

Indirect reduction of steel

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Indirect reduction is the production of steel from iron ore in two steps: first adding carbon, then removing carbon.

Note: Numerous details have been left out for the sake of clarity. The information below is not sufficient for the production of high-quality metal.

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Process overview

Pig iron (which is high-carbon iron similar to cast iron, but not intended as a final product) is produced in a blast furnace and then has excess carbon removed in an oxygen furnace.

Oxygen is blown into the molten pig iron at supersonic speeds, where it burns with carbon (a stronger reducing agent than iron) to produce carbon dioxide gas (which escapes) and heat. The reaction is highly energetic and serves to agitate the molten metal (mixing it) and also heats it (molten pig iron comes out of the blast furnace at less than the melting point of steel). The **Bessemer converter**, the original 19th century oxygen furnace, had a lining of acidic materials. The modern furnace is known as the **basic oxygen furnace**, due to its basic lining. This process lowers the carbon content of the metal to the desired value.

After the composition is further fine-tuned, the steel can be cast into various shapes.

Alternative process

Steel can also be produced from wrought iron or other low-carbon iron. If the iron is alternately heated in a furnace burning charcoal or coke (or graphite, diamond or other high-purity forms of carbon, though this does not make economic sense) and the slag expelled by hammering, the iron will eventually absorb enough carbon to become steel. This is the pre-industrial method and is known as **steeling**.^[1]

The wrought iron for this process would itself have been converted from pig iron (see wrought iron for details), making it a three-step process of adding carbon, removing carbon and then adding carbon again.

Direct reduction cycle

Iron can also be reduced via direct reduction by syngas ($\text{CO} + \text{H}_2$) at high temperature ($\sim 1200\text{K}$), producing Fe, CO_2 and H_2O ^[2]. That CO_2 and H_2O can then be recycled via a Zinc Sulfur Iodine reactor^[3] to regenerate the syngas, as well as a useful O_2 stream. This direct reduction iron (https://en.wikipedia.org/wiki/Direct_reduced_iron) can then be processed into steel, or other iron products in a secondary process.

Comparison with direct reduction

- Advantages
 - Simpler, provided that large quantities of carbon and oxygen are available.
 - Requires less instantaneous electric power (when compared to melting directly reduced iron with an electric arc furnace).
 - There is a reduced risk of hydrogen fracturing when compared to direct reduction by hydrogen gas.
- Disadvantages
 - Uses more energy overall.
 - Using hydrogen gas as the main reducing agent inherently implies direct reduction.

References

1. L. Sims - *The backyard blacksmith: Traditional techniques for the modern smith* 2006. ISBN 978-0-7858-2567-8 p. 46
2. https://www.researchgate.net/profile/Dabin_Guo/publication/309722185_fuel_process_techology/links/581eff1208ae40da2caf27fa.pdf
3. <https://doi.org/10.1016/j.apenergy.2013.03.019>

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