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THE MEASUREMENT OF RESULTING FORCES ON A ROLLER COMPACTOR

E. Jerome (1,2), A. Delacourte (2), P. Leterme (2)
and JC. Guyot (2) *

(1) Sahut-Conreur F 59 590 Raismes (France)

(2) Faculté de Pharmacie F 59 045 Lille (France)

ABSTRACT

In this study, a Pharma 250 Sahut-Conreur roller compactor and a MG 333 Frewitt oscillating granulator is used in order to obtain granules to be compressed. The compactor is fitted with strain gauges which measure the forces during compaction. The autors demonstrate that the force measured is a fonction of the rate between the speed of the

* To whom correspondence should be addressed

feeding screw and the speed of the wheeles; its depends on the pressure applied and on the configuration of the machine.

INTRODUCTION

In powder technology, it is often necessary to modify the characteristics of fine powders in order to obtain, more easily, a more stable mixture, a better flowability, or a better tablettibility.

We find these problems in the pharmaceutical laboratories where people have to develop new formulations. But the same problems occur in the chemical factories, where powdered drugs and excipients are manufactured in order to obtain raw materials characterised by technological properties.

To solve those problems, one of the possible techniques is to densify the fine powders into granules. Among the processes of densification, dry granulation is very interesting using either briquetting or compaction.

In a previous paper (1), we presented a new compactor - granulator specially developed for pharmaceutical technology according to good manufacturing practices. We studied the effects of compactor adjustmemts on the properties of powders (2,3). We demonstrated that, generally, the pressure applied by the movable wheel is not a predominant factor ; the most important factor is the speed of the precompactor screw in relation to the speed of the wheels. The compaction requires a ratio between the speed of the wheels and the speed of the precompactor screw which is a non-dimensional number characteristic for a given powder.

In order to obtain more information about the behaviour of the powder during compaction, and then to know how to optimize the adjustments of the compactor for a given powder, we have stuck strain gauges on the device and studied the curves of the resulting stress against time in different conditions.

In the present paper, we will describe the instrumentation developed and the general profile of the curves obtained. Then we will use this tool to study the influence of the compactor adjustments and we will give a few examples of pratical applications to demonstrate the interest of this instrumentation.

MATERIALS AND METHODS

Description of the instrumentation

During compaction, the stirrup-piece, which maintains the fixed wheel in position, presses on two hardened steel cylinders. On these cylinders, we have stuck strain gauges connected to measuring bridges (4). The signal obtained is visualised on a digital oscilloscope (5) and recorded on a high speed recorder (6).

For the calibration, the cylinder is pressed between a hydraulic jack and a standardized electronic device inside a press.

The amplitude of the signal is adjusted and the linearity is verified.

Experimental conditions

The compaction is carried out on a Pharmapress 250 Sahut-Conreur Compactor Granulator (7) fitted with wheels of 250mm in diameter and 40 mm in width.

On this compactor, it is possible to adjust the speed of the precompactor screw from 15 to 100 rpm, the speed of the wheels from 3.3 to 27 rpm, and the pressure applied by the movable wheel from 1 500 to 6 000 daN per linear centimetre corresponding to 60 to 200 bars on the hydraulic device.

The granulator is a Frewitt MG 333 oscillating granulator (8) fitted with different types of grids according to the product and the result which is aimed at.

The mixing of the granule with the lubricant is made in a Turbula mixer (9).

The compression is made on a Frogerais OA single punch machine (10) fitted with flat punches of 1 cm2 area (11.28 mm in diameter) instrumented with strain gauges connected by measuring bridges (4) to a computerised apparatus developed in our laboratory (11) which carries out the acquisition and the processing of the data obtained.

The hardness of the tablets is measured with the aid of dynamometric pincers developed in our laboratory (12).

RESULTS AND DISCUSSION

Curve profiles

The force measured by the sensor is the resultant between the force applied by the wheel and the resistance of the powder pushed by the screw of the precompactor.

For a given powder, this resistance is dependent on the amount of powder which is related to the speed of the precompactor for a given speed of the wheel.

At the beginning, the amount of powder is small, and the signal increases gradually during the rising phases (part 1 in fig 1).

The second phase (part 2 in fig 1) of the curve is more or less a plateau, the length of which depends on the bulk density of the powder (for the same volume of powder and a given speed of the wheels).

After this phase, the amount of powder between the wheels is not sufficient and the force decreases rapidly (part 3 in fig 1). This plateau is characterised by its height, in relation to the resulting force level, and by the shape of the indentation which are characteristic of a powder in certain conditions.

Figure 2 shows that, after the initial feeding phase, the profile is characterised by a pattern which is always the same during powder compaction. In this figure, we have the beginning of the curve and a further part of the curve after a lapse of time ; we can observe that the pattern is always the same with the same frequency and the same amplitude.

In figure 3, which is obtained with corn starch (13), the differences between maximum and

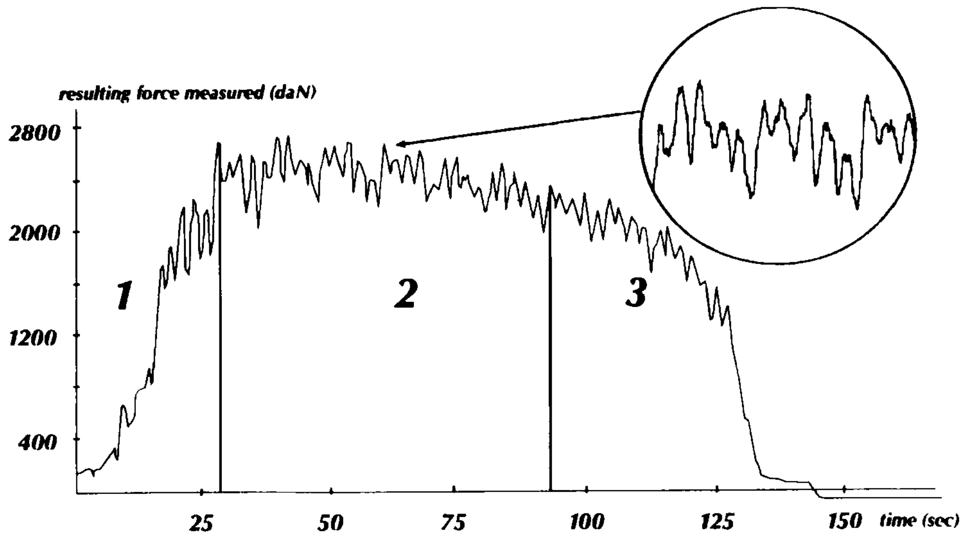

FIGURE 1. Example of compaction profile

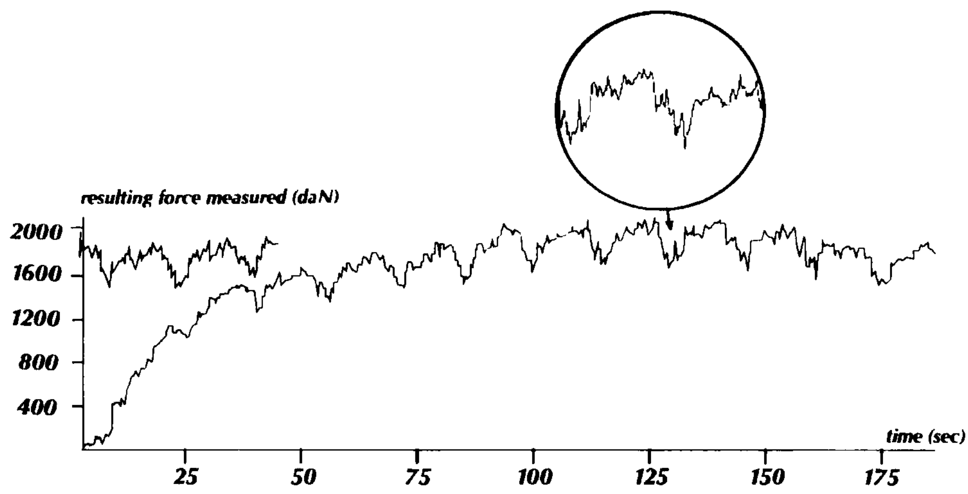

FIGURE 2. Characteristic compaction profile in good conditions for a given product

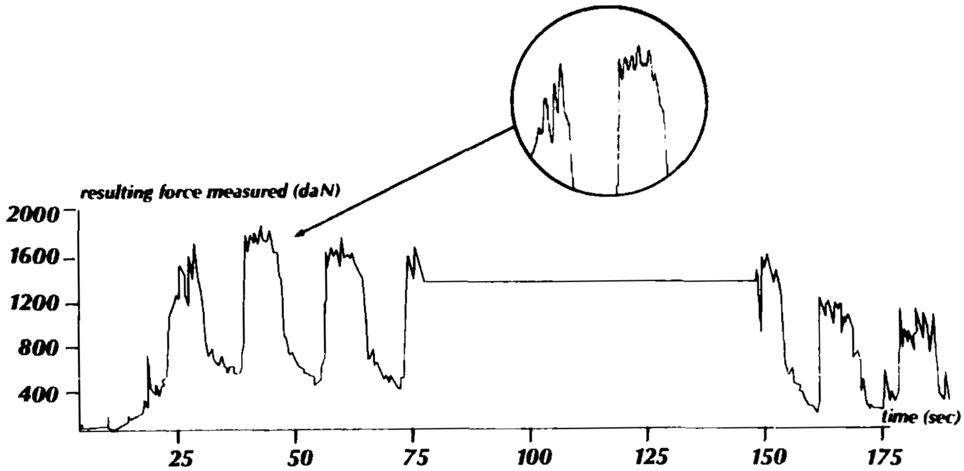

FIGURE 3. Compaction profile of powder with bad flowability

minimum are bigger. One of the reasons is the bad flowability of this powder with a double compaction as a consequence.

Figure 4 shows the differences obtained with two qualities of lactose (fine powder lactose and EFK lactose (14) compacted in the same conditions without perceptible differences during compaction.

Influence of the different adjustments of the compactor on the records

Type of wheels

The curve of figure 1 was obtained with pockets wheels (such as tyres used to obtain coal

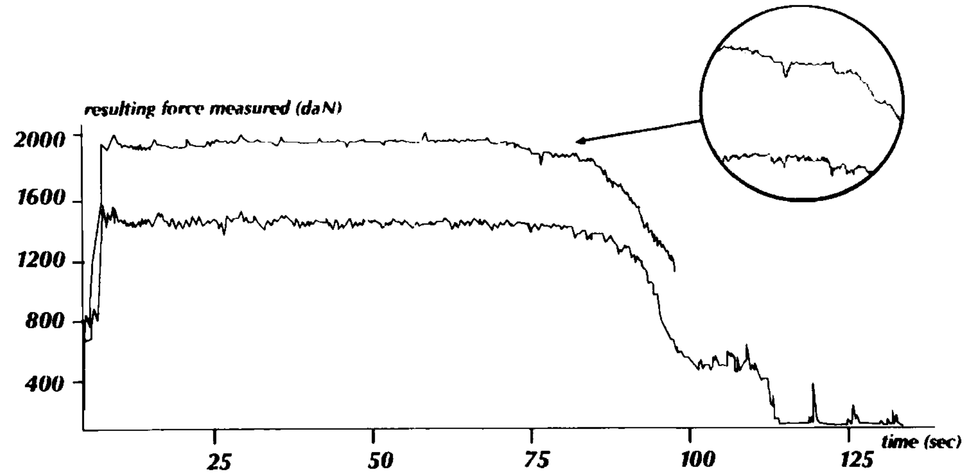

FIGURE 4. Compaction profiles of two varieties of lactose in the same conditions

briquettes). The profile is quite different using wheels with small sticks. Figure 5 shows the same product compacted in the same conditions, but with the two different types of wheels described above.

It is evident that the resistance of the powder depends on the shape of the pockets, but nowadays, we do not know how to choose the best wheels for a given product and for a given aim (flowability, ability to obtain right tablets with the powder produced by granulation of the compacts...).

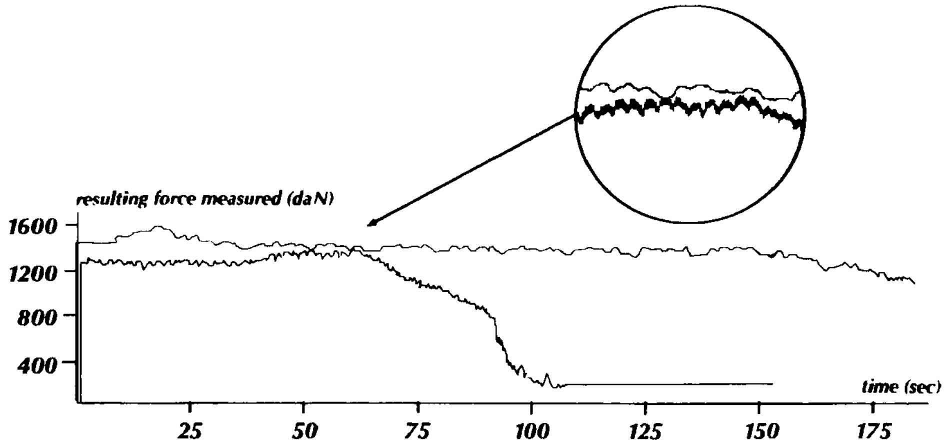

FIGURE 5. Compaction profiles of the same product using two different kinds of wheels

Influence of the pressure applied

In figure 6, we can see two curves of compaction of Elcema G 250 (15) obtained with the same speeds of the wheels (5.7 rpm) and of the precompactor screw (21.5 rpm), but different values in the adjusment of the pressure (120 and 150 bars). We can see that there is no significant difference between the two curvess, and particularly as far as the force level is concerned.

Influence of the speed of the precompactor

In figure 7, we have two curves of compaction of Elcema G 250 obtained with the same speed of

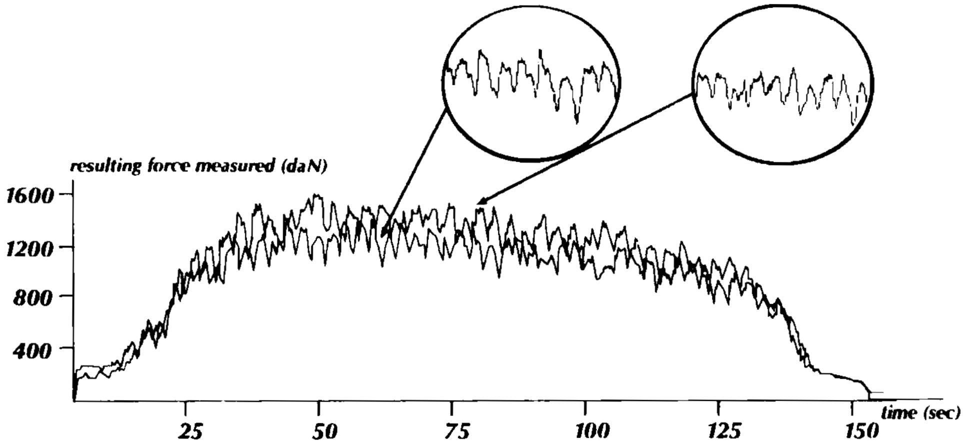

FIGURE 6. Compaction profiles of the same powder at two different pressures

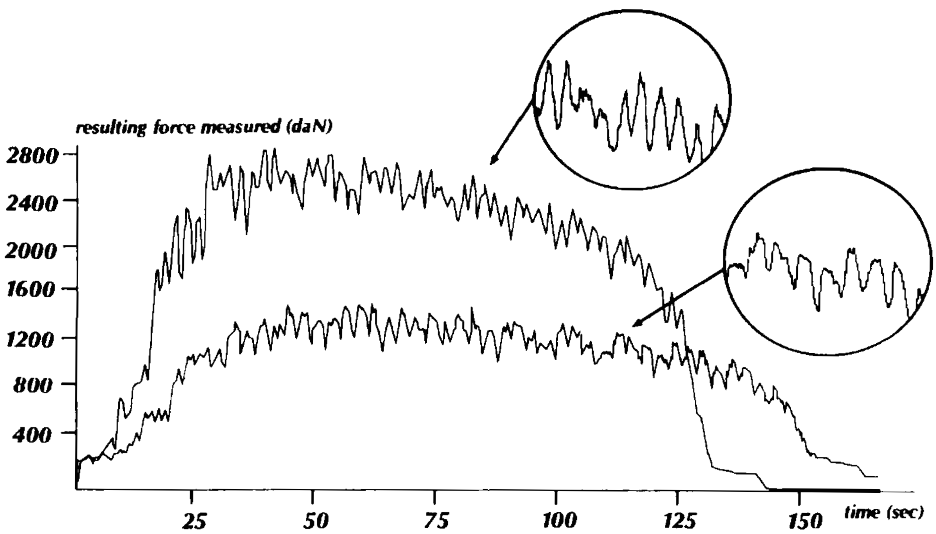

FIGURE 7. Compaction profiles of Elcema at two different speeds of the precompactor screw

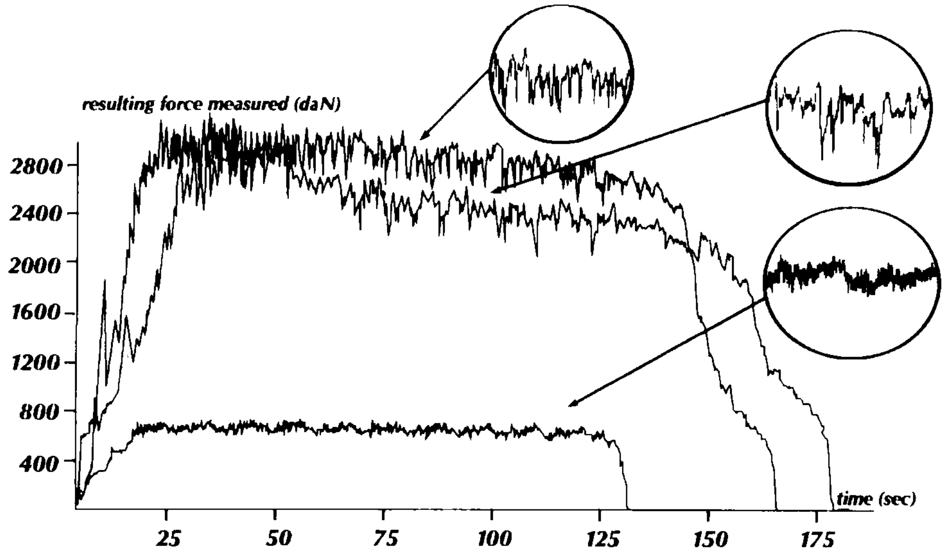

FIGURE 8. Compaction profiles of lactose at three different speeds of the precompactor screw

the wheels, the same pressure applied, but two different speeds of the precompactor screw. We can see a substantial difference on the measured force level, which can be opposed to the low influence of the pressure applied (fig.6).

An other example in given, in figure 8, where we can compare the curves obtained with lactose for three different adjustments of the speed of the precompactor screw but the same speed of the wheels (5.7 rpm) and the same pressure applied (120 bars). In this example, we can see that when the speed of the precompactor increases, the level of the force measured increases, but the relation between the speed and the force measured is not linear : from 17.5 to 18.5 rpm, the force increases from 700 to 2500 daN, and from 18.5 to 21.5 rpm, the force increases only from 2500 to 3200 daN.

Practical interest of this instrumentation

The interest of this instrumentation is to obtain, during the development of a new product, information about the best adjustments to achieve one's aim. We will give two examples :

The first example : is about the compaction and granulation of a product very sensitive to water content.

The problem is the following : the original product has a water content of 30 %. Compaction is easy, but the granulation of the compacts is difficult because there is a clogging up of the grid. At the opposite, after the drying of the product (water content of 14 %), compaction is difficult and results in a critical heating of the

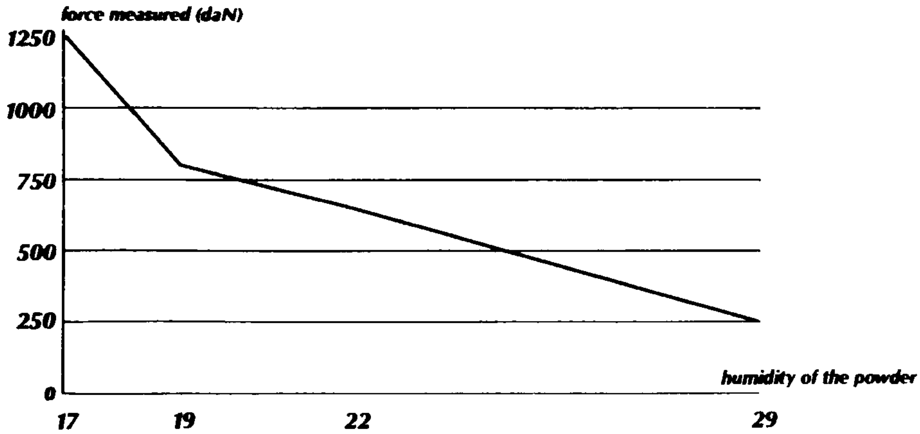

FIGURE 9. Level of the resulting force against humidity percentage of the powder

product. The granulation of the compacts is easy but we obtain too many fines. It is necessary to find a compromise between the water content of 30 and 14 %, but without instrumentation it is very difficult because we do not get any information during the compaction phase.

First the curves obtained (fig. 9) show that the level of the resulting force increases with the decrease of the water content of the product, particulaly under 20 %. This is logical because the increase in the plasticity of the mixture is in relation to the water content of the powder.

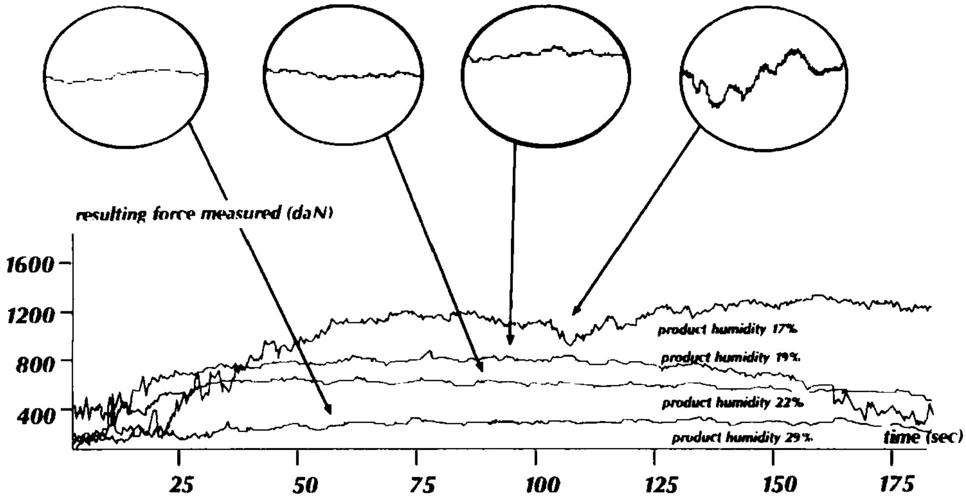

FIGURE 10. Compaction profiles in correlation with the humidity of the powder

Secondly, we see (fig. 10) that the profile of the curve for a water content of 17 % is quite different, characterised by the repetition of the same pattern and indentations. For the water content of 17 %, we can observe that there is no more heating during compaction and no more clogging up of the grid. Moreover the granulation does not produce too many fines. This demonstrates clearly that the instrumentation is useful to define the best compaction conditions.

Thanks to this instrumentation, the conditions proposed allow us to obtain the result

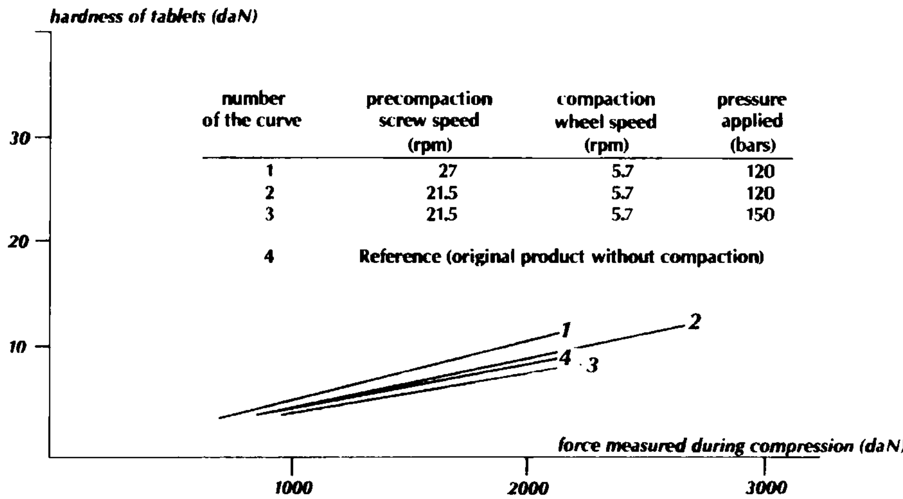

FIGURE 11. Capacity of powders for giving hard tablets, in correlation with their compaction conditions

aimed at without degradation of the product (controlled by an analysis).

The second example is the study of the modification of the tablettibility of Elcema G 250 in relation to the compaction conditions.

The compacts obtained are granulated in the same conditions. The mixture is compressed on an instrumented single punch machine at different adjustments of the eccentric. For each adjusment of the eccentric, we measure the maximum force during compression and the tablet hardness. We compare the linear phase of the curves of the hardness against the maximum force measured during compression. The steeper the slope is, the better the mixture is, as far as tablettibility is concerned (16).

We can see that mixture 2 obtains the same results as the original product (4) (fig. 11). With the same speeds, the increase of the pressure applied results in a decrease of the tablettibility (3). But if we increase the speed of the precompactor screw with the same pressure as for mixture 2, the tablettibility improves (1).

During compaction, it would be impossible to predict this difference because the aspects of the compacts in the different cases are quite similar.

Conclusion

Just as it is well known in tablet technology, so the measurement of the force during compaction gives an important piece of information on the behaviour of the powder during compaction. The instrumentation, that we have developed, allows the measurement of the powder resistance and the visualisation of the force evolution against time.

The level of the force measured is an indirect measurement of the energy developed during compaction. This energy, which is the resultant of all the parameters of the process and of the physical properties of the powder itself, may have critical consequences for the product. We have seen that the instrumentation allows us to set the limits for industrial production.

During the development phase this instrumentation is very useful to determine the optimal compaction conditions for a product.

The profile of the curves is very useful to visualise the behaviour of the powder during compaction and we have seen that for each product there is a particular profile characteristic of good compaction conditions.

Acknowledgements

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