Zinc, steel and rocketry: Western mainstreaming of empirical Indian technologies

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During the 18th century, the British, in their capacity as traders and colonialists, came across three technologies empirically developed in India over the years: zinc distillation, steel-making and rocketry. They were tested in Europe and incorporated into the industrial and scientific mainstreams without acknowledgement.

During the 18th and early 19th centuries Europe was keen to learn about and from India. How nature played out in the East, how people lived and worked there, and what achievements had already been made in the material culture were important questions to be addressed so that commercial benefit could be derived from the knowledge gained, human curiosity satisfied, and European faith and belief systems propagated. In the early days of their encounter with India, the British and Europeans in general displayed genuine interest in and respect for traditional empirical technologies of the East and desired to benefit and profit from them.

In the early days of their presence in India, Europeans depended on Christian missionaries in India for information. While the Catholic France asked the Jesuits for help, the Protestant nations approached the Mission at Tranquebar in South India, set up by a Danish king in 1706 and manned by Halle-trained German Lutherans. The German Biblical scholar Johann David Michaelis (1717–1791), who had been educated in Halle itself and was now a professor in Goettingen wanted to satisfy himself if the large animal behemoth mentioned in the *Old Testament* could be the elephant as had recently been suggested. He wanted to know about the elephant's habitat, food and reproductive habits. Obligingly, the missionaries spoke to the head of the mahouts in the kingdom of Tanjore and forwarded the questions to their acquaintances in India and Ceylon. Michaelis also wanted to know the maximum number of people an elephant could carry. The considered answer from India was 28, smaller than the figure of 32 mentioned in the *Bible*[1]. (The behemoth is now generally identified with hippopotamus.) The fact that statements in the *Bible* were being critically examined was a significant development. The general weakening of classical and religious authorities made Europe more receptive to new ideas and things from distant lands.

What Europe at large wanted from India was commercial and industrial intelligence. Johann Heinrich Pott (1692–1777), a chemistry professor in Berlin, who had earlier studied theology in Halle, was commissioned by the King of Prussia to study the composition of porcelain made at Meissen near Dresden so that the King could establish porcelain works in his own territory. A professionally trained medical doctor, Samuel Benjamin Cnoll or Knoll (1705–1767) came to Tranquebar as a Lutheran missionary in 1732 and remained in India until his death. In 1740, Pott asked Cnoll to investigate how borax was processed in India. Cnoll in turn gathered the information from or through a local contact. His communication was published by the Royal Prussian Academy of Sciences in Berlin in 1743, which had earlier elected him a member. In 1751, Cnoll also sent the description to Balthazar Johannes de Buchwald, professor of medicine at the University of Copenhagen, who in turn brought Cnoll's work to the notice of Linnaeus. Part of Cnoll's description of borax was published in German translation in *Acta Medica Hafniensia* in Copenhagen in 1753. Finally, the full article was reprinted in a German translation in 1756, and in French in 1759. Cnoll was also asked to send information on two other important industrial items: zinc and saltpeter. This he was unable to do because their source was far away from South India[2].

Europe learnt about metallic zinc from the marketplace, Indian steel in the laboratory, and Indian rocketry on the battle ground.

Zinc

The process of inverse distillation for extracting metallic zinc from its ore was invented in remote antiquity in India at Zawar, 40 km south of Udaipur, in the Aravalli hills in the present-day Rajasthan. Pure zinc could then be combined with copper to produce brass with requisite attributes[3]. Earliest known brass objects in the Indian subcontinent date to about 400 BCE and were found in Taxila in the present Northwest Pakistan. Incentive for obtaining pure zinc seems to have been the casting of Buddha's statues, because by adding sufficiently large amount of metallic zinc to copper, gold-like finish could be imparted to the idol.

A still older method of producing brass, prevalent in India and Europe, was the cementing of metallic copper with the calamine ore (zinc carbonate). This brass had low zinc content, was yellow in colour, but was not shiny like gold. Also, since the zinc content of calamine would vary from one lot to another, no consistence in quality was possible. Details of the cementing and smelting processes were Sanskritized in the course of time, although it is not possible to say when this was first done. Details of zinc distillation are given in the well-known *Rasaratnasamuchchaya* (usually dated 12th or 13th century CE).

It is widely believed that zinc metallurgy was introduced from India into China at some unknown epoch. Large-scale production of zinc is known to have begun in China in the late Ming period, that is, between 1580 and 1600 (refs 4, 5). Ancient Europe, on its part, viewed brass not as an alloy, but as 'a more valuable kind of copper'[6]. European brass came either from zinc-rich copper ore or was produced by the cementing process mentioned earlier (ref. 6, pp. 72–73). As late as 1735, the Swedish chemist Georg Brandt (1694–1768), who identified cobalt as an element believed that 'zinc could not be reduced to metal except in the presence of copper' (ref. 4, p. 403).

Metallic zinc was first brought to Europe by the Portuguese from the East. Some time before 1640, probably in 1620, the Dutch captured a Portuguese ship, from Malacca, laden with zinc which they sold as *speautre* (ref. 6, p. 97). In 1690, the British chemist Robert Boyle (1627–1691), who mentions Indian tin, Latinized the Dutch name to speltrum which in turn gave rise to spelter, the common term used to denote the ordinary commercial ingot zinc. India and China exported zinc to Europe in the 17th and 18th centuries, with bulk of supply coming from China rather than India[7].

In 1738, an English patent for the extraction of pure zinc (tontonage) through distillation was granted to William Champion (1709–1789), who set up his works in 1743 at Bristol. While the original patent application was deliberately worded in obscure language, we learn about the details from the unsuccessful petition he filed in 1750 before the House of Commons for renewal of the patent[8]. Even though Champion claimed that he had 'pursued his experiments for six years at great expense', 18th century European scholars, relying on personal accounts rather than written records, consistently maintained that the intelligence was brought into England from the East, although the accounts cannot agree whether the source was India or China. The Swedish professor Torbern Bergman wrote in 1780 that 'It is not known how zinc is extracted in China. A certain Englishman, who several years ago took a voyage to that country for the purpose of learning the art, returned safely home, indeed, and appears to have been sufficiently instructed in the secret, but he carefully concealed it'[9]. In 1786, Bishop Richard Watson in his *Chemical Essays* identified the Englishman as Isaac Lawson. In 1797 the German professor Johann Beckmann (ref. 6, p. 91), who coined the term 'technology', wrote that 'It is possible that this semimetal was discovered in India', adding that an Englishman 'went to India, in order to discover the process'. Curiously, for this he quotes Bergman's Latin text even though it explicitly says China (and not India). Since Beckmann's reference to India is in context, it is unlikely that he made an inadvertent error. It would seem that he was correcting what he thought was a mistake in the original source, that is, Bergman, without saying so. The name of the travelling Englishman, his destination, and the circumstances of transfer of knowhow would have been known at the time, but were not placed on record. This is not surprising. England could not at the same time declare Champion to be an inventor and document prior knowledge about it elsewhere.

Enquiry into colonial antecedents of European technological developments is a recent phenomenon. In the 18th and 19th centuries such a question would not even have arisen. In the absence of any authentic contemporaneous records, the debate on origins can only be repetitive, inconclusive and influenced by personal predilections. It is known that Champion did not travel to the East. Cocks and Walters[10] in their 1968 book on zinc smelting claim that his method was 'totally different' from 'that practised in China'. 'Totally different' is an exaggeration because all zinc-smelting methods were based on the principle of distillation. Curiously, the authors do not consider the possibility of the Indian connection. Joan Day[11], who has extensively studied Bristol brass industry, concluded that a comparison of Champion's and Indian methods 'strongly suggests' that the former was a 'derivation'.

Zinc connection between China and England has received the attention of Chinese scholars also. In a recent paper, Chen[5] (p. 88) asks 'whether the English invention originated from the Chinese method or was entirely re-designed'. Her considered answer is that technological exchange did not take place and the legend about an Englishman visiting China for the purpose was an exercise in exoticism. For some reason, she does not consider the possibility that India rather than China might have been the source.

Both Indian and Chinese methods were based on zinc distillation, 'per descensum' in the former case and 'ascensum' in the latter. Zhou *et al.*[12] choose to call the two principles 'fundamentally different', implying impendent origin. This is ingenuous. Basic ideas travel; details vary. There is incontrovertible evidence that zinc distillation was first carried out in India. Available evidence suggests that the basic idea was carried from India to China, and later from India to Europe.

More than a century previously, in 1608, the Dutch optician Hans Lipperhey (or Lippershey), was denied patent on telescope on the ground 'that it is evident that several others have knowledge of the invention'[13]. In case of zinc, however, it did not quite matter that the metallurgy was already known in the East. In a Euro-centric world, what was new for Europe did not exist before. What should have been the Zawar process is now the Bristol process.

Crucible steel

The English clock maker Benjamin Huntsman (1704–1776), based near Sheffield, introduced crucible steel in about 1740. He did not patent the process, but unsuccessfully tried to keep it a secret to protect his business interests. At last, in about 1750, the secret was stolen by a rival manufacturer Walker, who disguised as a tramp appeared shivering at the door of Huntsman's foundry, took permission to warm himself by the furnace and stealthily familiarized himself with the details of the process while pretending to be asleep[14].

Samples of Indian crucible steel, the wootz, arrived in England in the early 1790s (presumably in 1794). The sender was a Scottish surgeon Helenus Scott[15] (c. 1757–1821) who joined Bombay medical service in January 1783, became a member of the medical board, rose to become its president, and retired to London in 1810. He sent the samples to the President of the Royal Society Joseph Banks (1743–1820), who immediately ordered their investigation.

The samples would have been in the form of steel cakes, each about 5 inches in diameter and 1 inch thick. Wootz was tougher than any steel Europe was making at the time. Europe's interest in wootz was understandable because swords made from it had been used against the Christian Crusaders. Banks passed on a small amount of Indian steel to the London physician George Pearson (1751–1828) and the rest to James Stodart (1789–1873), maker of surgical instruments and cutlery.

Pearson tested the sample and presented his results before the Royal Society in 1795. This publication introduced the term 'wootz' to Europe at large[16]. Wootz is obviously an anglicization of an Indian term. It was stated as early as 1839 that the term comes from the Gujarati wuz[17]. Alternatively, it has been suggested that the root word is South Indian linguistic term 'ukku' (or its equivalents)[18]. The Gujarati origin sounds more plausible because in the 1790s, a British official located in Bombay was more likely to hear Gujarati than Tamil or Telugu. In either case the original term means steel, so that an expression like 'wootz steel' would be tautological.

Stodart first forged a wootz penknife blade which 'proved excellent, and fully justified and encouraged further trials'[19]. It would seem that three wootz blades were made in all which were presented to King George III, De la Place in Paris, and Thomas Frankland (ref. 18, p. 662). Stodart's 'first attempts to forge Indian Steel were attended with considerable difficulty, owing, in some measure, to the unmanageable shape in which it was imported, and to its want of homogeneousness'[20]. It is surmised that the feedback was passed on to Scott in Bombay, because we find him sending, in 1796, another consignment, of 183 lb, to Banks and [Sir] Alexander Johnson[21].

Five wootz cakes were now placed in the hands of the Scottish metallurgist David Mushet (1772–1847) for forging and investigation, who published his results in 1805. Frankland was so enamoured of wootz that he sealed his letters to Mushet 'with the Sanscrit characters denoting wootz, in full and prominent display' (ref. 18, pp. 662–663). From the steel which he forged out of wootz cakes, Mushet made several razors which along with the remainder of the bars were forwarded to Banks for inspection and circulation (ref. 18, p. 663).

Wootz obviously commanded high premium in English circles. One of Stodart's trade cards, dated about 1820, carried the rather long inscription 'Surgeon's Instruments, Razors and other Cutlery made from Wootz, a steel from India, preferred by Stodart to the best steel in Europe after years of comparative trial'[22]. In 1819, Stodart roped in the young chemical assistant at the Royal Institution, Michael Faraday (1771–1867) 'to make an experiment, with a view to imitating Wootz'. Indeed one of the earliest successes reported in a paper presented to the Royal Institution in 1820 was the preparation of a specimen which had 'all the appreciable characteristics of the best Bombay Wootz' (ref. 23, pp. 225–226). Faraday wrongly concluded that the strength of the wootz came from aluminium. It however was a fruitful error[23], because it gave birth to the new discipline of alloy steels. General and scientific interest in wootz persisted in Europe throughout the 19th century. In 1870, the Berlin professor C. Rammelsberg examined a sample in the Royal Gewerbe Akademie collection, the genuineness of which was guaranteed by a certificate from the East India Company, and compared his results with those of other researchers, including Faraday[24]. The subject can be said to have been neatly wrapped only in 1901, by Cecil Ritter von Schwartz[25].

A wootz sample by itself could not have revealed how it was made. This information which could only come from observing men at work in India, was provided by Francis Buchanan in 1807 and Benjamin Heyne in 1814. Next came the synthesis of European and South Indian steel technologies brought about by a European who spent three decades in India as a Company servant and entrepreneur, and returned home as an inventor. Josiah Marshall Heath (1791–1851) was educated at Haileybury College as a Company cadet, and appointed a civil servant in Madras in 1808. A casual request changed the course of Heath's life as well as steel manufacture. A friend stationed in North India asked Heath to send him 'some steel balls for boar spears'. To comply with this request, Heath 'was compelled to pay some visits to the Indian steel-workers'. He found that 'the capabilities of Southern India for the manufacture of iron and steel were extraordinary'. 'It became clear to him that India might supply the best and the cheapest steel iron for England and Europe.' He resigned his job in 1825, and went on to spend all his private fortune, 'and the produce of the retiring pension', in traversing the whole south-western coast of India; in visiting all the most celebrated mines and works in Sweden, in acquiring a familiar acquaintance with the processes of iron and steel manufacture; in verifying old, and in prosecuting new experiments'[26]. In 1833 Heath established a joint stock company called the Indian Iron and Steel Company, which in turn ran iron works at Porto Novo, in South Arcot district, which stood some 200 km south of Madras on the mouth of River Vellar. Frederick Adam, Madras Governor during 1832–1837, assisted the company with four lakh rupees, and private individuals came forward with a like amount. In addition, the Government granted leases of lands in the districts of Salem, Coimbatore, South Arcot, Malabar and Canara[27]. Heath left India for England in November 1837. Before following him to England, we shall briefly notice how his company fared.

Heath's company exported some pig iron to England for conversion into steel. A large quantity of it was used in the construction of Britannia tubular bridge linking the mainland of Wales with the island of Anglesey across Menai Straits. In 1851, the company displayed cast-steel buttons, about 2½ inches in diameter, 'this material being the Wootz , so celebrated in India for the preparation of Damascus blades. There is nothing to show directly in what way they have been prepared, but it is impossible to doubt from their form that they have been obtained in small crucibles'. The company won a prize medal for 'Wootz Steel and Manufacture'[28]. The company however was in deep debt and its glory short-lived. In 1852, a visitor described the Porto Novo works thus: 'the engine had been removed; the houses fallen down; the pits partially filled up with the earth carried into them by the rains; and, with the exception of the engine chimney – which stands alone as a monument – the whole place is a melancholy ruin'[29]. Introduction of railway revived hopes, but not the firm. A new company, East-Indian Iron Company, acquired the assets of the previous company for £30,000. For a number of reasons the company failed to recover, and was liquidated in 1874 (ref. 30).

Even though the Royal Asiatic Society of Great Britain and Ireland was primarily established to further Indological researches, it was sensitive to the country's broader economic interests. Accordingly, it set up a Committee on Agriculture and Commerce in 1836. In June 1837, the Society wrote to the Madras Governor asking for information on and specimens of wootz. The Governor passed on the letter to Heath, who replied to it on returning to England for good[31]. In his 1839 communication to the Society, Heath drew attention to two wootz-related British patents. David Mushet's patent, obtained in 1800, announced the 'discovery' that 'iron could be converted into cast steel by fusing it in a close vessel in contact with carbon' (ref. 17, p. 670). In 1825, Charles Mackintosh, better known as a patentee of the India rubber waterproof fabrics, took out a patent recommending the use of carbureted hydrogen gas in a closed vessel. Heath pointed out that both these patents were based on the Indian process (ref. 17, p. 671). He went on to do a similar thing. On 1 April 1839, Heath obtained a patent for the use of carburet of, or metallic, manganese in the steel-making process. This was immediately recognized as 'an invention of very great utility', as by its use cast steel of excellent quality could be produced from British iron. Such steel possessed the property of welding either to itself or to malleable iron. Heath however was unable to draw any financial benefit from his patent, because of its imperfect wording (ref. 26, pp. 230–232). The British inventor Henry Bessemer[32] (1813–1898), who introduced steel manufacture using oxygen rather than fuel, wrote in his autobiography that Heath conceived the idea of his 'invention' from 'noticing in the native Wootz steel-making of India the marvellous effect of manganese'.

To sum up, traditionally the quality of European steel had depended on the quality of the iron ore available. The Indian wootz process made it possible to produce high quality steel using even ordinary ore. Scientific investigations into wootz samples obtained from India began in early 19th century and resulted in three patents during 1800–1840. But there was a genuine scientific advancement too. Laboratory analysis of wootz led to the establishment of the new research field of alloy steel.

Not all leads were productive; there were dead-ends as well. In the early 19th century, 'A lady brought from India a work-box that had been varnished: the varnish looked particularly clear, and had borne the heat of the climate without cracking or changing colour. Some distinguished artists saw it, and admired its peculiar beauty. The lady contacted the Rajah from whom she had originally procured it, and he remitted her an hamper full of stone bottles, containing the varnish, informing her that it was employed in all his ornamental work, and that it was used just as it was extracted from the tree from which it was procured, by incision. The Rajah, however, did not send the name of the tree. Henry Bellenden Ker (1787–1871), barrister and legal reformer and Fellow of the Royal Society, sent the resin to John Frederick Daniell (1790–1845) FRS, chemist, inventor and the first professor of chemistry at King's College London. Daniell in turn subjected the resin to rigorous tests in his laboratory and published his findings in a scientific journal in 1818. His conclusion: 'There can be little doubt but that if this resin can be obtained in sufficient quantity, that it may become a very valuable acquisition to the arts'[33]. There was obviously no follow-up in this case. But his report was considered significant enough to be reproduced in various journals.

Mysore rocketry

In the closing decades of the 18th century, the British forces in South India were at the receiving end of war technology in the hands of the armies of Hyder Ali, the de facto ruler of Mysore, and later his son Tipu who declared himself to be the Sultan. The Mysore rockets were superior to any the British had known or seen. These rockets used tubes made of cast iron rather than of bamboo or paste board, and had a range of 1–2 miles[34]. They helped Mysore score a decisive victory against the Company forces in 1780 at the Battle of Pollilur. Europe at large became aware of Mysore rockets through a 1789 publication by Captain Innes Munro, entitled *A Narrative of the Military Operations of the Coromandel Coast*, which focused on the wars between 1780 and 1784.

During the fourth Anglo-Mysore War, on the night of 5 April 1799, Colonel Arthur Wellesley led a small column to clear the approaches to Seringapatam. At Sultanpet [Sultaunpet, Sultanpettah in colonial records] the column was greeted with such ferocious rocket attack that it had to disperse, with Wellesley himself narrowly escaping being captured. The incident would haunt the future Duke of Wellington forever[35], but did not alter the outcome of the War.

After the annihilation of Tipu, several rockets were sent to the royal arsenal in England for examination by William Congreve who, thus propelled, developed what came to be known as Congreve rockets. With the Mysore feature of metal casing incorporated into them, these rockets turned out to be effective in the Napoleonic wars as well as in the related war against USA in 1812.

As a mild digression, we may note colonial Indian connection in the composition of the American national anthem. It was the display of Congreve rockets that Francis Scott Key (1780–1843) saw on the night of 13–14 September 1814 that inspired him to write the first draft. It is believed that he was at the time under arrest on a 74-gun line-of-war ship HMS *Minden* built in 1810 in Bombay by the Wadia shipbuilders for the British Navy[36].

The use of rocketry may have given Mysore a short respite from the British, but the experience benefited the British in the long run in the sense that introduction to new war technology helped them tilt the European balance of power in their own favour.

During the era of European maritime trade and colonial expansion, empirical technologies developed in the East over centuries were taken to Europe, examined and incorporated into the scientific mainstream. At the time, there was no question of acknowledging the source. It is, however, instructive to see how technologies were transferred and appropriated.

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