CHAPTER V

MINING METHODS AND COAL PROCESSING TECHNOLOGY

5.1 INTRODUCTION

Mineral exploitation in which all extractions are carried out beneath the earth’s surface is termed as underground mining. Underground mining methods are employed when the depth of the deposit, the stripping ratio of overburden to ore (coal or stone), or both become excessive for surface exploitation (Hartman and Mutmansky, 2002). Underground mining method selection is one of the most important decisions that mining engineers have to make. Choosing a suitable underground mining method to extract a mineral deposit is very important in terms of economics, safety and productivity of mining operations (Alpay and Yavuz, 2009). Pabedana coal mine is an underground mine operated by government and at present is administered by a private company. Exploitation coal from Pabedana area was started in 1977 and proven coal reserves are around 41 million tons. Economically extractable seams are designated d2, d4, d5 and d6 and are situated 2400-2505 meters above MSL. Long wall mining method has been adopted at Pabedana for extraction of coal.

Extracted coal is transported by trucks to Zarand coal washery, which is 65 km south of Pabedana coal mine (Fig. 5.1). In Zarand coal processing was commenced in 1978 with a capacity of 2 million tons of raw coal with 61% production efficiency. Zarand coal washery is one of the biggest coal concentration plants in southwest of Asia. The design of coal processing plant is influenced by a number of factors including coal characteristics, market requirements, local infrastructure and regional preferences (Kamall, 2001). In this plant the coal concentration process involves, coal washing and decreasing ash-content and impurities,
which leads to increase in carbon percentage. Concentration process is carried out in four stages; heavy media, jig, dynawhirlpool and flotation. Final concentrations are transported to Eifahan iron melting plant by railway wagons. Waste material produced from coal washing process is pumped to a pond situated 600 m away from the coal washing plant.

Fig. 5.1: Location map of coal washing plant and coal mines.

5.2 PURPOSE OF COAL PREPARATION

Coal preparation serves several purposes. One important purpose is to increase the heating value of the coal by mechanical removal of impurities. This is often required in order to find a market for the product. Run-of-mine coal from a modern mines may incorporate as much as 60 percent reject materials.
Air pollution control often requires partial removal of pyrite with the ash to reduce the sulphur content of the coal. Ash content often must be controlled to conform to a prescribed quality stipulated in contractual agreements. Because of firing characteristics, it is often as important to retain the ash content at a given level as it is to reduce it.

Freight savings are substantial when impurities are removed prior to loading. Finally, the rejected impurities are more easily disposed off at the mine site remote from cities than at the burning site, which is usually in a populated area.

5.3 MINING METHOD AND EQUIPMENTS

Pabedana coal mine is an underground mine having 25 stopes. These stopes are active in workable coal seams, and the number of stopes in different coal seams are: 19 in d2 seam; 2 in d4 seam; 1 in d5 seam and 3 in d6 seam. d2 seam has the maximum number of mining stopes with production of 1,02,000 tons/year.

In the Pabedana coal mine, the average coal production is around 174400 ton/year which comes from different coal seams namely, d2=1,02,000, d6=30,000, d4=24,000 and d5=18,000 ton/year. Height of the tunnels varies from 2.5 to 4 m in underground paths. Tunnel dimensions depend on kind of tunnel and vary from 5.6 to 14.8 m² (Fig. 5.2). Wall and roof of drilled tunnels are supported by metal panels, concrete and timber. Supporting of mining stopes are implemented by wood pillars, timbering and hydraulic jacks.

Inclination of coal seam is the main parameter for determining the type of wall face of mining stopes. Therefore, for extraction of coal reverse benching method is employed for extraction of coal from seams having dip more than 40 degrees whereas longwall mining method is selected for seams with less than 40 degree dip. Classical longwall method has been
used rather than mechanized method for production, because the field is often subjected to severe tectonic movements (Hindistan et al., 2010).

Extraction by longwall mining is an almost continuous operation involving the use of self-advancing hydraulic roof supports, a sophisticated coal-shearing machine, and an armored conveyor parallel to the coal face. Working under the movable roof supports and riding on the conveyor frame, the shearing machine cuts and spills coal onto the conveyor for transport out of the mine. The major advantages of the longwall mining method include its suitability for mining at greater depth, higher recovery, and higher production rate compared to room and pillar method (Scott et al., 2009). In these days the underground mining practice involves lively mobile machineries, which drastically simplify preparatory and development operations of stope excavation, boost mining works, and minimize hand-labour due to the overall mechanization (Oparin et al., 2008).

In the Pabedana coal mine, where longwall mining method is practiced cutting machines such as oral and temp machines are employed; the cutting machines increase extraction efficiency by 4 times. Oral machine consists of a blade of 180cm length and 15cm thickness. Oral machine is used for cutting the lower parts of coal seam, so that due to gravity force the roof coal automatically falls into the open place from where it is collected. Temp machine contains large and strong drill bit which has the ability to rotate and move forward during cutting process of mining stope. Extractions by temp machines are not economic owing to the presence of fractures and joints in coal seams and lower coal reservoir volume.

Working cycle of mining stope includes: (1) drilling with hand perforator, (2) detonator operation periodically, (3) explosion of wall face, (4) periodic tunnel ventilation, (5) loosing operation, (6) survey of face wall, (7) loading of load-haul-dump (LHD) loader, (8)
installation of metal panels in roof and walls of tunnels, and (9) timber support with wood pillars in between panels.

5.3.1 Longwall mining process

The longwall mining system is comprised of a shearer machine, articulated face conveyor (AFC), and a system of longwall shields. The shearer machine cuts coal from the seam and on to the face conveyor to be transported to the surface. The shields are utilized to support the immediate roof and protect the employees and equipment from rock strata above. A system comprised of rubber conveyor belting suspended on steel structure, transports the coal from the continuous miner units and longwall units to the surface, so the coal can be prepared and processed for shipment to the customer. Through a series of physical and processes, coal is sized to specification. Non-coal material, such as sandstone and shales from the surrounding geology, are removed from the mined product. This process is often referred to as "cleaning" to ensure the highest quality coal for coal washing plant.

Coal can be mined by underground or surface methods depending on the depth and thickness of the deposit (Fig. 5.3).

The environmental impacts of mining vary depending upon mining methods employed, specific deposit characteristics, coal and rock strata chemistry, and the geography of the region. Figure 5.3 illustrates various methods of mining coal. Giant draglines are used to remove coal in many coal mines.

In some of regions, small holes are drilled through the overburden (dirt and rock above the coal seam) to the coal seam. Each is loaded with explosives which are discharged, shattering the rock in the overburden. Giant power shovels or draglines clear away the
overburden until the coal is exposed. Smaller shovels then scoop up the coal and load it onto trucks, which carry the coal to the preparation plant.

5.3.1.1 Jackhammer and Perforator

Tunnel boring machine (Picker) is used for extraction of coal. Drilling machine (perforator) is used for headway tunnels. A pneumatic jackhammer system typically consists of a trigger valve, chamber, piston, bit, target, and air reservoir. A schematic diagram of the system is shown in (Fig. 5.4). Jackhammer is a portable percussive drill powered by compressed air (though the same type of equipment mounted to construction machinery can also be hydraulically powered). It is used to drill rock and break up pavement, among other applications (Pang and Goldsmith, 1989). The operation is similar to a hammer and chisel, with an internal hammer driven in both directions by alternate blasts of compressed air: first down to strike the back of the bit, then back up to repeat the cycle, while the chisel (or bit) usually recovers from the stroke by means of a spring.

Jackhammers, in comparison with perforators, are more flexible and lighter. But perforator’s power is several times more than that of jackhammer. Weight of the jackhammers used in Pabedana mine vary from 7 to 10 kg, which are named as A7, A8, A9 and A10. Perforators work like percussion drill with compressed air.

![Fig 5.4: Schematic of a jackhammer system (Pang and Goldsmith, 1989).](image-url)
Perforators used for drilling wall faces and raises, are of different weights; 12, 14, 16, 18 and 22 kg. Diameter of drilling bit is 3.2cm and mode of drilling is rotary-percussion (Fig. 5.5). There are bigger sized perforators which are used for drilling face wall. These perforators consist of a telescope tripod which is attached to perforator. This device works with compressed air. The tripod provides an appropriate saddle for drilling and reduce angle of deviation of the drilling bit (Fig. 5.6).

5.3.1.2 Temp (coal cutting machine)

Tunnel boring machines are utilized for mechanized tunnel driving in all geological and all environmental conditions. Temp machine is one such machines which is used for cutting coal in longwall mining method. Temp machine used in Pabedana mine is made in Russia and weight 7 tons. It is composed of 7 heavy electromotors. Temp machine consists of a fixed cutting crown and a mobile cutting crown. Cutting crown can cut foot wall section of mining stope and mobile cutting crown can cut coal seams upto a high of 2.5m (Fig. 5.7). It is employed in stopes having 40 to 50 degree dip and resistant hanging wall rocks.

5.3.1.3 Raise boring machine

For decades, raise boring has been an accepted method for the installation of production and ventilation shafts and ore passes for mines. It is also a widely used technology in infrastructural projects for tunnel ventilation or surge shaft in hydro-electric power projects. Raise boring machine is similar to perforator and both are used for face drilling. Raise boring machine is used to drill raises of higher diameter. Due to its heavy weight, it is less frequently used in Pabedana mine. Raise boring machine is inapplicable for raise boring more than 8m length (Fig. 5.8).
5.3.1.4 Jumbo drill

Jumbo drill works with compressed air and hydraulic power. This machine has ability to drill holes in wall face up to 3m deep in 1 to 3 minutes time. The performance prediction of the jumbo drills is very important for the cost estimation and planning of the tunnel projects. The performance of jumbo drills mainly depends on machine parameters, operational variables, intact rock properties and rock mass characteristics. It is known that, if the intact rock properties are approximately same, drilling performance of jumbo drill depends largely on the discontinuities in the rock mass (Kahraman et.al., 2006). Jumbo drill is installed on chain belt and transmits along wall face route. Drilling bits are studded with industrial, diamonds. hence, it is suitable to drill hard rocks. There are three hydraulic jacks in both sides and back side of Jumbo drill. Hydraulic jacks have an important role in stabilizing the Jambo drill and they reduce the angle of deviation of the drilling bit. Therefore, drilling operation by Jambo drill is more appropriate than other drilling machines (Fig. 5.9). One of the disadvantages of Jumbo drill is that it consumes excessive oil during drilling process. Hence, it is uneconomic and at present this drilling machine is occasionally used in Pabedana coal mine.

5.3.1.5 Hydraulic jack

Hydraulic jacks are used for supporting tunnels. They can withstand 24 tons of loads. If pressure is more than standard limitation on these jacks, they have stability against pressures, because of these Jacks contain fine shots that prevent damage to jacks (Fig. 5.10). The length of the Jacks are variable from 50cm to 2.5m and depends on thickness of coal seams. Hydraulic jacks range in weight from 60 to 80 kg. Hydraulic jacks are widely used in inside extraction stopes while working with Oral machine. Hydraulic jacks are best suited for coal beds having a thickness of more than 80cm and maximum 35 degree dip. One of the
advantages of these jacks is consumption of less wood in stopes which in turn leads to increasing safety coefficient in extraction tunnel.

All longwall mines employ preventative maintenance. It is one of the largest sub-operations at any mine, and proves effective in that, when less attention is paid to maintenance, more faults occur. The optimum level of planned maintenance is difficult to determine because not all failures are age-related (Bongers and Gurgenci, 2008).

5.3.1.6 LHD underground loader

A Load-Haul-Dump (LHD) is a machine which has been widely used in underground mines or tunnel construction sites. Pabedana mine loading machines are made by Atlas Copco Company, Sweden. This type of loader is used for loading coal at wall faces. LHD machines have three functions; loading, carrying, and dumping the coal. Generally, the scooping task is carried out as follows: the bucket, which is located in front of the LHD body, is pushed into the coal pile and the coal is scooped by lifting the bucket. Then the LHD is moved to the dumping point (Takahashi et al., 2004). Operation system performs as loader spade and pours coal to the loader bucket. Loader bucket is situated at the back of loader. Volume of loader bucket is 200 lit and these loaders work using compressed air (Fig. 5.11). There are two keys on Atlas Copco loaders, one of them is utilized for transportation system on the rail and another for movement of the loader spade. The literature studies revealed that the highest number of fatalities associated with roof bolter, LHD, and longwall are attributed to “Working under unsupported roof”, “Failure of management to provide safe working conditions”, and “Failure of mechanical components”, respectively (Kecojevic and Md Nor, 2009).
5.3.1.7 Wood cutting machine

The main task of carpentry is the preparation and development wood to support mining stopes. Prepared wood support columns have different sizes that depend on tunnel space and stope size. Wood cutting machine can cut wood in three rows having 3m×25cm size (Fig. 5.12). Another application of wood in the tunnel is to align temporary rail line.

5.3.1.8 Locomotive charge workshop

Locomotives that have not been fitted with charger is taken to the locomotive charge workshop for battery charging, whenever needed. In order to charge 8.5 ton locomotive, 60 batteries fitted in a battery box are needed (Fig. 5.13). For 4.5 ton Locomotives, battery box is fitted with 40 batteries. Each battery after charging yield a maximum charge of about 2.5 V. For 4.5 ton locomotives 90-100V current is needed. These batteries charge during an hour and provide energy for working 8 hours (1 shift). Life of each battery is about 3 years when used in 3 shifts of 8 hours each per day. Right now, 3 locomotives with 8.5 ton weight and 10 locomotives with 4.5 ton weight are working in Pabedana coal mine.

5.3.1.9 Coal loading cycle

LHD loaders discharged extracted coal to tipper wagons. These wagons discharge coal on to conveyer belt. Conveyer belt is 200 m in length. Coal is discharged through the funnel to the conveyer belt and is transferred to four coal bunkers (Fig. 5.14). During transport by conveyer belt, extra material (wooden pieces, other non-coal material) from mining stopes will be removed manually. Coal stored in bunkers is loaded to trucks to be transported to Zarand coal washing plant.
5.4 COAL WASHING TECHNIQUES AND EQUIPMENTS

Coal washing is a process by which impurities such as sulfur, ash, and rock are removed from coal to upgrade its value. Coal washing processes are categorized as either physical cleaning or chemical cleaning. Physical coal washing processes, which involve mechanical separation of coal from its contaminants using differences in density and these processes are commonly used now-a-days. Chemical coal washing processes are currently being developed, but their performance and cost are undetermined at this time. In Zarand coal washing plant, coal cleaning are based on physical process.

Two physical coal washing processes are adapted:

(i) Separation based on differences in relative density (RD) between coal and associated mineral matter; pure coal has an RD of ~1.3 and associated mineral matter commonly has an RD of >2.2

(ii) Separation based on differences in surface properties between coal and associated mineral matter; coal is hydrophobic, whilst associated mineral matter is generally hydrophilic.

Other separation methods, which include magnetic, electrostatic, chemical or biological coal-cleaning processes, have also attracted considerable interest but, in general, these have yet to achieve commercial viability (Kamall, 2001).

During cleaning process, generally 30-50% of pyritic sulfur and approximately 60% of ash-forming minerals (residue left after coal has been burned) will be removed (Strickland et.al., 2008). Coal washing plant composes of four main units, including feeding unit, main building, drier building, storage building and loading building (Fig. 5.15).
5.4.1 Feeding unit

Feeding unit of coal washing plant receives from Pabedana coal mine. An amount of 1,00,000 tons of raw coal with 36% ash enter the feeding unit. When trucks arrive to coal washery, coal from each truck is sampled. Then the loaded trucks enter the feeding unit. Sampled coal is dispatched to quality control for determining ash content (Fig. 5.16 and 5.17).

Coals from trucks are directly discharged into tanks and conveyer belts transfer the coal to storage building. In the storage building 10 reservation tanks exist for each line with capacity of 700 tons of raw coal. Operation capacity is reduced due to sticking of coal to tanks walls. After the storage of each line, plant feed is moved to main building by conveyor belt.

5.4.2 Main building (Coal washing process)

Coal washing unit is housed in main building, where the coal is washed at five stages, viz. (i) Heavy media, (ii) Jig, (iii) Dynawhirlpool, (iv) Spiral and (v) Flotation stages. In these stages coal is washed and separated according to grain size viz., (+18mm), (+0.5-18mm), (+0.15-1mm) and (-0.5mm) (Fig. 5.18).
Fig. 5.18: Processing of coal washery in Zarand coal washing plant.
5.4.2.1 Vibration screen unit

Screening involves some form of sieving device usually constructed of wire mesh or metal bars. Dry screening is accomplished for relatively coarse sized coal, greater than 18 mm. Fines tend to ball up or stick to the coarser fractions. In zarand coal washing plant, vibration screen are used to size the coal into appropriate size classifications prior to cleaning (Fig. 5.19). Sieves are used to separate coal of relatively fine sizes and to separate coal from heavy media. Concentrate of this stage enter to heavy media separator with 1.7 gr/cm$^3$ density and then enter to another vibration screen.

![Vibration screen for separating grains less than 18mm.](image)

5.4.2.2 Heavy media separator unit

In coal washing plant, to improve the efficiency of coal cleaning separations, heavy-media is often used. In these cases, magnetite is mixed with water to produce a medium of the desired specific gravity to separate the coal. Specific gravity of this medium in two heavy media separators typically ranges between 1.45 gr/cm$^3$ and 1.7 gr/cm$^3$. 
The incoming raw coal is separated at 1/4 inch on an inclined screen. The “overs” proceed to a flat “prewet” screen, where the fine dust particles are sprayed off from the +1/4-inch coal. This increment is discharged into a heavy-medium vessel or bath, where the refuse (residue) is separated from the coal. The refuse is discharged to a “refuse rinse” screen, where it is dewatered. The refuse (residue) having density of more than 1.7 gr/cm$^3$ contains impurities (waste material) and is sent out of the system (Fig. 5.20). The slurry contains fine coal (less than 1/4 inch; density less than 1.7 g/cm$^3$) and floats on the heavy medium of magnetite. It is pumped to another heavy media 1.45 gr/cm$^3$ density separator (Fig. 5.19).

Heavy media separator consists of shaft-mounted steel drum containing an interior fixed magnet. The cylinder rotates within a vessel containing coal slurry and magnetite. Retrieval of solid magnetite from the slurry is by virtue of the magnetic quality of the magnetite and the magnetic field within the drum. The slurry recovered by virtue of the magnetic separation is sent to centrifuge and cyclone to recover finer clean coal.

Key factors in the operation of any dense-medium system based on magnetite are the control equipment and the efficiency of magnetic recovery for recycle.

**5.4.2.3 Magnetite separator unit**

The magnetite separation of sulfur and ash from coal is based on the difference in the natural magnetic properties of coal and its associated mineral impurities. Most of the sulfur-bearing and ash-forming minerals in coal are paramagnetic and can be separated from the remaining diamagnetic material. Magnetite is a very heavy mineral that gives the suspension properties similar to a true heavy liquid.
5.4.2.4 Jig separator unit

The Jig is relatively low cost, simple washing system generally considered efficient for coals that are relatively easy to clean. Jigs yield 75-85% coal at about 34% ash content. The Zarand coal washing plant consists of OM-18 model Jig. Feed of the plant is divided into two parts of grains of sizes of > 18mm and <18mm. Grains of > 18mm size is transferred to primary vibration screens and the grains of < 18mm size are fed to Jig canal. At the bottom of this Jig channels bar screen is provided which separates soft grains (1mm) of coal feed. A sieve bend is situated before the Jig separator for sorting grains of 1 to 18 mm size. Materials on sieve bend, which is considered as a feeding, enter the Jig circuit. In the sieve bend, grains between 1mm to 18mm size pass from the mesh. Soft grains enter to hydroclassifier where its overflows are passed to flotation and underflow is returned to the primary vibration screen.

Jig separator is composed of three baths where water under each bath is made to fluctuate by special mechanism piston, diaphragm or compressed air. Number of fluctuation ranges from 40 to 300 times per minute. In this part grains on the screen are classified according to the density. Density control is carried out by floatation body located in the jig bed (Fig. 5.21). In a jig, the column of water is maintained in a constant up-and-down movement by means of flow of air. Clean coal particles are carried to the top of the jig by this motion, while heavier refuse particles sink to the bottom. Jig washing is still widely perceived as a simpler, lower-cost option than dense medium separation and a range of improved jigs has continued to find wide application in Germany, India and China.

Density of these three baths respectively are 1.7, 1.45 and 1.1, g/cm$^3$. Overflow of each bath is poured to the next bath. In the first bath the underflow material (waste material) goes out of the system. In secend and third baths the underflow material goes out of system and
conduct to another jig (control jig). Overflow of the third bath is transferred to reservoirs which are called bucket elevator.

A sieve bend is situated before the jig separator for sorting grains 1 to 18 mm size. Materials on sieve bend, which is considered as a feeding, enter to jig circuit. In the sieve bend, grains between 1mm to 18 mm size is passed from mesh. Soft grains enter to hydro classifier where its overflows is passed to flotation and underflows is returned the primary vibration screen.

5.4.2.5 Control Jig unit

Control Jig is composed of three units and its work is similar to primary Jig. Baths size of control Jig is smaller than the primary Jig. Underflow of first bath as a waste material pours out of the system and the overflow of the second and third baths is transferred to Dynawhirlpool separator. Second and third baths production is 17 ton per hour. Overflow of third bath as a concentration is transferred to bucket elevator (Fig. 5.22).

5.4.2.6 Dynawhirlpool separator unit

Dynawhirlpool separator unit is added to the present coal washing plant equipments. This unit has the capability of washing grains which cannot be recovered from jig separator and flotation system. In fact, it is a type of gravity system which works with heavy media. Dynawhirlpool circuit gets its feed of grains from second and third baths of the control jig. The main section of dynawhirlpool separator is composed of vacant cylinder which can be inclined to an extent of 15-45° and the diameter of this cylinder varies from 150 to 600 mm (Fig. 5.23).
One of the advantages of this separator is that only heavy media needs to be pumped into system whereas the machine feeding in provided by gravity pressure, therefore operational charge is reduced.

5.4.2.7 Spiral separator unit

In coal washing plant, spiral separator is one of the appropriate separators used to recovery grains of 150 micron to 1 mm size. Height and diameter of spirals are 3m and 1m. Lighter material is separated from heavier material by five kinds of pressures, which include weight pressure, centrifugal pressure, friction, fluid resistance and elevator pressure (Fig. 5.24). Production from spirals is considered as the final concentrate and their waste materials, as the final tails.

5.4.2.8 Hydrocyclone

Hydro-cyclones are water-based cyclones where the heavier particles accumulate near the walls and are removed via the base cone. The fine coal and water slurry is pumped under pressure into a cyclone where the lighter clean coal fraction is concentrated toward the center of the cyclone and exists through the vortex. Heavy refuse gets concentrated near the walls of the cyclone and exists through the apex (Fig. 5.25).
Since point spirals have best efficiency for grains of 150 micron to 1 mm size, the hydrocyclone is utilized for prevention of < 150 micron size grains, entrance to spiral separator. Cyclone overflow, which is less than 150 micron, is dispatched to flotation section. Cyclone underflow is transferred to reservoir which divides the feed between the spirals. Table 5.1 is shows different methods of Jigs, dense-medium separators and hydro cyclones.

### 5.4.2.9 Flotation process

One of the common steps to improve the performance of a flotation unit is to separate the pyrite at an earlier stage using cyclones and spirals. Among the four influencing factors (namely, size distribution, feed concentration, oil consumption and oil ratio) size distribution is the main factor affecting the flotation performance, followed by oil ratio, oil consumption and feed concentration (Guang-yuang et al., 2009). In Zarand coal washing plant, grains size utilized for flotation processing of coal is smaller than 0.5mm.
Table 5.1: Comparison of different methods Jigs, dense-medium separators and hydrocyclones.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Jigs</th>
<th>Dense-medium separators</th>
<th>Hydrocyclones</th>
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<tbody>
<tr>
<td>State of technology</td>
<td>Commercial</td>
<td>Commercial</td>
<td>Commercial</td>
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<tr>
<td>Advantages</td>
<td>Large capacity</td>
<td>Good separation</td>
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<tr>
<td></td>
<td>Inexpensive</td>
<td>Second most common method</td>
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<td></td>
<td>Common type - world wide usage</td>
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<tr>
<td>Disadvantages</td>
<td>Lower separation than dense-medium</td>
<td>Small capacities</td>
<td>Water consumption</td>
</tr>
<tr>
<td>Costs</td>
<td>Inexpensive</td>
<td>Expensive</td>
<td>—</td>
</tr>
<tr>
<td>Suitability</td>
<td>Intermediate efficiency device. For moderately difficult to clean coal. Specific gravity &gt; 1.5-1.6, Size: 0.5-150 mm</td>
<td>For difficult or most difficult to clean coal. Specific gravity &gt; 1.3-1.9, Size: 0.5-150mm</td>
<td>For coarse to intermediate particles Size: 0.5-150mm</td>
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Flotation process, air is blown into slurry containing coal and water through the action of the impeller. Small amounts of reagents called frothers, typically alcohol-based compounds, are added to reduce the surface tension of the slurry. With this reduced surface tension and the mixing of the impeller, the air is sheared into small bubbles that attach to the hydrophobic coal particles. The coal-bubble aggregate then floats to the top of the cell where it is removed as froth with a skimmer. To increase the hydrophobicity of the coal, an oily collector is often added that coats the coal particles to enhance the coal-bubble attachment. The refuse minerals do not attach to the air bubbles and remain in the water and exit the cell through a tailings discharge (Fig. 5.26).
Flotation processing utilize collector as a hydrophobe material and for stability of bubbles of the frother. Oxidation is a natural process that can continuously decrease the hydrophobicity of coal. In the flotation pulp, not only the added chemicals but also the dissolved mineral species, released from coal itself during grinding and pulping, can play an important role in governing flotation. Water of the final concentrate got from flotation process is removed by filters.

When fine coal is subjected to the flotation process, greater amounts of promoter and frother agent are adsorbed due to high surface area (Fig. 5.27). In fact, the liberated fine mineral matter itself attaches to the hydrophobic coal particles, resulting in a slime coating with an attendant pseudo-depression phenomenon. As a result of these complications, the production of super clean coal by conventional froth flotation has been found to be a most difficult task.
Although some success has been achieved utilizing sodium hypochlorite for removal of sulphatic and organic sulfur, such oxidation practice has been generally unsuccessful in the removal of pyritic sulfur. These problems are most significant for coals such as bituminous (which contain medium and high volatile materials) and sub-bituminous coals. In most operating coal-cleaning plants, a significant amount of pyrite is recovered through the froth during flotation of high-sulfur coal, pyrite recovery is commonly believed to be a result of pyrite particles floating due to hydrophobicity. However, even though a wide range of pyrite depressants have been reported over the years, there is no use of these depressants for industrial coal flotation, which suggests that pyrite can become naturally hydrophobic at neutral pH under certain conditions (Kawatra and Eisele, 1997).

5.4.2.9.1 Collector

Collector is used in flotation process as a hydrophobe material. In coal flotation, white oil and disel oil are used as a collector and co-collector. Bituminous coals with high bituminization rank are floatable in frother whereas flotation of bituminous coals with medium bituminization rank needs non ionic oils (oil fuels) with 0.5-1.5 kg/ton value. Collector value for floating anthracite is about 1.5 kg/ton. For floating coals of bituminization rank huge amounts of collector are needed. This suggests that the effect of both the frother and collector on water transfer rates is first of all determined by the transfer of solids to the froth, and thus by the effect of these two agents on the solids transfer to froth (Boylu and Laskowski, 2007).

5.4.2.9.2 Froth flotation

Froth flotation, separation of fine coal particles selectively from associated minerals in water slurries, is achieved by attachment to rising air bubbles. Frothers are utilized in flotation process to enhance generation of fine bubbles and to stabilize the froth. Main role of the
frothers are maintenance of a large amounts of bubbles of suitable size. Produced bubbles should have sufficient resistance that enables to transfer coal grains of pulp area to froth area. But frothers should not be too resistant that can produce problems in filters.

In Zarand coal washing plant pine oil (peen evil) is used as a frother in floatation system. Pine oil is a convoluted alcohol derived from wood. Pine oil is an essential oil obtained by the steam distillation of needles, twigs and cones from a variety of pine species. Polyglycol ether and alcohol frothers present good correlation between fundamental two phase frother characterization indices and coal flotation performance (Gupta et al., 2007).

5.4.3 Drier building

Concentrates from jig, dynawhirlpool, spiral and flotation circuits need to be dried for reaching desirable moisture. Coal supplied to the Eisfahan iron melting plant should not contain more than 10% moisture, hence it is necessary to provide place for drying coal.

In the drier building, heat of the drier section is provided by five ovens. Since, electricity expenses on drier unit are high, coal is dried on platform constructed in the vicinity of main building with the aid of air and sunshine (Fig. 5.28). In this plant only 10% of production is dried in drier building and the remaining production (90%) is dried by atmospheric heat.

5.4.4 Storage building and loading concentrate

In this unit, four tanks have been constructed to store the processed fine coal. Capacity of each one is about 1200 ton. These tanks are equipped with a mobile conveyor belt. These conveyor belts are used for loading concentrate to wagons. The wagons are transported to Eisfahan iron melting plant.

Coal with 10% moisture and maximum 13% ash-content are loaded in 51 ton wagons and carried through the Zarand railway to Eisfahan. These coals are utilized to provide coke to
the blast furnace of Esfahan Iron melting. Coal washing plant has ability of washing about 2
million ton of coal. Right now, it is washing 3000 to 4000 ton of coal per day and produces
1500 to 2000 ton of coal concentrate. Production value of concentrate depends on the coal
value of Run of Mine (ROM).

5.5 BENEFITS OF USING WASHED COAL

- Increased generation efficiency, mainly due to the reduction in energy loss as inert
material does not pass through the combustion process.
- Increased plant availability
- Reduced investment costs
- Reduced operation and maintenance (O&M) costs due to less wear and reduced costs
  for fuel and ash handling
- Energy conservation in the transportation sector and lower transportation costs
- Less impurities and improved coal quality
- Reduced load on the air pollution control system
- Reduction in the amount of solid waste that has to be disposed off
Fig. 5.2: The entrance of a tunnel with 4 m height.

Fig. 5.3: Surface and underground plan of coal mining process.

Fig. 5.5: Jackhammer (a) and handing perforator (b).

Fig. 5.6: Telescope tripod that is separated from perforator.
Fig. 5.7: Temp as cutting coal machine.

Fig. 5.8: Raise boring machine for drilling raises less than 8m.

Fig. 5.9: Jumbo drilling machine for drilling resistance rocks.

Fig. 5.10: Hydraulic jacks for supporting tunnel walls.
Fig. 5.11: LHD loader for loading materials in face wall.

Fig. 5.12: Wood cutting machine.

Fig. 5.13: Battery to charge locomotive.

Fig. 5.14: Coal bunkers with conveyer belt.
Fig. 5.15: Photograph showing coal washery units.

Fig. 5.16: Feeding unit of the coal washery.
Fig. 5.17: Storage yard of the coal around feeding unit.

Fig. 5.17: Storage yard of the coal around feeding unit.

Fig. 5.20: Heavy media separator unit (1.7 g/cm$^3$ density).

Fig. 5.20: Heavy media separator unit (1.7 g/cm$^3$ density).

Fig. 5.21: Jig unit which containing of three baths.

Fig. 5.21: Jig unit which containing of three baths.

Fig. 5.22: Bucket elevator which replace jig production.

Fig. 5.22: Bucket elevator which replace jig production.
Fig. 5.23: Dynawhirlpool separators.

Fig. 5.24: Spiral separators and hydrocyclones.

Fig. 5.27: Photograph showing part of flotation unit.

Fig. 5.28: Drier platform in vicinity concentrate plan.