Development of a pilot scale thermal plasma reactor for research on in-situ plasma dynamics and thermal distribution

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Abstract: A test reactor was built to verify and further optimize a plasma torch design by utilizing the Schlieren method, measuring the thermal efficiency and distribution and the total gas stream. The reactor is designed minimizing external interference and maximizing visual clarity and data access, providing insight into the plasma behavior. A plasma torch optimized by a reactor of this kind allows the electrification of high-temperature industrial processes.

1. Introduction

The successful electrification of industrial heating processes in the cement, lime, and pulp industries would be a big step towards decarbonization. SINTEF has developed a prototype plasma torch. It can achieve the high temperatures necessary for calcination and clinkering (T>1450 °C) using CO_2 as the process gas, resulting in very pure CO_2 flue gas, well-suited for capture.

The Horizon EU project ELECTRA [1] aims for the adaptation to industrially relevant conditions. However, modelling and scaling a plasma torch requires detailed insight into the behaviour of the plasma, the arc, the gas flow and the thermal distribution. This type of investigations are very challenging to perform in regular operation. Thus, a dedicated, specialized research reactor for *in situ* investigations of plasma torches during operations was developed.

2. Methods

The reactor design is shown in Figure 1. A plasma torch will be placed in the top section, below are four segments. Each segment is equipped with a general instrumentation port for instruments such as enthalpy probes, a viewing port to directly observe the plasma from the side, and two large ports on opposite sides used for a schlieren setup. Additionally, there is a viewing port on the bottom section directly facing the plasma torch. The schlieren ports on the four different sections are in a staggered arrangement. Because the stacking order of the sections is interchangeable, all possible positions of the torch and the plasma within the reactor can be investigated.

A z-type schlieren system is mounted to the test reactor [2], shown in Fig 2. This comprises a purpose-built mountable unit, optimized to capture plasma morphology with high-speed cameras. The setup is unique in its large aperture (Ø200mm) and rugged design for harsh conditions.

The test reactor is designed to measure the closed heat balance during operation. Each section and the plasma torch itself have individual water-cooling circuits, where the flow rate and temperature change are measured. The off gas is cooled by a heat exchanging gathering the thermal data. Thus, all chamber faces are included for calorimetric effect evaluations.

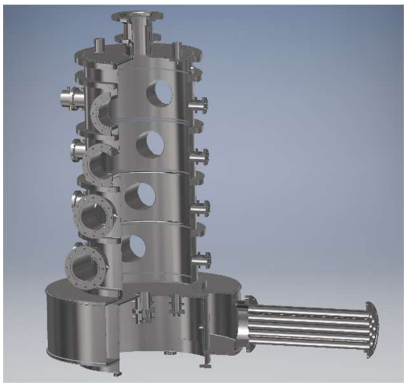
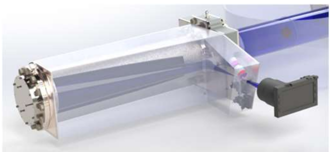


Fig. 1. Drawing of the reactor (above) for plasma torches / gas burners and **Fig. 2.** The schlieren system (below).



3. Discussion and Conclusion

A key figure is to accurately understand and measure the kinematics of the plasma phase boundary of the plasma torch to further progress the plasma torch development. The dynamic interactions and overall behavior of the plasma gas will be investigated, with the long-term objective of optimizing the design, performance and operational parameters of plasma torches.

Comparable studies with other types of gas burners, can also be performed with the test chamber, giving valuable input to future plasma modelling and process development.

4. Acknowledgement

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References

[1] https://www.electra-horizon.eu/
[2] Traldi et al., EPJ Techn Instrum 5, 4 (2018).