Review Study of Historical Iron and Steel making in Sri Lanka and its Future Trends

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Abstract: It has been reported that there is enough evidence to show that iron making industry was in existence in Sri Lanka in ancient times. This was revealed during the excavations carried out by the Department of Archaeology in Sri Lanka in the past. Some of the artifacts unearthed dates back to the 5th Century BC; confirmed by the radiocarbon dating. Dr. Ananda Kumaraswamy in his report published in 1904, has stated that he had inspected an iron making foundry in Balangoda, where the feed raw material used was the iron ore (Limonite) itself, pulverized to the size of walnuts; and by subjecting it into a laborious process, to obtain iron which was impregnated with impurities. The authors have undertaken research by studying the above process and introducing the cupola process. Initially, iron ore pellet of size 1 to 2 cms was prepared by subjecting the ore from Ratnapura to a beneficiation process so as to impart porosity and strength. The raw pellets would be subjected to a metallisation process followed by reduction in a mini cupola furnace fabricated in the lab, and the resulting iron would be examined chemically, microscopically and X-ray diffraction studies

1. Introduction

How exactly men came to discover that iron ore could be smelted and would yield a metal we do not know. Possibly, the discovery came when lumps of exceptionally rich iron ore for some reason, placed on a fire and wood burning down and forming charcoal, at least smelted them partially.

There is definite evidence to show that iron was smelted as long ago as 1400 BC and possibly even before [1].

When humans saw that it possessed very useful qualities such as strength and relatively high durability, it was utilized primarily in weapon making, usually as a blade of a sword or a tip of an arrow.

2. Evidence from Archaeological Excavations

It has been reported that the evidence of iron production in Sri Lanka was revealed during the excavations of buried cities. The evidence shown by carbon dating studies dates the unearthed artifacts back to the 5th century BC [2]. The material ordinarily termed wrought iron could be made to take up carbon by the cementation process (early making of steel). It is probably carburization. Such cemented steel or 'blister steel' is in some cases directly worked up in to tools having cutting edges, sharpened by rubbing against hard stones.

The Colombo museum contains a large number of interesting specimens of ancient tools and

implements of various kinds. Most of these artifacts have been obtained from the buried cities during the archaeological explorations (Annex) [3].

For Ex; Anuradhapura 437 BC - 769 AD
Polonnaruwa 769 AD - 1319 AD
Sigiriya 479 AD

Most of the irons manufactured are for making agricultural implements, cutting instruments, tools for building and other trades, War like implements and general articles.

The proto-historic iron in Sri Lanka dates back to 1000-800BC at Anuradhapura and Aligala in Sigiriya. The settlement at Anuradhapura was at least 50ha by 700-600BC and hence an existence of some sort of a 'town', possibly, an industrial estate. So far, no other settlements of early iron age have been located in Sri Lanka, except some potential locations of iron production on small scale has been reported at Kandarodai, Matota, Pilapitiya (in Kelaniya) and Tissamaharama but, the evidence has yet to surface.

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3. Possible Contacts with Other Countries

There is also evidence to suggest that in the art of steel making, Egypt has received assistance either from India or China, because of the constant stream of trade and commerce that had existed. Egyptians were able to carry out construction of temples, pyramids, statues, obelisks, sarcophagus (stone coffins) and tombs. Many of these were made out of very hard granites (both red and black), quartz, lime stone and sand stones. In fact, some of the Hieroglyphs (Fig. 1) have been cut or scooped out from hard stones to no less than two inches, requiring lots of high quality tools made out of steel.

Figure 1- Hieroglyphs on an ancient Egyptian scarab, circa 1350 BC[4]

According to Wiley [5], the ancient steel artifacts in Sri Lanka could be as old as 1200-1800 years and because of the short distance between India and Sri Lanka, there are good reasons to believe that iron/steel making would probably have reached Sri Lanka from India.

John Percy (1864) [6] has pointed out that if a lump of red or brown hematite, heated in a charcoal fire, well surrounded by or embedded in a furnace, it will more or less completely reduced, so as to admit as being easily forged at red heat into a bar of iron. Day [7], pointed out that iron has been discovered in the great pyramids, the oldest buildings known to men.

Dr Ananda Kumaraswamy, who was the Principal mineral Surveyor in Ceylon (1904), stated that the knowledge of iron is of great antiquity in India. Its use was certainly well known in the Vedic period. There is also abundant evidence that ancient Hindus were not only skilled in manufacturing steel but also working them as in the 'tempering' of steel. He

also gives an interesting summary of evidence of ancient Sinhalese iron and steel manufacture.

4. Ancient Iron making

In his report [8], Dr Ananda Kumaraswamy states, that he had inspected the iron making furnace at Hatharabage, in Balangoda.

The furnace is sheltered beneath the thatched roof of a shed which is open on all sides and is quite close to the house occupied by the smelter. The furnace consisted of two similar units (double furnace), as shown in Fig 2 and 3. Only one unit is used at a time and consists of a 'well' where the molten metal and slag is collected. A wall consisting of wooden sticks and mud ("A" in Fig. 3) is protecting the bellower from the heat of the furnace. The well has two openings, one in front through which the molten metal and slag runs out. A smaller hole on the back side of the furnace where a blast of air is forced from the bellows into the well. From this hole a rod is inserted from time to time to poke and test the iron to see whether it is ready to tap out. The ore, mainly limonite is broken up into pieces a little larger than walnut, and roasted previously before charging into the furnace. By roasting, a large part of moisture is driven off and some porosity would have thus been created facilitating an ingress of reducing gases required for reduction.

A - Wall of mud and wattle protecting bellows blower from heat of fire

B and B' - Bellows

C - Sticks acting as springs to pull up bellows

D - Stakes to which the strap supporting bellows blower back is attached

E - Furnaces

F - Slope of sand, over which the slag runs out when a stick is inserted

G - Flat surface of furnace about 2 ft. 9 in. above ground at K

K, L, M, and N - Line of section of fig. 3

Figure 2- Combined plan of double furnace at Hatarabage at the three levels I,II and III of fig. 3[8]

Figure 3- Sections of furnace, along KL and MN of fig. 2 [8]

The bottom of the furnace is covered thickly with sand which also fills up the front opening of the well. A charcoal fire is started at the bottom of the well, and subsequently covered with layers of ore and charcoal until the well is filled. A continuous blast of air from the bellows keeps up the fire. As the work proceeds, additional ore and charcoal are added. Occasional letting out the slag, kept one person fully occupied with the work. The bellows are operated by two persons and more than three hours are normally required before the iron is ready for the recovery. When iron is found ready, the sand is cleared away, and the bloom is pushed out through the opening, and then follows the process of 'cutting the iron'.

4.1 Iron Bloom

The bloom is taken up in long tongs made of green wood sticks tied together near one end, and is beaten a little into shape with thick sticks; and then, while it is held down on a log with two of the wooden tongs, a third man takes a 'katty' and cuts the lump of iron nearly half through. The gash is made, widened by the insertion of green log which is beaten in, so as to force the edges further apart. The appearance of iron from outside is spongy and the texture is far from homogeneous. The bloom is then thrown into water for cooling. The bloom, so made, is soft and malleable and weighs about six pounds. It is sold to blacksmiths for 50 cents. According to Dr. A. Kumaraswamy, there were three families producing about two hundred such pieces per annum.

5. Ancient Steel making

Dr Kumaraswamy, who also had inspected the manufacture of steel at Aluthnuwara, Balangoda was in the opinion that steel making process is more delicate than the smelting of iron.

Basically, the furnace for steel making is smaller than the iron smelting furnace and it contains a semi circular hearth (Fig. 4) with a depression in the ground and it is filled with charcoal, into which, a blast of air is injected from the bellows. The wall and bellows were identical to iron smelting furnace. Around the actual hearth, there is a clay wall rising 5 or 6 inches from the ground, having a thickness of about 14 inches, probably as a good thermal insulator. Into this, inserted clay tubes measuring roughly 8 inches long and 2 inches diameter (its thickness was not mentioned). Into each tube, 12½ ozs iron already prepared and 5ozs wood -Ranawara- (cassia auriculata) in the form of chips are placed [9].

- A - Wall of mud and wattle protecting bellows blower from heat of fire
- B and B' - Bellows
- C - Sticks acting as springs to pull up bellows
- D - Stakes to which the strap supporting bellows blower back is attached

Figure 4- Plan of steel making furnace [8]

The tube is then closed with a lid (of the same clay material) having several holes to escape gases, thereafter embedded in the charcoal, and fire started. Very soon the gases escape from wood burning. While this process goes on, the blowing is stopped and the blast is started and kept up continuously with more charcoal added. The tubes are turned about, often to

maintain even heat distribution within its contents [8].

When the steel is likely to be ready, a hole is opened in the front part of the hearth so that the blast goes right through the furnace. Meanwhile, the tubes are lifted up one by one using long iron tongs to see whether there is a liquid formation. Any which are not ready are back in the furnace for further melting.

The tubes, which are ready, are allowed to cool. The steel, it says, is highly crystalline and ready for use as best cutting steels. Each steel bar is thus worth 75 cents to one Rupee. The method employed probably dates from the early Aryan times, and without doubt, brought by the Sinhalese themselves, the report further adds. It is thus clear that both in India and Sri Lanka, this steel had a great reputation in mediaeval times and was much sought-after by the makers of swords [10], having even exported to Damascus for the manufacture of weapons.

The manufacture of steel from iron was one of the services rendered to the Sinhalese Kings by the people under the term 'Rajakariya', for the performance of which they were allowed grants of land. It has been reported that in the district of Ouvah (Uva), two blacksmiths of Dehigolla supplied 24 small bars of steel called 'Wana karal', to the King's stores annually, and 12 persons belonging to the same place furnished a sufficient quantity of charcoal for preparing the steel.

According to Ondaatje, 1854 [11] the following places were well known for iron and steel making:-

- Hanahappawela Kammala,
- Kosgama Kammala of Kandapalle
- Mahawalgaha in the Sabaragamuwa District
- Walantharakumbura near Bandarawela
- Medaperuwa near Bandarawela
- Yahalawalakanda near Ella
- Kendagolla off Badulla

Those days iron smelters were known as 'Yamannu', and were of low caste which, since the decay of the iron industry, have turned their attention to lime burning. The decay of the industry may be due to the introduction of cheaper English iron and steel, and increasing scarcity of wood fuel.

6. Recent Studies on Ancient Iron Extraction

The recent studies carried out by various researches in the Samanalawewa area, also found that the industry existed as far back as the 3rd Century BC. It is already

mentioned that famous Damascus swords [12] in Syria were made from the high carbon steel imported from Sri Lanka. Such productions were possible, if steel making furnaces are sited in locations, so as to make use of the northward wind blowing from Tissamaharama towards the wind openings of Samanalawewa foot hills. A recent experimental repetition of this process in the same location has yielded the best temperatures suited to make steel.

Recent research conducted at Aligala, Sigiriya has also indicated that the earliest date of iron smelting dates back to the 10th Century BC by making use of Carbon 14 dating studies. It is also likely that this technology commenced at some point in a time, during or before the 9th Century BC. The results yielded from the excavation in Anuradhapura Citadel area have also confirmed this evidence further.

6.1 Studies on Ancient Iron Smelting Technology in Sigiriya

Dehigaha-ala Kanda near Alokawewa village and Aligala in Sigiriya were identified ancient iron smelting sites, by the recent studies as a result of excavations done in these areas during the period 1990-1991 [13].

The excavations at the Alokawewa, indicated the existence of several iron smelting furnaces. The furnaces have been made by carving the bedrock, as shown in the Fig 5 and 6, into oval shaped pits. In all of these, the front walls were missing. The pressure marks on the lower part of the back-wall indicated the application of some sort of draught, which could possibly have been blown by bellows through tuyeres. The research further indicates that more than 10,000 tons of iron had been produced according to rough calculations made by examining the slag heaps remaining at these sites. The dating studies further indicate that the industry was in operation from about the 2nd Century BC to the 4th Century AD. This time included the period prior to the 5th Century AD Kashyapan period and was the main construction phase in Sigiriya city [13].

Figure 5- Drawing of series of furnaces [13]

Figure 6 - Reconstruction drawing of well preserved furnace at Dehigaha-ala Kanda [13]

6.2 Studies on Ancient Wind Powered Iron Smelting in Samanalawewa

Dr Gill Juleff, an archaeologist was interested in studying the ancient iron smelting in the Samanalawewa area. She did the melting trials in 1994 to find out the possibility of applying wind power in iron smelting.

Her studies revealed a kind of a 'furnace', with two basic design components comprising a semi-permanent rear wall and a temporary straight wall, across the front wall which was constructed on a foundation of reused tapering tuyeres (clay pipes), which are telescoped one into another and lay horizontally, to form a line (Fig 7). A further row of tuyeres, set higher up in the wall, act in the conventional manner allowing air to flow in to the furnace. The length of the furnace ranged from 1.2 to 2 meters from north to south; while the depth, as in the plan, the east west dimension is circa 0.3m, and the height no more than 0.5m [14]. Radiocarbon dating has indicated the site belonging to the 7th and early 11th centuries AD.

Figure 7- Drawing of a furnace found during the implementation of Samanalawewa Project [14].

Juleff further says [15], that similar furnaces have been found in Burma, Cambodia, Sarawak and Japan around the 13th and 14th Centuries. The designs are similar to those at Sabaragamuwa. Juleff further says that, the technology went from Sri Lanka probably through Buddhist channels.

7. Discussion

According to the review study, it is understood that ancient Sri Lanka has had much improved technology of iron production using available resources, but later, it was gradually declined due to arrival of cheap steel from European countries after the industrial revolution, and lately by the globalization and introduction of free economic policy. It was evidenced, by the closure of some of big iron and steel manufacturing companies during last 3 to 4 decades. However, recently, the demand for making steel in Sri Lanka has increased substantially. Currently, the main raw material for iron and steel making is imported in the form of sponge iron and pig iron. Therefore, the need has now arisen for the production of such raw materials within the country using available iron ore reserves in order to conserve foreign exchange.

The proven reserves of iron ore deposits in Sri Lanka have not been scientifically estimated yet. In addition, there is also no indication of the occurrence of coal deposits in the country for the utilization to produce iron in the form of pig iron using the blast furnace. Hence, putting up a blast furnace to make iron from local raw materials is not economically feasible for small scale iron production [16]. Therefore, it is important to use an alternative method to extract iron from the available iron ore reserves. Today, the knowledge of chemistry and thermodynamics of metallurgical processes are

very well advanced and we know that the metallic iron is chemically active in the presence of oxygen in air. Hence it does not occur in nature as free metallic state. It always occurs in the form of oxide, hydroxide and carbonates as ores and as complex compounds. The removal of oxygen from iron ores requires carbon or carbon monoxide as reductants at temperatures exceeding 680°C [17]. The existence of porosity in the raw material, and its purity are other important factors, enhancing the degree of reduction. If silica is present, lime has the capability of dissolving out silica in forming a slag. Apart from that, the slag - metal equilibria at high temperatures also play a major role in enhancing the iron formation. Therefore, the authors have under taken research on the production of high quality iron ore pellets [18] using locally available resources for the utilization as a substitute for sponge iron, which is imported. Subsequent research, by the authors, would focus on the manufacture of directly reduced pellets, for producing cast iron and steel using the cupola and the induction furnace.

It appears that, for the manufacture of iron in ancient times, the as mined iron ore had been used as such, without any processing. In the present exercise, the authors have carried out iron ore processing and converted the raw iron ore into pellets as in Fig. 8 by imparting porosity and strength. The porosity was introduced in order to facilitate diffusion of carbon monoxide through pellets during the reduction process. Subsequently, the sintered pellets would be subjected to reduction using the cupola furnace fabricated in the laboratory. The results of this investigation will be presented in due course.

Figure 8. Pellets prepared from Dela (Rathnapura) Iron Ore

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*CBRAS-Colombo Branch of Royal Asiatic Society

Annex: Ancient tools and implements of various kinds [3]

- 180. Arrow head – Sigiriya.
- 181. Arrow head – Sigiriya.
- 182. Arrow head – Pankuliya, Anuradhapura.
- 183. Arrow head – Sigiriya.
- 184. Arrow head – North of Hospital Premises, Anuradhapura.

- 185. Arrow head – North of Hospital Premises, Anuradhapura.
- 186. Spear head – Kali Devale, Polonnaruwa.
- 187. Sword blade – Polonnaruwa.
- 188. Guard of a sword – Polonnaruwa
- 189. Guard of a sword – Kali Devale, Polonnaruwa

- 190. Iron rod – Siva Devale, Polonnaruwa.
- 191. Iron rod – Sigiriya.
- 192. Pointed object – Sigiriya.
- 193. Pointed object – North Central Province.
- 194. Pointed object – North Central Province.
- 195. Pointed object – North Central Province.
- 196. Ring and Eyespike – North Central Province.
- 197. Ring and Eyespike – North Central Province.
- 198. Ring and Eyespike – North Central Province.
- 199. Old pen (stylus) – Sigiriya.

- 200. Old pen (stylus) – North Central Province.
- 201. Crutch for receiving the carrying pole of an image – North Central Province.
- 202. Door boss – Near Arrayagiri, Anuradhapura.
- 203. Door boss – Near Arrayagiri, Anuradhapura.
- 204. Door boss – Sigiriya.
- 209. Washer – Siva Devale, Polonnaruwa.
- 210. 80 leaf – shaped ornament – Pankuliya, Anuradhapura.
- 211. 80 leaf – shaped ornament – Pankuliya, Anuradhapura.

Annex contd.: Ancient tools and implements of various kinds [3]

- 212. Chisel - Sigiriya.
- 213. Stone cutting chisel - North end of Vessagiri, Anuradhapura.
- 214. Stone cutting chisel - Site of Buddhist Railing, Anuradhapura.
- 215. (Not stated) - Site of Buddhist Railing, Anuradhapura.
- 216. Chisel - North Central Province.
- 217. Chisel - Sigiriya.
- 217a. Chisel - Vijayarama, Anuradhapura.
- 218. Chisel (with collar) - Vijayarama, Anuradhapura.
- 219. Double-edge tool - North Central Province.
- 220. Double-edge tool - Abayagiri, Anuradhapura.
- 221. Edge tool - Sigiriya.
- 222. Edge tool - North Central Province.

- 223. Cutting tool - Siva Devale, Polonnaruwa.
- 224. Cutting tool - Siva Devale, Polonnaruwa.
- 225. Cutting tool - Sigiriya.
- 226. Cutting tool - North Central Province.
- 227. Cutting tool - North Central Province.
- 228. Plane blade (?) - North Central Province.
- 229. Plane blade (?) - North Central Province.
- 230. Knife - Puliyankulam Monnastery, Anuradhapura.
- 231. Pair of Scissors - Hospital premises, Anuradhapura.
- 232. Kattie - Near Ayton Road, Anuradhapura.
- 233. Kattie - Sigiriya.

- 234. Areca nut cutter blade - Sigiriya.
- 235. Areca nut cutter blade - North Central Province.
- 236. Areca nut cutter blade - North Central Province.
- 237. Areca nut cutter - North Central Province.
- 238. Reaping knife - North Central Province.
- 239. Reaping knife - Vijayarama, Anuradhapura.
- 240. Reaping knife - Vijayarama, Anuradhapura.
- 241. Reaping knife - Vijayarama, Anuradhapura.
- 242. Reaping hook - Sigiriya.

- 243. Sickle - Sigiriya.
- 244. Sickle - Puliyankulam Monnastery, Anuradhapura.
- 245. Sickle - Kali Devale, Polonnaruwa.
- 246. Knife blade - Vijayarama, Anuradhapura.
- 247. Knife blade - Near Thuparama, Anuradhapura.
- 247. Knife blade - Nilakgama, North Central Province.

Annex contd.: Ancient tools and implements of various kinds [3]

samples for analysis of micro & macro structure, specific gravity and strength

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