Managing Technological Change: The Case of Iron and Steel Manufacturing in India

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Abstract

Iron and steel making in India is a history of more than 125 years. For an overall growth of Indian economy, which is emerging as a prominent Rapidly Industrialised Country (RIC), managing the technological change in iron and steel making is very much essential, particularly in the wake of ongoing economic liberalization since 1991. While India has a large deposit of iron ore, a low-cost labour force, a highly-qualified technical manpower, and a geographically advantageous location in South Asia, it could not manage the technological change effectively. It was not able to generate the desired thrust to become technologically competitive in the global scenario. The paper critically analyses the reasons why India could not cope with the technological change satisfactorily in the field of iron and steel making. The study has been concentrated on the period after India acquired independence in 1947. It highlights how various factors like the governmental control, licensing policies, pricing policies, export-import policies affected the growth. It examines the limitations of adopting advanced iron and steel manufacturing technology in India. It also discusses the impact of socio-economic conditions of India on the technological advancement in this field. Suggestions are also given as to how the Indian iron and steel manufacturing industry can be rejuvenated for the country's growth during the economic reform process.

Keywords: Industrial innovation, Technological change, Manufacturing systems, India

Introduction

Steel is an important item symbolizing the growth and prosperity of a nation. The steel industry is technology driven. Management of technology has a profound influence on the prosperity of steel industry. For an overall growth of India, which is emerging as a prominent Rapidly Industrialized Country (RIC), managing the technological change in iron and steel making is very essential, particularly in the wake of ongoing economic liberalisation. The economic reform process, which started in 1991, have added new dimensions to the industrial growth in general, and steel industry in particular. Today, some of the top steel producing nations are developing countries. China is now the largest steel producing country in the world. India's position is tenth [Wilhelm 1998, Steel Scenario Yearbook 1998]. A recent survey shows three steel producers from India in the list of top hundred steel manufacturers – one in 12th position and the other two after 50th in the list [The Economic Times Calcutta 1999, March 15,]. While India has a large deposit of iron ore, a low-cost labour force, a highly qualified technical manpower, and a geographically advantageous location in South Asia, it could not generate the desired thrust to bring the technological changes.

The paper critically analyses the reasons why India was not able to cope with the technological changes satisfactorily in the field of iron and steel making. The study has been concentrated on the period after India acquired independence in 1947 from British colonial rule. The paper highlights how various factors affected the growth of the steel sector. It discusses the limitations in adopting the advances in iron and steel manufacturing technology in India. It also examines the impact of socio-economic aspects of India on the technological advancement in this field. Suggestions are given as to how the Indian steel industry can be rejuvenated for the country's growth during the ongoing economic reform process.

A Brief Pre-history

A brief pre-history of iron and steel making in India will provide a good linkage. The iron and steel making in India dates back 480 BC when Indian archers used arrows tipped with Indian steel. Iron pillar of Dhar near Indore in the State of Madhya Pradesh (about 321 AD), iron pillar of Kutab Minar near Delhi (about 400 AD), iron beams of Sun temple of Konark in Orissa (13^{th} century AD) are some of the examples of ancient India. A suspension bridge in Kashmir used iron manufactured in the state of Madhya Pradesh in 1830. Bengal Iron works at Kulti near Asansol in the state of West Bengal, which was subsequently renamed as Bengal Iron and Steel Company after change-over of hands, used to produce iron during 1874-1889. A significant milestone in the history of iron and steel making in India was the start-up of the Tata Iron and Steel Company at Jamshedpur in the state of Bihar in 1907. The other prominent steel manufacturers during pre-independence period are – Indian Iron and Steel Company (1922), Mysore Iron and Steel Works (1923), and Steel Corporation of Bengal (1937).

Evolution and Growth of Iron and Steel Making Technology in India

India has abundance of iron ore, many other raw materials for iron making, and cheap labour. It has the fourth largest iron ore reserves (10.3 billion tonnes) after Russia, Brazil, and Australia [Nakra 1996]. It has the third largest pool of technical manpower next to United States and erstwhile USSR. In spite of these advantages, it could not adopt the advancement of technology satisfactorily. After independence in 1947, five major integrated steel plants were set up under public sector during late '50s and early '60s. The total saleable steel production, which was only 0.9 million ton per annum (mtpa) in 1947, raised to nearly 19 mtpa in 1997-98 [Centre for Monitoring Indian Economy 1999, Steel Scenario Yearbook 1998].

Comparison of Steel Production Processes in India and Other Countries

The method of manufacturing steel gradually improved through the Bessemer Process, Open Hearth Process, Electric Arc Process (EAP), and finally Basic Oxygen Process (BOP). BOP, also known as Linz Donawitz (LD) Process, emerged in '50s and gained rapidly in the '60s and '70s due to its superiority in producing quality steel with less environmental pollution [Ray 1984]. The crude steel production of major steel producing countries in the world in 1998 using different processes is shown in Table 1. In 1998, 60% of steel produced in the world was by BOP.

Country	Production (Million Tonnes)	Basic Oxygen %	Electric Arc %	Open Hearth %	Others %	Total %
PR China	114.3	61.2	20.1	4.9	13.8	100.0
United States	97.7	55.4	44.6	0	0	100.0
Japan	93.5	68.1	31.9	0	0	100.0
Former USSR Countries	74.4	54.4	12.3	33.3	0	100.0
FR Germany	44.0	72.5	27.5	0	0	100.0
Republic of Korea	39.9	59.7	40.3	0	0	100.0
Brazil	25.8	79.2	19.3	0	1.4	100.0
India	23.5	53.9	31.8	14.3	0	100.0
Mexico	14.2	35.0	65.0	0	0	100.0
Egypt	2.9	48.1	51.9	0	0	100.0
World	774.4	59.4	33.9	4.6	2.1	100.0

Table 1: Crude Steel Production by Process in 1998
Source: International Iron and Steel Institution (1998)

India adopted the Basic Oxygen Process as early as 1956 to 1960. The chronology of adoption of BOP in India is as the following: Rourkela Steel Plant (1956 to 1960), Bokaro Steel Plant (1975 to 1978), Tata Iron and Steel Company Limited and Bhilai Steel Plant (1982 to 1985), Vizag Steel Plant (1989-90) and Durgapur Steel Plant (1991-). India's use of BOP is 54%, and it is comparable to many leading steel manufacturers in the world like United States and Republic of Korea. It is better than Mexico and Egypt. However, 14% steel is still produced using the obsolete Open Hearth Process in India. This has reduced the overall competitiveness of Indian steel manufactures in the global platform. Out of the major steel producers in the world, only erstwhile USSR countries still use Open Hearth furnaces for making 33% of its total production, followed by India (14.3%) and Peoples Republic of China (4.9%). As regards the use of Electric Arc Process, which is 32%, India is placed somewhere in the middle.

Structure of the Indian Steel Industry

Table 2 portrays the present structure of the Indian steel industry. While all 9 integrated steel plants are operating at their total capacity, only 67 Electric Arc Furnaces are working out of 184 and these are operating at 60% of their total capacity. Though EAP has lower capital costs, greater production flexibility, lower environmental impact, and more efficient small-scale operations, some of the important reasons for the reduction in the use of EAP are:

- The requirement of high quality scrap and its vulnerability to rising prices have become constraints in using EAP.
- The quality of steel produced using BOP can attain much higher quality at reduced cost as compared to EAP route.
- Many large manufacturers now-a-days are producing special steel items, where many of those items were being produced earlier by smaller units. Large units get the advantage of economy of scale.

- The high cost of electrical power is also a reason for switching over to the other processes from EAP.
- Due to upgradation of technology from EAP to BOP, many of the Electric Arc Furnaces became idle.
- Because of the government policies of reserving the development of new integrated steel plants to the public sector, many EAP-based smaller units were closed down.

(Capacity: Million Tonnes)

Sector	Type of producers	No. of units	No. of working units	Total capacity	Working capacity
Primary	Integrated plants	9	9	17.73	17.73
	Electric arc furnace	184	67	10.46	6.28
Secondary	Induction furnace	923	733	9.31	8.19
	Pig iron units	15	15	2.70	2.70
	Sponge iron units	21	21	6.01	6.01
	Re-rolling units	1703	1204	27.44	22.81
	HR units	10	9	3.02	3.01
	CR units	70	57	2.73	2.67
	GP/GC units	15	12	1.00	0.82

Table 2: Structure of the Indian Steel Industry
Source: Iron and Steel Review (1998)

Technology Transfer, Technology Adaptation, and Innovation

Developing countries cannot always afford to develop their own technologies. They need to import many technologies from developed nations [De 1999]. Since late ‘50s, large number of steel producers in India went for technical collaborations with the world majors. Many public sector steel plants were built with collaboration from countries like United Kingdom, Germany and erstwhile USSR. In earlier years, many of these plants faced problems in their collaboration projects. Due to elements of secrecy and other reasons, India had to deviate from what considered suitable by the countries aiding the project. As for example, Indian Iron and Steel Company (collaboration with British, Soviet and Japanese firms), Rourkela (collaboration with West Germany), and Bokaro (collaboration with Russia) had many teething problems during execution of the projects [Krishnamurthy 1987]. With the gradual adoption of technology for iron and steel making by Indian companies, these bottlenecks have reduced. Most of the state-owned plants and some private ones have gone for large capital-intensive modernisation programmes, mostly with foreign collaborations.

Techno-economic Parameters

The performance in terms of techno-economic parameters of iron and steel industry in India and some selected countries are shown in Table 3. The figures reflect poor productivity at different stages of the production process. The low level of most of the parameters for India indicates that the technology needs substantial updating. Though the Indian steel industry is using the superior BOP method for long years, its adoption has not become appropriate.

Techno-economic parameters	Indian	International
Sinter plant ($t/m^2/hr$)	0.07 to 1.20	1.5 to 1.8
Blast furnace ($t/m^3/day$)	0.46 to 1.54	2.2 to 2.8
BOF lining life (no. of heats)	120 to 470	800 to 3000
Continuous casting (metre/minute)	0.6 to 1.0	1.5 to 2.0
Rolling mills:		
Hot strip mills		
- Capacity utilisation	64 to 66	80 to 85
- Yield from slab (%)	95.5 to 96.9	98.5
Cold rolling mills		
- Tandem mill utilisation (%)	48 to 50	75 to 80
- Tandem mill yield	98.0 to 98.6	99.5
Energy consumption (Gcal/tcs)	8 to 13	4 to 6

Table 3: Techno-Economic Parameters: India and Some Selected Countries
Source: Iron and Steel Review (1998).

A specific example of the techno-economic parameters of Electric Arc Furnaces (EAF) in India and some selected countries are given in Table 4. The data show that the technology practices in making steel in India requires substantial improvements. Even for new plants in India, the electrical power consumption is higher than many other countries. New plants in India consume an average of 450-575 kWh/tonne of billet in EAF, whereas the figures for Japan, Germany and USA are 378, 410, and 430 respectively. Heating time is more as compared to that of all the six countries mentioned in the table. The furnace size used in India is also relatively small as compared to other countries.

Country	Power consumption kWh/tonne of billet	Heating time (Minutes)	Furnace size
Japan	378	71	80
Germany	410	60	60
USA	430	80	160
Italy	460	55	66
Switzerland	530	75	85
Argentina	460	73	40 to 45
India:			
Old plants	670	180	20 to 25
New Plants	450-575	85	50 to 55

Table 4: EAF's Techno-Economic Parameters: India and Some Selected Countries
Source: Iron and Steel Review (1998).

Cost Competitiveness of Indian Steel Industry

The cost competitiveness of Indian steel industry can be seen in Table 5. The cost of major raw materials like iron ore, coking coal, and other raw materials is less in India among the countries mentioned. The labour cost is low, but it is neutralised by its low level of productivity. The financial cost, and the cost of power, oil and some other materials are high. Energy accounts for about 35 to 40% of the cost of steel production in India, whereas it is about 28% in the developed countries [Ahmad and Dhillon 1991]. All these make the pre-tax cost of steelmaking in India higher than that of South Korea, Australia, Mexico, and CIS countries. Considering the low wage rate and other economic factors, the labour cost in India makes up around 15% of the cost of the steel as compared to around 30% in many developed countries like Japan and United States. In spite of these advantages Indian firms could not become cost-effective.

(As on March, 1998), Unit US$

Country	Major materials	Other materials	Labour costs	Total opr. Costs	Financial costs	Pre-Tax costs
CIS	117	138	39	294	37	331
S. Korea	113	109	51	273	62	335
Australia	99	142	120	361	42	403
Mexico	108	180	62	350	57	407
India (SAIL*)	111	170	62	343	70	412
U.K.	120	148	114	382	38	420
P.R. China	179	112	90	381	40	421
Brazil	132	122	112	366	75	441
Taiwan	121	154	102	377	81	458
Germany	131	143	153	427	40	467
France	125	132	150	407	62	469
Canada	136	166	121	423	48	471
Japan	118	134	147	399	75	474
USA	133	166	148	447	36	483

- SAIL: Steel Authority of India Limited. This consists of 5 major integrated steel plants in India with 43 % of India's crude steel production in 1997-98.

Table 5: Cost Competitiveness of Indian Steel Industry
Source: Iron and Steel Review (1998).

Impact of Liberalisation

The economic reforms initiated by the government in 1991 have added new dimensions to the industrial growth in general, and steel industry in particular. Some of the important features due to liberalisation are:

- Licensing requirement for capacity creation has been abolished.
- Steel industry has been removed from the list of industries reserved for the state sector.

- Automatic approval granted for foreign equity investment in steel has been increased up to 74% [Government of India 1999].
- Price and distribution controls were removed from January 1992 [Report to the Ministry of Industry, Science and Tourism 1997].
- Restrictions on external trade, both in import and export, have been removed.
- Import tariff reduced from 105% in 1992/93, to 30% in 1996-97. [Report to the Ministry of Industry, Science and Tourism 1997].
- Other policy measures like convertibility of rupee on trade account, permission to mobilise resources from overseas financial markets, and rationalisation of existing tax structure.

There was expansion of the steel sector after the economic reforms. The new entrants as well as the existing manufacturers went for technical tie-ups with leading steel producers of the world [Nakra 1996].

Factors Affecting Technological Growth of Steel Sector in India

Various factors that influence the technological growth of steel sector in India are mentioned below:

- For four decades since independence, the steel industry in India grew in protected and controlled environment with administrative control over prices, distribution and allocation of imports resources, and high tariffs [Government of India 1999]. In one respect, the productivity levels of state-owned large integrated steel plants remained low, and on the other hand private sector firms were deprived of many of the opportunities to grow.
- Due to inadequate growth of infrastructure sectors, the overall demand of steel remained low. As for example, in 1996 the per capita consumption of steel in India is only 24.1 kg as compared to 603.4 kg, 384.3 kg, and 400 kg in Japan, Italy, and United States respectively. [Steel Scenario Yearbook 1998]. Import of certain types of steel products due to liberalisation has further reduced the demand of in-house steel products.
- Technology policy of India has major impact on steel industry. India took a long time to develop its first technology policy in 1958. It lacked direction during the early formative years after independence. The next notable technology policy came only in 1983 after a gap of 25 years. The technology policy of India could not generate the desired thrust for a sustainable technological growth [De 1998a].
- The low level of R&D expenditure by steel manufacturers in India has impact on the technological growth of steel sector. Indian companies put less emphasis on R&D expenditure. Except a very few companies, the overall focus on R&D is too low. As for example, in 1997-98, companies like Tata Steel and Reliance spent only 0.14% and 0.29% of their sales value respectively on R&D. Out of large Indian companies only just a few spent a good amount (e.g., Ranbaxy 3.88%, TELCO 2.03%) in 1997-98 [The Economic Times Calcutta 1999, August 10]**.** The in-house research facilities in most of the large integrated steel plants are not properly organised. Many of them started their R&D activities late.
- Technology transfer did not take place properly. De [1999], Desai [1988] and Altekar [1975] highlighted the problems of technology transfer in India. Some of the major problems are: inadequacy of knowledge and skill to exploit the results and lack of confidence in the

successful exploitation of the projects on commercial basis. Bureaucratic efficiency, controls of royalty, inadequate price of technology, import restrictions are some of the major impediments considered serious by the technology suppliers [Desai 1998].

- Impact of poor infrastructure like high cost of electrical power, poor reliability of the availability of electrical power, inadequate transport facilities, less-developed logistic network decelerated the growth of steel industry [Imagawa 1999].
- Developing economy like India faced problems of building local technological capabilities. Due to this, the local manufacturing industry was not able to provide adequate technological support to steel sector. The steel manufacturers had to import many of their equipment besides technology.
- Cumbersome procedures to comply with the series of statuary requirements, and the corresponding poor efficiency of administrative machinery retarded the growth of steel industry [Imagawa 1999].
- Technological forecasting has not been done properly.
- Technical aspects like high alumina content in raw materials, adverse alumina to silica ratio in iron ore, and high content of ash in coal increased the cost of production.
- In many cases, particularly for medium and smaller size steel producers, initial high cost of adoption of newer technologies is also a major barrier to their technology adoption.

Impact of Socio-economic Aspects

Socio-economic aspects of India have influenced the technological growth of the country in general [De 1998b]. India has a good technology base and developed a high level of competency in the areas of information technology, atomic energy, and space sciences. Due to its poor socio-economic background, the country has to expend a lot of its efforts into meeting the pressing needs in providing food and shelter to its excessively large population.

Organisational adjustments for managing the technological change did not happen satisfactorily in most of the steel plants except in some private sector units. Like many other industrial sectors, steel industry also suffered from the "displacement effect of technology". A large number of steel plants, particularly the bigger ones, went for various voluntary retirement schemes to downsize the manpower. Low level of literacy affected the speed of implementation of new technology projects in most of the industrial sectors including steel industry. Though India started well with its liberalisation scheme, the recent political instability for last few years is delaying the technological transformation process in all sectors of industry. Training facilities in most of the steel majors are inadequate. In many cases, the training inputs are not satisfactory. The incremental learning as well as the overall impact due to the training programmes are less.

Suggestions

The following suggestions are given to rejuvenate the Indian steel industry technologically:

- Technology policy is to be so designed by the government that it will generate the thrust to update the technology by the steel producers.
- Further liberalisation towards tariff structure, full convertibility of Indian currency, more equity participation by foreign partners, rationalisation of tax structure etc. will be required.

- Steel companies must assess their core competency and realign their strategy to cope with the internal and global competition.
- R&D focus is to be increased substantially. Expenditure on R&D by steel plants should be increased. With a strong R&D base, organisations will be able to assimilate the technology faster.
- Organisational adjustments must be made while adopting newer technologies. Effective human resource policy will help speedier technology adoption. Socio-economic aspects should be dovetailed while selecting a technology.
- Training and re-training with updated inputs should be a continuous process in steel plants. Training programmes should be designed for people from different hierarchy including top level management.
- As economy is becoming more and more market-driven, steel sector should also tune to it.
- Technology transfer plans are to be worked out more carefully. Indian firms must select appropriate technology with proper scope of adoption.
- Firms must do technological forecasting, which is not common in Indian steel industry, to take better decisions on product mix and investment proposals.
- Resource utilisation must be more effective to improve on the productivity.

Conclusions

The paper critically analyses the reasons why India could not cope with the technological change satisfactorily in the field of iron and steel making. While India's adoption of sophisticated steel making technology was almost at the same time with many developed and rapidly industrialised countries (RICs), it could not achieve the full benefits due to improper assimilation. In spite of abundance of iron ore and many other raw materials, and availability of cheap labour and a large pool of technically qualified people, productivity of Indian steel industry remained low. Protectionism and administrative control over prices and distribution, till India embarked on a liberalised economic reform process in 1991, steel industry was not able to grow. Inadequate technology policy, less emphasis on R&D, government bureaucracy and poor socio-economic background are some of the important reasons for which the Indian steel industry could not attain technological advancement in this field. With adequate ore and other raw materials, a good technology base, and a well-framed technology policy, India has a very good potential to become highly competitive in iron and steel making in the global scenario.

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