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COAL BRIQUETTING TECHNOLOGY

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INTRODUCTION

Coal briquetting is one of the oldest applications of the forming process by agglomeration. At the beginning, the piston presses were used to produce coal bricks of about 0.5 to 10 kg made of coal fines that were mixed with binders such as pitch, bitumen or tar. These presses had reduced capacities (1000 bricks per hour maximum). The development of the double roll press has taken place during the second half of the 19th century because it offered higher production capacities under acceptable economic conditions : Europe was mainly concerned by this development, in particular France, Germany and Belgium : thanks to this technique, the annual production has reached up to 10 million tonnes of briquettes.

SAHUT-CONREUR was among the companies which have started manufacturing double roll presses since the beginning of the 20th century : the French company SAHUT-CONREUR is located near Raismes in northern France. SAHUT-CONEUR has supplied since the beginning of the 20th century more than 700 briquetting plants worldwide, and among them about 300 for agglomeration of coal fines.

The coal briquetting technology by means of the double roll press has mainly been developed for the upgrading of coal fines coming from coal screening and washing, used as fuel for domestic and/or industrial heating in the same way as coal.

The coal briquetting industry has expanded widely in Europe (mainly in France, Germany, Belgium and Great Britain) until the end of the Second World War : briquettes were used mainly for home heating. Later on, this source of energy has been progressively replaced by other fuels such as heating fuel oil and natural gas. To date, many coal briquetting units are no longer operating. In 1945, 7 million tonnes of coal briquettes were produced in France. In 1995, the annual production is only of 500 000 tonnes.

The manufacturers of double roll presses have then developed the use of this technology for other industrial applications : today, the original application only represents a 10 to 15 % share. The new coal briquetting units are located in the big coal producing countries (China and India) or the developing countries (Turkey) or used for coke production (Japan, South Africa, India and China) by upgrading of low coking coals (30 % of the load in a coke oven).

I – THE COAL BRIQUETTING TECHNOLOGY

I.1 - RAW MATERIALS

The raw materials used are coal fines and a binder.

I.1.1 Coal fines

The coal fines should possess the following characteristics in order to obtain good quality briquettes :
- good combustion characteristics : high calorific value, low ash content, medium percentage of volatile matter, low sulphur content for the environment
- good compactability : low size-range, low moisture content.

I.1.1.1 Size range of fines

The coal fines usually have a size range between 0 and 3 mm : a small quantity (a few per cent) of grains over 3 mm and under 5 mm is acceptable. In order to obtain good quality briquettes, it is essential to have the widest grain size distribution possible, with very fine grains among larger grains : during briquetting, the fine grains will interlock with the larger grains and it will ensure the highest possible compactness : this parameter is directly connected with the quality of briquettes, in particular their crushing and handling strength. If the quantity of fine grains is insufficient, a crushing of the large grains will occur while the material is running through the press rolls : these crushed and cracked grains will give more fragile briquettes. The optimum size range is within the 0 to 3 mm bracket with the following distribution :
- 50 % from 0 to 0.5 mm
- 25 % from 0.5 to 1 mm
- 20 % from 1 to 2 mm
- 5 % from 2 to 3 mm

I.1.1.2 Moisture of fines

For an optimum quality of briquettes, the coal fines will have a surface moisture of 2 to 3 %. Beyond this figure, the briquette quality is not so good, with a lower crushing strength and not such a fine appearance of the outer surface of briquettes (the skin has a duller glow). Beyond 5 to 6 %, briquetting may become difficult and in particular when removing the briquettes from the pockets : the briquettes adhere to the roll surface.

I.1.2 Binder

The coal fines are not self-agglomerating ie they require the addition of a liquid or solid binder in order to obtain briquettes of a sufficient quality : many industrial tests were carried out for briquetting of coal fines without adding any binder : if it is possible with certain coal qualities (subbituminous ones), heating of coal before briquetting (up to 450°C) is required as well as the use of high compaction pressures (5 to 10 times higher than briquetting with a binder) : these 2 factors have an essential effect on the investment and operating costs and briquetting of coal fines without binder appears not to be economical.

I.1.2.1 The various types of binder used for coal briquetting

The binders now used in the coal briquetting industry are :

- coal pitch (residue of coking) under solid or liquid form
- petroleum bitumen (oil refining) under solid or liquid form
- tar
- molasses (beet or sugarcane) with possible addition of lime or possibly phosphoric acid
- lignosulphonate (residue from paper mill)
- starch (maize, corn, potatoe)

Other binders (polymers) were lab tested and gave good results. However, they are sometimes difficult to use and demand high operating costs.
The first two binders in the above list are those commonly used. The last two are used for the production of smokeless briquettes ie without emission of smoke during combustion : the use of both binders requires, on the other hand, a high investment, in particular for the post-treatment of briquettes before storage (polymerisation or oven drying).
The briquettes produced with the first two binders (pitch and petroleum bitumen) give out fumes during combustion, due to the volatile matters in the binder : the quantity of volatile matter being high as far as coal pitch is concerned, in this case, the briquettes can be treated in a smoke curing oven to make them smokeless. The quantity of volatile matter being low with petroleum bitumen, the smoke emission will be somewhat lower and will not usually require any curing.
The briquettes produced with molasses with possible addition of lime have a very low strength at press outlet and have to be handled with care up to storage where they will be piled not very high up for about two days so that the hardening reaction can take place. Otherwise, the addition of lime increases the quantity of ash in the briquettes.
5 to 10 % of binder are added according to its binding efficiency : it depends on the size range of fines (with a fine product, it will be necessary to add more binder considering that the specific surface area is larger) and the quality required for the briquettes (the higher the quantity of binder used the higher the crush strength) : it should be of course tempered by the higher cost implied by the addition of binder and the possible difficulties in briquetting and clogging of pockets of rolls).

I.1.2.2 Choice of binder

The choice of binder has a direct effect on the operating costs and should be selected with care. The operating costs cover the cost of binder (price per tonne of binder and quantity of binder consumed per tonne of briquettes), the processing cost involved by the choice of binder and the cost of post-treatment of briquettes before storage. The choice is also based on the quantity of binder available locally.

The binder also has an effect on the quality of briquettes : their crush strength and drop test strength. It will be selected with the mechanical characteristics required for the briquettes in mind.
In certain areas of the world, it is also necessary to think about their moisture resistance : in particular, it is necessary to know if it is possible to store the briquettes on the ground and outside : under these conditions, the briquettes will have to withstand rain, snow, wind and other bad weather conditions without degrading. Otherwise, weatherproof storage will have to be provided, whose cost could be prohibitive. Pitch and petroleum bitumen give waterproof briquettes and allow a storage of briquettes outside. For the other binders, a coating of briquettes (paraffin for instance) will enable to reduce their water permeability.
The lignosulphonates are low resistant to moisture.
The briquettes manufactured either with starch or molasses with addition of lime have no resistance to moisture.

I.2 - THE COAL BRIQUETTING PROCESS

Therefore, a coal briquetting plant will include the following units :
- a screening and crushing unit if the coal grains are too large
- a drying unit if the coal moisture content is too high
- a binder addition and mixing unit
- a briquetting unit with the double roll press
- a briquette treatment unit (cooling, polymerization and drying dependent on the binder used)

A storage unit will be installed upstream for storage of the various qualities of coal fines, together with fines dosing and mixing equipment. A binder storage, preparation (reheating for instance) and metering unit will be installed next to the plant.
A dedusting unit will need to be installed in order to provide the plant operators with adequate working conditions.

I.2.1 A coal briquetting unit with petroleum bitumen

The enclosed sketch shows a flow-sheet of a coal briquetting unit using petroleum bitumen as binder (the design of the plant is similar when liquid coal pitch is used).

I.2.1.1 Dosing and mixing unit (Items 1 to 3 and Items 15 to 17)

This unit is composed of :
- a hopper Item 1 for storage of fines (crushed and/or dried if necessary)
- a coal dosing unit Item 2 (a weigh feeder preferably in order to have an accurage metering of coal and quantities of processed material)
- a hopper Item 15 for storage of recycling fines
- a dosing unit Item 16 for recycling of fines
- a crusher Item 17 to reduce the size of the recycled products (production of fines, half-briquettes and bad fabrication).
- a mixer Item 3 will homogenize the coal fines and the recycling fines : this mixer can be a twin screw mixer.

I.2.1.2 Kneading unit (Items 4 to 6)

This unit includes the following items of equipment :
- a vibrating feeder Item 4 spreading the flow of material at the inlet of the spraying hood Item 5 ;
- a spraying hood Item 5, where the liquid binder is spread on the free-falling product ;
- a steam pug mill Item 6 : this item of equipment is essential for the good operation of the plant. It plays two parts :
  . blending of fines and binder ie the diffusion of binder over the surface of all the coal grains.
  . reheating of the blend for easier binder distribution : this reheating is obtained thanks to the injection of superheated steam inside the coal mass : the quantity of steam (from 50 to 100 kg per tonne of briquettes) and consequently the temperature of the mixture (100 to 150°C) depend on the physical characteristics of the binder (more particularly, its softening point) : the temperature of the mixture will be of a few degrees Celsius above the softening point of the binder : a plastic paste is obtained at the outlet of the pug mill.

I.2.1.3 Briquetting unit (Items 7 to 9)

This unit is composed of the following items of equipment :
- the cooling screw Item 7 brings the temperature of the mixture down to the softening point of the binder ;
- the double roll press Item 8 converting the mixture into individual briquettes ;
- the trimming hopper Item 9 which removes the fabrication fines (coming from the web between the tyre pockets) and the joint flashes : the briquettes fall across the trimming grid usually composed of bars at an angle. Under normal operating conditions, the quantity of product that will be recycled represents 5 % of the press throughput.

The trimming hopper can be equipped with a bypass which enables, in case of bad fabrication of briquettes, to discharge this production directly into the recycling circuit. The bad fabrication appears in particular when the quantity of binder added to the mixture is insufficient or when the temperature of the mixture in the steam pug mill is too low or until the plant runs steadily.

I.2.1.4 Cooling unit (Items 10 and 11)

At the outlet of the double roll press, the briquettes have a temperature slightly under the softening point of the binder : therefore, their crush strength and drop test strength are too low for direct conveying to piling : it is then absolutely necessary to provide a briquette cooling system either by means of :
- belt conveyors of sufficient length to obtain strong briquettes ;
- wire mesh conveyors with forced air circulation by means of fans Item 11
- a water spraying system on the briquettes.

I.2.1.5 Recycling unit (Items 12 to 14)
This unit is composed of handling equipment (belt conveyors, elevators) collecting the fines at the trimming grid outlet Item 9 and under the cooling conveyors Item 10. These products are recycled upstream from the briquetting plant and mixed with the raw material.

I.2.1.6 Dedusting unit

The equipment on the whole is dedusted. The dust and steam in excess are treated in a wet dedusting system.

I.2.1.7 Binder preparation unit

This unit Item 19 is mainly composed of the following devices :

- a tank for binder storage and holding at temperature for easy pumping ;
- a supercharging and reheating circuit with recirculating pumps
- a metering pump for adjustment of the quantity of binder sprayed in the spraying hood
- a flowmeter
- spray nozzles installed in the spraying hood Item 5 in order to obtain droplets ; the liquid binder is sprayed by means of steam.

I.2.1.8 Steam production unit

This unit Item 20 is mainly composed of a steam boiler able to produce superheated steam at a temperature of 220-240°C and a pressure of 3-4 bar. The quantity of steam consumed is of 50 to 100 kg per tonne of briquettes produced.

I.2.1.9 Drive and control

The whole plant can be managed from the control room equipped with computers for drive and control of the equipment operation.
The drive and control system will include the following control loops :
- control of product level in the pug mill Item 6 by means of a coal weigh feeder Item 2 ;
- control of the quantity of binder sprayed by means of the metering pump for binder in relation to the throughput of the coal weigh feeder Item 2 ;
- temperature control at pug mill outlet Item 6 thanks to of the quantity of steam injected in the pug mill.
- level control in the press feeder Item 8 by control of the position of the gate at pug mill outlet.

It is advisable to have an operator present near the press : he will check the briquette quality regularly.
The plants can operate 24 hours a day with a few operators.

I.2.2 Capacity of briquetting plants

The capacity of a coal briquetting unit varies a lot : from a few tonnes per hour up to 100 tonnes per hour for the larger units.
For easy operating, it can be more interesting to have two or three lines of average capacity instead of a single line of high capacity : under these conditions, the throughput of the briquetting plant is adaptable according to the circumstances (the consumer demand for briquettes) : it offers high operating flexibility.

For the briquetting units using starch or lignosulphonate as binder, the throughput of each line is restricted to 20 tonnes per hour, because the maximum capacity of the drying ovens is of 20 tonnes per hour.

I.2.3 Technical description of the double roll press

A double roll press is composed mainly of two rolls rotating at the same speed. As they rotate in the reversed direction, the mix running through the rolls is converted into briquettes.

I.2.3.1 Double rolls

Each roll is composed of a forged steel shaft on which one or two steel rings called tyres are mounted : they are heat-shrunk on the shafts. The two (or four) tyres have the same dimensions (diameter, width). The diameter of tyres varies up to 800 mm ; the larger tyres have a width of 800 mm.

For a capacity of 15 tonnes per hour, the press will be equipped with two tyres with a diameter of 600 mm and a width of 380 mm.

For a capacity of 30 tonnes per hour, the press will be equipped with two tyres with a diameter of 800 mm and a width of 700 mm.
For a capacity of 50 tonnes per hour, the press will be equipped with four tyres with a diameter of 800 mm and a width of 565 mm.
For a capacity of 90 tonnes per hour, the press will be equipped with four tyres with a diameter of 800 mm and a width of 800 mm.

Cavities called pockets are machined on the outer surface of tyres : they will give the final briquette shape.
The pockets are cut either by mechanical milling which implies some limitation of the pocket shape or by electrochemical machining which allows much freedom of choice in the shape of pocket. Ofter, for marketing reasons, the producers want to differentiate their products from those produced by competitors : in order to do so, and thanks to the electrochemical machining, distinctive marks such as lines, marks, letters are added on the briquette surface.
The shape and dimensions of a coal briquette are shown on the sketch below : the dimensions are adapted according to the producer's requirements, notably for marketing reasons. The briquette can range in volume from 10 to 100 cm3.

The briquette shapes are called either "pillow", "ovoid" or "soap".
In order to avoid clogging difficulties inside the pockets, it is necessary to respect the dimensional criteria, in particular between the briquette height and its thickness.
The tyres are the main wear parts of a press : they will need to be regularly replaced. Their lifetime is directly linked with the quality of briquettes required by the user : this quality is measured mainly by the shape and the flash line of the briquette. Their lifetime depends exclusively on the coal characteristics : its abrasiveness and also its size-range : the tyres will also have a longer lifetime with fine grains.

I.2.3.2 Drive unit of rolls

Both rolls are rotating thanks to a two-output gear-box driven itself by an electric motor installed on the gear-box. The roll speed can go up to 22 rpm. The power consumed is relatively low : about 1.5 to 2 kWh per tonne of briquettes produced.

I.2.3.3 Press frame

Both rolls are installed in a mechanically welded frame : one of both rolls, the "fixed" roll is fixed in translation in the press frame. The second one can move inside the frame : its rotational axis can vary in its horizontal plane : this roll is called the "mobile" roll.

I.2.3.4 Hydraulic station

A load is applied on the mobile roll by means of hydraulic jacks. Considering the plasticity of the mixture, the loads applied on the mobile roll are relatively low as far as coal briquetting is concerned : they can be 10 times higher in some other applications of the double roll press (metallic powders, lime). The pressure applied on the mixture is expressed in Kn/linear cm ie the load applied on the mobile roll divided by the width of the tyre(s) of the mobile roll : for coal briquetting, the pressure is of 15 to 20 Kn/lcm.

Considering the low pressures applied and therefore the low power consumed, it is possible to use tyres with a large working width while keeping physical operating conditions (bending and torsion) acceptable for the shafts.
The hydraulic jacks are connected to a complete hydraulic system which includes mainly :
- a motor-driven pump for loading of the hydraulic circuit
- a manometer
- a pressure sensor for remote readout of the pressure value
- safety devices such as pressure limit valves
- an electrovalve for pressure release in the circuit

- nitrogen accumulators which absorb oil movements in the hydraulic circuit due to the movements of the hydraulic jack pistons : in fact, the mobile roll is constantly in translation inside the frame : the oscillations are of about 1 mm. These accumulators are in fact energy damping-restoring devices. Thanks to this mobile roll system and the nitrogen accumulators, the presses are designed in this way to be able to accept tramp materials (metallic parts) between the tyres without causing heavy mechanical damage : the only consequence will be, in most cases, a deterioration of the surface of tyres.

I.2.3.5 Gravity feeder

The presses are equipped with a feed system for control and adjustment of the flow of product being fed to the press, just above the tyres : in order to produce briquettes of good and constant quality, it is most important to have an effective feeding system on top of the tyres. The quantity of mix fed to the pockets has to be adequately measured : if the quantity is too large, compression of the briquettes will be too high and they will show a thick flash seam ; on the other hand, if the quantity of mix is too low, the briquettes will have no mechanical strength at all.

For many years SAHUT-CONREUR has developed a feed system specially adapted to the coal briquetting conditions : this system called “gravity feeder” is composed of :

- a cylindrical tank placed on the press frame and on top of the tyres : this tank is equipped with a vertical shaft fitted with horizontal arms rotating by means of a geared-motor. Thanks to this control and drive system of the plant, the level in the tank is kept constant by adjusting the position of the pug-mill discharge gate. An opening at the bottom of the feeder tank can be obstructed by means of an isolating gate.
- a feed box system placed under the feeder tank and on top of the tyres : this box is composed of vertical flaps with vertical and horizontal adjustment : these flaps provide a good distribution of the mix across the tyre width, as well as an adequate measuring in each pocket.