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DEVELOPMENT OF IRON AND STEEL TECHNOLOGY IN INDIA DURING 18th AND 19th CENTURIES

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INTRODUCTION

Once, Indians started making iron in the first millennium B.C., Indian iron and steel technology started growing steadily till the industrial revolution of 18th century. Indian iron and steel objects were in great demand and a 30 pound piece of steel was considered a worthy present made by the Indian king Porus to the world conquerer Alexander of Macedon. Iron objects including swords, daggers, spearheads, tridents, arrows, spades etc. from ancient burial sites at Adichinallur in Tinnevelly district belonging to prechristian era, bear testimony to the craftsmanship and antiquity of Indian iron and steel industry. The 4th century A.D. iron pillar of Delhi and large iron pillar at Dhar, weighing about 6 and 7 tons, respectively, prove the steady growth of iron metallurgy in India[1]. During medieval period large beams of iron were used in Sun temple at Konark and other monuments of Orissa. A large number of guns belonging to 16th and 17th centuries, some of which weighed over 35 tons, clearly suggest that India was in the forefront of making iron and steel objects and the industry was remarkable in quality as well as in forging and welding of heavy objects[2].

During 18th century there were thousands of furnaces working in various parts of India and were producing nearly 1/2 to 3 tons of iron per annum. Iron smelting was thriving in the areas where iron ores and the fuel were in abundant supply. The furnaces were made of clay and the smelting was done by rule of thumb methods, passed down to the artisan family.

1. INDIGENOUS IRON AND STEEL INDUSTRY DURING 18-19TH CENTURIES

During 18-19th centuries smelting of iron was being practised in almost all parts of the country but the industry was more prosperous in the present states of Assam, Bengal, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Orissa.

Iron Industry in Assam[3]*:* From 15th century, Assam was the seat of iron smelting; Tirugaon and Hattigar being the renowned centres of iron manufacture. The iron ore used was the ferruginous sand. In the early part of 19th century more than 3000 iron smiths were actively engaged in the industry, however the industry went into oblivion in the middle of 19th century. Cannons and Small arms were the chief products of this industry. In Khasi and Jantia hills also a large number of smelting furnaces were operating at the time and local weathered rock was mined and concentrated to serve as the ore. The quality of iron produced at Khasi was superior to the British iron and iron worth Rs. 55,000 to Rs. 70,000 was exported to neighbouring areas. Walters[4], Cracroft[5] and Yule[6] have described the smelting operation in the Khasi Hills.

Iron Industry in Bengal[7]*:* Birbhum and Burdwan districts were the centres of flourishing iron industry. The ore available locally contained 28 to 59% iron and 1.5% Phosphorus pentoxide. Burdwan district had very rich deposits of coal also. Indigenous industry was better developed in Birbhum district than elsewhere in India. Here the furnaces were comparatively large and working was more efficient. Some of the furnaces here also produced iron in molten condition and steel making process was a second operation which resembled puddling process. In 1852 there were 70 indigenous furnaces in this district. Each furnace produced about 25 maunds of iron in one smelting which lasted 4 complete days and nights. Cost of 25 maunds of iron was Rs. 17.

Iron Industry in Madhya Pradesh[8]*:* During 18th-19th centuries iron was smelted in various districts of Madhya Pradesh, viz. Jabbulpur, Sagar, Mandla, Bhandara, Raipur and Narsinghpur; Tendukhera and Omarpani were the most important sites. The ores of Omarpani producing excellent quality of steel were calcareous in nature and were worked upto 40-50 feet deep. In 1855 about 80 furnaces were in operation, producing about 40 tons iron per year. The rates for crude and refined iron were one rupee a maund and two rupees a maund respectively. Tendukhera iron was used in the suspension bridge over the river Bias in 1830.

Iron Industry in Andhra Pradesh[9]*:* Of the various iron smelting centres in Andhra Pradesh, Konasamudram produced excellent quality of steel known as Wootz or Nirmal. The daily output of a furnace was about 50 seers, valued Rs. 37. Persians from Isphan used to purchase steel from here which was used for making Damascus blades in Persia and elsewhere.

Iron Industry in Tamil Nadu : Iron industry in the Salem district of Tamil Nadu was well developed during 18-19th centuries[10]. Here, magnetite ore associated with quartz was used in manufacturing wootz. Each furnace yielded from 15-20 lbs. of iron per operation. For making steel either of the following two methods was adopted at each smelting centre, (*a*) by carburisation of wrought iron in crucible, and (*b*) decarburisation of cast iron. Furnaces for smelting iron were also in operation at Lakshmipuram[11] (West Godavari dist.) and adjoining provinces[12].

Iron Industry in Orissa[13]*:* In Orissa, iron industry was quite thriving at Balasore, Talcher, Sambalpur etc. In 1872 more than 3,000 persons were engaged in iron, smelting in Sambalpur and the annual output was nearly 1,000 maunds.

2. Ores, Their Mining and Preparation

The ores used during this period generally consisted of ferruginous sand, magnetite-hematite quartzite, hematite, magnetite and laterite deposits.

In Rajdoha (Dhalbhoom in Chota Nagpur) weathered magnetite occurring in the form of small brown lumps enclosing an unaltered kernel of black magnetite containing 90% oxide of iron was used as ore[13a]. In Malabar too, ore used was magnetite. At Omarpani ore was calcarious hematite.

Mining was generally restricted to surface out crops, lodes in laterites or gravels in river beds and weathered pieces of iron ores present on the surface. Ores in the massive form were avoided to save labour in mining. In case of Omarpani (Madhya Pradesh) mining was done upto the depth of 50 ft.

At times ore needed preparation by crushing the magnetite-hematite quartzite. Quartz was seperated by washing in a current of water or by winnowing while letting it fall to the ground from the height of a few feet.

3. Furnaces and Their Working

In India during 18th-19th centuries the furnaces used were of three types, namely (*i*) open hearths, (*ii*) small blast furnaces and (*iii*) tall blast furnaces.

(*i*) *Open hearths*[14]*:* It consisted of a bowl shaped hole in the ground lined with clay which baked to a hard and fairly smooth surface. These were small hearths for direct reduction of iron, using charcoal as fuel. Draught was provided by rude bellows, or by arranging the hearths at the top of a gully and taking advantage of prevailing wind.

(*ii*) *Small blast furnaces*[15]*:* Small blast furnaces as used at Rajdoha (Dhalbhoom in Chota Nagpur) were made from a mixture of mud from the white ant hills. A typical furnace generally had a height of 4′-6″, tapering from external diameter of 3′-6″ at the base to 1′-10″ at the top. Internal diameter at the top was 5″ and 1′-5″ at the point where the bloom was formed.

Blast arrangement: The blast was introduced by a single twyer which consisted of a hollow bamboo set with clay. The air was forced by means of a pair of goat skin bellows or sometimes bullock hides were used. The bellows were worked by hand by a person squating on the ground.

(*iii*) *Tall blast furnaces*[16]: In Malabar district, tall blast furnaces of stückofen type were used, which were 10 feet high from the hearth to the throat. It had a rectangular section and the inside measurements at throat were 1 foot from front to back and 3 feet from side to side. Interior of the furnace was widest about 4 feet from the top, where it measured 2 feet from front to back and 3′-6″ from side to side and from this point the furnace narrows down to the hearth.

General practice was to build several furnaces together over a common platform, which provided working space for the man who charged the furnace. The furnace walls were built of a mixture of red clay and sand. Immediately behind each furnace a pit was hollowed out into which slag trickled from a hole in the bottom of the furnace.

Blast arrangement: In front of each furnace two small platforms were erected on each of which a pair of goat skin bellows were fixed to be worked by a man for introducing blast through separate clay twyers—one on either side of the front of furnace.

Peep holes: Between the two twyers a row of about a dozen clay tubes was placed which enabled the workman to see the interior of the furnace. When not in use these holes were stopped with a daub of wet clay.

Charge: Each charge consisted of 4 lbs. of ore, 8 lbs. of charcoal and a few sea shells (as flux) were added at a time and the yield was about 20% of the ore used.

Fuel: Charcoal was the only fuel used by the Indians. In Malabar the wood of Irool (*Xylia dolaberiformis*) tree was used for making charcoal whereas in other areas hard wood of plants such as teak, babul (*Acacia arabica*), sal (*Shorea rubasta*), *Albizzia amara* (Thuringi-Tamil), bamboo, *Calatropis gigantea, Butea frondosa, Dipterocarpus marsupeam, Sethia indica* and *Acacia catechu* etc. were employed.

Flux: In general, no flux of any kind was used in most cases. In Madhya Pradesh, the ore used was often calcareous, serving as self-fluxing ore. In Malabar, however a small quantity of flux in the form of sea shells was used.

Nature of Iron Product: The bloom produced from the furnaces was either of the three types: (*i*) crude wrought iron, (*ii*) pure wrought iron and (*iii*) crystalline and steely iron.

4. Indigenous Smelting Process of Iron and Wootz Steel

(*i*) *Wrought iron:* Whether smelted in open hearths or in small and large blast furnaces, product was wrought iron. Indigenous method of iron production during the period was that of direct reduction. Indians took the advantage of the fact that despite the high melting point of iron (1540°C) iron oxide could be reduced to metal at a low temperature of 800°C. At a temperature of 1100-1150°C, this reduced iron flows together forming a semifused porous mass called as bloom. The bloom can be easily forged and worked. No use of flux was made in general save in the case where the ore was self fluxing. This had the disadvantage that lot of iron oxide passed into slag but helped in removal of phosphorus if present in the ore or fuel and also rendered the slag very fusible[17].

This low temperature smelting avoided the reduction of any other metal present in the ore and also diminished the danger of carburization of iron. The product was slag bearing wrought iron. It was fibrous in nature and could be easily welded and forged. Metal was very pure and no other metal including manganese was present. Sulphur was very low and consequently metal had high resistance to corrosion. For chemical composition of wrought iron refer to Table 3.

However, it must be admitted that the yield from best ore rarely exceeded 50% of iron in the ore. Ordinarily the yields were of the order of only 20% and the remaining was lost in the slag. Rich iron slags littered all over the country prove the point. (See Table 1).

TABLE 1

Analysis of iron slags from various smelting centres

Description of sample	SiO_2	Al_2O_3	FeO	CaO	Loss on Ignition	MnO	MgO	S	P_2O_5	Char-coal & Loss
Rewakanta—Bombay*	53·64	5·39	28·96	10·49	1·52					
Madhya Pradesh Rajdoha**	10·33	1·85	8·13 + 73·95	2·49		0·23	1·07	0·03	0·35	1·57

*Krishnan, M. S., *Bull. Geol. Surv. India*, No. 9, p. 54, 1954.
**Turner, T. See ref. 13A.

TABLE 2

Analysis of iron ore by Harris†

Ferric Oxide	(Fe_2O_3)	..	69·55
Ferrous oxide	(FeO)	..	19·50
Silica	(SiO_2)	..	5·83
Manganous oxide	(MnO)	..	0·22
Alumina	(Al_2O_3)	..	0·51
Lime	(CaO)	..	0·36
Magnesia	(MgO)	..	Trace
Sulphur	(S)	..	0·02
Phosphoric anhydride	(P_2O_5)	..	0·03
Moisture at 100°C		..	0·60
Combined water and loss		..	3·28
	Total	..	100·00

†Turner, T., See ref. 13A.

It is the power of wrought iron to resist outside atmospheric influences better than steel that has caused the production of indigenous wrought iron to survive side by side with modern steel works.

TABLE 3

*Percentage composition of some ancient & 19th century iron objects based on**

Description of the specimen	Fe	Carbon gra-phitic	Carbon	Carbon com-bined	Mn	N	S	Si	P
1. Delhi Iron Pillar, 5th cent. A.D.	99.768	—	0.23	—	—	0.0065	tr	0.026	0.180
2. Konark Iron, 1250 A.D.	**	—	0.11	—	—	—	0.024	0.100	0.015
3. Rajdoha crude iron, 19th cent. A.D.	98.180	0.66	—	—	0.013	—	0.005	1.110	0.028
4. Rajdoha Hammered & reheated iron, 19th cent. A.D.	99.947	—	—	0.03	—	—	tr	0.010	0.030
5. Modern Tribal Smithy iron from Koraput, Orissa.	**	—	0.23	—	—	—	0.006	0.100	0.015

* 1. Ghosh, M. K., Delhi iron pillar and its iron, *N.M.L. Technical Journal*, V, No. 1, 1963.
2. Friend, J. N. and Thornycraft, W. E., Examination of iron from Konark, *J.I.S.I.*, 1924.
3-4. Turner, T., See ref. 2, pp. 162-172, 1893.
5. Bhardwaj, H. C., See ref. 1, p. 161.
** Balance represents iron.

(*ii*) *Process of Making Wootz Steel*[18]*:* Indian steel generally referred to as wootz was made by a method resembling the modern cementation process or crucible process. Small pieces of wrought iron weighing $\frac{1}{2}$ to 2 lbs. were packed into crucibles with $\frac{1}{10}$ th of their weight of chopped dry wood and leaves of specific plants e.g. *Avaram* (*Cassia auriculata*). Crucibles were sealed with clay and up to two dozen of such crucibles were staked into the furnace which was maintained at high temperature by blowing air over charcoal fire. The process was completed within $2\frac{1}{2}$ to 4 hours. The cake so formed was forged at a very low temperature. Composition of wootz steel given by Percy[10] is:

Combined carbon	..	1.33 %
Uncombined carbon	..	0.31 %
Silicon	..	0.045 %
Sulphur	..	0.181 %
Arsenic	..	0.037 %

This composition agrees with high carbon steel, slowly cooled from above its melting point which would be nearly 1450°C.

5. Superiority of Indian Swords during the Mutiny of 1857

Before the advent of Britishers and even in the 19th century, Indian steel objects were recognized to be of excellent quality which is evident from the fact that Indian steel was in great demand by the cutlers in Europe and the remarkable quality of Indian iron and steel was a subject of great discussion among the 18-19th century British metallurgists. In the so called mutiny of 1857 British Govt. was dazed by the high quality of Indian steel weaponery and ordered their collection. Thousands of the swords were turned into non-military tools. It was mentioned that the Indian swords and weapons were hard to break and they could not be cut even with strong sheers. It was impossible to cut the thin edges of the Indian blades indicating that these were the highly carburised areas.

The superiority of the Indian steel could be accounted for by the high quality of Indian iron ores. According to an analysis[20] Indian ores contained 90% iron oxide and a very low amount of manganese, sulphur and phosphorus (Table 2). Secondly, the superiority of Indian iron was because of the fact that it was prepared in small quantities at a low heat, in apparatus with a minimum of reducing power, so that the reduction of iron oxides is incomplete and that of other oxides practically nil. Thirdly, in the manufacture of steel by the native methods, the molten steel was allowed to cool down slowly in the crucibles which is advantageous to the material.

6. Modernization of Indian Iron Industry under British Rule

Britishers having settled in India and being well acquainted with the high quality of Indian ore, became interested in modernizing Indian iron industry for large scale production. East India Co., British Govt. and a few private British entrepreneurs attempted to set up iron industry in the following areas:

1. Madras Presidency: Porto Novo, Salem and Beypur.
2. Bengal: Birbhum and Raniganj.
3. Madhya Pradesh: Indore and Warora.
4. U.P.: Kumaon.

Out of these the first two were more important and are described here:

Madras Presidency[21]*:* In 1830, an iron smelter was erected at Porto Novo on account of the efforts of J.M. Heath who was a commercial resident of East India Company. Three years later the concern got government assistance and was named Indian Iron, Steel and Chrome Co. Ores for this industry were obtained from South Arcot district and the fuel (charcoal) from neighbouring areas.

The blast furnaces used at Porto Novo were about 36 feet high; the hearth being 5 feet high. Each furnace could produce 6 tons of iron per day but for running one blast furnace about 1-2 acres of forest per day was required for charcoal. Because of the shortage of fuel and even sometimes that of the ore the blast furnace did not work to full schedule.

On similar lines an industry was set up at Beypur (Malabar) in 1833 for which the ores (laterite) were obtained from Feroke and Calicut.

However, according to the tests carried out in England the iron produced by these companies was of excellent quality. Thus, the iron produced here was regularly shipped to England. As regards quality and the cost it was found superior to the Ulver stone iron of England for making files and superior even to the most swedish iron for making steel. Because of this high reputation, the iron produced here (Porto Novo) was used in the construction of Britania Tubular and Menai Strait Bridges. The Bandra station (Bombay) has for its structure some of the pillars and arches supplied by this foundry*, which are still in good condition.

Indian Iron, Steel and Chromo Co. run by Heath ran into financial difficulties and was closed down in 1850. Three years later, a new company by the name of East India Iron Co. was created to produce iron in the districts of North and South Arcot, Salem, Coimbatore and Malabar but was eventually closed down in 1877.

Iron industry, in Bengal[22]*:* In Bengal, Birbhum and Burdwan were the most important centres where large scale production of iron was tried. In Birbhum, in the year 1774, the proposal of Mr. Inder Narain Sharma to produce iron on large scale was turned down by the government but in 1877, M/s Motte and Farquhar and M/s Sumner and Heatly were granted permission because they agreed to cast shells and shots and supply them to military authorities at Fort William, Calcutta at economical price. But by the end of 18th cent. the concerns ran into difficulties and folded up. Further efforts in the form of Birbhum Iron Co. in 1855 and M/s Burn and Co. in 1875 also did not succeed.

Burdwan iron industry[23]*:* In 1839, M/s Jessop and Co. made the first attempts of using coke but did not succeed as the iron could not be brought to molten state. In 1874, iron ore and coal from Raniganj field were sent to England for experimental production of iron by Siemen's process and Crampton's Rotary Puddling process. According to the report of Dr. C. W. Siemen in 1876, 2.75 tons of iron ore, 6 cwt. of lime stone and 2.25 tons of coal could give 1 ton of puddled bar iron. In the mean time, in 1874 Bengal Iron Works was formed at Kulti which had 2 blast furnaces and was producing 20 tons of pig iron daily. However, due to the high phosphorus content this iron was not fit for converting it to wrought iron or steel but was quite suitable for foundry purposes. The production of 1 ton of pig iron required 39 cwt. of the ore, 36 cwt. of coke, 23 cwt. of lime stone and 32 cwt. coal for the boilers and heaters. The cost of production at Kulti was high in comparison to England because of the high interest

* Joshi, S. D., (ref. 2), p. 97.

charged on the loans by the British Govt. (Rs. 38/ton at Kulti and Rs. 19/ton in England).

The industry at Kulti used 3,000 tons of coke, 1,100 tons of coal per month and employed nearly 3,000 people. Because of the short supply of coal and non-sanction of a loan by the Government, the factory was closed down in 1879. In total the factory produced 12,700 tons of pig iron, i.e. at an average of 20 tons per day. In 1882, it re-started under the names of Barker Iron Works and then M/s Bengal Iron and Steel Co- (M/s Martin & Co.) This concern completely remodelled the company in 1889. It employed nearly 2,500 people.

7. Conclusion

Modernization of iron industry in India has a chequered history. India was in the fore front in the field of iron and steel manufacturing up to medieval period but fast developments in Europe in the field of economy and mass production overtook Indian iron industry. In Europe hearth type bloomery furnace was improved to catalan furnace and by the 13th century Osmund furnace, the favourite of Swedish iron smelters was introduced. In early 14th century Stückofen furnace was introduced in West Germany which was adopted by the Britishers in 15th century and since then Britain has been the leader in iron industry.

Thus, the Indian iron and steel industry which was thriving on a high note till the beginning of 18th century had to take a back seat during 18-19th century. The reasons for the dwindling of Indian iron and steel industry can be summed up as follows:

1. Neither the Mughal government nor the people in the country were awake to the new technological developments in the field of mass production of iron and steel, which were spreading fast in Europe. It was despite of the fact that India was having contacts with outside world.

2. In India business leadership could not develop probably because the business was kept in low social scale as well as in cast system[24].

3. Climate was also not favourable for enterprising men to take up new technological adventures because of their pre-occupation with political objectives.

4. The Britishers, who initially arrived as a trading company, started flooding the Indian market with cheap iron, produced in Britain on a large scale. The high cost and the labour involved in preparing iron by native methods forced the artisan families to quit their jobs for survival,

5. The Britishers were very selective in extending the financial assistance to entrepreneurs interested in reviving Indian iron and steel industry. The turning down of the proposal of Mr. Inder Narain Sharma for large scale production of iron in Birbhum in 1774 whereas a few British entrepreneurs (who agreed to supply iron shells and shots to military authorities at Fort William, Calcutta at economical price) were granted the permission, indicates towards this fact. Even in the cases where the permissions were granted, the British government withdrew their support on political grounds when the concerns ran in heavy water, making the failures inevitable.

6. High rate of interest charged on loans given to iron smelting works raised the cost of production of Indian iron.

7. The Britishers did not try to share their technical knowledge in the field of iron industry with the natives because of the fear that the high quality of steel produced by Indians could be used against them in the form of weapons. Thus, no efforts were made by the Britishers to use coal and coke for smelting iron until the middle of nineteenth century. However, these experiments too failed because of the poor quality of coal.

8. Shortage of fuel was another reason. The Indians used only charcoal as the fuel which was obtained from the wood. Thus, for running only one blast furnace it was necessary to cut down about 1-2 acres of forest per day. Further, a law enacted by the Britishers to save the forests, made the fuel less readily available, which was so heavily consumed in the iron industry.

9. The ores and the fuel were at times not present in the juxtaposition and no suitable and cheap mode of transportation was available and this also gave a set back to the development of Indian iron industry.

10. Indians avoided deep mining and thus for big furnaces even sufficient ore was not available and not even half the capacity of the furnace was used regularly.

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