POSITION PAPER ON
"DEVELOPMENT OF IRON ORE PELLELISATION INDUSTRY IN INDIA"

CENTRE FOR TECHNO-ECONOMIC MINERAL POLICY OPTIONS (C-TEMPO)

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ABOUT US

The Centre for Techno Economic Mineral policy Options (C-TEMPO) has been set up under the aegis of Ministry of Mines, as a think tank to evolve policy options and help address the technology and management gap for non-ferrous minerals.

The objective of C-TEMPO is primarily to prepare and present attributable and non-binding techno-economic advice on various issues related to the mineral and mining sector. The aim of the Centre is to facilitate effective interaction between the investors, entrepreneurs, mining industry and the Central and State Governments and evolve policy options for stakeholders of the mineral sector.

In the centre, a data bank of countries of interest in respect of their geology, mineral resources, export potential, technology etc. is being developed in coordination with Indian Mission abroad of the respective countries. This information will be leveraged to meet the growing demand of minerals in India to sustain the GDP and also from the view of strategic planning.

The Centre is also preparing and presenting Position Papers and studies on various techno-economic issues for the consideration of the Government, industry and other stake holders. It also undertakes networking with Industry and Government for coordinated research in the mineral sector.

PREFACE

Steel Industry in India is on an upswing because of the strong global and domestic demand. India's rapid economic growth and soaring demand by sectors like infrastructure, real estate and automobiles, at home and abroad, has put Indian steel industry on the global map. According to the latest report by International Iron and Steel Institute (IISI), India is the seventh largest steel producer in the world.

The current status of iron ore and its future prospects have direct relationship mainly with steel production in India. The total iron ore resources in India are approximately 25,249 Million tonnes (out of which Hematite constitutes 14,630 MT and Magnetite constitutes 10,619 MT).

Out of the total production, 56% of iron ore production comes out as fines and 44% as boulders which have to be sized to 10-30 mm for blast furnaces and 6-18 mm for sponge iron plants. Iron ore in a finely ground state is not easily transported or readily processed .Thus it is necessary to agglomerate the fine ground ore into pellet using binders. The use of pellets increases the productivity in blast furnace and reduces coke consumption. There is need to focuses on the development of pelletisation activities for the beneficiation of Indian steel Industry.

The present position paper has been developed based on the contributions made by Dr. A.K. Kashiba, Former industrial advisor (Ministry of Steel) and valuable inputs from Dr. A.K. Mukherjee, Scientist (Tata Steel).

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DEVELOPMENT OF IRON ORE PELLETISATION INDUSTRY IN INDIA

INTRODUCTION:

The national steel policy aims at 110 million tonnes (Mts) finished steel by the year 2019-2020, around 170 Mts of quality iron ore (+63% Fe) is required. Besides that around 100 Mts of quality lump ore is required to meet the export commitments. All together, 270 Mts of calibrated lump and fines are required which corresponds to mining of around 400 Mts of run-off-mine (rom) iron ore every year. At this rate of mining, the proven reserve may last 32-35 years. It is for this reason the national steel policy envisages investment in modern mining and beneficiation methods for value addition and utilization of iron ore fines. In order to increase the resource base the option available are either to find the new resources or to use the existing resources judiciously. While the former option in all likelihood will be taken in its own stride, the latter option calls for detailed scientific characterization and advanced process synthesis for the utilization of iron ore within the framework of zero waste processing. This will also involve development of alternative mineral processing technologies for iron ore beneficiation such as magnetic carrier technology, solid liquid fluidization, hybrid separation techniques, etc and also development of agglomeration processes like sintering & pelletisation.

This note focuses on the need of development of pelletisation activities. **Pellets** are approximately spherical lumps formed by agglomeration of the crushed iron ore fines in presence of moisture and binder, on subsequent induration at 1300°C.

Low grade iron ore, iron ore fines and iron ore tailings/slimes accumulated over the years at mine heads and generated during the existing washing processes, need to be beneficiated to provide concentrates of required quality to the Indian steel plants. However, these concentrates are too fine in size to be used directly in the existing iron making processes. For utilizing this fine concentrate, pelletization is the only alternative available.

ADVANTAGES OF PELLETS:

Iron ore pellet is a kind of agglomerated fines which has better tumbling index as compared to that of parent ore and can be used as a substitute for the same. Iron ore pellets are being used for long in blast furnaces in many countries where lump iron ore is not available. In India, the necessity of pelletisation is realized because of several reasons and advantages. The excessive fines generated from the iron ore mining and crushing units for sizing the feed for blast furnace and sponge iron ore plants are mostly un-utilized. Pelletisation Technology is the only route that is going to dominate the Indian steel industry in future. Pellets have;

- **Good Reducibility**:

  Because of their high porosity that is (25-30%), pellets are usually reduced considerably faster than hard burden sinter or hard natural ores/lump ores.

- **Good Bed Permeability**:

  Their spherical shapes and containing open pores, gives them good bed permeability. Low angle of repose however is a drawback for pellet and creates uneven binder distribution.

- **High uniform Porosity (25-30%):**

  Because of high uniform porosity of pellets, faster reduction and high metallization takes place.

- **Less heat consumption than sintering.**

  Approx. 35-40% less heat required than sintering.

- **Uniform chemical composition & very low LOI:**

  The chemical analysis is to a degree controllable in the concentration processing within limits dictated by economics. In reality no LOI makes them cost effective.

- **Easy handling and transportation.**

  Unlike Sinter, pellets have high strength and can be transported to long distances without fine generation. It has also good **resistance to disintegration.**

The other Advantages of using iron ore pellets are:

1. The rotary kiln can produce 25% more without any changes in the design.
2. Specific consumption of coal will come down by 10%.
3. Campaign life will increase to almost 60%.
4. Metallization will be better compared to lump ore.
5. Reduce the generation of fines to 5% in the finished product against 35 to 40%, when produced with lump ore.
6. There are no losses of handling iron ore, as pellets will not break during transport or handling.
7. Finally, we will have better environment to work.

INDIA'S PRODUCTION AND EXPORT OF IRON ORE:

Production from 2005-06 to 2009-10

(Value in Rs. Crores)

		2005-2006		2006-2007		2007-2008(R)		2008-2009(P)		2009-2010(E)	
Mineral	Unit	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value	Qty.	Value
Iron Ore	th. tonnes	165230	10803.88	187696	14204.31	213246	23379.04	215437	25150.52	226008	22654.30

Domestic demand-supply matrix in 2009-10

Demand*		***(in million tonnes)***
(i) Captive mines of SAIL and TISCO		32.12
(ii) Supply from non-captive stand alone mines:		
– RINL	5.13	
– Other major producers	21.41	
– Sponge iron units	33.18	
– Miscellaneous	10.00	69.72
		101.84 or 102 MT

****Note:*** *For producing 1 Tonne of crude steel/ sponge iron, 1.6 tonnes of iron ore consumption has been assumed.*

Supply

Production of iron ore	226
Mine-head stocks	73
(IBM Nagpur)	Total= 299

	Surplus
Demand-Supply matrix= 299-102	= 197.00
Exports	= 117.37
Surplus available (including stocks at mine- heads)	= 79.63

India's Export of iron ore during 2008-09:

S.No.	Commodity	Quantity (in thousand tones)	Value (in Rs. Crores)
1.	Non Agglomerated iron ore lumps(60% Fe and above)	5542.19	2038.63
2.	Non Agglomerated iron ore lumps(Below 60% Fe)	2801.59	562.33
3.	Non Agglomerated iron ore Fines (62% Fe and above)	29562.07	116979.71
4.	Non Agglomerated iron ore Fines (Below 62% Fe)	28894.23	6286.41

NEED TO MAXIMISE THE CONSUMPTION OF IRON ORE FINES:

About 56% of iron ore production comes out as fines and 44% as big boulders which have to be sized to:

10-30 mm. for blast furnaces
6-18 mm. for sponge iron plants

Net Result: In final analysis 65-70% of total iron ore productions lands as fines either after sizing or handling:

Lumps-	67.80 MT
Fines-	158.20 MT
	226.00 MT

Generation of fines is more in Goa and Karnataka where ore is friable. (ultimate ratio of lumps to fines in Goa and Karnataka may work out 20:80)

Fines Requirements

S.No.	Organization	Production capacity (MT)	Fines used after sintering/ pelletisation (%)	Plant designed to use pellet/ fines (%)
1	SAIL	15	72	
2	TISCO	7	70	
3	RINL	3.6	75	80
4	Essar steel	4.6	70	100
5	JSW	5.5	100	100
6	Ispat Industries	2.6	66	
	Total	38.3		

- SAIL and TISCO use fines produced from their captive mines.
- Total fines requirements of other plants do not exceed 30 MT.
- These plants procure fines from non-captive standalone mines, including NMDC.

Remarks:

From the above it may be seems that, fines produced/ generated are surplus and the domestic demand is not adequate.

STATUS OF IO PELLET INDUSTRY IN INDIA:

Pelletisation of agglomerated fines has taken a great stride recently in the Karnataka-Goa region. Thus Jindal-Vijaynagar steel plant is setting up a slime disposal facility in the Bellary district in Karnataka with an investment of 11.7 crores. VSP-NMDC has recently submitted a report on the pelletisation and slime beneficiation at Donnamali, Karnataka. Ministry of steel has proposed a feasibility report on the pelletisation plant in Goa. Janaki Corporation, a private organization is working on a feasibility report on the installation and pelletisation of 0.6 MTPY pellet plant at Bellary and Sidimongla village near Bellary and Tungabhadra Mineral Pvt. Ltd. proposes 1.2 MTPY iron ore pelletisation plant in Karnataka region. The status of the various commissioned pellet plants and the plants under commissioning/ Engineering in India are given in ***Annexure-I.***

Pelletisation of iron ore fines is practiced by the major iron ore producing countries. The status of Global pellet capacity and production as well as export of iron ore pellets is given in ***Annexure- II.***

TECHNO-ECONOMIC POLICY OPTIONS:

Before coming to process technology, let us understand the mechanization of pellet formation.

(I) MECHANISM OF PELLET FORMATIONS:

Ball Formation – Surface tension of water & gravitational force creates pressure on Particles, so they coalesce together & form nuclei which grow in size into ball.

Green pelletizing:

Theory of ball formation-

The forces responsible for the agglomeration of ore fines are surface tension and capillary action of water and gravitational forces of particles due their rotation in balling unit. When the solid particles are come in contact with water, the ore surface is wetted and coated with water film. Due to the surface tension of water film, liquid bridges are formed. As result of the movement of particles inside the balling unit and of the combination of the individual water droplets containing ore grains, first agglomerates, called seeds, are formed. The liquid bridges in the interior of these seeds hold them together as in a network. With the further supply of water, the agglomerates condense and become denser. Capillary forces of liquid bridges are more active in this stage of green ball formation. The optimum of this ball formation phase is attended when all the ports inside the balls are filled with liquid. When the solid particles are fully coated with water, the surface tension of water droplets becomes fully active dominating the capillary forces. Besides this effect, the rolling movement of grains and movement or shifting of particles relative to each other plays an important role.

Pelletizing in discs-

Green pellets with a size range of 8-16 mm are prepared in balling drum or discs. Discs are preferred to produce quality green pellets as these are easy to control operation with minimum foot space. The disc is an inclined pan of around 5 to 7.5 meters diameter rotating at around 6 to 8 rpm. The inclination of disc is around 45^o and it can be adjusted in the off-line between 45^o to 49^o. The pre wetted mix is fed into the disc at a controlled rate. Ore fines are lifted upwards until the friction is overcome by gravity and the material rolls down to the bottom of the disc. This rolling action first forms small granules called seeds. Growth occurs in the subsequent revolutions of the disc by the addition of more fresh feeds and by collision between small pellets. As the pellet grows in size, they migrate to the periphery and to the top of the bed in the discs, until they overflow the rim. Pellet growth is controlled by the small amount of water sprayed in the disc and the adjustment in the disc rotational speed.

Induration (Heat Hardening):

Pellet induration consists of three main steps:

1. Drying of green pellets.
2. Firing of pellets at around 1300^oC to sinter the iron oxide particles.
3. Cooling of hot pellets before discharging.

During drying (180^o-350^{o}C), moisture content in the green pellet is evaporated. Surface and interstitial moisture evaporates at lower temperatures where as chemically combined water (as goethite or limonite) or any hydrate or hydroxide combinations lose their water at slightly higher temp. During pre-heating (500-1100^{o}C), decomposition of carbonates, hydrates takes place. Gasification of solid fuels like coal or coke and conversion of iron oxides like goethite, siderite to higher oxide state, hematite, also takes place. Commencement of solid oxide bonding and grain growth are the important steps in this stage. During firing stage (1200-1300^{o}C), the temp. is below the melting temp. of major oxide phase but within the reactivity range of gangue components and additives. Formation of oxides and slag bonds is decisive in this stage.

Bonding of mineral grains developed during induration of pellets is affected by the following factors:

1. Solid oxide bonding: Oxidation of ferrous iron oxides to ferric iron oxides results in bonding and bridging, but only to limited amount.
2. Recrystallization of iron oxides: Essentially a physical process in which smaller particles consolidate into larger ones with the loss of surface energy. Continued growth of iron oxide crystals imparts sufficient strength. Grain growth for hematite starts at around 1100^{o}C.
3. Slag bonding: Gangue by forming melt transport medium for ferrous or ferric oxides facilitate grain growth and crystallization of oxide grains. It also enables the mechanism to proceed at lower temperatures than would be required in its absence.

(II) PROCESS TECHNOLOGY:

There are several iron ore pelletizing processes/technologies available in the world. Some of them are Shaft Furnace Process, Straight Travelling Grate Process, Grate Kiln Process, Cement Bonded Process (Grangcold Process, MIS Grangcold Process, Char process etc. and Hydrothermal Processes, (COBO Process, MTU Process, INDESCO Process) etc. However, currently, **Straight Travelling Grate Process and Grate Kiln Process are more popular processes**.

In the **straight grate system**, a continuous parade of grate cars moves at the same speed though the drying, induration and cooling zones. Any change in one section effects the residence time in another.

In the **Grate-Kiln System**, independent speed control of the grate, kiln and cooler are available to the operator. This provides process flexibility to adjust to changes in concentrate feed

Many Indian entrepreneurs have been looking at foreign, particularly, the Chinese suppliers for setting up pelletization plants. However, in China and most foreign countries, where pellets are used in blast furnaces, the feed material for making pellets is magnetite ore concentrate, which is much easier to pelletize. Furthermore, out of the two commonly used pelletization processes, i.e. Straight grate and Grate-kiln, but suitable more for low LOI magnetite ores. India having both hematite and magnetite types of ores, which contain varying LOIs and alumina levels, pose a serious challenge to the Indian researchers and entrepreneurs to chose the right process and use it economically and efficiently. This is also pertinent because of typical nature of Indian iron ores containing high chemically combined water, high alumina and a very fine concentrate arising out of a high degree of grinding required during beneficiation. The pellet manufacturing technology, followed in North America, China and other advanced countries, largely apply to magnetite ores. The adaptability of these processes for the typical Indian hematite/ goethite ores needs to be examined in detail. Already some of the plants set up recently based on Chinese technology are struggling.

Main technology supplier in Indian pellet industry is Outocompo, based on which about 26 million tonnes annual capacity has been set up/being set up in the country. All these plants are of international capacity of 3-5 million tonnes per annual. However to revolutionize pellet manufacturing in India , there is need to develop indigenous technology based on our raw materials suitable to smaller capacities (60,000-150,000 TPA).This call for promoting R & D efforts in the country. It is a matter of satisfaction that some initiatives have been taken by the Ministry of Steel who are providing financial assistance for three such projects. More such efforts are required to be made involving private sector players.

RECOMMENDATIONS:

(*i*) The country's iron ore requirement is going to increase substantially (almost 340 Mt/yr by 2020) in line with domestic steel production requirement outlined in National Steel Policy. Limited reserves of high grade iron ore pose a great challenge in long term sustainability of Indian iron & steel industry. In order to ensure optimum use of existing iron ore resources with special emphasis on conservation of high grade ores, there is a pressing need to utilize existing low grade iron ores including slimes and dump fines which are stockpiled in millions of tonnes in different mine heads. The solution lies in beneficiation which will not only help in utilization of hitherto wasted low grade ores/ slimes by upgrading its Fe value, but also mitigate environmental hazard, arising out of large stockpiling of slimes/rejects.

(*ii*) Newer and modern beneficiation techniques are required for up- gradation of low grade iron ores with high yield. Because of varying mineralogical characteristics of ore bodies, specific beneficiation technology solution need to be developed by R&D organizations for recovery of micro-fines for each of the deposit through extensive test work and development of flow sheet.

(*iii*) Present estimate of proved reserves had been arrived at long back and have become outdated. Therefore, a need is felt for taking up fresh exploratory investigations by GSI & IBM to ascertain proved reserves as per International Convention. Further, the present classification of ore reserves need to be modified by reclassifying the reserves into four grades viz. high grade (Fe +62 %), low grade (Fe +52%), poor ores (Fe +45%) and very poor ores (Fe below 45%) and for each grade, proved reserves need to be separately estimated.

(*iv*) The Government needs to provide all sorts of encouragement by way of policy support, incentives, so as to facilitate entrepreneurial initiative towards up-gradation of low grade iron ores including slimes in tailing ponds by beneficiation and subsequent utilization of concentrate for sintering/pellet making.

(*v*) Beneficiation of low grade ores, mostly at micro-fines level, provides concentrate which can be used in iron making in the form of pellets. Therefore, pelletisation technology will have a predominant role in supplying the prepared burden for iron making. Adoption of suitable pelletisation technology of varying capacity is encouraged to meet specific needs with respect to availability and type of iron ore fines/concentrate in the country.

(*vi*) Major efforts are going on to develop new cost effective hot metal/steel production technologies based on utilization of iron ore fines/slimes and non coking coal (because of limited global reserves of coking coal).Some of these are-Hismelt technology. Finnex technology, Romelt technology etc. There is need to encourage adoption of some of these technologies taking in account of Indian raw materials. This will not only lead maximization of fines but will conserve our natural resources.

(*vii*) Prospective entrepreneurs are apprehensive about the continuous availability of iron ore fines from same sources on long term basis because of sensitivity of the beneficiation technology to different iron ores. Therefore, there is need to develop some mechanism to provide iron ore linkages to them.

(*viii*) In view of increasing demand of high quality iron ore and for environmental protection against dumped fines and slimes in the tailing pond, an improved beneficiation technique for iron ores , dumped fines and slimes, use of blue dust, through sintering and pelletizing need to be encouraged.

(*ix*) While allocating /renewing iron ore mines, preference should be given to those who undertake to produce pellets/sinters.

ANNEXURE-I

STATUS OF THE COMMISSIONED PELLET PLANTS IN INDIA

Sl.	Plant Location	Process	Comm. Date	Cap. Mt/yr.	Machine size	Supplier	Status	Remark
1.	Chowgule & Co., Pale, Goa	Travelling Grate	Oct. 1966	0.5	110m^2 (2.5×44)	Lurgi	Dismant Led In 1980	Not operational
2.	TISCO, Noamundi	Grate Kiln	1971	0.9	–	Polysius led In 1981	Dismant operational	Not
3.	Mandovi, Shiroda, Goa	Travelling Grate	20.05.079	1.8	399m^2 (3.5×114)	Voest Alpine	Stopped from 1981-91 (Now operating)	Dry grinding of Iron ore fines
4.	KIOCL, Mangalore	Travelling Grate	14.01.87	3.5	492m2 (4×123)	Lurgi & UEI	Operating	Magnetite concentrate used till recently
5.	ESSAR STEEL Ltd. Vizag	Travelling Grate	06.11.96	4.0 (4×105)	420 m2	Lurgi	Operating	Initially wet grinding of Iron ore fines. Recently, switched over to haematite concentrate
6.	KIOCL Mangalore	Shaft furnace	20.08.00	0.5	–	MR&E USA	Stopped	Suitable only for Magnetite ores
7.	JSW Vijayanagar	Travelling Grate	Nov. 2000	5.0	464m2 (4×116)	Kvaerner Metals (formerly Davy), USA	Operating	Dry grinding of Iron ore fines.
8.	ESSAR STEEL Ltd. Vizag	Travelling Grate	2006	4.0	444 m2 (4×111)	Lurgi	Operating	Haematite concentrate
9.	Bharat Mines and minerals, Ispat Ltd. Hospet	Grate Kiln	2009	1.2	–	Shougang	Operating	
10.	Arya I&S Co. Matkambeda, Barbil	Grate Kiln	2009	1.2	–	Shougan	Operating	

STATUS OF PELLET PLANTS -UNDER COMMISSIONING/ENGINEERING

Sl.	Description	Client
1.	4 Mt incl. beneficiation & slurry transportation, Jajpur road	Brahmani River Pellets Limited. (Stemcor Group)
2.	5 Mt at Angul, Orissa	JSPL
3.	10 Mt in 2 phases at Barbil,keojhar,	JSPL Orissa
4.	6.0 Mt at Jamshedpur	Tata Steel
5.	1.2 Mt at Hospet,Karnataka	MSPL Ltd,
6.	0.5 Mt at Dalli mine head	BSP
7.	2.0 Mt at Koppal, Karnataka	XIndia Ltd.
8.	1.2 Mt at Raigard, Chhatisgarh	MSP LTD.
9.	2.5 Mt at Angul, Orissa	Bhushan Energy& Power Ltd

ANNEXURE-II
GLOBAL PELLET CAPACITY AND PRODUCTION

(in Million Tonnes)

Sl.	Major producers	Capacity	Production
1.	Australia	6.00	5.70
2.	Brazil	52.00	50.60
3.	Canada	28.00	26.00
4.	China	43.00	35.00
5.	India	11.60	11.50
6.	Kazakhstan	9.50	9.40
7.	Russia	32.00	35.00
8.	Ukraine	28.00	16.30
9.	Sweden	16.10	15.90
10.	USA	56.00	54.00

GLOBAL EXPORT OF IRON ORE PELLETS

(in Million Tonnes)

Sl.	Country	Exports
1.	Australia	1.30
2.	Brazil	46.00
3.	Canada	16.00
4.	China	0.00
5.	India	6.10
6.	Kazakhstan	7.70
7.	Russia	9.50
8.	Ukraine	7.40
9.	Sweden	9.90