CARBONIZATION OF NON-COKING COAL

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CERTIFICATE

This is to certify that the thesis entitled, **'Carbonisation Of Non-Coking Coal'** submitted by **Kishore Kumar Behera(111MM0355)** and **Sushil Kumar Behera (111MM0356)** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Metallurgical & Materials Engineering at the National Institute Of Technology, Rourkela is a bonafide and authentic research work carried out by them under my supervision and guidance over the last one year (2014-15).

To the best of my knowledge, the work embodied in this thesis has not been submitted earlier, in part or full, to any other university or institution for the award of any Degree or Diploma.

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Kishore Kumar Behera

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Abstract:

Since coking coal reserves all over the world is not suffcient to meet the demand of fuel used in iron making,DRI route of iron making is being adopted.Taking into account the current scenrio ,India produces around 20 MT per annum in which noncoking coal is used extensively.In this project work,studies on effect of different carbonisation temperatures(400,600,800,1000),chemical and physical propeties(Proximate analysis,caking characteristics,porosity) of different coal samples,obtained from different mines in India were conducted for their effective use in sponge iron making.In the project work studies has been done on chars prepared from Jagannath,Lingaraj Mines,ananta mines,bhubaneswari and Talcher open field mines .Noncoking coals at four different Carbonisation temperatures were analysed for detremination of their physical and chemical properties.It was concluded that increase in carbonisation temperature,volatile matter and calorific value decreases where as fixed carbon content and ash content increases.It was also found out that Bhubaneswari mines coal has high fixed carbon content.Talcher mines coal has highest calorific value.This test examines which coal is best applicable for industrial applications like sponge iron making.Studies on different soaking rate as well as different soaking time was also investigated.

Keywords:Non-coking coal, proximate analysis, calorific value, fixed carbon content,ash content,moisture content,volatile matter content,density, porosity,carbonization, soaking time, heating rate

Chapter 01

Introduction:

1.1 Theory and Objective:

Coal plays a very important role in sustainable development and economic progress of india.Coal is used as a basic energy source for electricity generation and most importantly for steel making in industry.According to the world coal association,Coal contributes to 41% of total electricity generation and 70% of total steel production . In india 66% of total energy production is based on coal.But most of the coal reserves in india are of inferior quality.Also during mining,their quality further deteriorated due to lack of sofisticated hardware components.Most percentage of non-coking coal has high ash content of around 40% to 45% and sulphur content . So noncoking coals have very limited use in industrial area except power generation.Another drawback of indian coal is due to poor washability and presence of near gravity materials.

Coal definition:

Coal is a carbonaceous material formed from fossilized plants buried in the soil and consisting of amorphous carbon with various organic and inorganic substances.

Origin of coal:

Formation of coal happened hundreds of millions of years ago when the earth was covered in thick plant life.Many of the plants were in flooded forests or swamps.When the plant died they fall into the water,so they did not decay all the way instead they turned into peat.Peat is partially decayed plants and over living things.As time went by,sand and dirt covered the peat –deep-burying it and compressing it.Heat from inside the earth and the pressure from the dirt above gradually turned the peat into lignite-a soft brown form of coal.When more sediment buried the lignite deeper,it increases the pressure.As the lignite was buried deeper,it was exposed to more heat from inside the heart.Over long period of time increased pressure and heat turned lignite into a harder types of coal that burn better.

Different stages of formation of coal

Biomass → Peat → Lignite → Subbituminous coal → bituminous coal → Semi anthracite → Anthracite → Graphite

Lignite to anthracite is called coal.As we proceed from lignite to anthracite ,the maturity of coal increases.Maturity gives an idea about the rank of the coal.

As we proceed from lignite to anthracite ,the rank of coal increases.Out of these various types of coal, sub bituminous and bituminous coals are called coking coals.

Rest are called non coking coals. Non coking coal is one type of bituminous coal from low to middle level of metamorphism as it has been oxidized in its early formation stage .The moisture content of non coking coal is higher than common bituminous coal in addition to over 10% oxygen and high ash content.

1.2 Reserves of Coking and Noncoking coals in india:

A total amount of 301.56 billion tonnes of coal reserves has been estimated as on 1st april,2014.Out of which the prime coking coals are 5.313 billion tonnes,medium and semi coking coals are 28.76 billion tonnes.Out of total coal reserves 41% are proved coal reserves and 48% are indicated coal reserves and remaining 11% are inferred coal reserves.

Table 1.1 Year Wise coal reserves:

As on(BT)	Proved(BT)	Indicated(BT)	Inferred(BT)	Total(BT)
01.04.2007	99.060	120.177	38.144	257.381
01.04.2008	101.829	124.216	38.490	264.535
01.04.2009	105.820	123.470	37.920	267.210
01.04.2010	109.798	130.654	36.358	276.810
01.04.2011	114.002	137.471	34.389	285.862
01.04.2012	118.145	142.169	33.183	293.497
01.04.2013	123.181	142.632	33.101	298.914

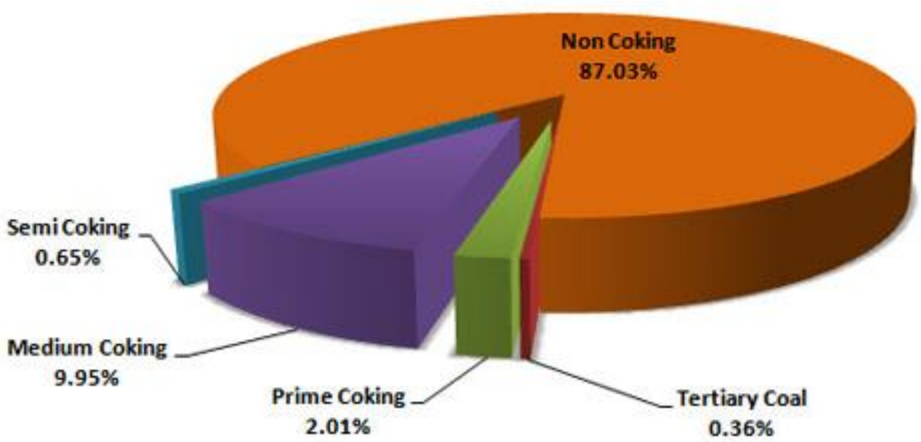
Table 1.2 Depthwise coal reserves:

Depth range	Proved	Indicated	Inferred	Total
0-300	95.092	69.936	10.581	175.609
300-600	12.045	58.544	16.384	86.973
0-600	13.760	0.452	0.00	14.212
600-1200	2.283	13.699	6.135	22.117
Total	123.180	142.631	22.100	298.911

Table 1.3 Global Coal Reserves:

World Total	826.0 Billion Tonne
United states	238.3 Billion Tonne
Russia	157.0 Billion Tonne
China	114.5 Billion Tonne
Australia	76.2 Billion Tonne
India	58.6 Billion Tonne
Ukraine	33.9 Billion Tonne
Kazakhstan	31.3 Billion Tonne
South Africa	30.4 Billion Tonne

India Ranks Fifth in global Coal reserves.Out of Total Coal reserves in india ,non coking coal contributes to 87.03% ,tertiary coal is around 0.36% and rest balances the coking coal which is around meagre 1%.



(Figure 1.1 coking and non coking coal reserves in India)

Table 1.4 State wise Coal Reserves In india:

Name of the State	Reserves In billion tonnes	% total of Reserves
Odisha	75.07	24.89
Jharkhand	80.71	26.76
Madyapradesh	25.67	8.51
Chattishgarh	52.53	17.42
West bengal	31.31	10.38
Maharastra	10.98	3.64
Andhra Pradesh	22.48	7.48
Others	2.81	0.95
Total	301.56	100

STATEWISE COAL RESOURCE (in billion tonne)

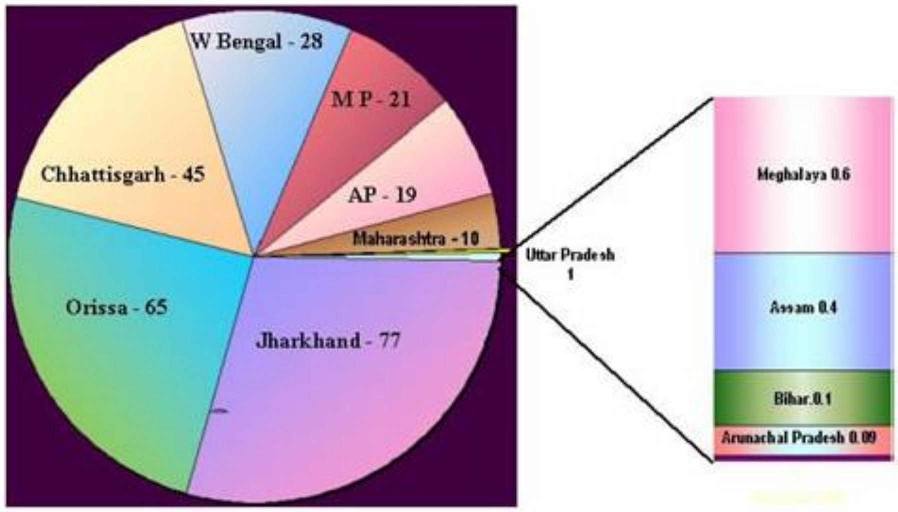
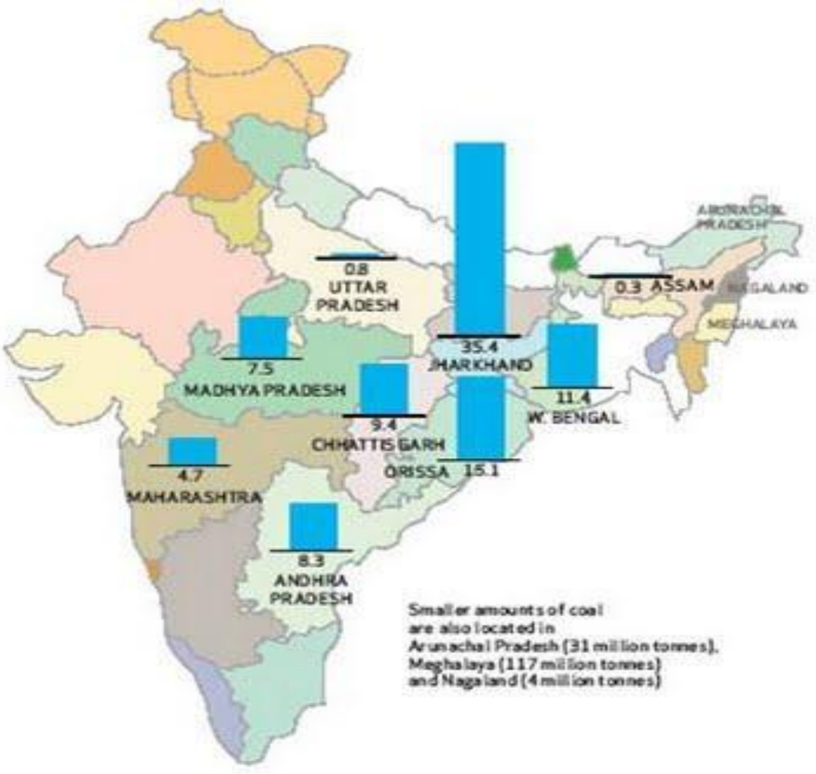


Figure 1.2 Statewise coal reserves in India



Though ,an appreciable amount of coals are available in the states of Odisha and Chattishgarh,But they are of poor quality .They are between the grades D to G.The poor quality of the coals is due to their high ash content.

Drawbacks of high ash content-

- Fixed carbon content/total carbon content in the coal goes down
- Enormous amount of Ash is generated
- Ash is non desirable material in the metallurgical industry
- High amount of ash in the metallurgical reactors consumes high amount of Lime stone /Dolomite which is used as flux in iron making.
- Heating values of the coal goes down There becomes an ash Disposure problem.
- Ash emission in the atmosphere creates hazardous and heat removal problem.
- Cost of the coal goes down
- Transportation cost becomes higher

The coals of Jharkhand and west Bengal are of relatively superior quality (Grade A-C) Because of its lower ash content which is around 20 to 25%.

The state of Assam also contains an appreciable amount of coking coal.This coal contains low ash content(<10%).But this coal is not exploited for its use in metallurgical industry Because of its High Sulphur content. Which is around 3 to 5%.Other coal deposits in India are having lower sulphur content. Which is around 1 to 2%.

Harmful effects of Sulphur in Coal:

1.It increases the flux consumption during Iron making operation

2.Energy consumption during Iron making also becomes high.

3.It produces red/Hot shortness in the finished steel.(hot shortness refers to Brittleness at High temperature.

1.3 Grading of Indian coal:

Indian Coals have been graded on the basis of their ash and moisture content.Various categories like A,B,C,D,E,F,G and H.Coals of Jharkhand and west Bengal are of superior quality that is A to C grades.Coals of Odisha and Chattishgarh are of inferior quality that is D to G grades .As one proceeds from A to G ,The quality of coal decreases.

Table 1.5 Grades Of Noncoking Coal:

Grade	Useful heat Value(UHV)(KCAL/KG)	Corresponding Ash% +Moisture % at (60% RH & 40 degree celsious	Gross calorific Value GCV(Kcal/KG) At 5% moisture level
A	>6200	<19.5	>6454
B	5601-6200	19.6-23.8	6049-6454
C	4941-5600	23.9-28.6	5597-6049
D	4201-4940	28.7-34.0	5089-5597
E	3361-4200	34.1-40.0	4324-5089
F	2401-3360	40.1-47.0	3865-4324
G	1301-2400	47.1-55.0	3113-3865

1.4 MAJOR CONSUMERS OF COAL IN INDIA:

Mainly energy consumed by steel and iron industry is based on coal power plants.In the below table it has been outlined the energy consumed by some of major coal consumer sectors.

Table 1.6 Use of coal in different industrial sector

Sector/Year	**Budget estimates (in million tonnes)**			**2016-17 Projection by planning commission (in million tonnes)**		
	Demand	**Supply**	**Gap**	**Demand**	**Supply**	**Gap**
Coking Coal						
Steel industry	52	20	32	67	35	32
Non-Coking Coal						
Power	555	450	105	738	594	145
Cement	30	15	16	47	23	24
Sponge iron	35	24	11	50	57	-7
others	100	71	29	77	85	-8
Non coking sub total	721	560	161	913	760	154
Total raw coal demand	**773**	**580**	**193**	**981**	**795**	**186**

1.5 Different Routes Of Iron Making:

1.Blast furnace route:

In this process pig iron is produced from its iron ore (Haematite) where Coke is used as fuel for reduction of iron ore.

Disadvantages of blast furnace route:

1.This process of iron production is too costly since it needs bigger infrastructure to complete the setup.

2.Capital investment in this plant is too high.

3.The byproduct gases are not so environmental friendly.

4.High gestation period

2.Sponge iron route or DRI route:-

Normally 85% of indian coals are non coking coal.For effective utilisation of those non coking coals,DRI route of sponge iron making was introduced.In this process iron ore is direct reduced by carbon in stead of carbon monoxide as in blast furnace.Also mixture of CO and coal is used as reducing agent.

Advantages of DRI route of iron making over blast furnace route:

1.Minimal investment cost

2.High flexibility in production of iron

3.Simply plant management

4.Energy or fuel cost is very low than that of the blast furnace route

5.Easy availability of non coking coal

1.6 Factors to be Considered for Selection of Coal in Sponge Iron making:

The chemical composition of coal has a strong influence on its combustibility.The quality of coal is judged on the basis of the following properties.

1. Content of Petrographic constituent
2. Proximate and ultimate analysis
3. Energy value/heating value or calorific value
4. Caking Power/Index
5. Reactivity towards oxidising Gases (CO_2,H_2O,air/O_2)
6. Ash chemistry
7. Ash fusion Temperature
8. Porosity
9. Bulk Density
10. Swelling Index
11. Crushing Strength

Petrographic Constituent:

Petrographic constituent of Coals means the content of the vitrinite ,semivitrinite,inertinites(fusinites and semifusinites),liptinites and exinite.

Vitrinite and Exinite are fusible constituents.Semivitrinite is fusible to some extent only.Inertinites means fusinite and semifusinite.

Caking power of vitrinite is 93.Caking index of exinite is 92.& caking index of inertinite is 13-19..That is vitrinite is approximately equal to that of exinite and that is much greater than that of inertinites.

CAKING INDEX:

Caking power of coal is nothing but measure of sticking tendency of coal particle.Higher the sticking tendency ,more is the caking index of coal.That is the vitrinite or exinite is the main responsible constituent in imparting the caking power to the coal.Non coking coals are having lower C.I. only because of less or nil content of fusible constituents.Coking coals having caking index more than 20 whereas majority of the non coking coals have caking index less than 1.

Fixed And total Carbon :

Fixed carbon means the solid carbon present in the carbonaceous material.

% total C content = % of fixe carbon content +% of C in gaseous constituents of carbonaceous materials.

Energy value or heating value:

The amount of heat energy released as a result of complete combustion of unit weight of Coal/wood etc. are called energy value or heating value.

Calorific value is divided into two categories.

1.Net calorific value (NCV)

2.Gross calorific value (GCV)

Table 1.7 difference between NCV and GCV

Net calorific Value	Gross calorific value
Does not take into account the latent heat of vaporization of water	It takes into account the latent heat of vaporization of water
Most useful parameter in the industry because the gaseous products are in general allowed to join in the atmosphere in majority of the industries	It gives an idea about total energy value.However it is less important than NCV in the industry.

Reactivity of Coal towards oxidizing gas (CO_2,H_2O,air,O_2):

Rate of reaction=dW/Dt means weight loss/time (Unit $mg.Min^{-1}$)

In actual practice ,the reactivity measured by this formula is unit less that is it is simply a number .Reactivity is an ease which denotes the ability of the carbonaceous material with oxidising gases.

In metallurgy we are following some other technique to determine the reactivity of coal or coke.

Important Reactions in metallurgy:

$C + O_2 = CO_2$ –This is called Combustion Reactivity

$C + O_2 = 2CO$ – This is called Boudard or solution loss reactivity or reactivity towards CO_2

In metallurgy,Reactivity is expressed in terms of CC of CO/wt of C/Sec

Combustion recativity becomes important where sufficient amount of heat energy has to be generated inside the reactor.Reactivity towards $C+CO_2$ reaction becomes important in the reactor where high amount of CO is required for the reduction of Iron ore.In wider of the thermal power plant ,we want higher combustion reactivity where as in sponge iron making we want higher reactivity towards CO_2 gas.In actual Practice,it is the reaction of coal char with oxidizing gases.

ASH chemistry:

Ash is the waste of residue obtained after complete burning of carbonaceous material.Different constituents of coal ash are Al_2O_3,SiO_2,Fe_2O_3,CaO,TiO_2 etc.The content of $Al_2O_3+SiO_2$ >= 90%. In the coal ash is generally more than 90%.The third important constituent in the coal ash particularly obtained from west Bengal,Jharkhand,Odisha, and Chattishgarh is Fe_2O_3.The color of the soil in this region is reddish.In indian coal ashes,The CaO and TiO_2 contents are very small amount or sometimes nil.Melting point of Al_2O_3 is around 2000^0C.Melting point of SiO2 is 1710^0C.Larger the amount of these constituents in the coal ash,more will be the amount of heat energy required for melting of these constituents.Hence the energy consumption becomes high.

ASH fusion temperature:

There are four characteristics of ash fusion temperature.

1.IDT-Initial deformation temperature

2.ST-Softening temperature

3.HT-Hemisperical Temperature

4.FT-Flow/fluid temperature

Out of these IDT,and ST are more important for selection of coal in metallurgy.

How to determine AFT:

A cube is made from 3-4 mg of ash powder and is heated in a sophisticated furnace fitted with a microscope.During heating ,the changes in the shape and size of the cube are noted down regularly with the help of micro scope.The temperature at which shrinkage occurs is called IDT.The temperature at which rounding of corners occurs is nothing but the ST.The temperature at which the cube becomes semi cube and takes the shape of hemisphere is noted down.It is HT.The temperature at which the cube becomes completely fluid and spreads over the surface is noted down.

POROSITY-is classified on the basis of pure size

*macropore

*micropore

*mesopore

Other modes of classification is

*open pores

*closed pores

Method of determination of porosity:-

i)by Hg impregnation method(Hg-porosity)

ii)By hot test boiling water method or K-oil method

By Hg-Impregnation method:-

In this case the mercury is allowed to impregnate into the material by creating vacuum there.The volume of the pore is determined by noting down the gain in wt of the material.

By hot-test boiling water method:-

Hot water molecules have higher kinetic energy. So they can easily impregnate into the sample.

Let D=wt of dried sample in air

Keep the sample in boil water for 20 to 30 minutes with the help of thread.

S=suspended wt of thread +sample while immersed in water

W=wt of the water saturated sample in air

Apparent Density=D/[D-(S-s)]

Apparent Porosity (%)=(W-D)/[W-(S-s)]*100

True porosity(%)=[1-(app density/True density)]*100

As porosity increases,no of sites available for the accommodation of other reactant molecules increases and thus the rate of reaction increases.

Limitation:-

Higher porosity decreases the strength of material

Bulk density:-

Bulk density of material gives an idea about its amount to be accommodated in a given volume of the reactor.Higher the bulk density,more is the amount of material accommodated in a given volume of the reactor.Hence higher bulk density of material gives higher yield of liquid metal etc from the reactor.Higher the bulk density lower is the transportation cost.

Bulk Density=(Wt of the material totally filled in a container)/(Vol of the container)

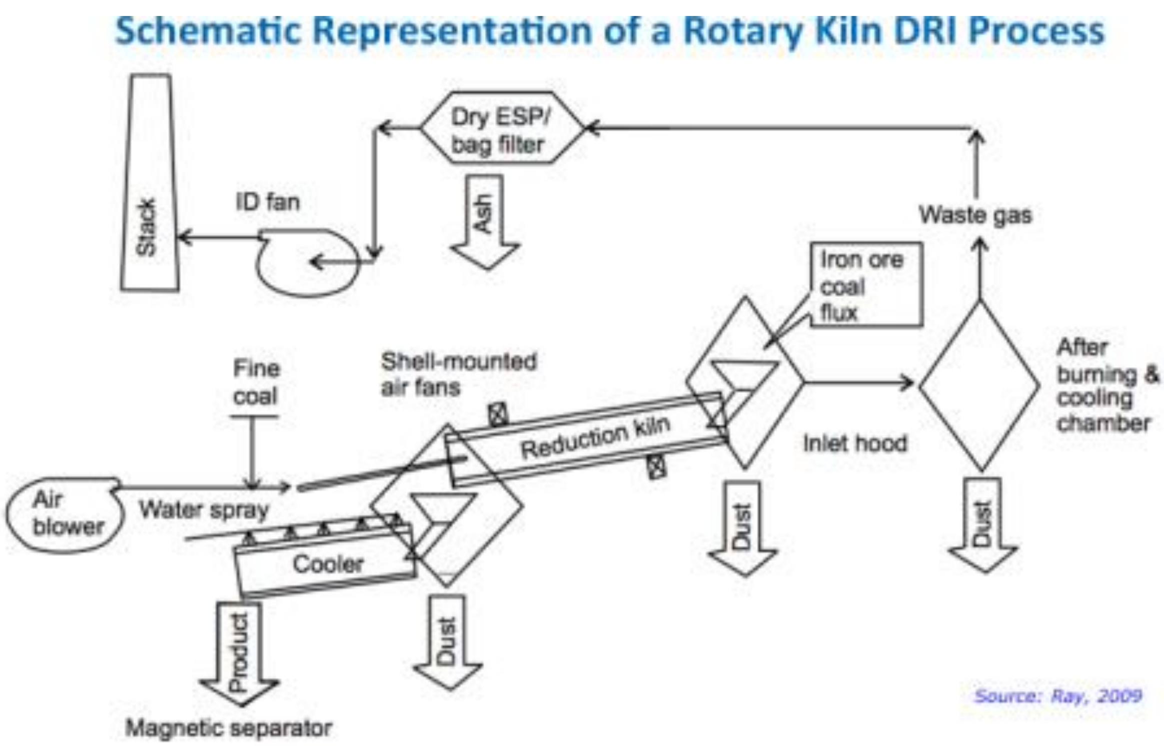
Swelling index-S.I means %change in vol

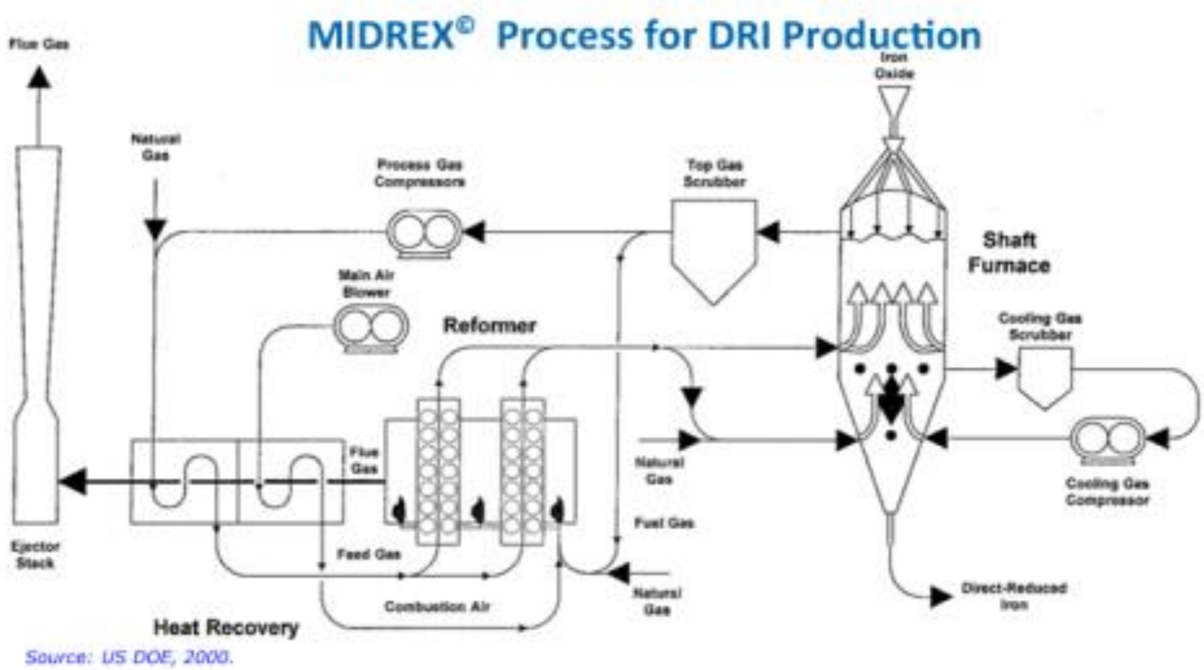
It is a phenomena observed in some of the coals during heating in the temperature range of 300 to 600 degree centigrade.

Δ V% change in weight=$\frac{Vf-Vi}{Vi}\ x\ 100$

Due to swelling ,the strength of coal goes down and the coal may break into fines .The fines generated may choke the voids between the solid material and the flow of gas will be difficult.As a result ,operation may get stop .Permeability is the pathway formed between the material and the porosity is the characteristics of an individual lump also.Usually permeability is responsible for the flow of gas through the solid material.Hence solid weight must be permeable inside the reactor.

1.7 Schematic Representation of Rotary kiln DRI process:





(Figure 1.3 MIDREX process for DRI production)

CHAPTER -2

2. Literature Review:-

Aydin S.,Narcin N., Sesen K.,Dikee F reported that reduction potential of coal sample is dependent on fixed carbon content and by using proximate analysis and ultimate analysis,total carbon content present in the coal sample can be determined.Iron ore reduction by using domestic lignite coal in semi rotary tube furnace mainly depends on coal consumption ratio(C_{fix}/C_{total}).Narchin et al found out that that at coal consumption ratio 0.40 and temperature 1000 degree Celsius,reduction of iron ore was fast and complete in 90 minutes.

Synergetic effects during carbonization of polish orthocoking coals:

V. Zubkova,M. Kosewska,K.Wrobelska,V. Prezhdo reported that synergetic effects were observed under the action of coal type 35.2(polish orthocoking coals) producing an increase in the interlayer pressure,a change in plastic layer thickness and a displacement of nonvolatile mass compared to normal value.Due to synergetic effect a solid residue was obtained which has slight different volume than that of the original value.

DD.Holder:

Beneficiation of noncoking coal was done to improve the properties like char characteristics ad strength,volatile matter content,heating value reducing the inert content.Beneficiation of noncoking coal was carried out to impart all suitable properties to coal which are essential in iron making.The study of upgradation of noncoking coals is that coal particles recovered should have the same properties as that of coking coal and combustible behavior in case of non coking coals which is the prerequisite for iron production.

Romeo M. flores Of el-

Mr. Romeo M. Flores reported that because of compositional variation of coal their physical and chemical properties like porosity ,volatile gas permeability vary from their original values that affects the combustion process of coal. Percentage of fixed carbon determines calorific value of coal .Gaseous content in coal measures its shrinkage and swelling characteristics .

John W. Saren:

He conducted research work on the effect of dissolved CO_2 on coal and analyzed their different physical and chemical properties.Carbon dioxide normally helps in swelling of coal by dissolving in its matrix.As a result of which it decreases coal's softening temperature thus act as a plasticizer.He analyses dissolving capacity of different gases like CO_2,methane ,ethane and similar molecule size gases. But found out that CO_2 has higher dissolving capability than other gases.The reason being that lithostatic pressure acts as a driving force for higher solubility in coal.

Atefeh Shakiba,Khatereh Edalati,J. Vahdati Khaki,Ahad Zabet conducted research work on layered reduction of haematite ore by non coking coal.They studied that due to high coal reserve of noncoking coal noncoking coal must be used in an efficient way to increase iron production..They studied the reduction of iron ore by non coking coal in the range of 800^0C to 1500^0 c.At 800^0C ,74.9% of volatile matter and gases leave the coal.They investigated that with increase in temperature reduction power of iron ore by coal gets increased.At around $1000ash^0$ C ,the reduction power gets maximum. And then decreases gradually.Also addition of Calcium carbonate to noncoking coal increases time rate of reduction on noncoking coal for optimum use in industries.

Asish Kumar Sahoo conducted dry beneficiation of non coking coal enriched in high ash content using air dense medium fluidized bed.Air dense medium is required in dry separation process.He studied about the dynamic stability of the fluidized bed.Considering the experimental data,he characterizes the stability of the fluidized bed based on Froude number,reynold number,ratio density of fluid.Coarse size coals (-10 to 0.1mm mesh size) can be beneficiated in the fluidized bed .Analysing the ash content ,quality of beneficiation can be judged.

Characteristics of non-coking coals by M. Kumar and S.K. Patel (2008) :

Kumar and patel conducted study on characterization of non coking coal obtained from different mines.They found out that sulpher content ranging from 0.44 to 0.66 is not a problem.Also many coal mines have nil caking index but high ash fusion temperature(ST>1349,IDT>1400,FT>1500,HT>1500).Their results summarizes that with increase in temperature fixed carbon content the chars increases and majority of chars have higher reactivity than coal.Their result shows that the most of the coals can be used effectively for use in industrial purpose.

India Prof. Kalyan sen of emeritus (2008)

Prof Kalyan Sen examines the physical and chemical properties (Proximate and ultimate analysis,ash fusion temperature,calorific/energy value,chlorine & sulpher content) of different coals procured from different mines in India.He found out that calorific vale of Indian coals lies in the range of 4940-6200Kcal/KG and maximum ash content is around 30%.Most of the coal ashes have high ash fusion temperature (IDT>1280).All the characteristics are useful while using coals in sponge iron plants and blast furnace.

Petrographic content study of coal by Claudio Avila et al :

Claudio Avila et al conducts his research work on 25 different coal samples collected from different mines across the globe.Characterization of coals results in seemingly changes in vitrinite content (it leads to porosity) along with intrinsic potential. Proximate analysis is done in two stages.One is after collecting the coal samples and then after drying the coal sample. The output results that volatile matter and fixed carbon content is higher in 2^{nd} case that is dried sample than that of 1^{st} case.After drying of sample The ratio of carbon content to volatile matter increases.Then the microstructure of the sample was examined by using microscope with 10x320 magnification. The experiment conducted by Claudio Avila et al reveals its texture property of coal.

Chapter 03

3. Aims and objective of present project work:

1.Carbonisation of non coking coals procured from 5 different mines at different carbonization temperatures 400^0C,600^0C,800^0C and 1000^0C.

2.Determination of char yield after carbonization of coals

3.Determination of calorific values of coal

4.To study proximate analysis of coals obtained from five different mine

5.Calculation of moisture content,ash content ,volatile matter content and fixed carbon content of char obtained after carbonization at different temperature

Chapter 04

4. Experimental procedure:

4.1 Selection of Material: -

Five different types of non-coking coals were collected from lingaraj,anata,Jagannath,Bhubaneswari and Talcher open field mines.

4.2 Proximate analysis:

Proximate analysis is defined as the determination of percentage of moisture content, volatile matter content, percentage of ash content and percentage of fixed carbon content in the coal.

4.3 Moisture content:

1 gm powder coal smaple of size -72 mesh size is taken in a borosil /crucible made of glass.The borosil /crucible is then kept in an air oven maintained at a temperature of 105^0 C to 110^0 C.This sample is taken out from the oven and weight loss is recorded by electronics balance.

The percentage weight loss is nothing but the percentage moisture in the same.

% Moisture content $= \frac{Weight\ Loss}{Initial\ Weight}\ X\ 100$

There are normally two types of moisture in the coal.

1.Free moisture

2.Combined moisture

Free moisture:Which may get removed during the exposure of coal sample in the air. when the moisture content in the coal sample comes in equilibrium that of air,further removal of moisture stops.This is called air drying of the sample.

Combined moisture:

It gets removed from the sample during heating in an air oven at a temperature of 105-110^0C.

4.4 Volatile matter content:

1gm of powdered coal sample of size -72 mesh size is taken in a cylindrical crucible(heated with lid).The crucible is made of silica.The crucible s then kept in a muffle furnace maintained at a temperature of 925-950 degree Celsius. And kept at this temperature for 7 minutes.The crucible is then taken out and lose in weight of dry coal sample is recorded by means of electronics balance.

% volatile matter =% loss in weight -% moisture content

$$= \frac{Weight\ loss}{Initial\ weight\ of\ coal}\ x\ 100\ \text{- \% moisture content}$$

4.5 Ash content:

One gram of air dried powdered coal sample of size -72 mesh size is taken in a shallow silica disc/crucible.The crucible is then inserted in a muffle furnace maintained at a temperature of 775^0C – 800^0C. and kept at this temperature till complete burning.Usually 1 hour is consumed in complete burning .As reactivity of coal/wood increases ,the time of ash determination decreases.

4.6 Fixed carbon content:

The fixed carbon content calculated as Fixed carbon % = 100 – (%moisture+%ash+%volatile matter)

4.7 Calorific/heating value :

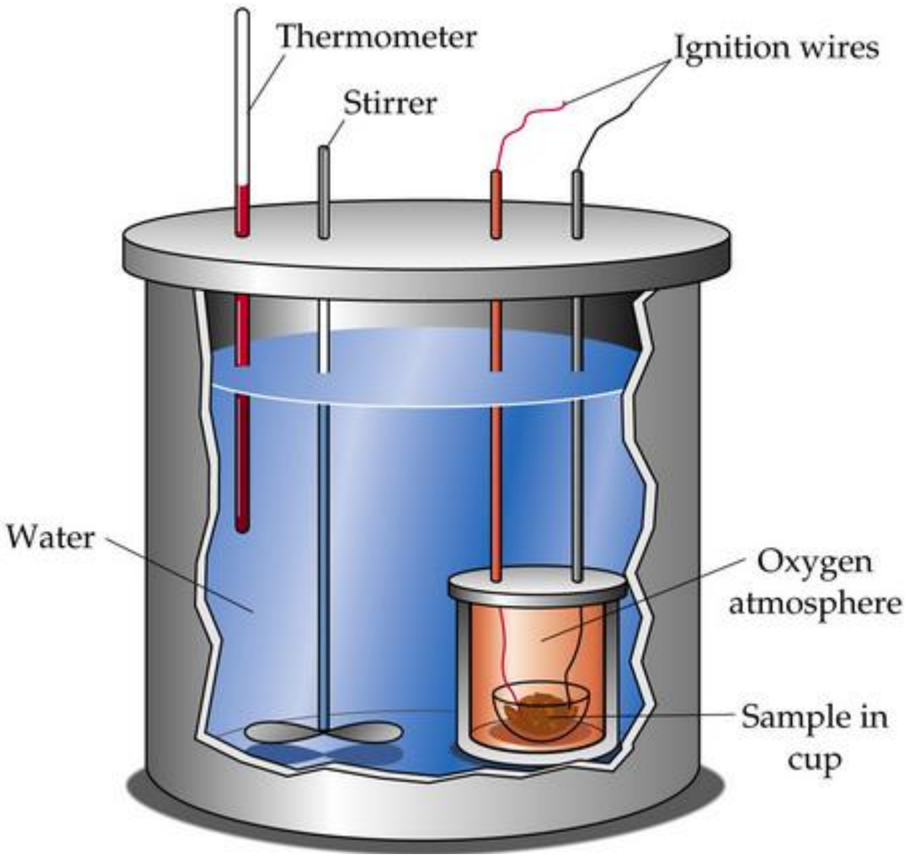
The amount of heat energy released as a result of complete combustion of unit weight of coal or wood etc is called calorific value or heating value.The calorific values of noncoking coal is measured by indian standard.The coal used should have high calorific value in order to meet the thermal requirement of energy.Contribution to calorific value are hydrogen and carbon contents.Calorific value is normally determined by Bomb calorimeter in the laboratory.

Process:

The bomb is made of stainless steel..The bomb along with all the connections and containings are kept in a steel vessel containing 2 liters of water.Outer steel jacket does not allow the heat to go out when the current is switched off ,the fuse wire burns,cotton thread catches fire and combustion of sample stats.As a result ,heat is produced .Heat is generated is absorbed by the water in the inner steel vessel.The water is continuously stirred to homogenise the temperature in the water.The rise in temp of water is continuously recorded at an regular interval. Of time (1 minute).Maximum rise in temperature is noted down.during cooling also the decrease in temperature water is also noted down at a regular interval of time and the formula is used.

Calorific value of cotton=4250 Kcal/KG.

Weights of the fuse wire and the cotton thread are noted down to calculated the heat released by them.This has to be substracted.



(Figure 5.1 Schematic diagram of bomb calorimeter)

$$GCV = \frac{WE*(\Delta T+.04)\}}{W}$$

G.C.V=Gross calorific value

WE: Water equivalent = 2400kcal/^{0}c

W: weight of the sample

ΔT: Temperature difference between maximum and minimum temperature

W: weight of the sample

4.8 Carbonization of non-coking coal:

Carbonisation is a heat treatment process of coal to produce metallurgical grade coal for industrial applications.It is defined as the heating of coal in absence of air or oxygen to increase its mechanical strength,crushing strength,fixed carbon content,true density,C-C bond strength andwear resistance.

Procedure:

Five different coal samples were collected from five different coal mines.Then each coal samples were prepared to make -72 mesh size and 100gm of each coal samples was weighed in an electronics balance.

The weighed coal is put in a stainless steel crucible and inserted in to the furnace.Then the furnace is switched on and temperature is set to carbonization temperature of 400^0C,600^0C,800^0C and 1000^0C for different coal sample.

The rate of heating in the furnace is set to 10^0C per minute.The soaking time is at these temperature was one hour.After one hour the furnace is switched off and the samples are allowed to cool in the furnace itself.

After carbonization the coals are converted to char and then taken out and weighed.The obtained chars are then processed for proximate analysis and char yield calculation.

Chapter 05

5. Results and discussion:

Characterisation of coal samples:

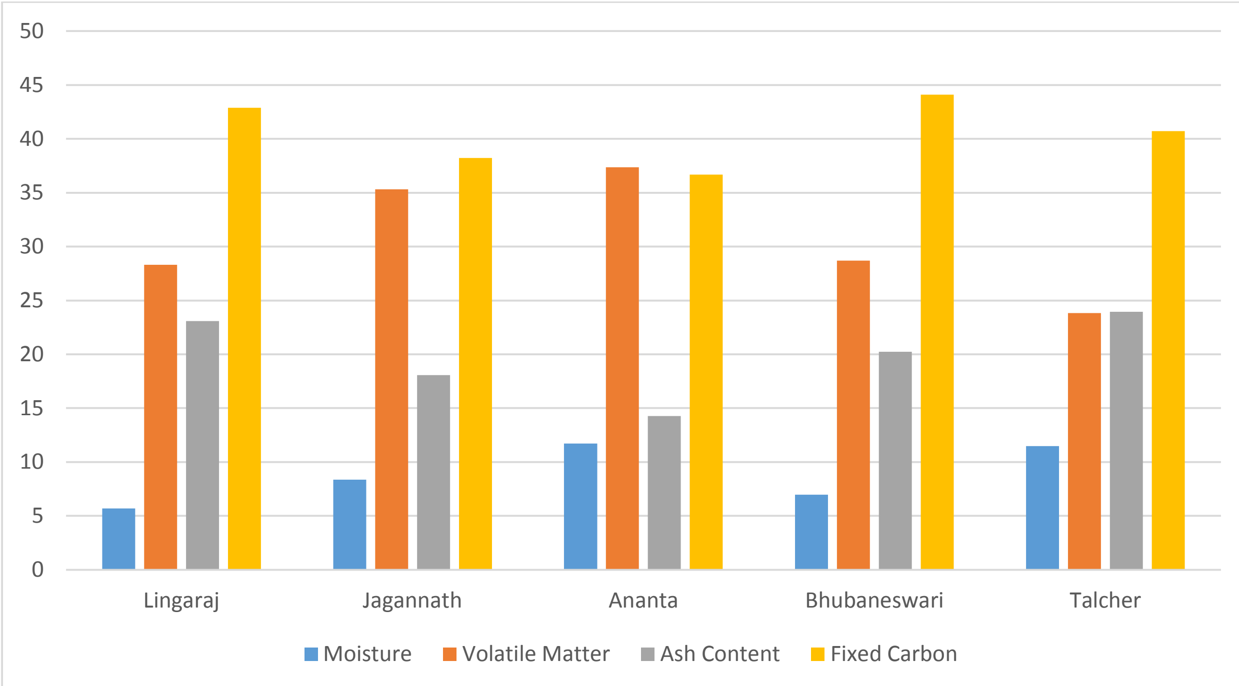
Chemical and physical properties(Proximate analysis,char yield,Calorific value)of different coal samples collected from different mines were carried out and datas are prescribed below.Proximate analysis shows about ash content,moisture content,volatile matter content and fixed carbon content.Fixed carbon content is a important characteristics to be examined before its use in any industrial application.Fixed carbon content refers to the amount of carbon present in the coal which is required for the reduction of iron ore.Proximate analysis of different coals indicates that Ash content,volatile matter content and fixed carbon content lies in the range of 12-35%,10-32% and 40-60% respectively.It was found that Bhubaneswari open field mines has higher fixed carbon percent following Lingaraj Open field mines.It was found that Talcher mines have higer calorific value which is highest among all samples.For efficient use of coal in sponge iron plants ,the coal should have fixed carbon content around 40% and volatile matter content around of 25-30%.Jagannath and talcher mines coal are better suitable for Sponge iron making.

Proximate analysis of coals procured from five different mines:

Table 5.1

Mines name	Moisture content (%)	Volatile Content (%)	Ash Content (%)	Fixed Carbon Content (%)
Lingaraj	5.7	28.3	23.1	42.9
Jagannath	8.37	35.31	18.08	38.24
Ananta	11.71	37.35	14.27	36.67
Bhubaneswari	6.98	28.69	20.24	44.09
Talcher	11.49	23.83	23.96	40.72

Analysing the data from the above table we concluded that Bhubaneswari mines coal has relatively high carbon content and relatively low ash content.where as Lingaraj mines coal has low moisture content.So overall Bhubaneswari mines coal is more suitable for industrial purpose.

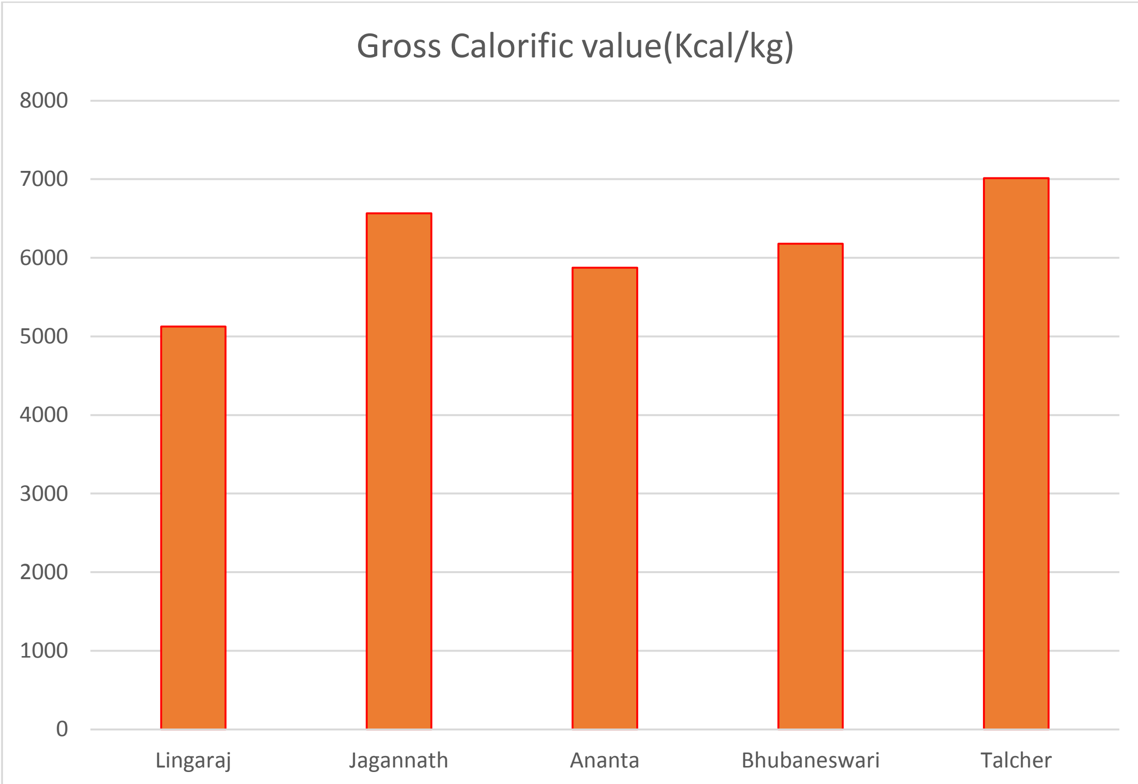


(Figure 5.1 Chart representation of Proximate analysis of coal)

Analysis of Calorific Value:

Table 5.2

Mines name	Gross Calorific value(Kcal/kg)
Lingaraj	5125
Jagannath	6568
Ananta	5876
Bhubaneswari	6178
Talcher	7015



(Figure 5.2 Graphical representation of Calorific value of coal)

Calorific values of different coal samples were calculated and It was found out that Talcher coal mines have highest gross calorific value and Jagannath mines has second highest calorific value.Talcher mines coal generates 6568 Kcal energy per burning of 1 Kg of coal.

Proximate analysis and Calorific values of Chars obtained from Lingaraj Open field mines:

Table 5.3

Carbonization Temperature (^0C)	Soaking time	Char yield	Proximate analysis			Calorific value
			%V.M	%Ash	%Fixed carbon	
400	1	90.72	26	25	44	5338
600	1	84.39	19	27	50	5534
800	1	79.49	13	28	57	5643
1000	1	78.85	9	32	60	5807

Proximate analysis and Calorific values of Chars obtained from Ananta Open field mines:

Table 5.4

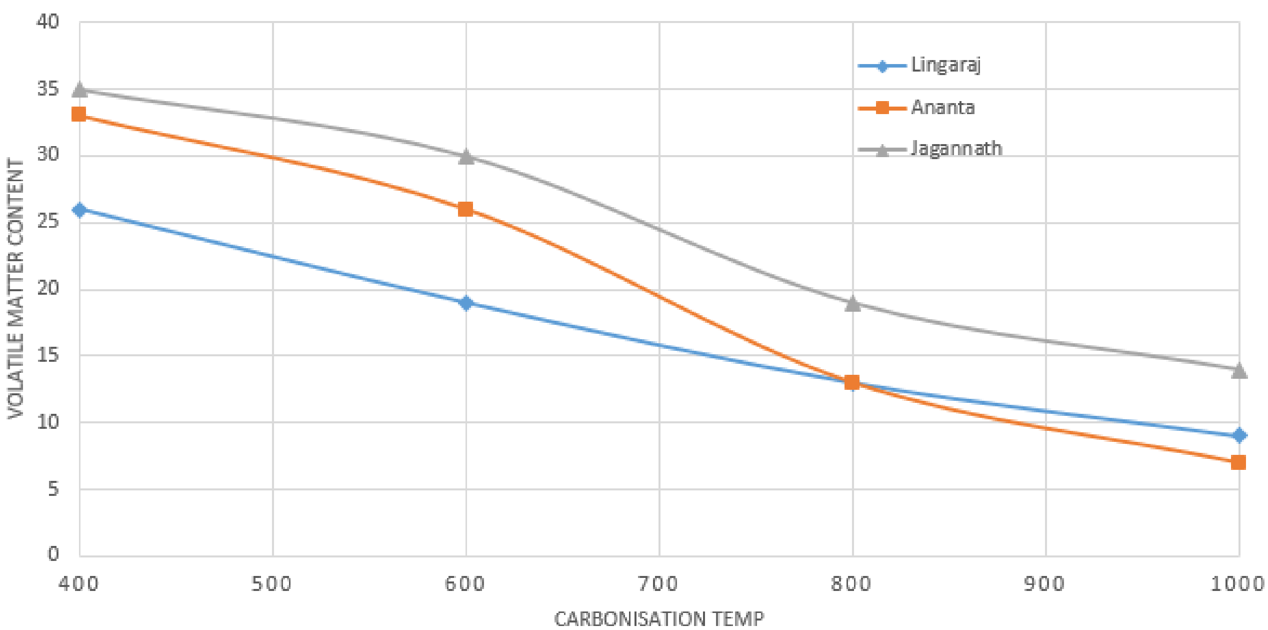
Carbonization Temperature (^0C)	Soaking time	Char yield	Proximate analysis			Calorific value
			%V.M	%Ash	%Fixed carbon	
400	1	80.94	33	18	40	5889
600	1	65.69	26	23	44	6034
800	1	59.07	13	28	55	6143
1000	1	55.03	7	35	57	6407

Proximate analysis and Calorific values of Chars obtained from Jagannath Open field mines:

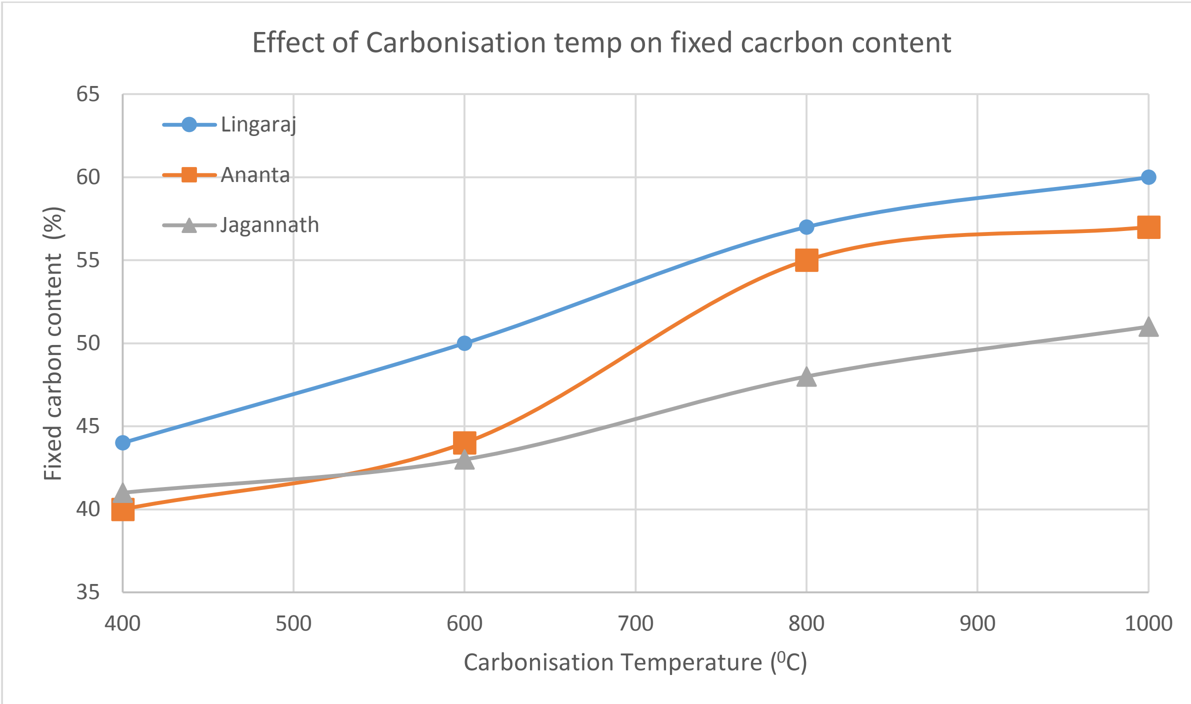
Table 5.5

Carbonization Temperature (^0C)	Soaking time	Char yield	Proximate analysis			Calorific value
			%V.M	%Ash	%Fixed	
400	1	85.29	35	16	41	6638
600	1	71.80	30	20	43	6734
800	1	66.33	19	29	48	6843
1000	1	64.94	14	33	51	6860

(Figure 5.3 Variation of volatile matter with increase in carbonization temperature)

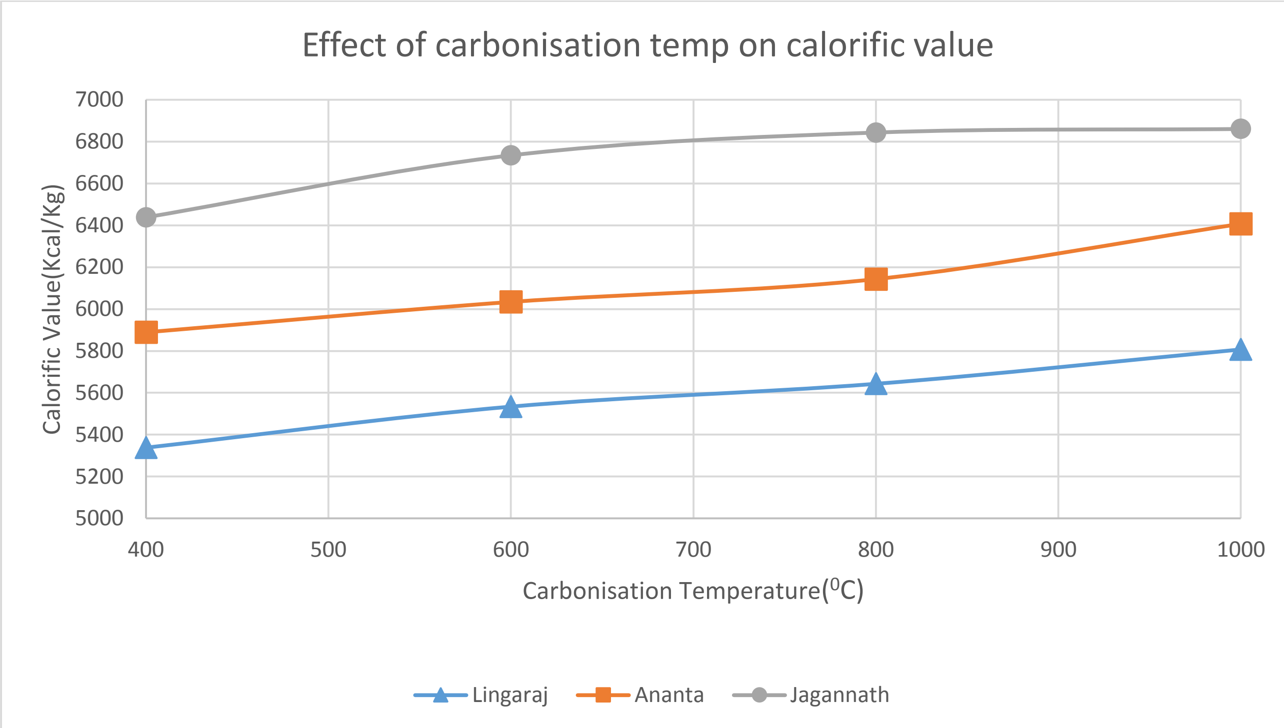


The relationship between Volatile matter content with carbonization temperature has been established in the above graph.It shows that volatile matter content decreases with increase in carbonization temperature of Coal.This occurs because of expulsion of gases from the coal.



(Figure 5.4 variation of fixed carbon content with carbonization temperature)

The relationship between Fixed carbon content content with carbonization temperature has been established in the above graph.It shows that fixed carbon content increases with increase in carbonization temperature of Coal for all three coal samples.



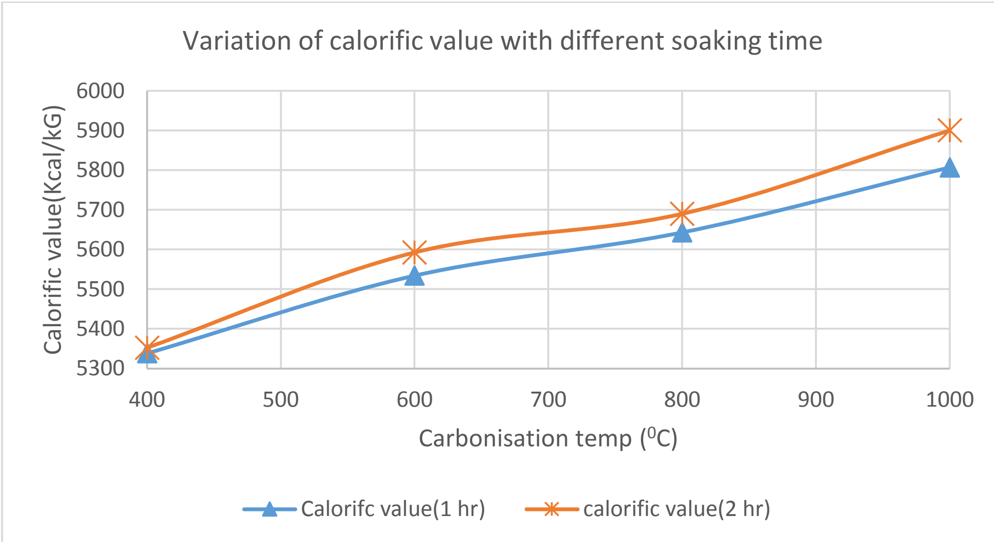
(Figure 5.5 variation of calorific value with carbonisation temperature)

This graph shows that with increase in carbonisation temperature,calorific values of coal increases.Lingaraj mines coal has higest calorific value.

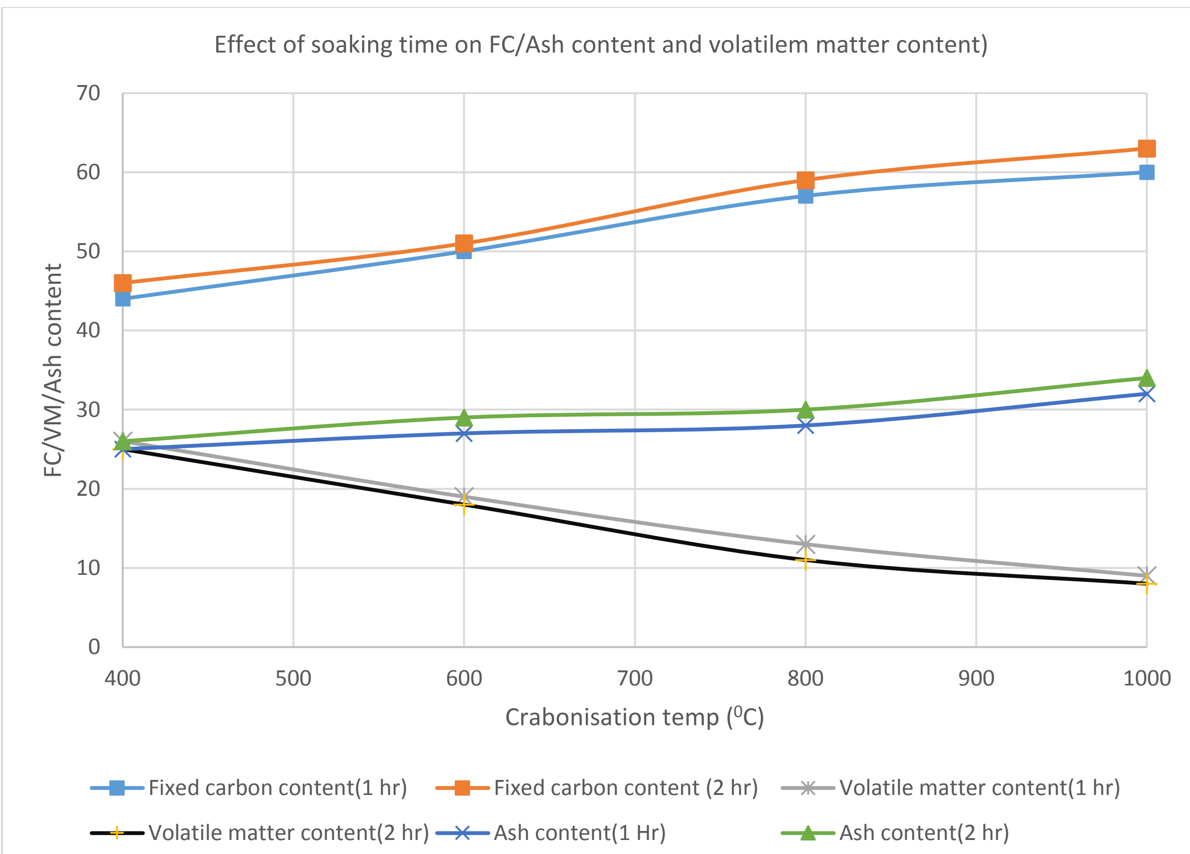
Effect of different Soaking time on proximate analysis and calorific value during carbonisation of coal of Lingaraj mines:

Carbonization temperature (°C)	Soaking time	Fixed carbon content (%)	Ash content (%)	Volatile matter (%)	Gross calorific value (kcal/kg)
400	1 hr.	44	25	26	5338
600		50	27	19	5534
800		57	28	13	5643
1000		60	32	9	5807
400	2hr.	46	26	25	5352.22
600		51	29	18	5592.6
800		59	30	11	5690
1000		63	34	8	5900

Carbonisation of lingaraj coal is done taking different soaking(1 hour and 2 hour) time.Their physical and chemical properties were examined.It was found that ash content , and calorific value increase with increase in soaking time while volatile matter content decreases with increase in soaking time at the same carbonisation temperature.



(Figure 5.6 variation of calorific value with carbonization temp at diff soaking time)



(Figure 5.6 variation of FC/VM/Ash content with carbonization temp at different soaking time)

Chapter 06

[Conclusion and scope for future work]

CONCLUSION:

Studies are done to characterise different physical and chemical properties and their variation with different carbonisation temperature were investigated.Following results are concluded.

- Proximate analysis of coal samples were carried out.It was obtained that Lingaraj and Bhubaneswari mines are more suitable for sponge iron plant.
- From the above experiments we observe that there is significant increase in calorific value of char as temperature increases.
- Further with increase in temperature,volatile matter content decreases and fixed carbon content increases .
- It was found that Char content decreases as carbonisation temperature increases.
- Calorific value of coal is comparable to chars obtained after carbonisation.

Scope for the future work:

1) The studies carried out in the current project can be applicable for other coals also.
2) Studies on other physical as well as chemical properties of coal are also suggested to be carried out in future.
3) Studies on direct reduction of iron ore by using these noncoking coals also need to be carried out in future which can provide wide scope of iron production

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