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BRIQUETTING AND GRANULATION BY COMPACTION
NEW GRANULATOR-COMPACTOR FOR THE PHARMACEUTICAL INDUSTRY

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ABSTRACT

This document shows the agglomeration and granulation by compacting techniques. After a theoretical principle of the tangent wheel press, a technical description explains its main parts : feeding systems, roll building, hydraulic system, instrumentation.

Those techniques are used in many applications with several various objectives : each product has a special condition of treatment : pressure, temperature, binder eventually. The size range of the compactors is very large : up to 100 Metric Tons per Hour.

Thanks to a long experience in the granulation by compacting Sahut Conreur has developed a new compactor-granulator for the pharmaceutical industry in collaboration with the Laboratory of Pharmacotechnology - Faculty of Pharmacy of Lille.

1 - INTRODUCTION

Briquetting and compaction are densifying techniques for dry powders. Thanks to the tangent wheel press which is capable of considerable throughputs (50 kg to 100 Tons/hour) under high pressures in a continuous operation, quite a wide selection of dry powders can be briquetted/compacted.

This technique appeared at the end of the last century with the briquetting of coal fines. The new briquetting presses have gone through a noticeable technological evolution and their fields of applications has widened considerably.

Although it is a technique based on experience, a few rules can be worked out by means of a simplified theory.

The basic principle is the densification of solid particles between two rolls rotating in the reverse direction. The powder is brought between both rolls through a feeding system defined according to the type of powder. The pressure applied on the material is produced by an hydraulic system.

2 - DEFINITION OF BRIQUETTING-COMPACTION

The fundamental principle of the compaction or briquetting operation is based on the dry densification of a fine powder to obtain briquettes of a specific shape (one speaks then of briquetting) or fragments of flakes (one speaks then of compaction) of undefined shapes.

The equipment used to carry out this operation is the tangent roll press. The product to be treated is fed between both rolls of the same size which rotate in reverse direction. The surface of rolls depends on the shape of the material to be obtained :

- For individual briquettes, there is a pocket pattern on the whole surface of the roll. The shape of a pocket represents a half briquette.

- For flakes, the pattern on the roll is not so deep engraved either in the shape of shallow pockets or corrugations.

A preparation-mixing-dosing unit for the various components and possibly a binder is provided before the tangent roll press.

In general, the flakes produced by the tangent roll press are crushed to obtain granules screened to the size required by the user.

3 - SIMPLIFIED THEORY OF COMPACTION

When the material is fed through both rolls, the material goes through the following stages (Figure 1).

Between α and β (Figure 1), i.e. in the feed area, the material is drawn into the gap by rubbing on the roll surface. The densification in this area is obtained by rearrangement of particles between them. The speed of the material is then lower than the peripheral speed of rolls.

Between α and the horizontal axis (Figure 1), the material is in the compaction area. α is called the compaction angle or nip angle. The material is then submitted to the compaction forces : the particles undergo plastic deformations and/or are crushed. The nip angle varies according to the material (size range, density,..) : its value is of about 12 degrees.

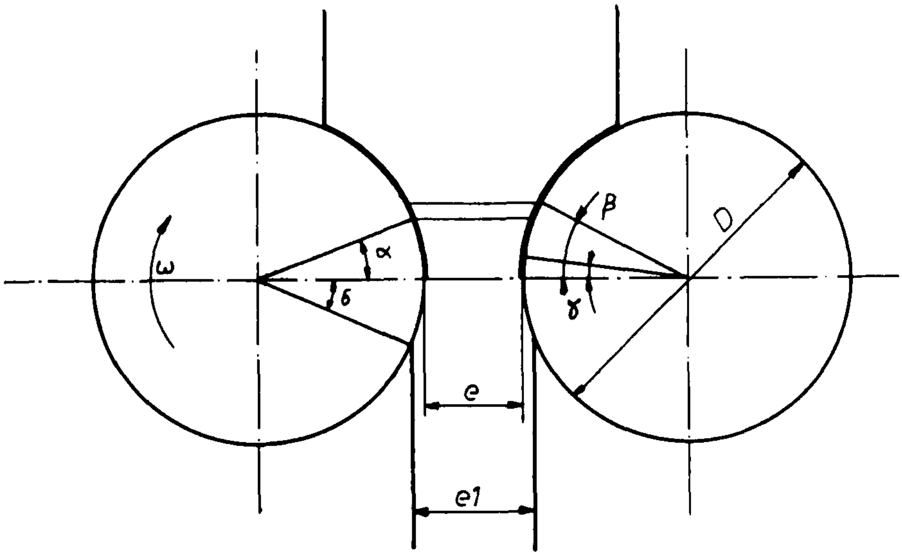


FIGURE 1

γ is called the neutral angle and corresponds to the point where the pressure applied on the material by the rolls is the highest.

δ is the elastic deformation : as a matter of fact for some materials, the thickness e1 of flakes obtained at the compactor outlet can be higher than the gap e between the rolls. Assuming that the layers of material in the compaction area remain horizontal and move at the peripheral speed of rolls, the following formula can be made out :

$$e1 = D \frac{do}{d1 - do} (1 - \cos\alpha)$$

where D is the diameter of the rolls

do is the density of material at angle

d1 is the density of flakes.

If one considers that the angle α is independent of the diameter of rolls (and this is close to reality), the formula shows the linear variation of the flake thickness e1 with the diameter.

However, in fact, the flake thickness e1 depends also on the roll speed, the roll surface, the compaction pressure : these parameters have an influence on the value of density d1 of flakes. If the same flake thickness e1 is obtained with rolls of different diameters, the flake density will be then higher with the larger diameter rolls.

The roll speed is determined in such a way that the compression time is not too short. Indeed the compression time should increase as the ratio of the bulk density to the real density of the feed material decreases. The tangential speed generally lies between 0.06 metre per second and 1 metre per second.

4 - FEED SYSTEMS

According to the material to be treated, the tangent roll press will be fitted with one of the following feed systems :

- gravity feed by simple hopper
- gravity feed with simple flap hopper
- gravity feeder with flap distribution box
- force-feed with force-feeder

4-1 Gravity feed by means of simple hopper (Figure 2-a)

This type of feed is used when the equipment to be processed has good rheological characteristics i.e. it flows in the hopper without any difficulty. The materials which have these characteristics can be compacted very easily, e.g. frozen food, ... These are generally products with a powder density over 1.

FIGURE 2 - FEED SYSTEMS

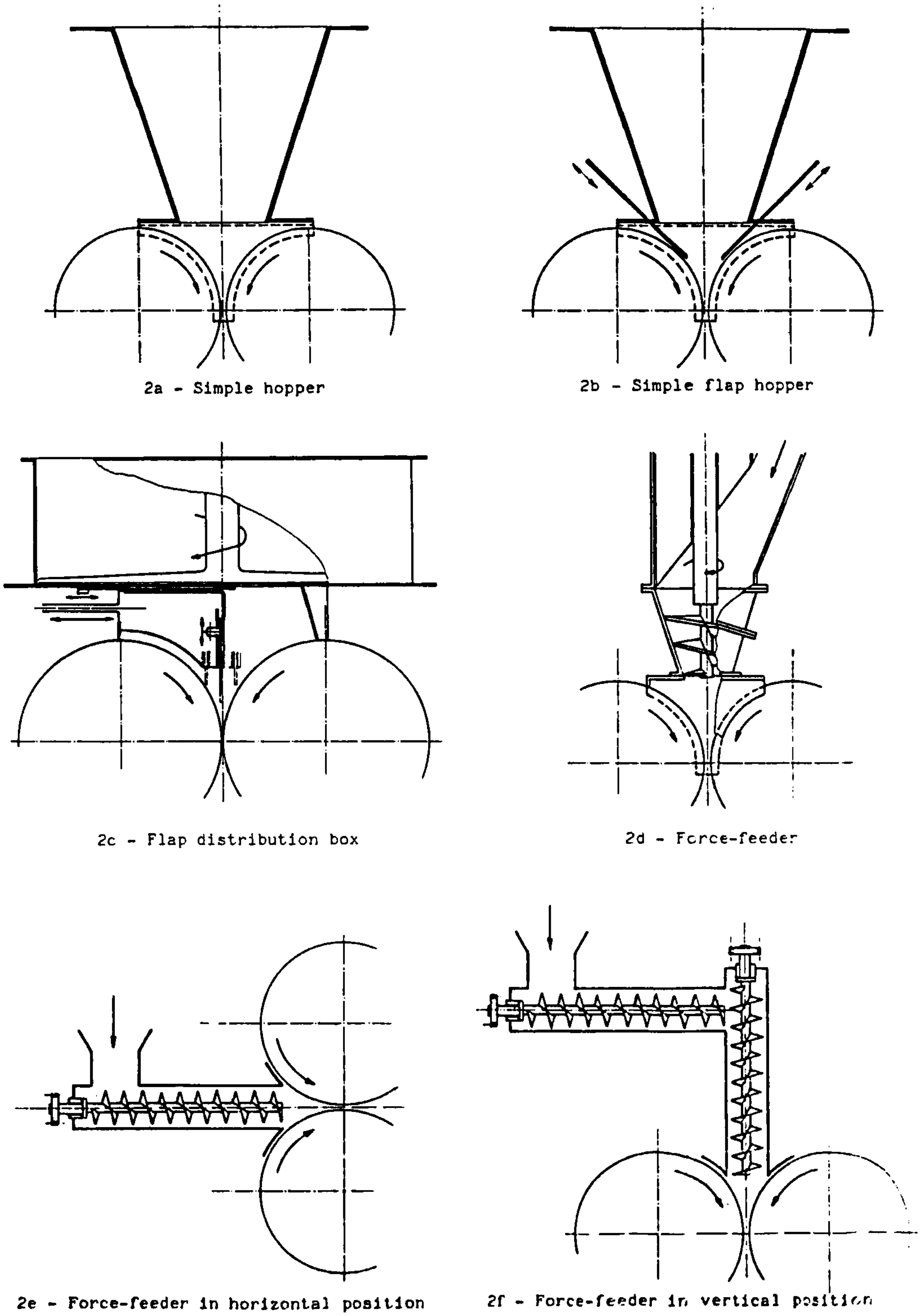


FIGURE 2 - FEED SYSTEMS

4-2 Gravity feed with simple flap hopper (Figure 2-b)

With some materials (sodium chloride, ...) which have a good flowability, it is necessary to check the flow of material just above the rolls and namely obtain a good distribution of the material on the whole width of the rolls.

4-3 Gravity feed with flap distribution box (Figure 2-c)

This type of equipment is used for materials which have not so good rheological characteristics and should mainly be processed with a binder. It is advisable to use a gravity feeder then. As in cases 4.1 and 4.2, the rolls are fed by gravity but the mix should be kept moving before the feed area between the rolls by means of arms in the cylindrical tank. At the bottom of the tank, an opening above the rolls is provided for the flow of material. A vertical flap distribution box is fitted under the tank so that the flow of material can be checked just above the nip angle. In fact, the flaps can be adjusted in a vertical position but also in a cross position to increase or decrease the flow section between the roll surface and the flap base. This system provides a uniform distribution of paste onto the whole width of the rolls (same quality of briquettes on the sides and in the middle). This feed system is used for materials such as coal, ores (iron, manganese, chromium, ...) and metallic oxides. These are generally materials with a powder density above 1.

4-4 Force-feed with force-feeder (Figures 2d-2e-2f)

For some materials, the use of a force feeding can be considered. The material to be processed is then fed to the rolls by means of a feed screw. According to the makers, the feed screw will have a vertical position 2f, or an horizontal position 2e when the rolls are in a vertical position. Sometimes the screw is tilted in order to improve its feed. The feed hopper is then vertical and thus the load in the hopper can force-feed the material between the rolls.

In most cases, the shape of the screw 2d is conical and its design is most important : the number of turns, the pitch between turns are determined according to the material to be processed.

When the material is not very aerated, the conical screw will act simply as a feeder : the pitch of turns will go on increasing in order to have a constant displaced volume.

For aerated materials, the conical screw will have two functions : a feeding one and a pre-densification one : the turn pitch will be constant and indeed sometimes decreasing.

The force-feeder can carry out 30 to 40 % of the total densification work of the force-feeder compactor unit. This is therefore a major component of the compactor. The number of screws used in the force-feed system is defined by the width of rolls. From a roll width of 400, the use of two screws (twin force-feeder) will be considered.

5 - OPERATION PRINCIPLE OF COMPACTOR EQUIPPED WITH ONE FORCE-FEEDER (Figure 3)

A compactor or tangent roll press is equipped with two rolls. The shafts which support the rolls are equipped with bearings fitted in housings which are placed in the frame of the machine. The rolls can be built in several ways :

- monobloc rolls
- rolls with tyres
- rolls with sectors

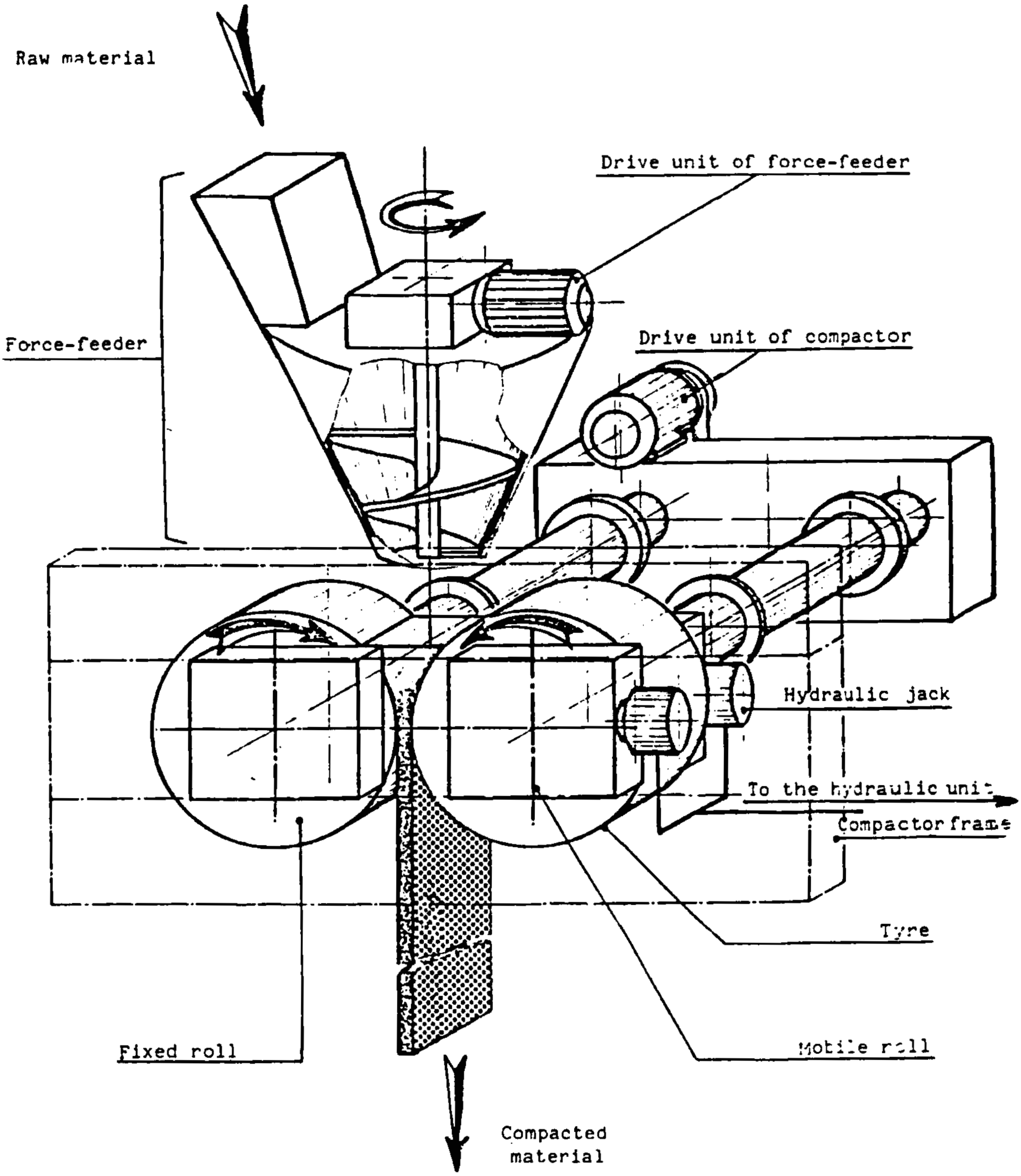


FIGURE 3 - OPERATION PRINCIPLE OF COMPACTOR EQUIPPED WITH 1 FORCE-FEEDER

The choice between these three main techniques is specified by the operating conditions : temperature of material, abrasion, chemical corrosion caused by the material which is processed, compaction pressure and also the economical cost. Actually, the roll is a wear part as it is the mechanical part in contact with the material and the replacement cost should be taken into consideration as well as the stop time of the plant during replacement and the life-time of the roll.

The pockets or engravings on the rolls are obtained either by mechanical machining or by electrochemical machining when a very hard steel is used for the rolls. In the latter technique, an electrolytic liquid erodes the roll on the whole surface covered by an electrode; it moves with the erosion in the metal until the required depth is obtained. With this technique any type of steel can be machined and also any shape of pockets which can also show trade mark prints.

The rotation of rolls in the reverse direction is ensured by a motor and a gear-box. As they should rotate at the same speed in order to be perfectly synchronized, they are driven by a two-output gear-box via extensions with curved-tooth couplings where the lateral and circumferential adjustments can be done. One of the shafts is said to be "fixed" in the frame as it cannot move in a horizontal line, and the second is said "mobile" as it can move horizontally.

A load is applied on both housings of the mobile roll by means of hydraulic jacks which keep the mobile roll in position and which generate the compaction pressure on the material.

The feed system above both rolls consists in a conical tank with the feed screw which is driven by a gear-motor.

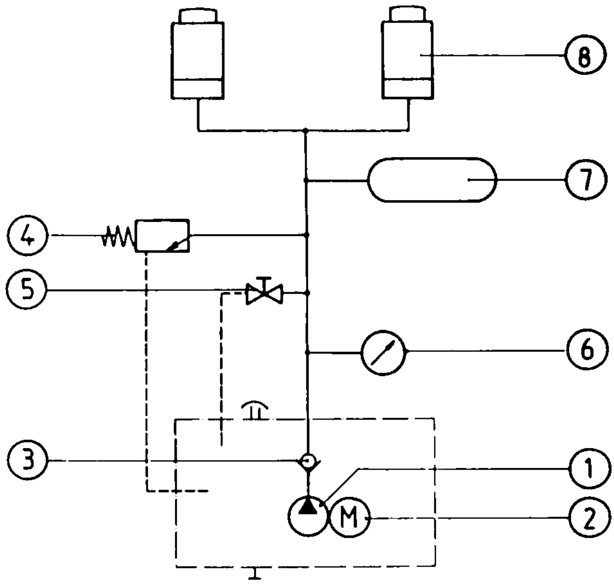


FIGURE 4 - HYDRAULIC UNIT

6 - SKETCH OF THE HYDRAULIC UNIT (Figure 4)

The hydraulic circuit includes the following elements :

- one or several hydraulic jacks (item 8) on the housings of the mobile roll;

- one or several nitrogen accumulators (item 7) which absorb the oil movements in the hydraulic circuit and give flexibility of floating roll displacements if a foreign body is encountered or if the feeding is too important;

- a motor-pump (item 1 and 2) putting the circuit under pressure when the compactor starts;

- a solenoid valve (item 4) to reduce pressure;
- a manometer (item 6).

The oil pressure p in the hydraulic circuit determines the load C applied on the mobile roll. As a matter of fact, the load is given by : $C = n \times S \times p$
where n is the number of jacks
S is the section of jacks.

The operating conditions (processing) of the material are then featured by the following data : Pressure P calculated with the formula :

$$P = \frac{C}{L}$$ where L is the width of a roll.

This measure is often given in kN per linear centimeter or in Tons per 1cm; it characterizes the processed material. This characteristic is very important as it defines the sizing of the compactor.

7 - INSTRUMENTATION OF COMPACTORS

The compactors are machines capable of a continuous operation 24h/day : they are often equipped with controllers to have a safe continuous operation without human intervention.

Some parameters are analysed constantly, connected with the control room by alarms; these parameters are : the bearing temperature, the oil temperature of gear boxes, the roll speed, the power absorbed by the rolls and the force-feeder, the pressure in the hydraulic circuit. In this case, the alarms are triggered when the parameter measured has reached its limiting value beyond which the operation of the machine is dangerous.

Regulation devices are often installed on the new machines; they control the quality of the product processed by the compactor thanks to the regulation of the pressure applied on the mobile roll (pressure in the hydraulic circuit), of the gap between the rolls and of the power absorbed by the motors. For instance, the gap between the rolls is kept at a set-value specified by the operator owing to the adjustment of the feed screw speed.

8 - POSSIBLE BINDERS

If the mutual force of adhesion between the grains of the feed material is low, a binder is essential to reinforce this adhesion. The physical properties of the raw material, the intended use of the briquettes and the cost must be taken into account when selecting a binder.

The binder must be mixed with the feed material with great care as it must permeate through the whole mass and coat each grain with a fine film.

The binder used are very numerous; for example water, pitch or bitumen, lignosulphonates, flours, molasses and lime, sodium silicate, calcium silicate, cement, clay, bentonite, synthetic resines, polymers, etc...

9 - FLOW DIAGRAM OF A BRIQUETTING UNIT (Figure 5)

A briquetting unit makes possible the production of briquettes which have well defined shapes and sizes. The briquetting press supplies directly the end product. The plant is made up of :

- the mixing-dosing unit where a thorough mix with the raw material, the recycled fines and possibly the liquid or solid binder(s) takes place;
- the briquetting press;
- the recycling unit for fines coming from the briquetting process which are recovered just at the briquetting press

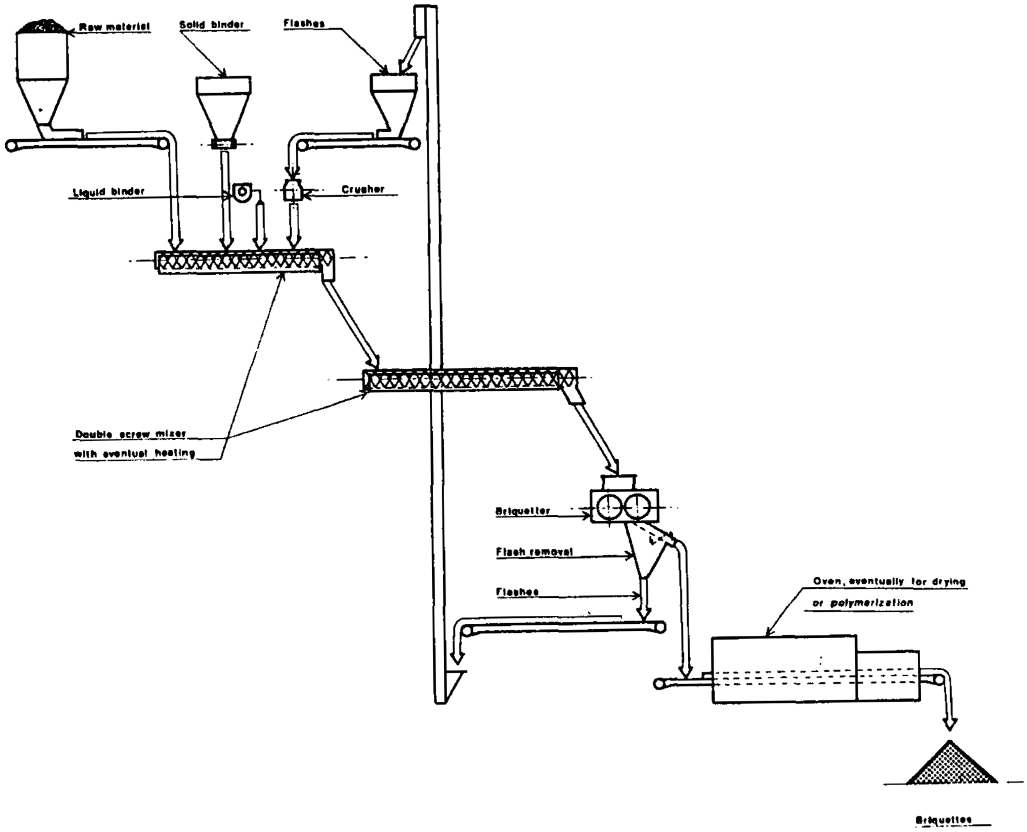


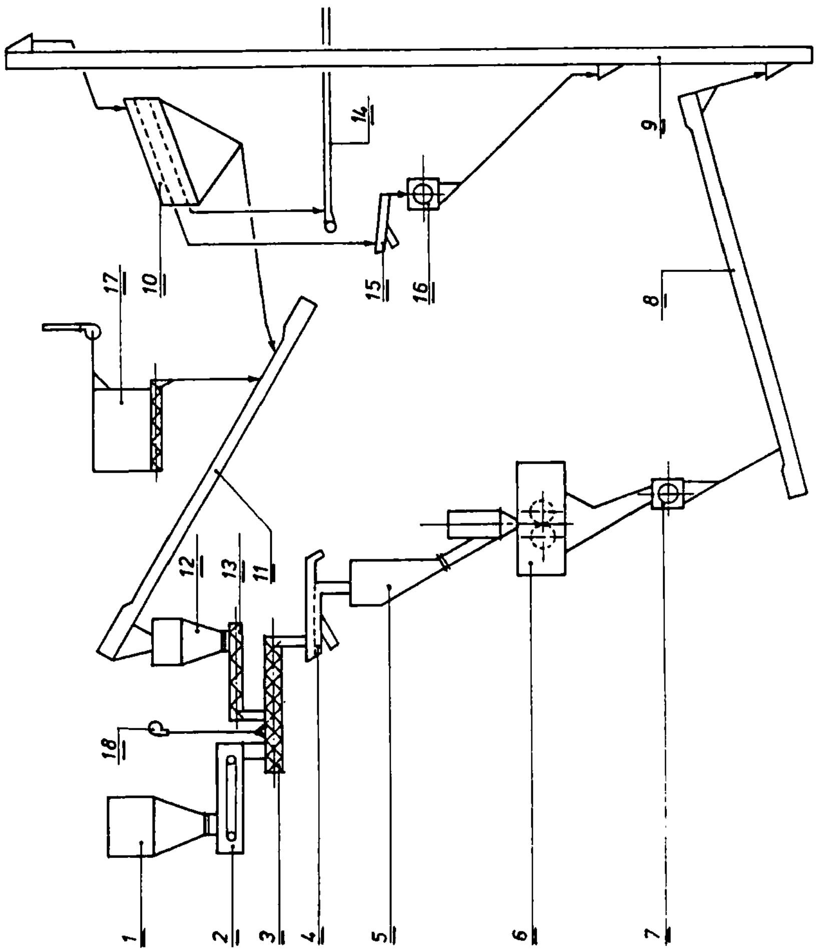
FIGURE 5 - A BRIQUETTING UNIT

outlet by means of a trimming grid. In order to obtain an homogeneous mix before briquetting, the fines have to be crushed before recycling;

- According to the binders used, it is possible to have a drying or curing oven too.

10 - FLOW DIAGRAM OF A GRANULATION UNIT (Figure 6)

A granulation by compaction unit is used for the production of granules of a definite size with an indefinite shape. The unit



1 Buffer hopper
2 Weigh feeder
3 Mixing screw
4 Protection screen
5 Feed hopper
6 Briquetting press
7 Primary hammer-mill
8 Chain conveyor
9 Bucket elevator
10 Double-deck screen
11 Chain conveyor for fines
12 Storage hopper for fines
13 Extracting screw for fines
14 Conveyor for granules
15 Vibrating feeder
16 Secondary hammer-mill
17 Dedusting equipment
18 Water spraying

FIGURE 6 - A GRANULATION UNIT

consists of the following equipment :

- a mixing-dosing unit where a thorough mix is made with the raw material, the recycled fines and possibly the liquid or solid binders;
- the compactor to transform the fine material into a high density compacted flake;
- a primary hammer-mill;
- a screen which sorts out the merchant granules (required size)the recycling fines and the oversize granules;
- A secondary hammer-mill for oversize granules.

The output can vary between 50 kg/h up to 50 Tons/h.

In case of low throughput industrial plant, to cut down on investment expenses, the secondary hammer-mill can be left out. Oversize granules at the screen outlet are processed by the primary hammer-mill. However in this case, the yield i.e. the ratio between the merchant granules output and the compactor output, is lower than the one obtained with a two stage crushing. Indeed the primary and secondary hammer-mills do not work under the same conditions to optimize the yield of the plant. This yield can vary between 35 % and 80 % according to the materials treated and the final size-range required by the user. For commercial reasons the surface quality of the granules can be improved either by rounding up in a polishing drum and/or coated with an adequate chemical agent in a coating drum.

11 - WHY BRIQUETTING OR GRANULATION BY COMPACTION ?

The applications of the briquetting-compaction technique are extremely numerous and varied :

- to obtain a definite shape from a powder (briquettes from 2 cm3 to 150 cm3);
- to densify a powder to cut on storage, transport and handling costs; the density can be multiplied by 2 to 4;

- to recover dust and fines to valorize them in case of high value materials or for ecological reasons;
- to improve the flowability, and the handling, transport and storage conditions;
- to stabilize unstables mixtures i.e. obtain an homogeneous mix of materials which have different physical characteristics (flowability-rheology) and avoid the risks of segregation during transport;
- to improve the treatment of powders : a compact powder can be more easily treated in a thermal oven than to feed the oven with a powder.

12 - APPLICATIONS OF BRIQUETTING AND GRANULATION BY COMPACTION

The applications can be divided into several fields :

1. low pressure processing (lower than 20 kN/lcm)
2. medium pressure processing (between 20 and 60 kN/lcm)
3. high pressure processing (above 60 kN/lcm)
4. without binder
5. with binder
6. at ambient temperature
7. at medium temperature (100° C)
8. at high temperature (up to 1000°C)

For example :

. coal, charcoal : 1+5+7
. ores (chromium, manganese, iron,...) : 2+5+7
. metallic oxides : 2+5+6 (possibly 7 at 400° C)
. metallic powders (chromium, ...), turnings, sponge iron, ... : 3+4+8
. lime, magnesia : 3+4+6
. carbonates, phosphates : 3+4+6 (possibly 8 at 1000°C)
. clay : 1+4+6
. potash : 2+4+7
. fertilizers : 3+4+6 (possibly 7)

. glass batches : 2+4+6

. salts (NaCl, ...) : 2+4+6

. detergents : 1+4+6

. frozen food : 1+4+6 (-20°C)

. pharmaceuticals : 1+4+6.

13 - CAPACITY OF COMPACTORS

Considering the wide range of industrial applications for this type of equipment, the size range of these machines is very wide :

- output : up to 100 Metric Tons/hour
- roll diameter : from 200 to 1200 mm
- roll width : from 40 to 1000 mm
- power : up to 700 kW
- weight of a compactor : up to 100 Metric Tons
- compaction pressure : up to 120 kN/1cm or more.

14 - NEW COMPACTOR-GRANULATOR

Owing to the experience Sahut-Conreur has acquired in the field of granulation by compaction, a new range of compactors-granulators has been specially designed for the pharmaceutical powders (building materials compatible with the powders to be processed, easy cleaning, disassembly, and adjustment of parameters, simple operation of compactor : roll speed, force-feeder screw speed, compaction pressure, ...).

This new compactor-granulator has been developed in collaboration with the Laboratory of the Industrial Pharmacotechnology of the Faculty of Pharmacy, Lille, France.

An experimental study was carried out to know the effects of the compactor variables on the pharmaceutical powders, and namely the influence on the flowability, the density, the compression ability (1).

CONCLUSION

Although briquetting and granulation by compaction have been in existence for a good many years, they remain an experimental science. Research has been made and scientific patterns were attempted at for a better understanding of the phenomena at work. However, each material having its physical characteristics, no general theory has been brought out so far.

This densification technique gives noticeable results on a large variety of powders without using additives and therefore without polluting the powder by foreign matters. And besides, very large quantities of materials can be treated at low operation costs.

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