

# Ancient Indian Metallurgy\*

*Vedic texts give us unique insights into the development of ancient Indian metallurgy*

Man and metals have an age-old relationship. Different periods of early human Civilization have been named after metals. The attributes of gold influenced the mind and heart of Indians so much so that they conferred upon the supreme spirit the designation of *hirnyagarbha*. It was so called, because he remains in a golden egg as an embryo. The two important sources for the History of Indian metallurgy are archaeological excavations and literary evidence. Although a considerable amount of information on this subject from the study of archaeological finds is available, literary evidence has not been studied to the extent it deserves. Unique information related to metals and metallurgy is available in different Sanskrit texts beginning with Vedic texts to medieval and pre-modern texts. There are both direct and indirect types of references. An attempt has been made here to give a glimpse of some such references.

The *Rigveda* has widely referred to *hiranya*, which is the oldest Sanskrit word for gold. It has also mentioned products made from gold, such as water vessel, necklace and visor. Chariots decorated with gold have also been mentioned. The *Rigveda* (10.75.8) mentioned that the river Sindhu (Indus) contains gold. The word *hiranyayi* was used for the river. Another *Rigveda* hymn (8.26.18), states that the path of the river Sindhu contains gold, and the word used for it is *hiranyavartanih*. It is interesting to note that Sayana translated this word as *hiranmayobhayakula*, i.e. both banks containing gold. The above hymns are some of the earliest indirect references to the alluvial placer gold deposits in India. The river Sindhu was an important source of gold in ancient times. It is interesting to note the references for the availability of alluvial placer gold in the river Sindhu are also reported in modern times. Tucci reported in 1977 that "there was near the Indus (Sindhu) source, as there are even now, great mines of gold in the region of the Manasarovar and in Thokjalyug". Further, in the itinerary in *Khotanese Saka* from Gilgit to Chilas (written between 958 – 972 A.D.) the Indus is called *Ysarnijittaji* -- the golden river, which is not a mere poetic attribute, but a reality.

Gold obtained from the river Jambu was called *jambunanda* and that from the river Ganga was called *gangeya*. These were also, alluvial placer gold. The *Pali* text Anguttara

Nikaya narrated the process of the recovery of gold dust or particles from alluvial placer gold deposits in allegorical form.

The *Mahabharata* referred to *pipilika* gold (ants' gold). Heaps of this type of gold was presented to the king Yudhishtira at the time of *rajasuya yagna* ceremony. Pipilika gold was powdery in nature and of high purity. It was obtained by panning the auriferous soil of ant hills formed by ants or termites as a part of their nature on the land containing placer gold deposits and hence the name ants' gold. *Kautilya* described a variety of gold called *rasavidha*, which was naturally occurring dissolved gold in liquid form. He stated that one *pala* (a measure) of this solution converts one hundred *palas* of silver or copper into gold, which refers to the cementation of gold on the surface of metals like silver and copper. A similar type of dissolved gold known as *hatakprabhasa* was mentioned in *Gandavyuhastra*. Kalidas also mentioned such gold solutions and termed it *Kanaka rasa*. It is astonishing to note how people recognized such gold solutions in the past.

Native gold is invariably by no means a pure metal. It contains upto 20 percent silver, copper, iron, lead, bismuth, platinum group metals and other metals, as impurities. Thus, native gold would have different colours depending upon the nature and amount of impurities present. It is logical to assume that the different colours of native gold were a major driving force for the development of gold refining process. Although, evidence of gold refining is available in Vedic texts in an allegory form, it was the *Arthashastra* of *Kautilya*, which presented it in detail.

Gold refining was a two-stage process. The first stage was the melting of impure gold alongwith lead, which removed base metal impurities, but not noble metals like silver. The second stage was to heat impure gold sheets with the soil of Sindhu State, which contained salt. The sodium chloride present in the soil reacted with silver and the resulting silver chloride absorbed in the surrounding soil. This was a solid state process, which involved diffusion of silver in impure gold and the subsequent formation of silver chloride at the gold-soil interface.

It is important to note that *Kautilya* stated that the starting sheet of impure gold must be thin, as this would improve the kinetics of the solid state refining. Usage of gold in granular form, as was the case at least in part in the Sardis refinery of the Lydian kingdom of Anatolia, would result in lower yield.

Another important metal referred to in *Rigveda* is *ayas*. It has a shining appearance. *Ayas* has different meanings in different periods. In early Vedic period, it means either

copper or copper alloys. One of the important products made from *ayas*, as stated in the *Rigveda*, was the weapon of Indra called *vajra*. It was made by the process of *sinchan* (casting). In the later Vedic period *ayas* or *karshnayas* means iron. In the *Atharvaveda*, *rajata* (silver), *trapu* (tin) and *sisa* (lead) have been mentioned.

Kautilya also described the method for refining silver, which was similar to the first stage process used in gold refining. Further, Kautilya stated a very interesting qualitative test for ensuring the purity of cast silver ingots. According to it, the surface of the cast pure silver ingots should exhibit an appearance of *chulika*, i.e., projections similar to cock's comb. In other words, the top surface of the pure silver ingot has a rising appearance at certain places. In fact, this is a reference to the spitting and sprouting behaviour of silver. Oxygen dissolves readily in molten silver. Molten silver dissolves approximately 20 times its own volume of oxygen near the melting point at one atmosphere pressure of oxygen. Just below the melting point, the solid silver can dissolve oxygen only upto half its own volume under similar conditions.

The large difference in solubility of oxygen in the liquid and solid state causes the evolution of oxygen during solidification of molten silver. Bubbles of oxygen are then given off, resulting in "spitting" at the free surface. As a result, liquid silver from the interior is ejected on the surface of the ingot and a shape similar to a cock's comb is formed on the top surface after solidification. This author carried out the experimental replication of the formation of *chulika* on a small size cast pure silver. If silver contains base metals such as lead and copper, then the dissolved oxygen would combine with it to form respective oxides. In such a situation, the phenomenon of spitting would not be observed and the surface would be smooth.

In this context, it is interesting to note that the law governing the solubility of gases in metals, known as Sievert's law, came into existence only in the early 20<sup>th</sup> Century. However, ancient Indians recognized the practical aspect of Sievert's law in judging the purity of silver.

There is a rich Sanskrit terminology for metals, from which interesting information on history of metallurgy can be derived. Only a few uncommon terms would be cited. Silver has a tendency to tarnish. It tarnishes readily when exposed to atmosphere containing sulphur, and looks blackish. Due to this characteristic, an uncommon Sanskrit name of silver is *durvarna*. The copper produced in Nepal was called *naipalika* or *nepalaka*, and was of high purity. Tin recovered from lead-tin alloy was called *nagaja*, i.e. "that obtained from *naga* (lead)". Similarly, tin recovered from the impure gold containing tin was called

*svarnaja*. India was not rich in tin metal. Our ancestors were conscious of this problem and also exploited secondary sources for tin recovery. The presence of lead adversely affects the characteristics of gold and hence, it was also called as *hemaghna*.

The *Rasaratnasamuchchaya* described three types of ferrous materials, viz, *munda*, *tiksna* and *kanta*. When iron ore pieces are reduced by charcoal in solid state, iron blocks containing porosity results. For this reason, the reduced iron blocks are also called sponge iron blocks. Any useful products can only be obtained from this material after removing the residual porosity by hot forging. The hot forged sponge iron blocks are also termed as wrought iron. *Munda* was wrought iron. As the name suggests *tiksna* has superior hardness as compared to *munda*. *Tiksna* represented crucible steel made by liquid metallurgy and also probably further carburised wrought iron. Special varieties of iron were called *kanta*. An exciting example of wrought iron produced in ancient India is the World famous Delhi Iron Pillar. It was erected in the present position in Delhi in the 5<sup>th</sup> Century AD by king Chandra Varman. However, the engraved Sanskrit inscription suggests that it was probably brought here from elsewhere in the Gupta period. The average composition (wt%) of the wrought iron of the pillar is – Fe – 0.15 C – 0.05 Si – 0.05 Mn – 0.25 P – 0.005 Ni – 0.03 Cu – 0.02 N. The most significant aspect of the pillar is that there is no sign of any corrosion, in spite of the fact that it has been exposed to the atmosphere for about 1,600 years.

Another striking feature of the pillar is its manufacturing technology. It was made by successive hot forging of directly reduced sponge iron blocks produced from the solid state reduction of iron ore by charcoal, in a die. The joint lines that have not been completely removed by forging are clearly visible on the pillar. This author discussed this aspect in detail and opined that this procedure is basically very similar to current metal powder forging techniques, with a difference that the latter is not usually used to make a long product by joining pieces together (*Powder Metallurgy*, 1990, 33 (2), 119). In both the cases, hot forging in a die is done not only to give the required shape, but also to remove the residual porosity present in the starting material.

Indian crucible steel was a celebrated material worldwide. It was usually produced by simultaneous carburisation and melting of wrought iron in closed crucibles. Valmiki referred to it by the term “refined iron”. Kautilya termed it *vratta*, because it was of circular shape. Dr. Helenus Scott sent specimens of a variety of crucible steel, available in Mumbai area, to sir Joseph Banks, the then President of the Royal Society, London, for experimental investigation in 1794. He referred to this steel as *wootz* in his letter. Recent researches by this author have revealed that the actual name of this steel was the Sanskrit *utsa*, which was

erroneously transliterated in Roman Script as *wootz* by Scott. James Stodart, fellow of the Royal Society, did extensive work on this steel and mastered its hot forging, Stodart was so overwhelmed with its quality that he mentioned this name *utsa* in Devanagari Script on his trade card, alongwith a note that it is to be preferred over the best steel in Europe. It was named *utsa* because it had a characteristic of oozing out of low melting point liquid phase when heated to moderate temperatures.

Historically brass, an alloy of copper and zinc, was known to man much earlier than they were able to extract zinc from its ore on a large scale. In early period, zinc was designated as *sattva* of zinc ore. In medieval period, its was designated, as *yashada* in Sanskrit. Zinc oxide, known as *pushpanjan*, has been referred to in *Charak Samhita*. *Rasaratnakar* (second Century AD) provides the earliest documentary evidence for the cementation process for brass making and reduction-distillation process for zinc extraction. *Rasarnava* and *Rasaratnasamuchchaya* described a typical crucible, known as *vrintak*, having a shape similar to that of a long variety of brinjal, to be used for making the reduction-distillation chamber. The basic principle of the process resembles that of the large scale 12 Century industrial process for zinc extraction uncovered at Zawar near Udaipur. It is a unique discovery and the retorts used at Zawar are similar to the *vrintak* crucible.

The *Mahabharata* and some *Puranas* have referred to ferrous arrowheads, which were subjected to '*tailadhauta*' treatment. Valmiki used this terminology in the context of battle axe. Some of the commentaries of *Ramayana* have defined *tailadhauta* as the process used for hardening (of ferrous objects). Clearly, this terminology was used in the sense of oil quench-hardening of ferrous materials.

Manasollas, written in 1131 AD gives detailed information on fine quality metal image casting by *madhuchchhishta vidhan* (lost wax process). Both *sushira* (hollow) and *ghana* (solid) images were cast. Although the documentary evidence is of a later period, it had been used since a very long time ago. The famous bronze dancing girl from Mohanjodaro was made by this process. *Shilparatna* (later part of 16<sup>th</sup> Century) has mentioned the process of making fine gold powder from thin gold leaves for painting applications. The powder produced would have a flaky shape, which gives higher covering area per unit mass.

In the Indian tradition, people with expertise in technical disciplines were highly regarded. This is reflected in a hymn of *Atharvaveda*, in which, *karmar* (ironsmith or metalsmith in general) has been called *manishi*, i.e., a wise or learned person. Further, it has been stated in the *Kavyamimansa* (10<sup>th</sup> Century A. D.) that goldsmith, ironsmith and

similar other people should also be invited by kings in the *kavya-parik-sa sabha*, i.e., literary meetings organised to judge the scholarship of poets.

ये धीवानो रथकाराः कर्मा ये मनीषिणः ।  
उपस्तीन् पर्णं मह्यं त्वं सर्वान् कृण्वभितो जनान् ॥ ६ ॥

[Atharvaveda, 3.5.6]

Metal technology, for that matter, all other technologies, are human creations shaped historically by context. The examples discussed here illustrate how ancient Indians solved metallurgical challenges, which helped in the development of Indian metallurgy and also the scientific and technological temper in the people of those times.

It is understandable that most of the metal technologies of the past are not relevant in present times. However, examples from the past can re-energise us towards encouraging local innovations and enterprise at all levels. Finally, it is clear that Vedic and classical Sanskrit texts are knowledge texts, and the study of Sanskrit has value because Sanskrit is not just a classical language, but a vehicle of discovering our knowledge inheritance and assessing its contemporary relevance.

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\* by Dr. R K Dube, retired Professor and Head, Department of Material Science IIT Kanpur.  
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