South Asian History, Culture and Archaeology

Vol. 4, No. 1, 2024, pp. 89-93

URL: http://www.esijournals.com/sahca

Archaeo-Metallurgical Advancement of Iron Furnace System(s) in India

Saravanan, R.

Assistant Professor, Research Dept. of History, PSMO College, Tirurngadi, Malappuram, Kerala, India. E-mail: shavun@gmail.com

Abstract: *Copper and Iron smelting technology are correlated with each other. The man has invented Iron smelting technology while smelting Copper. In short, Iron has came out from Copper smelting furnace which is getting sufficient temperature to extract Iron from Copper ore. Initially, this operation has occurred in accidently. Later, they have developed to manufacturing Iron according to their need. The certain factors are influence to produce high quality of metal smelting process particularly fuel and good supply of air. A part from Copper and Iron technology, we have evidence of other metals also in this context. This paper is attempting to analysis some basic concepts related to the manufacturing and technology of the smelting furnaces in India. It also traced that construction process, smelting process and also various types of furnaces.*

Keywords: *Copper, Furnaces, Iron, Metallurgy, Smelting and Technology*

Received : 21 March 2024

Revised : 28 April 2024

Accepted : 21 May 2024

Published : 30 June 2024

TO CITE THIS ARTICLE:

Saravanan, R. 2024. Archaeo-Metallurgical Advancement of Iron Furnace System(s) in India. *South Asian History, Culture and Archaeology*, 4: 1, pp. 89-93.

Introduction

Metallurgy is the analysis of science and technology of metals. Metallurgy as an art has been developed since ancient period. The man knew and used many native metals for their needs. The art of smelting, refining, forging and shaping metals was highly practiced by an indigenous communities (Avner, 1974: vii). The beginning of Iron technology is the part and parcel of Iron Age. We have very few habitation sites belonging to this period. However lot of artefacts has given light into the technological development of the particular metal. In fact every aspects of man's life become so completely dependent on the metallurgy and its technology. The inhabitants have provided sufficient material evidence to us. It will helpful to frame an outline of the technological progress during this period (Hegde, 1981:189).

Advent of Metal: Copper and Iron

Stone was the most dominant tools of man before the advent of metallurgy. Stones are brittle and they were easily blunted or broken. It has limitation to do his production in agriculture and animal husbandry. Gradually, they have shifted their tools from stone to metal with the advent of metallurgy. Metals were malleable. It could be easily made sharp by the process of cold or hot forging when the working edge is blunted. It can also melt. Therefore, old or broken tools could be fabricated afresh into new ones. Copper was the first metal to extract from its ore. Copper metallurgy is dates back to the beginning of the Chalcolithic culture in Indian subcontinent. The pre Harappans did not use metal tools so extensively. However we have evidence of few artefacts occurred from archaeological excavation. It suggest that the advent of metal technology during this period (Hegde, 1981:189,190). The ancient furnaces have relatively larger hearth diameter. The reason is that the furnaces have produced semi-solid sponge iron and liquid slag instead of molten cast iron and slag. Sometimes the liquid cast iron or Munda loha was flowed out of the furnace which was brittle and it could not be shaped by forging operation. The smelters considered it was a bad omen (Prakash, 2011:386).

Art of Furnaces Smelting System in Ancient India

The minimum requirements of Copper smelting furnace is divided into two categories. First, an enclosed space where heat could be raised to 1200°C and also retained temperature until the completion of smelting process. Next, the maximum heat was produced by ordinary charcoal fire not reach beyond 700°C. Therefore they were used some technique to attain their goal through natural draught or forced draught. Natural draught of air is induced by a high chimney through furnace. A forced draught would have provision for an air blast blown by bellows through a tyre. Forced draught furnaces have two types i.e. furnace which do not tap slag and slag tapped one. This copper technology helped to the beginning of Iron metallurgy in India. It is little bit difficult task of smelters to smelt Iron than Copper. This is because of several factors like Iron melts at a much higher temperature than copper; affinity of Iron to oxygen is much stronger than Copper to oxygen and Iron ore is more impure than Copper (Hegde, 1981:194-196).

The furnace hearth was prepared by lining it with charcoal powder mixed with clay. The mixture of charcoal and clay was used to cover opening of the front wall. Now the blow pipes were adjusted in the larger opening of the tuyere and the two bellows were fixed. The furnace was charged with dried wood chips after furnace dried and then filled with charcoal up to the top. The bellows were operated slowly to build the fire inside the furnace when the wood starts burning. The blowing rate was increased to raise the furnace temperature after the yellow flame appeared at the mouth of the furnace. The blowing was continued till a translucent blue flame appeared at the top. The blue flame means that the furnace has reached a temperature of 1000°C or more than 1000°C and the charcoal is being burnt to generate CO gas. At this point, It better to increase the air blowing rate to consolidate the reduced iron into a large porous lump and separate it from the FeO rich fayalite (2FeO.SIO,) slag. Air blowing was stopped when the charcoal has almost completely burnt. At this stage, preparations were made to take out the hot iron sponge (Prakash, 2001:61,63). They knew the simplest methods of measuring the temperature of a metal is by noting the color of the hot metal. There is possible interrelation between the temperature and color of the metals like farnt red, dark red, dark cherry, cherry red, bright cherry, dark orange, orange and yellow There is an issue to find out apt temperature of a metal because perception of color varies with the individual (Avner, 1974: IX-X).

Measurements of Furnace Construction: *Angula, Bitta and Hasta*

The dimensions of the furnace was measured by sticks were cut and used as scale in desired length. The centre of the hearth and the shaft taper were marked by dropping a small green clay ball from the central point and the inner edge of the top opening. Thus the verticality as well as increase in diameter at the tuyere level and hearth could be easily measured and controlled. The top of the bellows was made of the buffalo hide. It had to be soaked in water and bound tightly around the bellow body. Man's fingers *Angula* was a unit of measurement used for construction of furnaces. One *Angula* is – 80mm. However the smelters have used other unit of measurement also i.e. Bitta and Hasta. *Bhitta* is the distance between the tips of the little finger and the thumb in the expanded form and *Hasta* is the length of the fore arm.(Prakash, 2001:58,59,61).

Typological analysis of Iron Furnace

Banerjee states that there are three varieties of furnaces. First, it was circular conical structure being border at bottom. They were 2' to 4' high and 10'' to 15'' wide at bottom and 6'' to 10'' at the top. Fuel and ore has put in from the top. The furnaces bottom contained two holes: one for blowing the blast and another for extracting slags. This type of furnaces was mainly used in South India. Second type is cylindrical. It is 2' to 6' tall and 15'' to 18'' in diameter. The bloom was taken out from the top. This type of furnace was used in parts of Central India. Last, It was a high platform to introduce ore and fuel. It is 8' to 10' high and 1' 6' across, square in plan. The metal produced in all these three furnaces was only wrought Iron. This wrought Iron was made into carburization (Rao, 1970:260). One of the oldest Iron smelting furnaces found at Naikund. This furnace is dated back to 700 BC (Prakash, 2001:57). It can be seen that this furnace was constructed using curved bricks made of refractory clay i.e. kaolin (Rao, 1970:260).

S. J. Mahmad has classified these furnaces into two major groups-Fosse type and Aerial type. The Fosse type of furnace was constructed below the ground level either by digging a Small cylindrical pit or shaft or a bowl type furnace was constructed in one of the faces of a large square pit. The Aerial type of furnace could be further classified into two categories i.e., furnaces having their hearth and the slag pit constructed below the ground level and the tapered circular shaft standing above it. This type of furnace constructed at Jiragora. It was constructed completely above the ground level or on a raised platform. Although these furnaces look crude in appearance their design criteria like throat diameter/maximum diameter ratio, furnace height/maximum diameter/2 ratio, stack angle and volume of iron were almost constant in all the furnaces except the furnace inner volume required per kg of iron (Prakash, 2001:57,58). Shrivastava has examined Iron smelting furnace and classified as Bowl shaped, Dome shaped and Shaft shaped furnace: furnace with a channel for slag tapping and slag pit furnace. Among them, Bowl furnace is the earliest specimen of copper smelting. It is simple pits in earth. It must have been covered with fuel mixed with other combustible materials the top layer. It has clay super structure of dome shape. A tuyere was inserted in it and bloom settled at bottom resting above the slag. The capacity of this furnace is very small (Shrivastva, 1999:40). In case of bowl furnaces, generally the slag was allowed to get collected and solidified at the bottom of the furnace. In the case of other furnaces, it was tapped out through the slag hole (Prakash, 2001:61,63). Dome shaped furnace is another type of furnace. A cylindrical cavity was made in blank of the clay in these furnaces. There are two opening which is facing each other . Through one of the opening allows to insert tuyeres. This design is more suitable for maintaining condition. Inside furnaces, an opening was provided at the top for intermittent feeding of fuel and ore during the process of smelting. This furnaces could generate temperature up to 1200°C. Shaft Furnaces are small in size. However they are more efficient than other furnaces. Furnaces were designed with shaft with the development of technology. Later, this type of furnaces are using with a few variation (Shrivastva, 1999:40).

Bowl furnace has reported from Chalcolithic sites like Pandu Rajar Dhibi in Bengal. This is dated back to 1045-+55 B.C. -950+50 B.C. There are some other examples for bowl furnace like Jodhpur and Noha in Rajasthan and Atranjikhera in Uttara Pradesh. Dome shaped furnaces has been reported from Atranjikhera and Noha. The Naikund furnace of Vidharbha Megalithsand Northern Black Polished furnace at Kairadih in Uttara Pradesh are fall in to shaft furnace type. (Shrivastva, 1999:40). Gogate has attempted to evaluate the efficiency of iron smelting carried out at Naikund. He states that they were using about 10 to 12 kg of ore operation. The Megalithic builders were able to produce 3 to 4 kg of pure Iron (Possehl, 1999:164). The excavations at Kodumnal in Tamilnadu yielded important evident on the manufacture of steel by crucible process as early as c. 300 BC. The excavations have exposed two crucible furnaces. The main crucible furnace was surrounded by more than 12 small furnaces. At Guttur near Krishnagiri brought to light for the first time in Tamilnadu an industrial centre datable to c. 500 BC where iron articles were produced by casting. The excavation revealed a twin-elongated oval shaped furnace (Sasisekaran, 2001:98,100). Another kind of furnace used in Kathiawar region. It has rectangular cross section and is oblong in plan. In Manipur, furnace was a small trunacated cone 18” high with a slightly wide diameter. The fuel and ore was put in through chimney. (Rao, 1970:260)

Discussion

Ancient iron reveals the traditional knowledge of ancient people in the field of metallurgical and pyro-technological advancement. Iron was mainly used to make for agricultural objects, kitchen utensils, weapons, ornaments etc (Ahmad Qureshi, 2023:333). Classification of iron into wrought iron, cast iron, steel, etc. was not prevalent in ancient times, i.e. these terminologies were not known. All the products were known as iron (Chatterjee, 2008:3). There is very little knowledge available on the scientific basis of Indian metallurgy. There could be two reason for it. Firstly, metallurgy was a practical skill of craftsman who had little contact with the elite class. Secondly, there must have existed a theoretical basis for the craft but the formulations have got lost in the course of time (Tripathi, 2008:3). They did not leave any written records of their metallurgical activity. Therefore, it is very difficult to reconstruct the progress of their technical skills in sequential order (Hegde, 1981:191). Although, analysis of the slag (a waste product of Copper smelting industry) throw useful lights on the ancient Indian Copper smelting and metal working technology (Ghosh, 1989:321,322). We need to understand the smelting and manufacturing techniques to trace the origin and development of metal technology particularly Iron (Agrawal, 2003:253). It is also well established that ancient Indians did not really work with liquid iron. They produced iron with very low carbon contents which was not possible to obtain iron in the liquid form. Therefore, they did not employ the casting technology for manufacturing large objects. However, they had achieved required carbon content for the process of manufacturing wootz steel (Balasubramaniam, 2008:11). We have hundreds of mining and smelting sites reported in the Indian subcontinent. Unfortunately, our knowledge regarding these furnaces is very scarce. In future, Academic historians, professional archaeologist and research scholars will put new effort to enrich the knowledge in this field. This challenge will have been undertaken by them.

Acknowledgement

Author is thankful to **Dr. M R Manmathan,** Associate Professor, Dept. Of History, University of Calicut, for the suggestions and guidance given for the preparation of the manuscript.

References

Agrawal, D.P. and Kharakwal, J.S. (2003). *Bronze and Iron Ages in South Asia*, Aryan Books International, New Delhi.

Ahmad Qureshi .Mo Rizwan , Nishkarsh Srivastava, Alok Kumar Kanungo, Amit Arora and Krishna Raj K. (2023), *Iron technology in medieval Kerala: archaeometallurgical studies on iron artefacts from Triprangode,* Current Science, Vol.124, No.3, 10 Feb.

Avner, H., Sidney (1974). Introduction to Physical Metallurgy, Mc Graw-Hill Book Co., singapore

Balasubramaniam, R. (2008). *Marvels of Indian Iron Through the Ages*, Rupa and Co., New Delhi.

Chatterjee, Amit and Ahindra Ghosh. (2008). *Iron making and Steel Making: Theory and Practice,* PHI Learning Private Limited, New Delhi.

Ghosh, A. (1989). *An Encyclopaedia of Indian Archaeology,* Vo.1, Munshiram Manoharlal Publishers Pvt. Ltd., New Delhi.

Hegde, K.T.M. (1981). Scientific Basis and Technology of Ancient Indian Copper and Iron Metallurgy, *Indian Journal of History of Science*, 16(2).

Possehl, L., Greegory and Gullapalli, Praveena. (1999). The Early Iron Sage in South Asia. In Vincent Pigott (Ed.), *The Archaeometallurgy of the Asian Old World*, MASCA, Research Papers in Science and Archaeology, Vol. 16, University Museum Monograoh, Philadelphia.

Prakash, B. (2001). Ferrous Metallurgy in Ancient India. In 2001 P. Ramachandra Rao and N.G. Goswami (Ed.), *Metallurgy in India: A Retrospective,* NML Jamshedpur.

Prakash, B. (2011). Ancient Indian Iron and Steel : An Archaeometallurgical Study, *Indian Journal of History of Science*, 46(3).

Rao, Gururaja. (1970). Development of Iron Technology During the Iron Age in South India. *Indian journal of history of Science,* Vol. 5, No. 2.

Sasisekaran, B. and Raghunatha Rao, B. (2001). Iron in Ancient Tamilnadu. In P. Ramachandra Rao and N.G. Goswami (Ed.), *India; Metallurgy in India: A Retrospective,* NML Jamshedpur.

Shrivastva, Rina. (1999) Smelting Furnace in Ancient India, *Indian Journal of History of Science*, 34 (1).

Tripathi, Vibha. (2008). History of Iron Tecnology in India: From Beginning to Pre-Modern Times, Rupa and Co., New Delhi.