OXY-COMBUSTION OF COKE BREEZE FOR INTEGRATED DRY REFORMING FOR STEELMAKING DECARBONIZATION

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Abstract
The iron and steel sectors are responsible for approximately 2.6 Gt of CO_2 emissions annually, representing around 7% of global energy-related emissions. Today, this sector remains the largest industrial consumer of coal, with the Blast Furnace–Basic Oxygen Furnace (BF–BOF) route accounting for roughly 70% of global steel production. This route has a high carbon footprint, emitting about 2.15 tonnes of CO_2 per tonne of crude steel. The ProSynteg project aims to reduce the specific coke rate and associated CO_2 emissions from the BF by developing a novel process for the on-site production of hot hydrogen-rich syngas, which can be directly injected into the shaft. The syngas is generated through dry reforming of coke oven gas (COG) and/or natural gas, using hot CO_2 obtained via oxy-combustion of coke breeze. A key innovation lies in the revalorisation of coke breeze, a fine-grained by-product of the coking process, currently used in sintering but expected to lose market value due to the gradual shutdown of sinter plants. Its use as a solid fuel in an oxy-combustion reactor enables both energy recovery and CO_2 generation for reforming, creating a circular, integrated route within the steel plant. The pilot-scale installation will be supported by laboratory characterization of the solid fuel, burner development, and process simulations to define optimal combustion and reforming conditions.

Overview of the pilot plant concept
The ProSynteg project addresses the challenge of reducing CO_2 emissions in the steelmaking sector through an innovative approach that integrates coke breeze valorization and gas reforming processes. The core concept consists of utilizing the thermal energy and carbon dioxide generated by coke breeze oxy-combustion to perform the dry reforming of hydrocarbons from coke oven gas (COG) into a synthesis gas (syngas) rich in H_2 and CO. This syngas is valuable for injection into the shaft of a blast furnace (BF) as a reducing agent, thus decreasing the utilization of metallurgical coke and subsequently lowering CO_2 emissions. A key element of the project is the design and operation of a pilot plant capable of demonstrating the feasibility of this concept under industrially relevant conditions. The pilot plant is composed of two main subsystems: 1) a combustion zone, that enables controlled oxy-combustion of coke breeze, generating high-temperature flue gases containing

CO_2; 2) a dry reforming reactor zone, where hydrocarbons and CO_2 react at high temperatures to produce syngas. The first zone is mainly characterized by a solid fuel burner, which is designed to perform coke breeze oxy-combustion. After that, the produced CO_2-rich flue gases are properly combined with the compressed COG, to start the dry reforming process. This integrated system enables the valorisation of coke breeze, currently used in sinter plants but otherwise destined for disposal as these plants are progressively shutdown. **Figure 1** shows the pilot plant concept scheme with the main reactions occurring in the two zones.

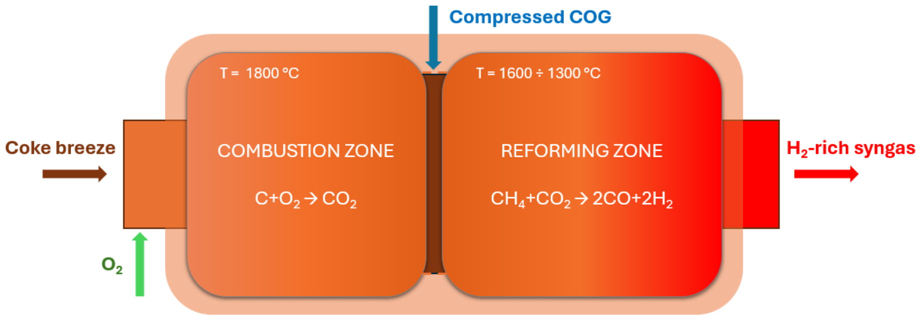

Figure 1. *Pilot plant concept scheme.*

Coke breeze oxy-combustion process

Coke breeze, a fine-grained carbonaceous residue from coke production, is being revalorised within the ProSynteg project as a solid fuel in an innovative oxy-fuel combustion system (see the main coke breeze characteristics in **Table 1**).

Table 1. *Coke breeze characteristics*

Value	Unit	Coke breeze
Bulk density	kg/m^3	854
Volatile matter	% (db)	2,2
Ash	%(db)	11.8
Fixed carbon	%(db)	86.0
Carbon	% (db)	96,2
Hydrogen	% (db)	0,3
Nitrogen	% (db)	1,5
Sulphur	% (db)	0,8
Oxygen	% (db)	1,2

The combustion tests will be carried out in a custom-designed pilot-scale combustion chamber. The system comprises: 1) a **combustion section**, with an internal diameter of 0.9 m and an effective length of 2.5 m (total 2.9 m), capable of operating up to

1600 °C; 2) a **cooling section**, 2.5 m long, ensuring a temperature drop to **150 °C** before gas release; 3) a **flue gas stack**, 1 m in length and 0.4 m in diameter.
Oxygen is supplied through a dedicated supply ramp capable of delivering up to **800 Nm³/h**, with precise regulation via PLC-based flow control. The burner is designed to allow stable operation with solid fuels and ensure a controlled flame front, promoting uniform heat release and effective conversion.

CFD burner model set up and results

The kinetic model of combustion and reforming reactions preliminary employed has been imported into the Fluent environment to verify the reliability of the kinetic scheme in a complex simulation (CFD). Preliminary simulations were carried out using the draft technical drawings of the burner, due to the final version of the burner drawings has not yet been finalized. The simulations of the combustion of coke with pure oxygen in a stoichiometric quantity were performed using a bidimensional axial-symmetric model. This allowed to reduce the number of cells with consequent reduction of computational time. **Figure 2** below shows the evolution of velocity and temperature in the combustion section of the reactor.

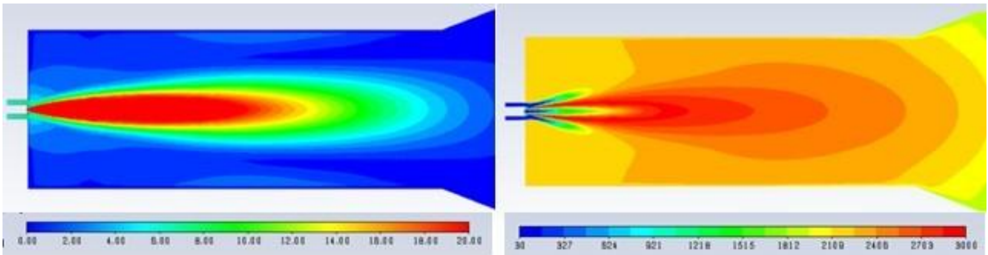

Figure 2. *Preliminary results of burner simulation. Left: velocity (m/s), right: temperature (°C).*

The results showed a long flame, but results are realistic if we consider that temperature related to oxy-combustion processes are high. The results show that:

1. the maximum temperature of 2900 °C.
2. The temperature of the flue gas to the reforming section is about 1800 °C.

Considering that the CFD simulation is related to the oxy-combustion of coke breeze the results obtained can be considered realistic.
Despite the promising results from simulations, the pilot plant trial will test a flow of oxygen slightly above the stoichiometric conditions. This is a safety procedure to avoid incomplete conversion during real working conditions.

Acknowledgments

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