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Ammonia Direct Reduction of Iron Oxides – Preliminary Assessment

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ABSTRACT

Decarbonization in the iron and steelmaking industry is vital for achieving a net-zero economy as it contributes 7% to 10% of global CO2 emissions. Considering the technology readiness, hydrogen-based direct reduction is amongst the most promising route for producing green steel despite some technical issues in storing, distributing, and transporting hydrogen. Ammonia is considered as an excellent hydrogen carrier due to its high hydrogen volumetric density, practical storage temperature, and its profound worldwide production quantity and supply chain. This paper discusses the feasibility of using ammonia as an iron oxide reductant, through a thermodynamic analysis and some preliminary experiments.

Keywords: Ammonia direct reduction, Direct reduced iron, Decarbonization, Ironmaking, Ammonia metallurgy

INTRODUCTION

1. Background

For the past two centuries, the BF-BOF steelmaking technology has dominated steel production [1]. It was estimated by the International Energy Association (IEA) that this technology was used to produce around 70% of steel globally [2] due to its efficiency in heat and mass transference as a result of the counter-current flow system. However, minimizing CO_2 emissions and the environmental impact of each steelmaking facility has become a significant challenge as BF-BOF integrated plants emit 1.8 to 2.2 tonnes of CO_2 per tonne of crude steel [3]. AS a result, numerous studies have been conducted globally for coke and coal replacement with materials such as biomass and hydrogen and several programs have been established worldwide, such as COURSE50, ULCOS, hydrogen flash ironmaking technology, and HYBRIT [4]. However, while these initiatives have made significant progress, they still need to overcome some challenges, such as the availability of adequate supplies of sustainably sourced biomass and the limited heat distribution by the partial use of hydrogen as a replacement for coke.

Ammonia is regarded as a key hydrogen carrier, due to its high volumetric hydrogen density of 10.7 kg H_2/100L, compared to liquid hydrogen which has a density of 0.089 kg H_2/100L at 1 MPa and 25ºC [5, 6]. Moreover, in comparison to liquid H_2 which needs to be liquefied at -253ºC, ammonia is readily liquefied by pressurizing at only -33ºC at ambient pressure [7]. The easier handleability properties of ammonia compared to liquid H_2, means that ammonia has been forecast to become the preferred transportable source of renewable hydrogen-based energy [8].

Despite the challenges regarding the utilization of hydrogen as a potential reductant in ironmaking and the potential advantages to using ammonia as a replacement, there are only few studies that have been carried out to assess the feasibility of using

