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CO₂ MITIGATION FOR STEELMAKING USING CHARCOAL AND PLASTICS WASTES AS REDUCING AGENTS AND SECONDARY RAW MATERIALS

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Abstract

The effects of the partial substitution of coal by charcoal or plastic wastes at two stages of the iron production, coking plant and blast furnace, were investigated in terms of the quality of the coke produced and the gasification behaviour in the raceway. From an environmental point of view, the routes proposed bring various potentials in terms of reducing CO₂ emissions. The more efficient CO₂ reductions ranging from 2 to 28 % imply the availability of biomass grown and charcoal production in a sustainable way, or C-neutral classification of plastic wastes.

Keywords: *Coal, Charcoal, Plastic wastes, Cokemaking, Blast furnace, Steelmaking, CO₂ mitigation*

INTRODUCTION

Blast furnace ironmaking process is a mature technology that has reached during the past five decades its most efficient development [1-2]. The improvements of blast furnace productivity are related to the optimization in the reductant structure at increased oxygen enrichment to the hot blast, in ferrous burden and in coke quality. The blast furnace process (BF) is based on the chemical reduction of iron ores by the carbon monoxide generated from the carbon of the coke which is produced by

carbonization of blends of specific rank coals at temperatures to 1400 K in the absence of oxygen.

The coke ratio in conventional BF is set at nearly 450 kg/t hot metal and this ratio can be lowered by the partial substitution of coke by other (hydro)carbon sources such oil, coal and more recently, plastic wastes. Among them, the pulverized coal injection (PCI) into BF is today a well-established technology, growing in use from the 90s [2]. A reduction in coke rate up to 300 kg/t HM implies high levels of injection of reductants via the tuyeres. By applying PCI and working in optimum conditions, the pulverized coal can reach 200 kg coal/t hot metal. Coke cannot be totally replaced in a blast furnace for physical reasons. At present, there is no other satisfactory material available in its role of permeable matrix necessary for slag and metal to pass down into the hearth and for hot gases to pass upwards into the stack and, at the same time, a strong material to support the iron-bearing burden. Thus, the carbon consumption at the blast furnace is now close to the theoretical limit. Calculations show that the reductant rate of today's optimised blast furnace is only 5% above the limit of an "ideal" blast furnace [2].

In the context of post-Kyoto protocol, the iron and steel industry faces new environmental challenges related to CO₂ emissions. Individual plants may be able to achieve some further carbon reductions, but large reductions of CO₂ generation

will require the development of new technologies and successful implementation [3]. In a long term perspective, the running ULCOS –Ultra-low CO₂ steelmaking- Programme [3] -supported by the European Commission within the Research Fund for Coal and Steel (RFCS) and the 6th Framework Programs- explores, in its first stage in the period 2004-2009, a wide spectrum of innovative low-carbon technologies based on: 1) improvements in BF operation with top gas recycling into the blast furnace (decarbonation and reinjection) combined with CO₂ capture and storage; 2) the use of energy and reducing agents not based on carbon (hydrogen, electricity, natural gas); 3) the use of sustainable biomass; 4) CO₂ capture and storage. ULCOS ambition is to reach 50 % reduction of CO₂ emissions compared to current steel production [3]. However, the schedule to reach an industrial application of some of them cannot be shorter than 10 or 20 years.

In a shorter term, other tracks exist to mitigate the CO₂ generated at the blast furnace, even though they are much less efficient. Some of them constitute the subject of the SHOCOM project which has received support from the European Commission within the RFCS Programme during 2005-2008. SHOCOM looks at less ambitious targets (10% cut in CO₂ emission) and on potential application in a shorter term. The main results of the SHOCOM project are summarized below.

RESULTS AND DISCUSSION

The options proposed in SHOCOM are based on 2 ideas:

- the lowering of the thermal reserve zone temperature of the BF, so as to decrease the carbon need.
- the use of two alternative kinds of raw materials: renewable charcoal and plastic wastes.

Integrated steel plants via the blast furnace offer two potential options for using CO₂ -lean or -neutral materials: (1) the injection of such materials into the blast furnace via the tuyeres to be used as reductant, replacing other materials such as coal in the production of iron from iron ore; and (2) the incorporation of such materials into coal blends as secondary feedstocks, provided there is no significant negative effect on the quality of the coke produced. The two options have the main advantage of the use of the current coke plant and blast furnace

facilities, without large modifications and investments and, hence, with a faster industrial application.

A. Charcoal and plastic wastes as secondary raw material in cokemaking

The feasibility of using charcoal from various biomass and plastics from municipal wastes of various compositions as additives to coal blends for the production of blast furnace coke was investigated, paying special attention to the effects of such secondary raw materials on: coal thermal behaviour, coking pressure and quality of cokes produced in semipilot and pilot movable wall ovens.

The use of charcoal in the coal blend has a double advantage: take benefit of a CO₂ neutral source of C, and enhance coke reactivity in order to lower the reserve zone temperature of the blast furnace. Indeed, the incorporation of charcoal produces more reactive cokes and one can expect a decrease by 100 to 200 °C in the threshold temperature of the Boudouard reaction. With a charcoal addition of 3 wt% in a fluid enough blend and by gravity charging, all coke properties keep a correct level, but the gasification temperature was reduced by only 100°C.

In relation to plastic wastes, the effect of adding 2 wt% of different wastes to coal blends was studied. The relative proportion of polyolefins to other types of plastics in the waste is a critical factor in order to maintain or improve the quality of the coke produced.

B. Charging of a small amount of charcoal at the top of the BF

In order to get the largest reduction in reserve zone temperature, the use of charcoal charged together with coke was studied. By charging only 20 kg charcoal per t of hot metal, the reserve zone temperature would drop down to charcoal gasification threshold temperature. That charcoal would be consumed in the upper part of the BF, without impairing the permeability of the furnace. The calculated saving is around 30 kg of coke per t of hot metal. Due to a lower coke need, the production of blast furnace gas would be lower, and it must be compensated by natural gas purchase: this was taken into the global CO₂ balance.

C. Charcoal and plastic wastes injection into the BF

To assess the benefits of the use of charcoal injected into the tuyeres of modern large BFs, the research has been focused on: the charcoal gasification behaviour in the raceway; the secondary reactions of charcoal that takes place outside of the raceway; the optimum conditions for its injection. Coal used for injection was used as a reference and different mixtures coal: charcoal were also tested.

As regards plastic wastes as reductant, the gasification of plastics to produce a syngas to be injected into a Midrex shaft or into a blast furnace was evaluated. The selected gasification process for the generation of the reducing gas is based on the circulating fluidized bed with steam.

D. Evaluation of CO₂ emissions of the proposed routes

The objective of this part of the research is to assess the real efficiency of the use of plastic wastes via the coking and BF processes and the use of charcoal via BF process in term of CO₂ mitigation and costs in steelmaking. Five different scenarios are analyzed together with the possibility of using plastic wastes in the Midrex Direct Reduction process:

Scenario 1 (BF) is based on an integrated plant with technical ratios established from the mean European values. This scenario is the reference for scenarios 2, 3 and 4 and it is taken from ULCOS project. In this reference, a PCI ratio of 200 kg/tHM is taken.

Scenario 2 (PChI). Full or partial replacement of coal injection by charcoal injection.

Scenario 3. (TRZT). Charging of 20 kg of charcoal to reduce the reserve zone temperature down to 750 °C.

Scenario 4 (CkPla). Plastic waste addition of 2 wt% to coal blends for the production of coke to be used in the BF.

Scenario 5 (BFPla). Gasification of plastics with the help of COG and injection of the syngas produced into the BF tuyeres.

Scenario 6 (Midrex). The Midrex Direct Reduction Process in this scenario is based on natural gas.

Scenario 7 (MidPla). Based on the gasification of plastics and the use of the syngas in the Midrex process.

The boundaries chosen for the calculation are the same than in the ULCOS project, that is to say up to the hot rolled coil (HRC). Figure 1 shows the total CO₂ emissions of all the analyzed routes and the relative mitigation, assuming neutral effect of charcoal and plastics. The choice between the two options depends on the way of charcoal production, if it is obtained in a sustainable way or not and on how the regulation considers plastics which can vary from one country to the other.

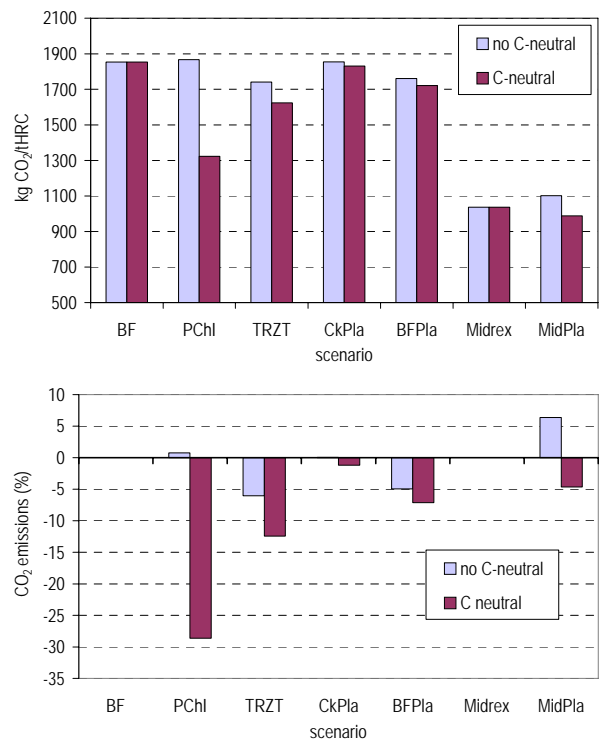


Figure 1. CO₂ emissions and relative mitigation of all routes with two options: plastics and charcoal as a source of CO₂ (no C-neutral) or assuming a neutral effect. BF, reference for scenarios PChI, TRZT, CkPla and BFPla. Midrex, reference scenario for MidPla.

The use of charcoal as additive to coal blends for coke manufacture was not included in the evaluation, since the use of charcoal as a raw material to charge at the blast furnace top gives better results.

Charcoal injection in BF at a rate of 200 kg/tHM gives the highest efficiency with a 28 % reduction of CO₂ emissions. However, in a BF operating at maximum capacity, its productivity decreases by 10 %.

Lowering the reserve zone temperature down to 850°C, by charging 20 kg/thm of charcoal at the top, gives 9% mitigation, with a negative impact on BF productivity of only -4%. If the temperature goes down to 750°C, 12% CO₂ mitigation will be achieved, but with a productivity loss of 14%.

The incorporation of plastic wastes as additives at a rate of 2 wt% in cokemaking brings 2 % CO₂ mitigation. Moreover, the use of plastics for syngas production and injection into BF tuyeres provides a much larger reduction (7 %). Thus, if the combination of the two routes for plastic wastes, coking and blast furnace processes, is considered, the global CO₂ reduction could be estimated for about 9 %, which is close to the SHOCOM target.

The syngas produced from plastics can be also used in a Midrex DR plant and it is estimated that this alternative route results in 5 % CO₂ mitigation.

CONCLUSIONS

Charcoal and plastic wastes as reducing agents in blast furnace process and as secondary raw materials in coke production have shown various potentials in terms of CO₂ mitigation in the steel industry. They can be implemented, if local conditions and quality criteria allow it, like the availability of biomass grown and charcoal production in a sustainable way, or C-neutral classification and quality criteria of plastic wastes. The results presented maybe provide a useful guide for its application by the steel industry.

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