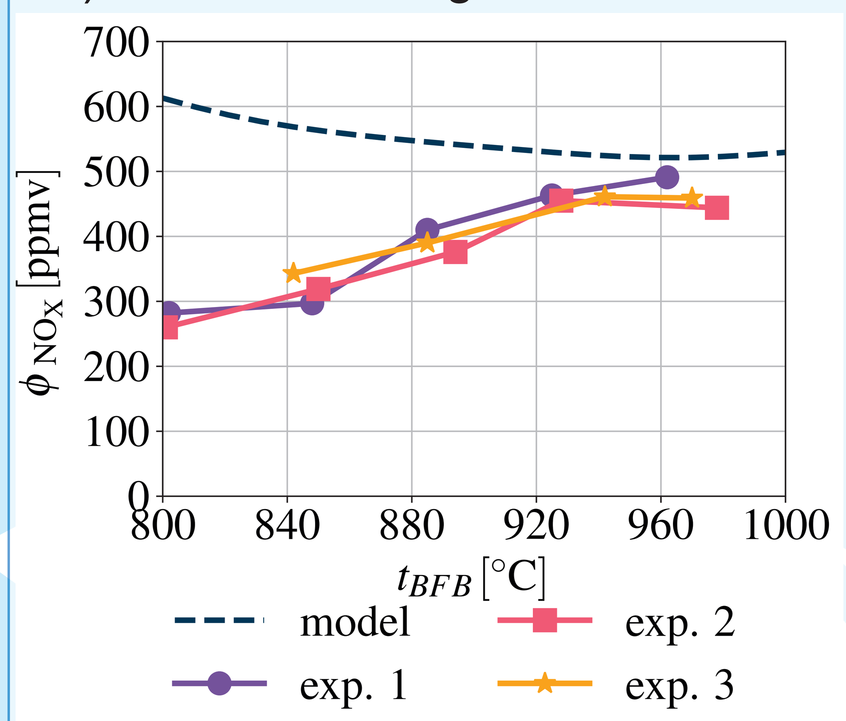


b) combustion of wood

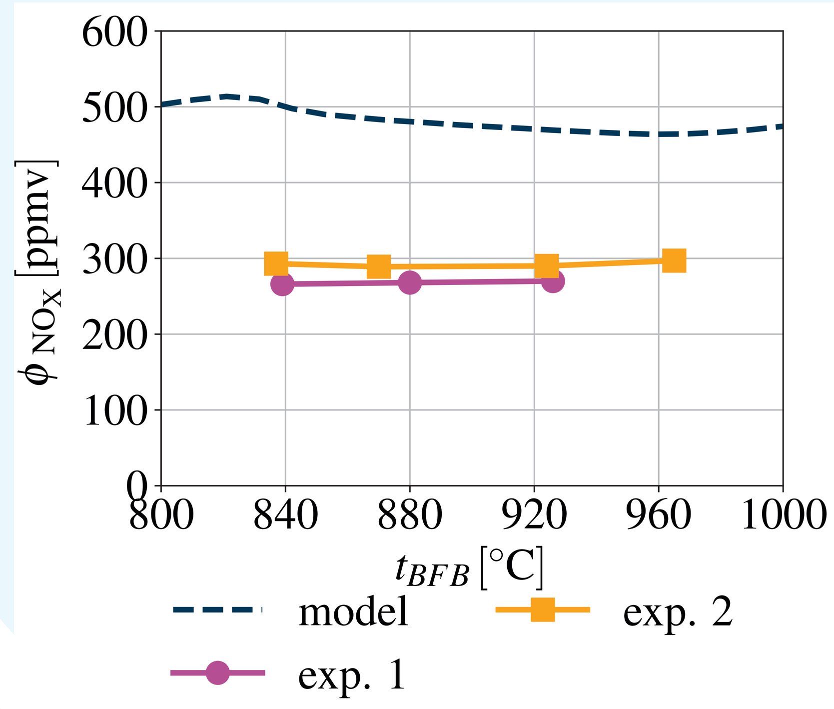


- **effect of fluidized bed temperature:**

a) combustion of lignite

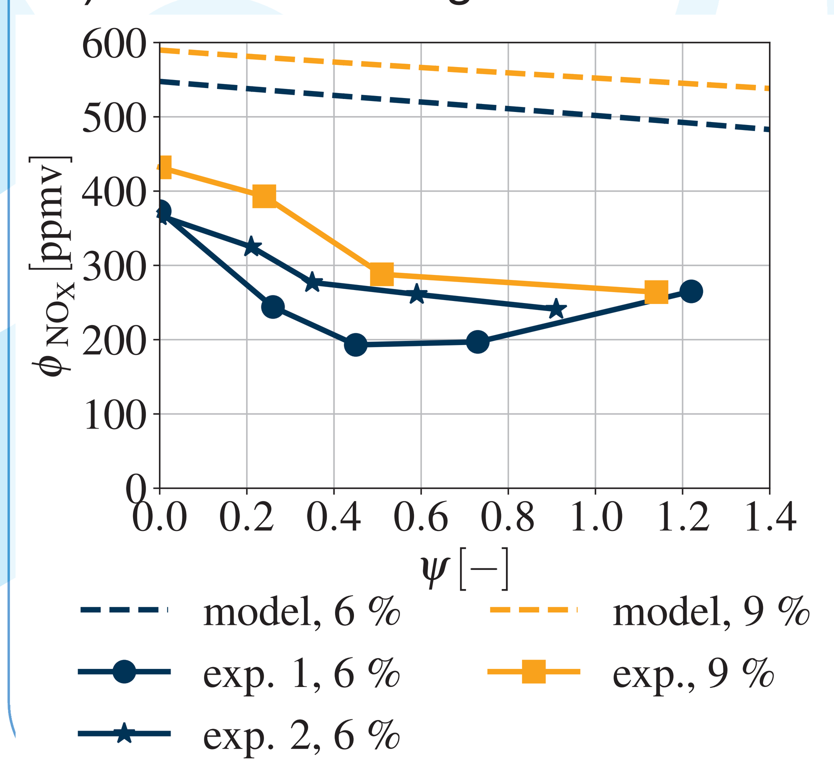


b) combustion of wood

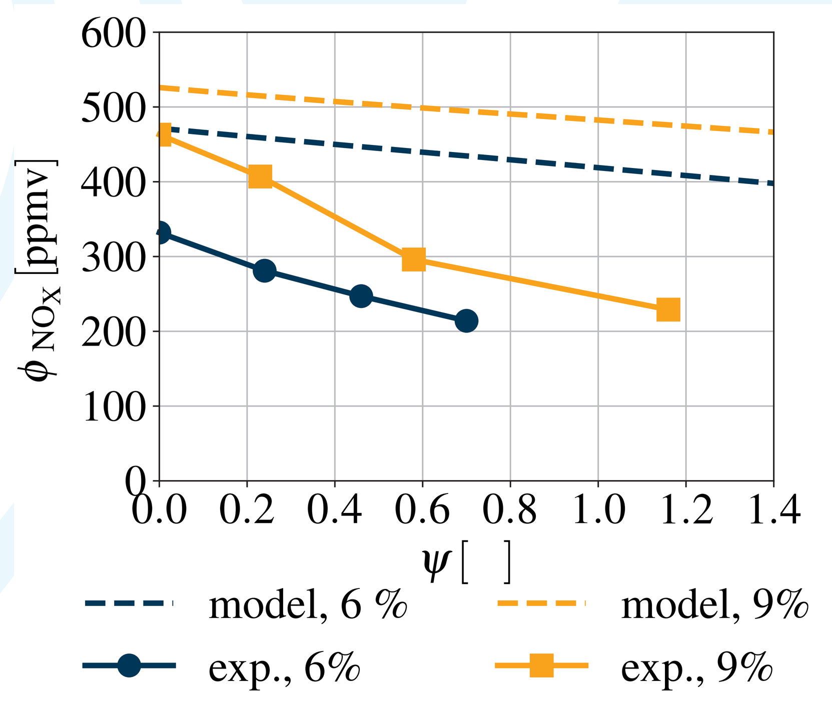


- **effect of staged supply of oxygen:**

a) combustion of lignite



b) combustion of wood



CONCLUSIONS

- all the goals of this thesis were successfully met
- four different kinetic mechanisms were used within the numerical model and the results were compared; the mechanism that led to the lowest formation of NO_2 was selected for further analysis
- both numerical and experimental results showed that the formation of NO_x is highly sensitive to oxygen stoichiometry for both fuels; a sensitivity to fluidized bed temperature was observed only in the case of lignite combustion; staged supply of oxygen led to a significant NO_x reduction (about 40-50 %)
- it was not possible to meet the 100 ppmv limit, therefore secondary measures in the post-combustion process are inevitable; research on this topic is needed
- oxy-fuel combustion brings two significant problems that need to be handled - condensation of water vapor and air ingress into all flue gas streams

AUTHOR'S PUBLICATIONS

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- M. Vodička, J. Hrdlička, and P. Skopec, "Experimental study of the NO_x reduction through the staged oxygen supply in the oxy-fuel combustion in a 30 kW_{th} bubbling fluidized bed", Fuel, vol. 286, p. 119 343, 2021. doi: 10.1016/j.fuel.2020.119343.
- J. Hrdlička, M. Vodička, P. Skopec, F. Hrdlička, and T. Dlouhý, "CO_2 capture by oxyfuel combustion", in CO2 Separation, Purifcation and Conversion to Chemicals and Fuels, Singapore: Springer, 2019, pp. 55–78.