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DEVELOPMENT OF A BURNER CONTROL SYSTEM TO COMPENSATE FOR VOLATILE HYDROGEN COMPONENTS BASED ON OPTICAL FLAME SIGNALS

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Aim of the work & Objectives

This work is a crucial component of the "GreCoCon" project, which is an integral part of the "TTgoesH2" initiative. TTgoesH2 aims to seamlessly integrate hydrogen into industrial thermal processes, even those highly sensitive to fluctuations. Our study zeroes in on optimizing these processes through the innovative use of optical flame sensors for real-time combustion monitoring. These sensors are vital for continuously tracking combustion parameters, ensuring consistent performance, and maximizing energy efficiency without requiring extensive infrastructure changes. Achieving this objective involves four critical milestones:

- **Identification:** Identified **s**uitable radical for prediction of process status.
- **Experimentation:** Performed experiments under varying process conditions to observe the behavior of the selected radical.
- **Evaluation:** Processed and evaluated experimental results to derive essential findings and identify patterns in radical behavior.
- **Control algorithm development: D**eveloped a control algorithm to identify and control the burner's status based on the identified pattern.

Fig.1: Milestone path for control concept development

Methodological Framework and Experimental Setup:

- Experiments involved varying process parameters to observe the behavior of OH* and CH* radicals, which was then analyzed to establish consistent behavioral patterns.

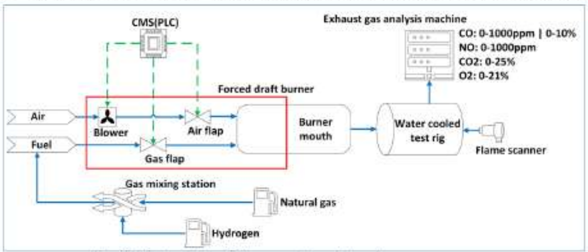

Fig.2: Schematic of the experimental setup

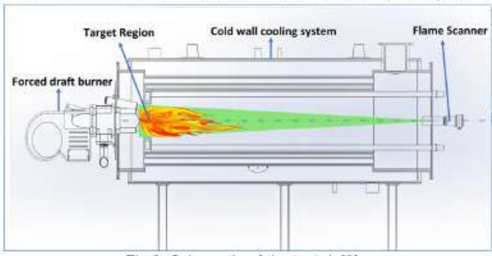

Fig.3: Schematic of the test rig[2]

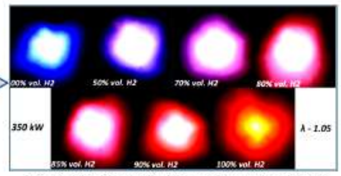

Fig.4: Variations in flame color with change in H_2 concentration

Experimental Process Parameters:

Parameter	Values	Set points
Power [kW]	140-500	9 steps
H_2 [vol.-%]	0-100	10 steps
Lambda λ	1,05-1,50	5 steps

Gas Station -1	145
Gas Station -2	158
Repeatability	45
Total	348

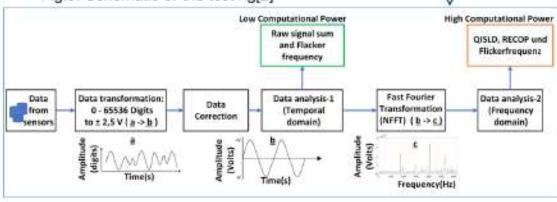

Fig.5: Schematic representation of experimental data evaluation process

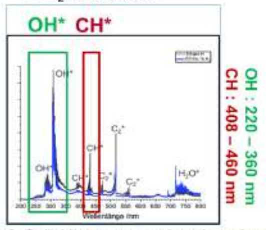

Fig.6: Suitable target wavelength regions [1]

Analysis, Results and Conclusion

- Identified a new parameter called RECOP (Relative Concentration of PSD) through a novel approach.
- Used RECOP and Flacker frequency (zero crossing frequency) data from experiments to interpolate and derive intermediate values between the collected experimental points.
- Harnessing interpolated data allows for the real-time dynamic determination of burner status, including precise gas concentration, burner power, and lambda (λ) values.
- A flame scanner calibrated to these experimental data can be commercialized for industry use, allowing direct integration with the burners.
- The tests revealed that a minimum data collection duration of at least 20 seconds is necessary to ensure data stability and reliability from the flame sensor.
- The repeatability tests confirmed that these parameters exhibit good reliable behavior, with a defined tolerance range.

RECOP:

- Relative Concentration of Power Spectral Density.
- $RECOP = \frac{PSD_{10-50\ Hz}}{PSD_{all}\ Hz}$
- It is the ratio of PSD of a specific frequency range in the signal to the PSD of total frequency range of the signal.

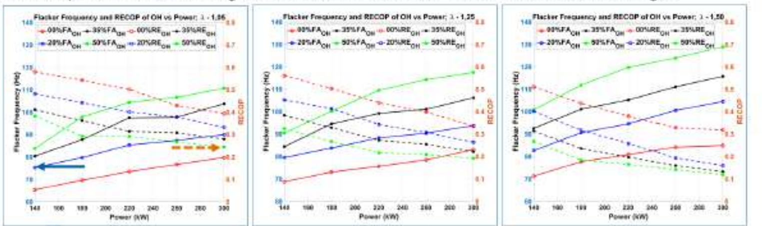

Fig.7: Plots of Flacker frequency and RECOP of OH vs Power

Outcome:

- This work presents a novel approach to developing a commercially available flame sensor that dynamically outputs RECOP and flacker frequency values. These features are essential for identifying burner status by measuring burner power, hydrogen content in the fuel, and the universal air number.
- This setup can be directly integrated into industrial furnaces with minimal infrastructure changes.
- The findings of this work can significantly ease the transition from natural gas to hydrogen in industrial applications.
- The results and conclusions drawn from this study were tested exclusively on a single burner setup within one chamber.

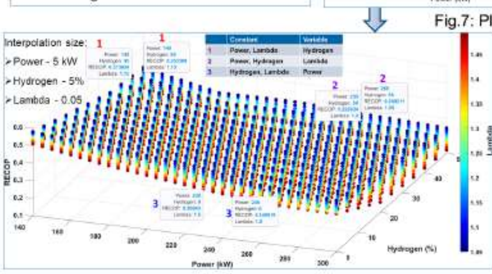

Fig.8: 3D plotting of Interpolated RECOP-OH data

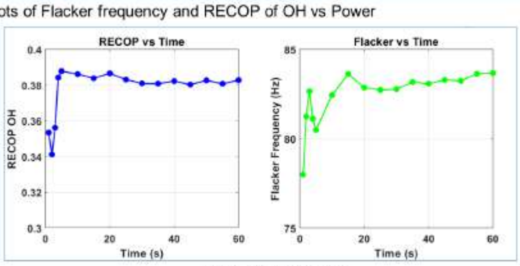

Fig.9: Sensitivity plots

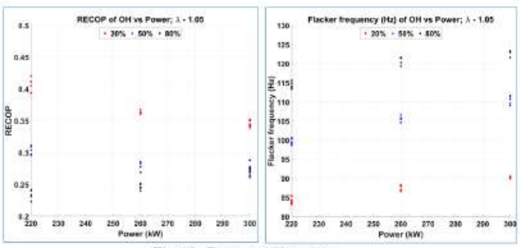

Fig.10: Repeatability plots

References

[1] K. Mohri, S. Görs, J. Schöler, A. Rittler, T. Dreier, C. Schulz, and A. Kempf, "Instantaneous 3d imaging of highly turbulent flames using computed tomography of chemiluminescence," Applied Optics, vol. 56, no. 26, pp. 7385–7395, 2017

[2] A. Gosh, "Untersuchungen zu Brennerregelungen für hohe volatile Wasserstoffanteile auf basis von optischen Flammensignalen," 2023

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