



Tata Steel harvests hydrogen

Steel-making can be a dirty business. The global steel industry is a big emitter of greenhouse gases, producing 1.9 tonne of carbon dioxide for every tonnes of steel produced. The question of how to reduce this very large carbon footprint has for long been a prime concern for steelmakers. One rather unique solution came up in the course of a casual conversation between Tata Sons Chairman Ratan Tata and Tridibesh Mukherjee, deputy managing director, Tata Steel, in August 2005.

A year earlier, Mr Tata had been appointed by the Government of India to head its national task force on the use of hydrogen as an alternative fuel.

Hydrogen is considered to be a clean and green fuel as it burns without adding greenhouse gases to the atmosphere. Unfortunately, the commercial production of hydrogen is still highly dependent on fossil fuels, which implies another vicious cycle of depletion of natural resources and increases in greenhouse gases.

While chatting in the car on the way to Kolkata airport, Mr Mukherjee suggested to Mr Tata the possibility of hydrogen formation during water quenching of molten slag. Slag, a by-product of the steelmaking process, is discharged at temperatures well above 1,500°C. When water is added at this stage, it breaks down into hydrogen and oxygen molecules, and the oxygen gets trapped by the metal in the slag, thus making it theoretically possible to collect the hydrogen gas generated.

The idea promised immense potential. If it worked, hydrogen could be cheaply generated from water instead of fossil fuels by using the heat already trapped in the hot slag.

Tata Steel's R&D department carried out a feasibility study of this hydrogen harvesting (H2H) process. The hydrogen harvesting team consisted of members from research and development, ferro alloys plant, Bamnibal; Corus RD&T, IJmuiden; Tata growth shop (TGS); steel-making shop; rawmet ferro-chrome and the project monitoring committee. The team first looked at the thermodynamic calculations of the different reactions and tried to determine if the idea had potential. The report was a disappointment as it indicated that the gas collected would not be adequate to make the process viable. However, it was decided to conduct a trial, a decision that eventually proved to be the right one. The R&D lab trial with about 15kg of slag was an unexpected success. The gas collected contained about 23 per cent hydrogen, along with a mix of other gases, including air that gets sucked in during the collection.

This result was enough to convince the team of the path-breaking potential of the idea. They moved into top gear, looking for ways to improve the efficiency of the hydrogen collection, while keeping capital and operational expenditures low. Fresh experiments were conducted over the next two years with the help of members from the steel-making shop



PROMISING INNOVATION

The company has come up with a process that uses waste heat of molten slag generated in the steel-making process to split water molecules (H₂O) to collect hydrogen that can be used as a low-cost, green fuel.

(LD#2), TGS, and ferro alloys and minerals division (FAMD), with each yielding higher percentages of hydrogen.

Innovation

Integrated steel plants use the basic oxygen-based process of steel-making, thus producing large volumes of slag, as much as 120-150kg of slag per tonne of steel. This slag has to be cooled, but the granulation or quenching processes that are normally used for cooling slag are not environment-friendly. There is a significant amount of heat (about 550kJ / kg of slag) and chemical energy available in the molten slag that is wasted in the cooling processes.

In Tata Steel's novel H2H process, hydrogen-rich gas is produced by thermo-chemical decomposition of water in the presence of catalytic fluxes. The hot slag plays two roles: (1) It provides heat for the water decomposition reaction, (2) It prevents the reverse reaction between hydrogen and oxygen gases as the metal particles and sub-oxides present in the slag react with the oxygen.

Hurdles

The main and critical challenge to the hydrogen harvesting project was that of safety. The team had to work with molten slag at temperatures above 1,500°C, plus the mix of gases generated in the slag-quenching process — hydrogen and carbon monoxide — are not only explosive in nature, they are also extremely toxic. The set-up design had to be thoroughly checked for various safety aspects such as gas leakage, explosive pressure release mechanism, no water entrapment in molten slag zone, etc. Hazard assessment studies and safety checks were carried out at every stage. This planning, along with the efforts of the team to follow and maintain safety standards at every stage, resulted in an accident-free, safe and successful project.

Another challenge was the design and fabrication of the pilot set-up. The high temperature of molten slag, explosive gas mix, corrosive atmosphere, and cyclic nature of the process were



The Tata Steel team being awarded by Mr Tata for their innovation, hydrogen harvesting, in the 'Promising innovation' category at the JRD QV Award 2009 function in Mumbai

critical issues in the selection of materials. The team had set self-imposed critical rules like minimum disturbance to plant operations, no additional energy input and low Capex and Opex. Team members from TGS helped in the design and fabrication of pilot and online demonstration set-ups. The harsh conditions in the reactor make it difficult to determine what is happening inside the H2H reactor. This understanding was necessary for the optimisation of the process and design parameters. The team finally opted for simulation of the conditions inside the H2H reactor, using computational fluid dynamic modelling tools, with the help of Tata Research Development and Design Centre, to simulate the rate and flow of products of various reactions inside the reactor.

Success

The team spent a total of four years working out the dynamics of the process. In 2007, when they worked with 10 tonnes of slag, they managed to collect a gas that had 70 per cent hydrogen.

Meanwhile, the R&D team continued to find ways to optimise the results. An online plant demonstration at the Bannipal ferro-chrome plant of Tata Steel in Orissa in March 2009 achieved 78 per cent hydrogen. Today the team is certain that with further improvements, they can capture 95 per cent hydrogen

in its purest form.

The success of the hydrogen harvesting process has several remarkable implications for the steel industry:

- ▶ It creates a clean fuel source at a low cost by using waste heat and waste water.
- ▶ Hydrogen fuel cells are a new product area with uses in transport and other industries.
- ▶ The process has the potential of increasing revenue as well as added benefits in terms of carbon credits and patents.
- ▶ The gas can be used as a fuel in drying furnaces, reheating furnaces, ladle pre-heaters, captive power plants, etc. With this, consumption of coal and other fossil fuels reduces and CO₂ emissions can come down by about 25kg / tonne of steel.

The process makes steel-making technology more environment-friendly by reducing energy consumption and release of smoke and gases into the atmosphere, and improving working conditions.

The R&D team has filed four patents for the process. The benefits of the process are so remarkable that other industries are interested in understanding this process technology. Tata Steel's hydrogen harvesting process is indeed a big step forward towards a cleaner, greener metallurgical industry. ●

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