Peak BOF steelmaking has occurred

The last five years have seen a significant rise in the production of steel via the electric arc furnace (EAF) route, particularly in China. It has resulted in the first fall in the percentage share of steel made by the basic oxygen furnace (BOF) route, and so is a significant milestone. The drivers are climate change, EAF process efficiency gains and scrap availability.

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With reference to *Table 1* the percentage of EAF steel produced worldwide has increased from 25.4% in 2013 to 28.8% in 2018; with a corresponding decrease in BOF share from 73.3% to 70.8%. This is the first time that the percentage of BOF steel has decreased over a significant time scale since the process was invented.

China has contributed significantly to this event. The amount of steel produced annually by the EAF route in China has increased from 48.4Mt in 2013 to 107.6Mt in 2018, a phenomenal increase (*see Table 2*). This equates to a share of 5.9% and 11.6% respectively for those two years. 11.6% is still low compared to the three next highest world steel producing countries: India at 53.3% EAF, Japan at 25.0% EAF and USA at 68.0% EAF, but with such a large steel industry in China, this increase is highly significant. Note: China now produces more EAF steel than the total steel output of any of the other three countries mentioned.

That there will be a reduction in BOF tonnage has been suggested by a number of authors, eg, ref **[2]**, but not before about 2025. The above data is still showing an increasing tonnage of BOF steel, but at a lower percentage, so using that definition it would appear that peak BOF has occurred!

The drivers worldwide for increased EAF production relate to:

- Climate change – the need to reduce CO_2 and energy consumption per tonne steel produced
- Other environmental concerns such as NOx, SOx and dust
- The increased availability of, and reducing cost of, renewable electricity
- The increased availability of scrap. In China in particular, scrap availability will continue to increase as steel from consumer goods, transport and some infrastructure produced during the earlier years of industrialisation becomes available for recycling
- The increasing cost and process competitiveness of EAFs (note their increasing capability to produce steels historically restricted to the BOF route:
  - Copper levels are now readily controllable by better scrap selection and benefication, better copper removal processes, and use, when needed, of DRI or HBI
  - Nitrogen levels are now better controllable, even for low C steels
- The rise of mini-mills with their smaller capital footprint, flexibility (ie, on-off) and low conversion costs
- The BF-BOF route is increasingly adversely affected by constraints over the cost and availability of good quality coking coals and iron ores.

2018 still saw 1.28 billion tonnes of steel produced by the BF-BOF route. The BF remains a very efficient converter of iron ore into liquid iron, and has seen off competition from alternative ironmaking methods for over two centuries. The BF-BOF route does, however, have a high carbon footprint (typically producing about 1.8 tonnes of CO_2 per tonne steel produced), compared to a scrap fed EAF of about 0.25 tonnes and a DRI fed EAF of about

Year	Crude steel Mt	EAF Mt	EAF %	BOF Mt	BOF %
2013	1650	420	25.4	1210	73.3
2014	1669	433	25.9	1227	73.5
2015	1620	404	25.0	1205	74.4
2016	1627	415	25.5	1202	73.9
2017	1730	472	27.9	1207	71.4
2018	1808	520	28.8	1280	70.8

Table 1 **Steel production by year and method [data ex Ref 1]**

Year	Crude steel Mt	EAF Mt	EAF %	BOF Mt	BOF %
2013	822	48.4	5.9	765	93.0
2014	822	54.3	6.6	768	93.4
2015	804	47.5	5.9	756	94.1
2016	808	50.9	6.3	757	93.7
2017	832	77.5	9.3	754	90.7
2018	928	107.6	11.6	821	88.4

Table 2 **China steel production by year and method [data ex Ref 1]**

0.50 tonnes. Worldwide there are many research projects and pilot/demonstration projects currently working or being planned, aiming to reduce the carbon footprint of the ironmaking route. These include variations of smelting-reduction, top gas recycling to the BF, H-based ironmaking and CO_2 capture and storage. The H_2-based Energiron process data, for instance **[3]**, suggests 90% of the coal based reductant can be replaced by hydrogen, however, to be commercially viable, renewable electricity needs to be as low as $0.03/kWh and capital costs reduced. The Hybrit project **[4]** (which incorporates Energiron) is divided into three stages

- 2016-2017 – A feasibility study to investigate all conditions
- 2018-2024 – Trials at a pilot plant
- 2025-2035 – Trials at a demonstration plant

The objective is to have a completely fossil-free process for steel making by 2035.

Another significant project, the HIsarna ironmaking process **[5]**, separates the BF into two parts, a cyclone converter vessel for ore melting and pre-reduction, and a smelting-reduction unit. A 35% reduction in CO_2, plus lower NOx, SOx and dust emissions are thought possible Trials on a 65kt/y pilot plant were considered successful.

CONCLUSIONS

The BOF will continue to decline and the EAF to rise as, over time, scrap availability increases and capital-intensive coke, sinter, pellet and blast furnace plants reach their end of life (worn out or unable to meet the required environmental standards) and are replaced by EAF plants. Some industry estimates suggest the ratio of BOF to EAF will stabilise at about a 50:50 production split by around 2050. The still-significant remaining blast furnaces (or their process equivalent replacements) will have a lower carbon footprint than today's variants. **MS**

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This article was first published in Millennium Steel China 2019, pp16-17. At the time of printing, data for BOF/EAF tonnages were not available for 2019, although the total crude steel produced in China and the world increased to 993Mt and 1,842Mt respectively (refer Tables 2 and 1 above) It will be interesting to see if the predictions were correct.

REFERENCES

1. World Steel Association statistics database at **https://www.worldsteel.org**

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4. HYBRIT Hydrogen Breakthrough Ironmaking Technology **http://www.hybritdevelopment.com/hybrit-research-project-1**

5. Development of a low CO_2 iron and steelmaking process route for a sustainable European steel industry **https://cordis.europa.eu/project/rcn/194922/factsheet/en**