

IRON MAKING

MT410502

Reference Books:

**Modern Iron Making by R.H.Tupkary (Khanna
Publication)**

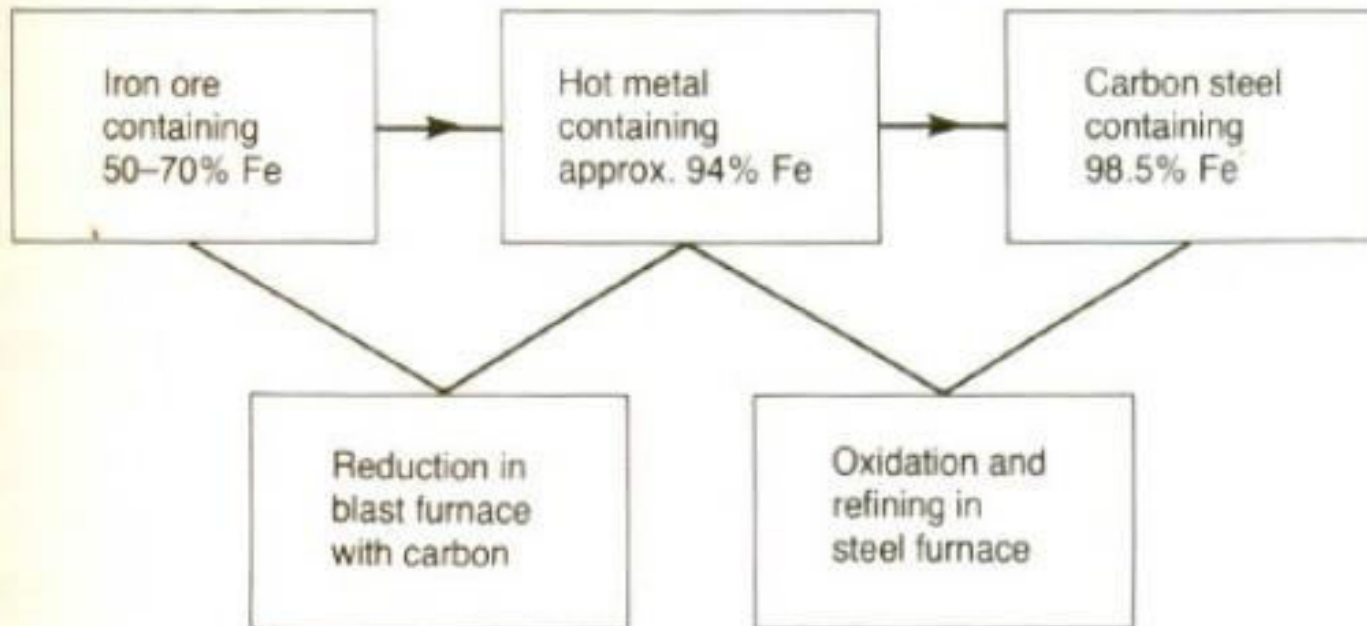
**Iron Making and Steel Making: Theory and
Practice, A. Ghosh and A. Chatterjee,
(Prentice Hall)**

SYLLABUS:

○ **Unit – I**

- **General:** History of iron making. Occurrence, distribution and evaluation of raw materials(iron ore, coal and flux) for iron making.
- **Burden materials and burden preparation:** Burden preparation, Burden qualities.
- **Agglomeration- Sintering-process, variables and machines.**
- **Pelletization process, Theory of bonding. Mechanism of ball formation, Disc and drum pelletizer, Induration of pellets, cold bonding technique and testing of pellets.**

The Process route from ore to steel



HISTORY OF IRON MAKING, IRON & STEEL INDUSTRIES IN INDIA, DISTRIBUTION & EVALUATION OF RAW MATERIALS.

- Iron-meaning something hard from the sky. Of extra terrestrial origin. In India highly developed Iron culture.- Ashoka iron pillar near kutub minar—1500 yrs old.
- Bronze/Copper age older than iron because Copper has lower melting point than iron.
- Iron making involved furnace made of stone & clay. It passed through various stages of development and culminated in modern BF with Computer controlled activities.
- Primitive iron smelter used charcoal as fuel & natural draught of air for burning fuel. It produced a spongy mass of iron. In Spain, Germany and Europe developments took place.

- After 1621 coked coal was developed, exhaust gas utilization, hot blast generation, BF gas cleaning, pig casting machine etc were developed.
- In addition Use of fluxed sinter/pellets, oxygen enrichment of blast, high Top pressure etc introduced.
- In India tradition of iron & steel making continued till last century. The Swords, daggers and other articles bear the testimony. Traditional iron making consisted of producing pasty and malleable iron blooms.
- Bengal iron & steel works was established in 1870 and started iron Production in 1875 using iron ore and coke produced from Jharia coal.
- The furnace capacity was 20 t/day. C-2.84%, Mn-0.97%, Si-1.13%, P-0.36%, S-0.12%.

- This undertaking passed into the hands of Indian Iron and steel making. Then Jamshedji Tata established TISCO in 1908 started production in 1912.
- In 1953, Bengal Iron and Steel Co. was amalgamated with IISCO. In 1974 it was taken over by Hindustan Steel Limited.
- In 1918, Mysore Iron & Steel was started with BF of 60t/day capacity and electric arc furnace was added.
- In India real development of iron & steel started with 5 year plans. It set up RSP -1.8 MT, BSP-4.0 MT, Durgapur- 1.8 MT, Bokaro -4.0MT.
- In 1970, SAIL was set up to control, develop & supervise iron & steel Industry in India.

- In 1980, GOI changed the policy to liberalization & private sector was allowed to set up steel plants. MESCO, MID EAST, MALVIKA Steel, USHA ISPAT etc were set up.
- The modern BF is now a consummation of accumulated experience & developments over several centuries. In the year 2000, iron production by BF was 85%, DRI was 15%, Electric smelting 0.3%.

OCCURRENCE, DISTRIBUTION AND EVALUATION OF RAW MATERIALS.

- Iron ore – Naturally occurring material containing iron. Economic extraction of iron from ore. It can be in the form of:
 - oxides- hematite & magnetite.
 - Hydroxides-limonite & goethite.
 - Carbonates-Siderites, spasthose iron.
 - Sulphides-pyrites & pyrrhotite.
 - Complex – Ilmenite, silicates etc.

Characteristics of Iron Minerals

<i>Type</i>	<i>Class</i>	<i>Composition % Fe</i>	<i>Specific gravity</i>	<i>Colour</i>
Iron	Native (meteo- ric)	Usually alloyed with nickel	7.3-7.8	Iron grey
Magnetite	Black oxide Fe_3O_4	72	4.9-5.2	Iron black
Hematite	Red oxide (spe- cular iron, kidney ore) Fe_2O_3	70	4.5-5.3	Red to blackish
Limonite	Brown hematite $2Fe_1O_3 \cdot 3H_2O$	60	3.4-4.0	All shades brown to yellow
Goethite	Brown $Fe_2O_3 \cdot H_2O$	Variable but more than 60%	4.0-4.4	Brownish black
Pyrites	Iron pyrite FeS_2	64	4.8-5.1	Greenish or brown- ish black
Chalybite	Carbonate, spa- those iron or siderite $FeCO_3$	48	3.7-3.9	Pale yell- low brownis balck
Ilmenite	$FeOTiO_2$		4.5-5.0	Black



WORLD DEPOSITS AND IRON DEPOSITS IN INDIA

- India ranks 5th in the world in iron ore resources and 3rd largest producer & exporter of iron ores.
- Hematite ores are available in Bihar, Orissa, M.P., Karnataka and Maharashtra.
- In Goa it is in the form of blue dust and exported to Japan in the form of pellets.
- In A.P. rich hematite deposits are found.

- Total inferred reserves are 23000 MT & 85% is hematite, 8% as magnetite and rest 7%.
- Out of proven deposits of 13200 MT, nearly 10500 MT are hematite with 55% iron & 2800 MT are magnetite with 30% iron.
- Overall situation is good.
- Hematite ore -67% iron, 0.63% SiO₂, 1.87% Al₂O₃.
- Goa ores- 60-63 % iron, 1.4 -4.7 % SiO₂, 3.9 -4.2 % Al₂O₃.
- magnetite ore- 42% iron.

- Factors affecting valuation of an Iron ore:
 - Richness,
 - Location,
 - Composition of gangue material,
 - Treatment and preparation needed before smelting.
- Richness- % of iron in the ore. 55- 60 %Iron. 1 mt pig iron require 2 mt Ore in India. In Australia 1.5 mt ore required. 68% iron. Also fuel and flux requirement is less.
- Location – both geographical and geological location is important. Underground mining is costly affair but if ore is in the form of Hill, it is easy to do mining.

- Mode of transport requirement, infrastructure cost.
- Composition of gangue – Can reduce the value of ore. P can get reduced back. Alumina and alkali also affect ore quality. Lime & magnesia are ok.
- Evaluation also requires size of the reserves, location, difficulties in mining. Distance and mode of transport required.
- The treatment and preparation of ore before charging determines the cost of Ore. e.g. Dense ore, Fine ore, carbonates form etc.

COAL ANALYSIS:

- Metallurgical coal – Not suitable as a fuel because too fragile / dense.
- It is heated out of contact with air to form coke which is free from volatile Matter, strong and porous.
- Coke – 2% volatile matter, 10% ash, Min 85% fixed carbon, 0.018- 0.04%P & 0.60- 1.5% S.
- The coals which produce coke of good physical properties are known as prime coking coals. USA, USSR, UK, Australia have good quality metallurgical coals.

- India has 192000 MT coal but only 14000 MT are in Jharia region and of prime coking variety. Gondwana fields are in WB,MS,BIHAR,ORISSA ,MP,UP etc
- For optimum utilization prime variety is blended with medium & weekly coking coals.
- 50 years of reserves at the present rate of consumption.
- Production of coal was 100MT in 1980 and would go up to 133 MT in near future.

FLUXES:

- **FLUX** – Lime stone and dolomite are added during smelting to bring down the softening point of the gangue material, to reduce the viscosity of slag & to decrease the activity of some of its components to make them stable or unstable in the slag phase.
- The gangue arises in the BF from the ore & the ash of coke.
- Flux itself may contain similar gangue oxides. Silica & alumina are gangue materials in Iron ore and coke ash is also of the same character.
- The amount of flux required in the BF is determined as per the composition of the burden & composition of the slag.

EVALUATION OF THE FLUX

- The quality or value of flux is expressed as 'available base' since it may contain oxide impurities similar to gangue.
- The available base value depends upon the basicity (ratio of base to acid content) of the slag under operating conditions.
- In BF normal basicity range is **1.0 -1.30**.
 - $B = \frac{\%(\text{CaO} + \text{MgO})}{\%(\text{SiO}_2)}$
- The available base is
 - $\%(\text{CaO} + \text{MgO}) - \%(\text{SiO}_2) \cdot B$ where B is basicity.

- In general CaCO_3 should be 95%min.
- $\text{SiO}_2 < 5\%$, MgO & $\text{Al}_2\text{O}_3 < 3\%$ each in the lime.
- 0.50t of lime is required for making 1.0t of pig iron.
- In India limestone is available in MP and Orissa.
- The BF feed is -80 to +25mm. The reserves of lime are satisfactory from quantity viewpoint but not from quality viewpoint.

UP NEXT

- **BURDEN PREPARATION,**
- **BURDEN QUALITIES & CALCULATIONS.**
- **AGGLOMERATION-NODULISING & BRIQUETTING,**
- **SINTERING PROCESS VARIABLES & MACHINES**

BURDEN PREPARATION

- Since the quality of naturally occurring raw materials may not be upto the mark, it can be improved as far as feasible by preprocessing the Natural raw materials suitably.
- These pre treatments or pre processing are known as burden preparations.
- It includes iron ore, coke & lime stone.
- Burden qualities are both Physical and Chemical.

PHYSICAL QUALITIES:

1. It should have close size range with minimum fines.
2. Withstand physical stresses in handling at various stages.
3. Non decrepitating nature.
4. To withstand mildly reducing conditions at lower temperatures without breaking.
5. Good reducibility to obtain close equilibrium conditions in the stack
6. Low swelling tendency during reduction
7. A high softening temperature with a narrow temperature range of fusion.

CHEMICAL QUALITIES:

1. A high percentage of iron and low gangue contents.
2. Low percentage of silica & alumina and low alumina/silica ratio.
3. Proper overall chemistry of the burden to ensure desulphurization of metal and absorption of coke ash in the slag.
4. Proper overall chemistry to ensure clean slag and metal separation at minimum temperature & free flow of metal & slag.

- Initially advantages gained by ore preparations were not understood, but now it has been proved that cost of ore preparation can be easily compensated by way of higher production rates, good control of furnace, consistent & better quality.

BENEFICIATION

- Beneficiation of iron ores- It is carried out by crushing & grinding. This further breaks down the ore into smaller fragments.
- The structure, properties, and characteristics of the mineral deposit have important bearing on the method of the beneficiation to be adopted.
- Properties like magnetic susceptibility, grain size and shape, density, electrical conductivity etc are important in this respect.

METHODS OF BENEFICIATION:

1. Magnetic Separation
2. Gravity separation.
3. Flotation.
4. Electrostatic separation.
5. Magnetic roasting followed by a low intensity magnetic separation.
6. Washing and Calcination*

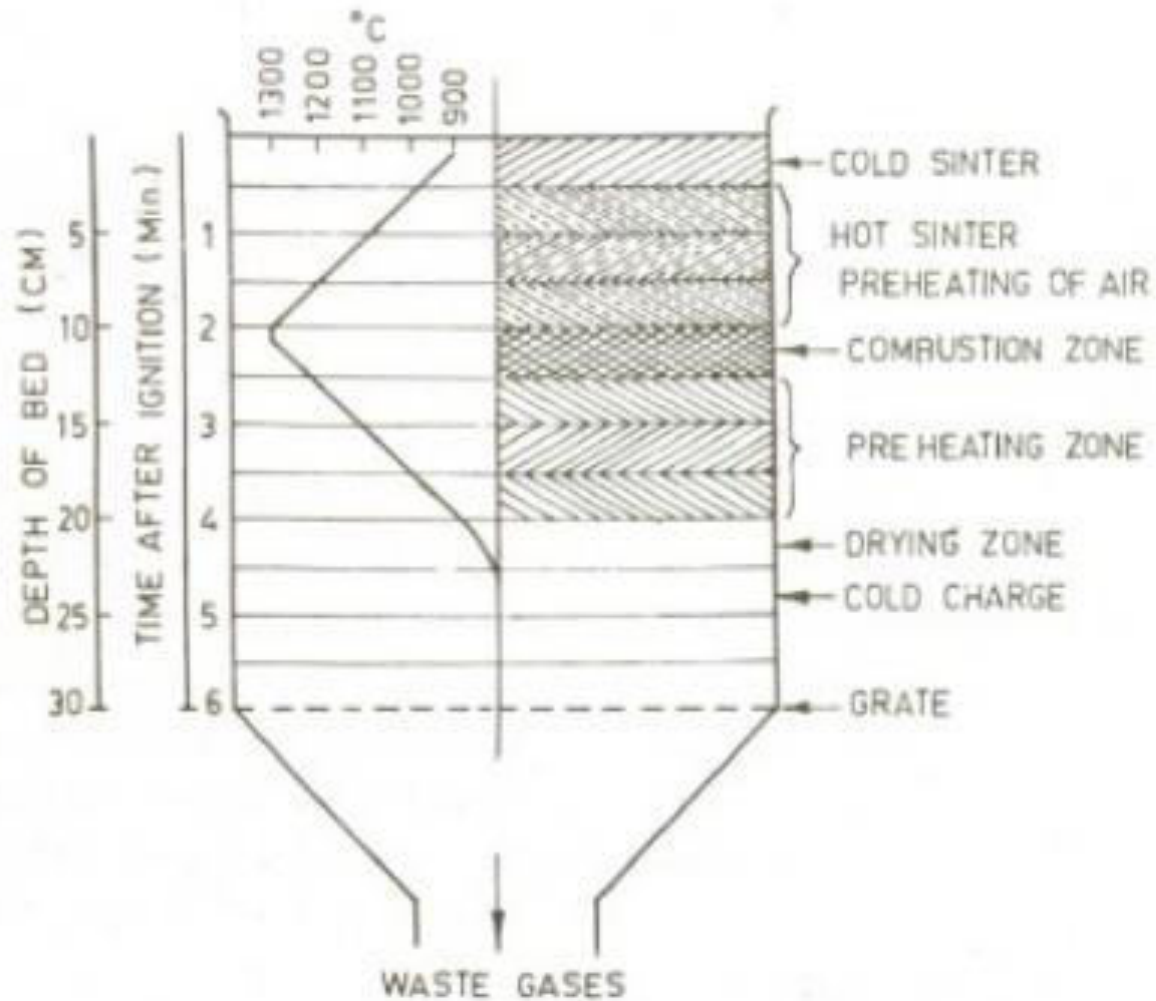
- Magnetic separation applied for Fe_3O_4 and Fe_2O_3 separation.
- Gravity methods –Heavy media, Jigging, Tabling, Spirals.
- Flootation, Electrostatic separation, magnetic roasting, washing, Drying and calcination roasting of hydroxides, carbonates, sulphide ores is done before use.
- Indian iron ores are rich but high in silica and alumina contents. If alumina is less than 2%, many of the problems can be solved.

- Iron ore fines can be agglomerated into lumps for use as BF feed.
- This is done by Briquetting, Nodulising (rotary kiln sintering), vacuum extrusion, sintering and pelletising.
- Nodulising-flue dust, pyrite residue or fine concentrates along with some carbonaceous material like tar are passed through a rotary kiln. It is not much in use.
- Vacuum extrusion- Moist air with or without bentonite as a binder is passed through deairing chamber and extruded into cylindrical form.

SINTERING :

- Principle – Iron ore sintering is carried out by putting iron ore fines mixed with coke breeze on a permeable grate.
- The top layer is heated to the sintering temperature (1200-1300 deg.C) and air is drawn through the grate with the help of exhaust blower underneath.
- The narrow combustion zone developed initially at the top layer travels through the bed raising temp layer by layer.

Situation in a sinter bed few minutes after the ignition of the top layer



- The cold blast drawn through the bed cools the sintered layer and preheats the lower layers in the bed.
- As combustion advances, each layer gets dried and preheated.
- In the combustion zone bonding takes place between the grains & strong, porous aggregate is formed.

- The process is over when the combustion zone has reached the lowest layer of the bed.
- The sinter is then tipped, broken, screened & cooled to get desired fraction.
- This is a down-draught process since, the air is drawn through the sinter bed downwards.
- Dwight –Lloyd sintering machine is the only large scale machine for both ferrous and non ferrous ores.
- During sintering aggregate of particles are heated & cooled.
- Hence, bonds are developed at the points of contact of particles with each other.

- Bonding of grains is a high temperature phenomenon and function of temp. and time for which the mass is maintained at high temp.
- Area under the curve determines the nature and strength of bonds developed.
- Temp. around 1000°C or so is effective.

VARIABLES OF SINTERING PROCESS

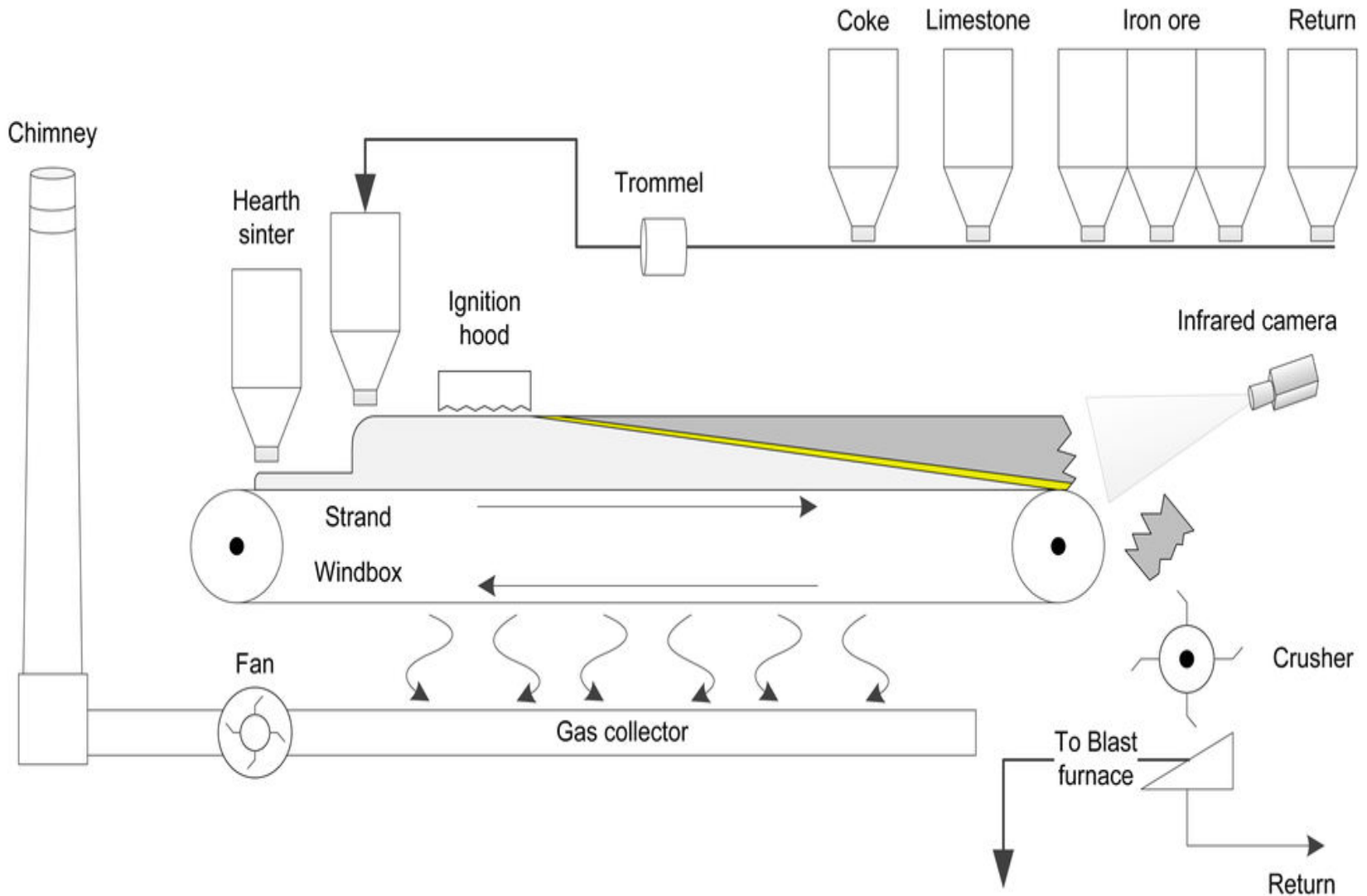
- Bed permeability
- Thickness of bed
- Volume of air blast drawn through sinter bed,
- Amount of Carbonates in the charge,
- Moisture content in the charge,
- Chemical composition of ore fines,
- Solid fuel in the charge,
- Non uniformity in the bed composition.

- The sintering process is fast enough in that steady state is not reached.
- The permeability and faster rate of heat exchange oppose each from the strength of sinter point of view.
- Optimum adjustments should be done.
- Normal blast volume is 700-1100 m³ /t . (specific volume).
- Reactivity of the fuel and the oxygen content of gas will decide fuel consumption.

- The time required for the waste gases to reach peak temp. is related to gas velocity & heat capacity of the gas phase.
- The flame front and heat front should travel together to obtain maximum temp. This is known as matching.
- If the fuel is highly reactive low oxygen partial pressure will be OK to do The matching of flame front and heat front .
- A significant amount of sulphur can be removed in sintering.

DWIGHT – LLOYD SINTERING MACHINE

- Design has undergone many Improvement but essential features still continue to be adopted.
- Upto 8.0 mtr width and 500 m² grate area machine is in use and capacity is 24000t/day.
- It is an endless band of pallets moving over the rails.
- Raw material is loaded at one end and top layer is ignited under ignition hood.
- Sintering is completed when pallets move over the entire useful length of the machine.



Dwight Llyod Sintering Machine

- After sintering, crushing, screening, cooling is done -9 mm size is returned to the machine, oversize goes for rescreening.

The exhaust gases from the wind boxes are let off into the atmosphere through a chimney after dust extraction. The important parts of the machine are as follows.

1. Storage bins , mixers
2. Charge leveler
3. Ignition hood
4. Band of pallets and rails.
5. Drive mechanism
6. Sinter breaker, screen
7. Spillage collector
8. Wind boxes , dust extractor , exhaust fan , chimney etc

EFFICIENCY OF SINTERING MACHINE

- In terms of
 - a) productivity (Mt/ per sq.mtr per –hr.)
 - b) Effective suction.
 - c) Quantity of air drawn through the bed per unit time

PURPOSE OF SINTER

- Increase the size of ore fines acceptable to blast furnace.
- To form strong agglomerate with high bulk reducibility.
- To remove volatiles like CO₂, H₂O, Sulphur from ores.
- To increase flux in the burden.

TYPES OF SINTER

- Acid sinter, Fluxed sinter (flux will be required in proportion to Iron ore charged in the furnace.), Super fluxed sinter (Entire amount of flux for 100% ore charge).
- When 50-80% sinter is charged in Blast furnace no separate flux is required even though small quantity of fine grade ore is added.
- High basicity sinters are not desirable since permeability of the bed in lower portion of blast furnace is reduced.

OBJECTIVES OF SINTERING.

- To increase the size of ore fines to acceptable BF level.
- To form a strong and porous agglomerate.
- To remove volatiles (CO_2 from carbonates, S from Sulphide ores etc).
- To incorporate flux into the sinter.
- To increase the BF output and decrease the coke rate.

Mechanism of Sintering

Two types of bonds may be formed during sintering.

Diffusion or Recrystallization or Solid State Bond : It is formed as a result of recrystallization of the parent phase at the point of contact of two particles in solid state and hence the name.

Slag or Glass Bond: It is formed as a result of formation of low melting slag or glass at the point of contact of two particles, depending upon the mineral constitution, flux addition, etc.

As a result the sinter can have three different types of constituents:

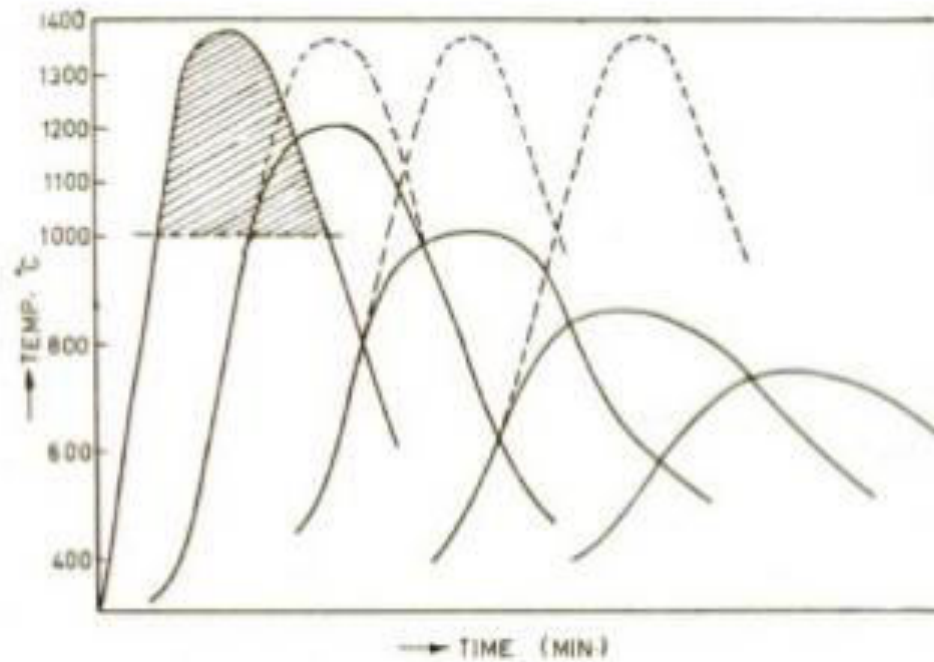
- ✓ Original mineral which has not undergone any chemical or physical change during sintering.
- ✓ Original mineral constituents which have undergone changes in their physical structure without any change in their chemistry. Recrystallization is the only change at some of the particle surfaces.
- ✓ Secondary constituents formed due to dissolution or reactions between two or more of the original constituents

Cont...

The proportion of each of the physical and chemical change during sintering depends upon the **time-temperature cycle** of the process. The higher is the temperature more will be the proportion of new constituents by way of solutions and interactions whereas lower is the temperature and longer is the duration more is the process of recrystallization in solid state.

The more is the slag bonding, **stronger is the sinter but with less reducibility** and, more is the diffusion bonding, **more is the reducibility but less is the strength**. **Since ores are fairly impure slag bond predominates. On the other hand in rich sinters slag bond is of minor importance.**

Temperature cycle during sintering of iron ore fines



Pelletising

During mining and ore dressing operations, especially where very fine grinding is necessary for wet concentration, **a large amount of - 0.05 mm fines is generated which are not amenable to sintering because of very low permeability of the bed**. They can, however, be agglomerated by balling them up in the presence of moisture and suitable additives like bentonite, lime, etc. into 8-20 mm or larger size. These *green pellets* are subsequently *hardened* for handling and transport by firing or *indurating* at temperatures of 1200-1350°C.

The Pelletisation Process

Pelletisation essentially consists of formation of green balls by rolling a fine iron bearing material with a **critical amount of water** and to which an external binder or any other additive may be added if required. **These green balls of nearly 8-20 mm size** are then dried, preheated and fired, all under oxidising conditions, to a temperature of around 1250-1350°C. Bonds of good strength are developed between the particles at such high temperatures.

The **pelletisation process** consists of the following steps:

- Feed preparation.
- Green ball production and sizing.
- Green ball induration:
 - (a) Drying
 - (b) Pre-heating
 - (c) Firing
- Cooling of hardened pellets.

The balling stage

The observations on ball formation that eventually led to the development of the theory of balling are as follows:

- ❑ Dry material does not pelletise and presence of moisture is essential to roll the powder into balls. Excessive water is also detrimental.
- ❑ Surface tension of water in contact with the particles plays a dominant role in binding the particles together.
- ❑ Rolling of moist material leads to the formation of balls of very high densities which otherwise is attainable by compacting powder only under the application of a very high pressure:

The ease with which the materials can be rolled into balls is almost directly proportional to the surface area of the particles, i.e. its fineness.

The capillary action of water in the interstices of the grains causes a contracting effect on them. The pressure of water in the pores of the ball is sufficiently high so as to compact the constituent grains into a dense mass. The compressive force is directly proportional to fineness of the grains since the capillary action rises with the decrease in pore radius and the latter decreases with increasing fineness. **An optimum moisture is important** since too little of water introduces air inclusions in the pores and too much of water would cause flooding and destruction of capillary action. The **optimum moisture content usually lies between 5-10 percent or more, the finer the grains the larger the requirement.**

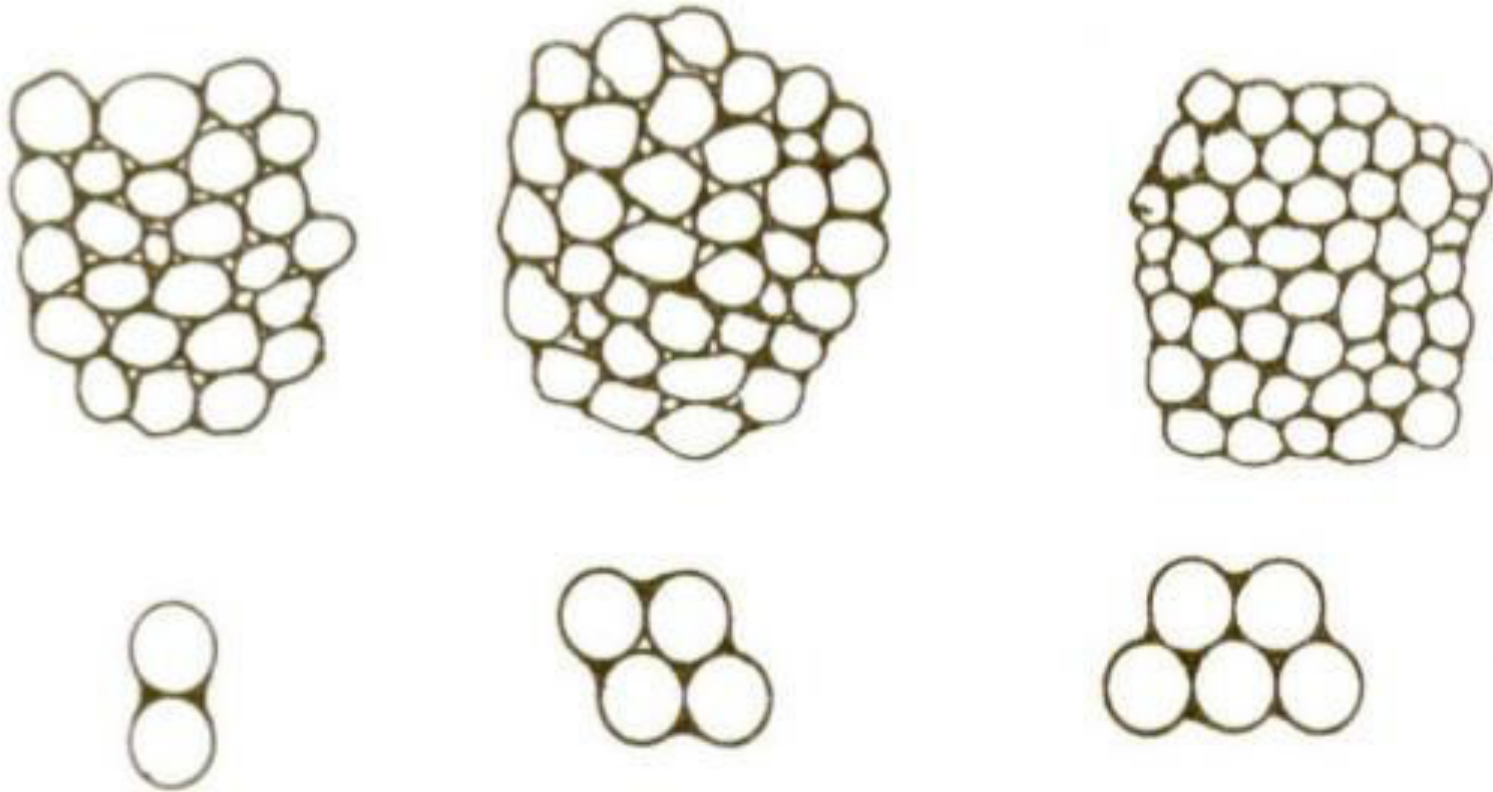
- ▶ Besides the bonds formed due to surface tension mechanical interlocking of particles also plays a significant role in developing the ball strength.
- ▶ Maximum strength of a green ball produced from a given material will be obtained by compacting the material to the minimum porosity and with just sufficient water to saturate the voids. The rolling action during pelletisation is beneficial in reducing the internal pore space by effecting compaction and mechanical interlocking of the particles.

Water-particle system

From fundamental studies it has been concluded that there are three different *water-particle* systems:

- ✓ The **pendular** state, when water is present just at the point of contact of the particles and surface tension holds the particles together.
- ✓ The **funnicular** state, when some pores are fully occupied by water in an aggregate system.
- ✓ The **capillary** state, when all the pores are filled with water but there is no coherent film covering the entire surface of the particles.

Water-particle system



(a) Pendular state.

(b) Funicular state.

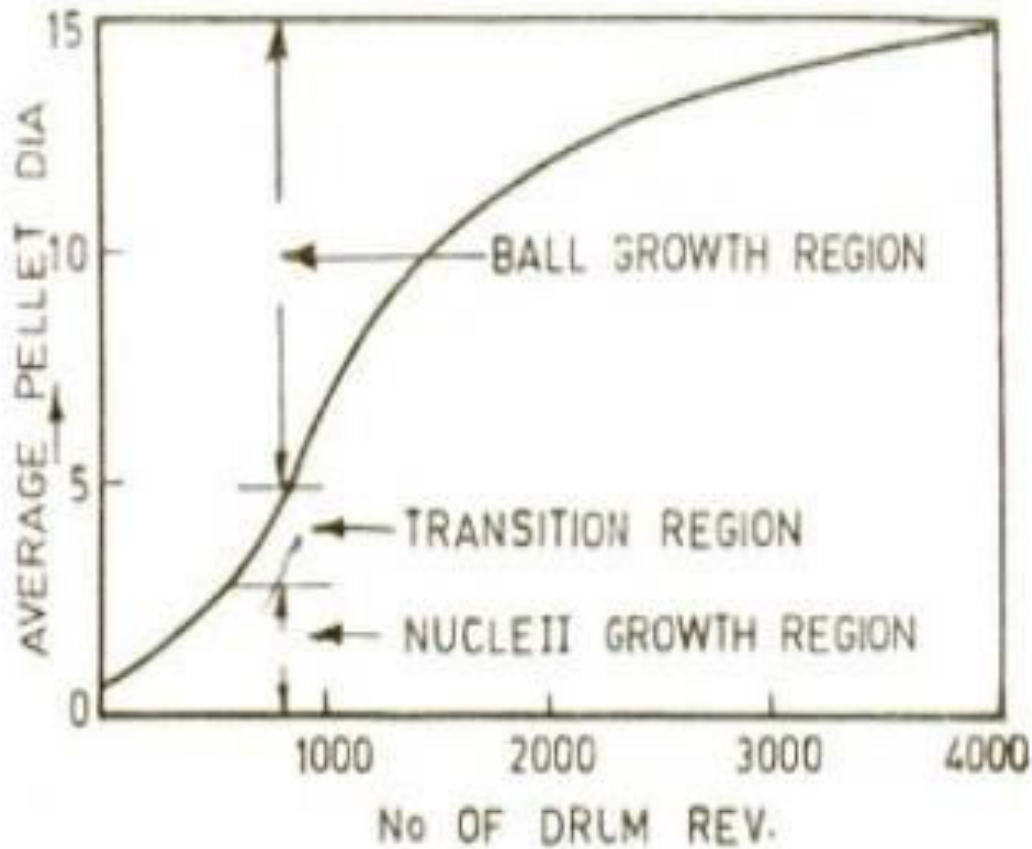
(c) Capillary state.

Mechanism of Ball Formation

The ball formation is a two stage process, *i.e.* **nucleation or seed formation and their growth**. The formation of balls on a pelletiser depends primarily on the moisture content. Seeds are formed only if **critical moisture level** is maintained and without which the process cannot proceed properly. Growth takes place by either **layering or assimilation**. It has been observed that the size of the balls produced in a pelletiser from a charge containing right amount of moisture depends on the time and speed of the pelletiser, *i.e.* number of revolution.. Three regions can be clearly observed, during ball formation. :

- **Nucleii formation region**
- **Transition region**
- **Ball growth region.**

Mechanism of Ball Formation



Nucleii formation region

When a wet particle comes in contact with another wet or dry particle a bond is immediately formed between the two. Similarly several such particles initially join during rolling to form a highly porous loosely held aggregate and crumbs which undergo re-arrangement and partial packing in short duration to form small spherical, stable nucleii. This is the nucleation period, a pre-requisite for ball formation since these very nucleii later grow into balls.

Transition Period

After nucleii are formed they pass through a transition period in which the plastic nucleii further **re-arrange** and **get compacted** to eliminate the air voids present in them. The system moves from a **pendular state** through **funicular state** to the **capillary state** of bonding. Rolling action causes the granules to densify further. The granules are still plastic with a water film on the surface and capable of coalescing with other granules. The size range of granules in this region is fairly wide.

Ball Growth Region

The plastic and relatively wet granules grow if they are favorably oriented. In this process some granules may even break because of impacts, abrasion, etc. Growth takes place by two alternative modes.

- ✓ **growth by assimilation** is possible when balling proceeds without the addition of fresh feed material.
- ✓ **growth by layering** is possible when balling proceeds with the addition of fresh feed material.

Growth by Assimilation

If no fresh feed material is added for balling the rolling action may break some of the granules, particularly the small ones, and the material coalesces with those which grow. The bigger the ball the larger it will grow under these conditions. Since smaller granules are weaker they are the first victim and growth of the bigger balls takes place at their expense.

Growth by Layering

Growth of the seeds is said to be taking place by layering when the balls pick up material while rolling on a layer of fresh feed, The amount of material picked up by the balls is directly proportional to its exposed surface, *i.e.* the increase in the size of the balls is independent of their actual size.

Growth by layering is more predominant in the disc pelletisers and growth by assimilation is more predominant in drum pelletisers, atleast beyond the feed zone

DISC PELLETISER

- Disc pelletiser – It is a disc with a sloping peripheral wall and rotating in inclined position. 3.6 – 5.6 mtr dia. Scraper is provided to prevent build up of material.
- The time required for balling may be obtained by dividing weight of material being actively balled on the disc by the feed rate.



THE RATE OF PRODUCTION OF BALLS ON A DISC IS FUNCTION OF:

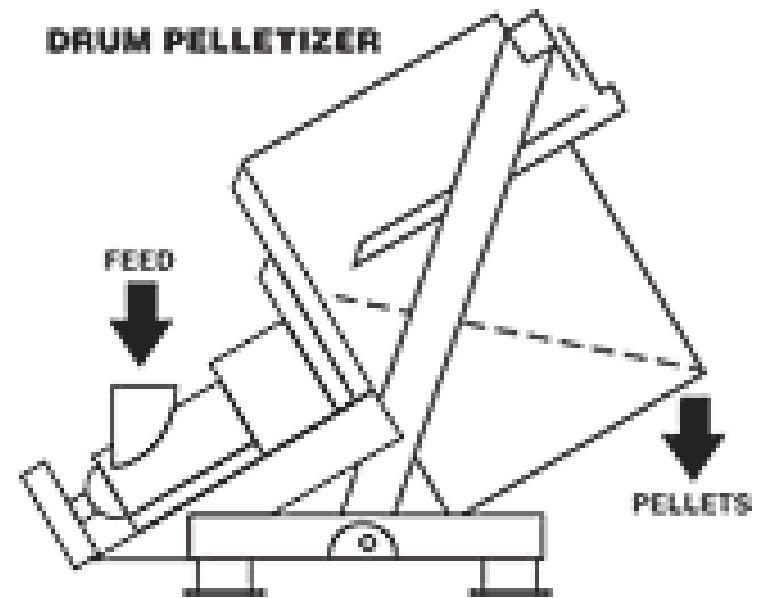
1. Disc dia.
2. Height of peripheral wall
3. Angle of inclination of disc
4. Speed of rotation
5. Place of feeding mix and water
6. Rate of feed
7. Rate of moisture addition
8. Rate of withdrawal of product.
9. Nature and size of feed
10. Desired size range of pellets & % of recycled load
11. Other additions like binder, flux etc.

- For optimum utilization of a given disc the residence time of the charge must be the same as the balling time i.e. feed rate must be equal to the rate of discharge.
- Excessive speed may result in breakage of pellets by impact. This can be obviated by reducing the slope of the disc.
- For a given slope & feed rate the residence time can be adjusted to some extent with height of peripheral wall. Loading beyond 0.20 t/m² hampers balling operation.

- The rate of nucleation & growth can be adjusted by adjusting the points at which charge and water are fed.
- If feed point is such that on addition of feed it immediately comes in contact with rolling balls, then growth is more dominant than the rate of seed formation. The product in that case will be more closely sized.
- Converse is true if the feed point is farther.(wider size range of product).
- The size range becomes narrower as growth rate tends to attain steady state conditions, particularly if it occurs by layering than by assimilation.
- On a disc pelletiser, the recycle proportion is 15%.
- The finer the feed, the higher is the growth rate of pellets.

DRUM PELLETIZER:

- It is a steel drum open at both ends ($L / D = 2.5 - 3.5$), rotating around its own axis in a slightly inclined position. 2-3 mtr dia and 6-9 mtr length.
- The size range is large as it does not act as a classifier as disc. It must be operated with a screen.
- The balls of 10-16 mm are screened & undersize/oversize is shredded before being recirculated.



RATE OF PRODUCTION:

1. Speed of rotation,
2. Angle of inclination,
3. Diameter of drum,
4. Rate of feed,
5. Depth of material in residence,
6. Moisture content
7. Nature and size of feed,
8. Binder or flux addition.

The correct speed of rotation is 25-35 % of critical speed i.e. speed at which material will centrifuge.

- The residence time (time of balling) is determined by the slope, water content, speed of rotation and feed rate.
- Optimum loading and correct speed leads to correct tumbling action eventually resulting in a continuous steady state operation.
- A high recycle rate favors growth by layering and produces a product of close size range.
- For a continuous steady state operation, the net rate of production of seeds must equal the rate of production of green balls and the rate of incremental growth during the passage through the drum should give rise to the correct size of the green balls.

ADDITIVES-

- Many times even a right amount of water may not produce green balls of required strength, hence a small amount of certain binders have been successful in improving the balling operation.
- Ferrous sulphate, alkali chlorides, alkaline earth carbonates are used successfully. Organic substances are not preferred.
- Bentonite (0.5-1.0%) is added in the feed during its preparation. Excess addition leads to undesirable properties.
- Use of lime or dolomite is beneficial because it produces slag bonds during Induration and which is exhibited as better strength of pellets.

INDURATION OF PELLETS

- It involves drying, preheating, firing & cooling.
- Three different types of heat hardening equipments are in use.
 1. Vertical shaft furnace
 2. The travelling grate
 3. The grate kiln.
- **Drying** :The green balls are dried by passing hot air through the bed of balls led on a grate. The moisture content and nature of the ore decide time and temperature for drying. Drying can be done using downdraught or updraught .

Preheating and firing: The solid state bond & slag bond may be formed during firing. The strength develops in the outer shell and then progresses towards the centre with time at firing temperature.

Firing temp is 1250 – 1350 deg. C. Higher temp causes excessive slag formation and less porous pellets.

There are three main types of pellet firing machines.

1) Shaft kiln: Developed in 1950s. The green or dried balls are fed vertically downwards in a shaft of rectangular cross section,

Fuel is burnt in two fire chambers and hot gases enter the main shaft. Fired pellets are cooled in the lower portion.

2)Grate machine- This is a modification of Dwight Lloyd machine. The green balls are fed at one end and the hardened and cooled pellets are discharged from other end. The length of machine is divided into four zones,

Drying, preheating, firing and cooling.

Hot air from the cooling zone is circulated to carry out drying, preheating etc

Dravo Lurgi straight grate systems are in use. Peculiar feature of this system is need of protective layer of previously fired pellets on the sides and bottom to prevent overheating.

The Grate kiln – It is a combination of a grate & a kiln and hence the name. Drying and preheating is carried out on the straight travelling Grate and firing is completed in a long rotating kiln wherein fuel is burnt to generate temperature.

The hot gases from the kiln are carried over the grate to carry out drying and preheating.

The life of the grate is very high.

Comparison of pellet forming machines -

Induration time for Continuous grate is very short.

Next is for grate kiln process machine.

The shaft furnace requires too long a time for induration.

The fuel consumption of a shaft kiln furnace is only slightly less than the other two.

Capital cost of grate kiln is much more than the other two.

Cost of maintenance of travelling grate is more.
Shaft furnace requires minimum cost.

Product cost is highest for continuous grate, lowest for shaft furnace.

Indian steel plants do not use pellets as burden feed. Pellets are exported except that TISCO.

Pelletisation process is not competitor but complimentary to sintering.

Pelletisation is adopted only in case of very fine ores, concentrates. Transportation of pellets is easier.

Pelletisation can be carried out on a small scale to utilize small reserves of ore fines & then transported to any distance to blast furnace.
Pellets from Mandavi – Goa and Kudremukh – Karnataka are entirely exported.

1.8 MT and 3.0 MT resp. are exported.

Sinter vs. Pellets

In general natural lumpy ore or sinter or pellets or a suitable combination of two or more of these form the burden.. The modern large capacity furnaces necessarily need fully prepared burden to maintain their productivity since the required blast furnace properties cannot just be met by natural lumpy ore. The selection of the process of agglomeration, whether sintering or pelletising, will depend upon the type of ore fines available, the location of the plant and other related economic factors involved.

Sintering is preferred if the ore size is -10 mm to + 100 mesh and if it is -100 mesh pelletising is generally adopted. Pelletising in fact requires ultrafines of over 75% of -325 mesh. These processes are therefore not competitive.

Advantages of Pellets

- ✓ Minimum closure of pores by fusion or slagging; open pore system; very good reducibility due to high microporosity . Porosity of sinter is 10-18% and that of pellets is 20-30%.
- ✓ The shape of pellets is near spherical and hence bulk permeability of the burden is much better than that obtained from sinter which is non-uniform in shape.
- ✓ The shape, size and low angle of repose give minimal segregation and an even charge distribution in the furnace.

Advantages of Pellets

More accessible surface per unit weight and more iron per unit of furnace volume because of high bulk density, 3-3.5 tonnes/m³. Larger surface and increased time of residence per unit weight of iron give better and longer gas/solid contact and improved heat exchange;

Degradation of sinter during its transit is much more than that of pellets. The sinter therefore has to be produced nearby the blast furnace plant while pellets can be carried over a long distance without appreciable degradation. Ease in handling

It should also be noted that If high rates of productivity demand elimination of fines and since sinter happens to contribute more to the generation of fines than that of pellets, the later will have to be chosen as the burden in preference to

sinter.

Disadvantages of pellets

- The installation cost of a pelletising plant will be 30-40% more than that of sintering plant of an equal size.
- The operating cost of sintering is slightly less than that of pelletising.
- Difficulty of producing fluxed pellets.
- Swelling and loss of strength inside the furnace
- Fluxed pellets break down under reducing conditions much more than acid and basic sinters and acid pellets.
- Strong highly fluxed sinters, especially containing MgO, are being increasingly preferred to pellets.

