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Roller Compaction Process: Components, Mathematical Modelling and Recent PAT Tools

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ABSTRACT

The roll compaction process is a dry granulation technique used for the compaction of powder material to increase its density in the absence of solvent, which ultimately improves its flowability. Roller compaction process being cheaper than other granulation techniques such as high/low shear wet granulation, offers flexibility in operation, reduced operation time, the omission of residual solvent analysis, and better scalability. In this review article, the various factors that contribute to the ribbon production during dry granulation and subsequently the physical properties of the resultant granules produced, and modern tools for PAT will be discussed.

INTRODUCTION:

Pharmaceutical formulations such as tablets and capsules require the feed powder to have good flow properties to achieve blend uniformity, uniformity of dosage units, content uniformity of dosage units, and reduced weight variation. Active Pharmaceutical Ingredients (APIs) that are micronized often exhibit high bulk volume and thus, reduced flowability. APIs that have finer or coarser particle size compared to the diluents used are reported to segregate into the void spaces between particles on account of difference in the particle size (1,2). This results in the segregation of the API from the bulk excipients during manufacturing, leading to issues such as blend uniformity, uniformity of dosage units, and drug product assay. The segregation of API possesses a significant hurdle in the manufacturing of a potent or low dose formulation. To improve the flow properties and uniform feeding, granulation techniques are utilized; namely, dry granulation and wet granulation. A process that reduces the bulk volume of a material is called granulation. Dry granulation can be manufactured in two ways: slugging, where a large compact is formed and broken down into granules; or roller compaction, where the material is compressed into a ribbon before breakdown. Roller compaction is gaining popularity in the pharmaceutical industry due to its ease of operation, batch to batch consistency, high throughput, reduced manufacturing steps, time, and absence of solvent for binder addition. The Roller compaction process is carried in the absence of a liquid binder, thus eliminating the need for the drying process. This is highly preferred for drug substances that are sensitive to moisture and heat. Dry binders can be used to increase the density as well as porosity of the compacts, which reduces the number of fine particulates produced during milling (3).

Theory of dry granulation:

A process that utilizes the powder's capability to plastically deform under external pressure forming stable compacts is called dry granulation. This process of deformation results in increased density and size of the particles. When an external force is applied, the granular bond is formed. Initially, the particles undergo plastic rearrangement in which the void space of the particles gets reduced on account of stress as the particles move closer to each other. Plastic deformation occurs when the applied compression force is further increased leading to increased contact angle between the particles. An excess of force applied with respect to particle surface hardness will result in plastic deformation. On further increase in the compression force, the particles undergo plastic fragmentation at which the particles fragment into pieces and interlock with each other. This will allow the formation of van der Walls forces to create on account of the interfacial surface energy of the particles resulting in interfacial bonding. On removal of the stress, the remaining elastic recovery of the particles will cause elastic/plastic rebound which results in loss of particle bonding and flaw development. The amount of recovery/rebound is indirectly proportional to the applied force on the particles. Elastic and plastic deformations can take place simultaneously but only one type of force will prevail (4–6). The schematic diagram of a typical roll compactor is depicted in Figure No. ***1***.

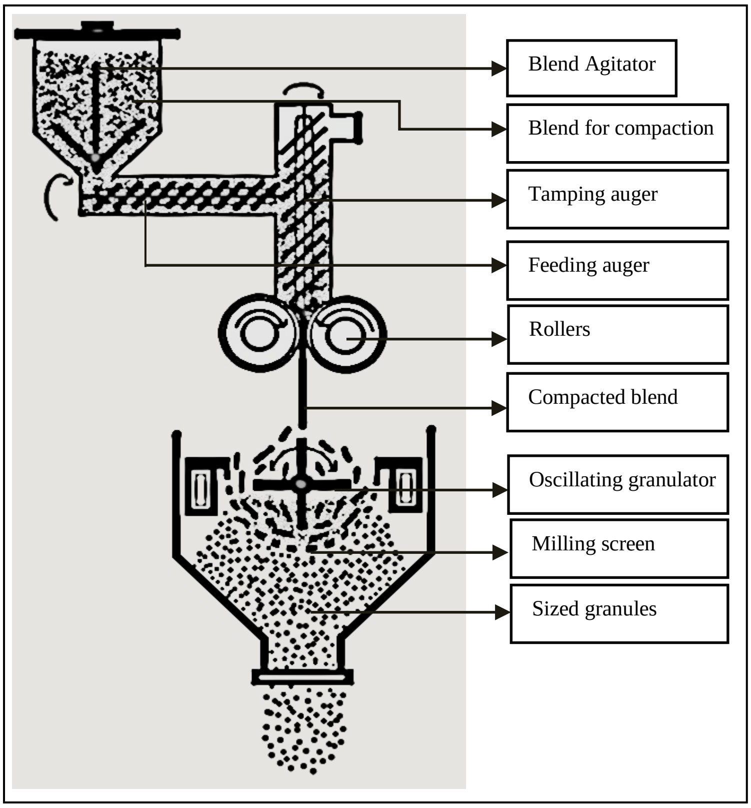

Figure No. 1: Diagram of Vertical type of Roller Compactor

Working principle and design of components in Roller compactor:

A) Feeder components:

Material to be compacted is fed by two main types of feeders; gravitational feeders and force feeders. Gravitational feeders as the name suggest utilizes the effect of gravity for the flow of material. These types of feeders are appropriate for lab-scale compaction machinery and for materials that have good flow property. The total throughput is dependent on the flow property of the material on account of gravity. Coning is often an issue in gravitational feeders for powders that have inadequate flow properties. Thus, the powder often needs external stress for uniform powder distribution between the rolls. Force feeders utilize speed-controlled screws called the feeding auger and tamping auger (Figure No*. **1***) for feeding the material into the rolls. The effect of gravity is diminished in force feeders unlike gravitational feeders (7). The total throughput of the process is dependent on the rotational speed of these force feeder screws (8). This assembly is especially useful in delivering high bulk volume material into the rolls with force since the influence of gravity is not sufficient to provide the required flow. These force feeders can cause pre-compaction of the material which may result in chocking of the flexible powders. The chocking phenomenon is usually seen in twin-screw feeders in large scale equipment. An increase in the diameter of feed screws results in an excess force on the rolls, increased power consumption, and escalates the uneven distribution of powder on the rolls. Thus, the diameter of the screw is generally 50% of the diameter of the rolls (9).

Modern techniques of feeder systems:

a. Vacuum de-aeration system

The uneven distribution of the powder in the roller gap occurs due to the entrapped air in low bulk density powder. The air entrapped in such powders undergoes compression in the nip angle which forces it to move to the edge causing fragmentation, called edging. Edging in turn increases the number of fines produced and also results in breaking across the ribbon width. The vacuum de-aeration system thus becomes necessary for the processing of low bulk density material (<0.3 g/cm^3). This system is designed to remove the entrapped air just before the nip angle, using a metal jacketed vessel incorporated with dry filter and suction negative pressure pump. The deaerated powder flows efficiently between the feed screws into the compaction rollers thus increasing the throughput of the roller compaction process. Deaerated powder leakage around the rollers is relatively less when compared to aerated low bulk density powder. It was first introduced by Miller RW, 1994 (10).

The friction of the inner walls of the feeding zone cause reduced motility of the powder blend on the sides causing a laminar flow effect. This in turn results in more powder fed from the center of the feeding zone in the rollers resulting in the densification of the ribbon in the center and production of fractures on the edges (11). To achieve even distribution of the powder across the roller width, novel 3D printed feeding guiders were utilized by Yu M, et.al, 2020 (12). Online thermal imaging of the resultant ribbon revealed even distribution of temperature across the ribbon width, indicating even densification of ribbon on account of the material being pushed to the sides using convex feeding guiders.

B) Compaction

a. Sealing systems:

The primary reason for the high amount of fines is the slip of powder from the sides of rollers during compaction. Production of fines impacts the flow property of the blend and ultimately impacts the die fill volume during tablet compression or encapsulation. Thus, a sealing system is employed. Two types of sealing systems for commercial roll-compactors are available as shown in Figure No***. 2***:

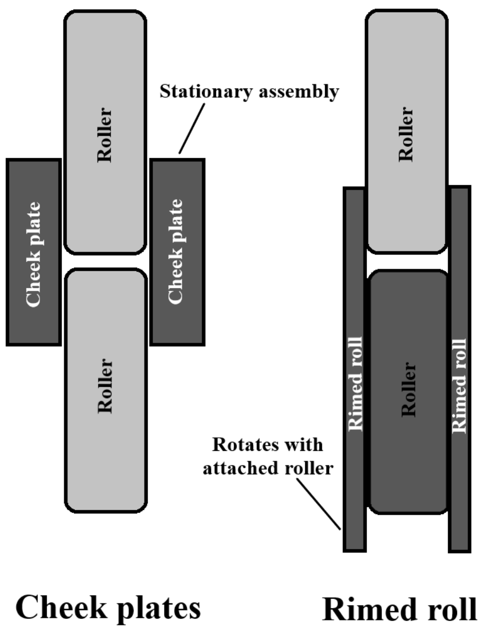

Figure No. 2: Roller compactor sealing system

i. Cheek plates: These are two side plates that seal the escape route of the non-compacted powder. They are fixed beside the rollers i.e. they are stationary.

ii. Rimed roll: Rimmed roll is flat and attached on both sides to one of the rolls which then rotates along with the attached roll. Perez-Gandarillas L, et.al, 2016 (13) demonstrated the impact of both the sealing systems on the ribbon properties of MCC (Avicel PH-101) and Mannitol (Pearlitol 200SD) and subsequently on the amount of non-compacted powder produced during operation. It was concluded that regular shape and length of ribbons of MCC were produced using cheek plates as sealing systems while irregular ribbons were observed when produced with a rimed roll. This could be due to the momentary adhesion of MCC on the inner wall of rimed rolls causing it to produce fractures on the ribbon during rotation. While irregular shape and length of ribbons were observed for Mannitol, irrespective of the sealing system. This was accounted for due to the brittle nature of Mannitol. On the other hand, d_{10} of MCC compacted using cheek plates was lower when compared to rimed roll indicating a higher amount of fines. The same authors later utilized 3D Finite Elements Method (FEM) modelling to understand the effect of sealing systems on the compacted ribbon's density distribution and concluded that the cheek plates assembly caused a non-uniform roll pressure and density distribution, while the rimmed-roll shows an overall more uniformly distributed resultant pressure and density distribution for MCC (Avicel PH-101) (14). A high amount of fines produced when using cheek plates is also proved, which is due to non-uniform feeding distribution of powder in the compaction zone (15). In conclusion, the rimed rolls produced non-uniform ribbons but provided better uniformity in compaction force applied on the ribbon width, thus producing more amounts of granules.

b. Compaction system:

Material fed from the feeding system is passed through two rollers that rotate in the opposite direction for compaction. The powder is fed into the rollers with the help of tamping auger and feeding auger as shown in Figure No*.* ***1***. In a manually operated roller compactor, the roller speed, roller force, and screw speed can be adjusted which results in a certain roller gap. Most modern industrial automatic roller compactors are equipped with a gap controlled mechanism where initially the roller speed, roller force, and roller gap is set, while the feeding auger and tamping auger screw speed are set by the machine’s response on the internal feedback system to achieve the desired roller gap and force. The amount of material that is fed to the rollers of manual type depends upon rotation speed of the feeding auger and tamping auger, while the amount of material fed into the rollers of automated type of roller compaction machine depends upon the roller gap and press force on the rolls (16).

An increase in the pressure applied to the rollers impacts the relative density and porosity of the ribbons. Larger sized granules are produced on account of the increased relative density of the ribbon due to increase in the ribbon solid fraction, whereas an increase in the roller gap results in the decrease in the solid fraction (17). The impact of variation in roller pressure was found to be the most significant critical process parameter that affects the resultant ribbon density and granules size (D50) in the roller compaction process (18).

The arrangement of rollers can be vertical, horizontal, or inclined as shown in Figure No***. 3***. Roller arrangement can be vertical, horizontal, or inclined as shown in Figure No***. 3***. The direction of material entry influences the rearrangement of powder in the slip region (19). The impact of powder rearrangement in the slip region will influence the distribution of force along the ribbon width and ultimately uniformity in ribbon density or solid fraction, defined as mass per unit volume of the ribbon, can be characterized using online thermal imaging (20).

Compaction of a flexible powder causes a reduction in its compressibility. This leads to capping or breaking issues at higher compression force during tablet compression when compared to the direct compression technique (21).

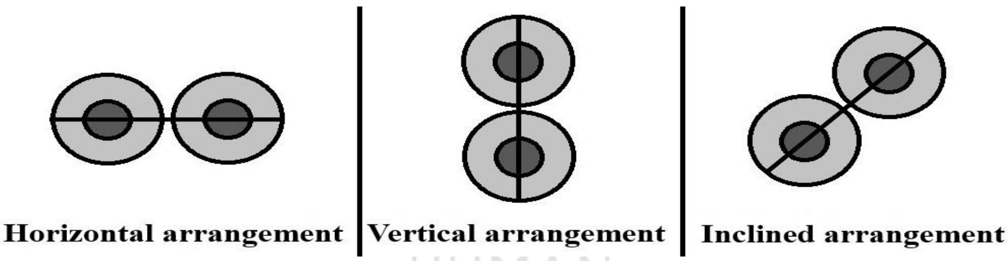

Figure No. 3: Common roller arrangement

Roller compactor model:

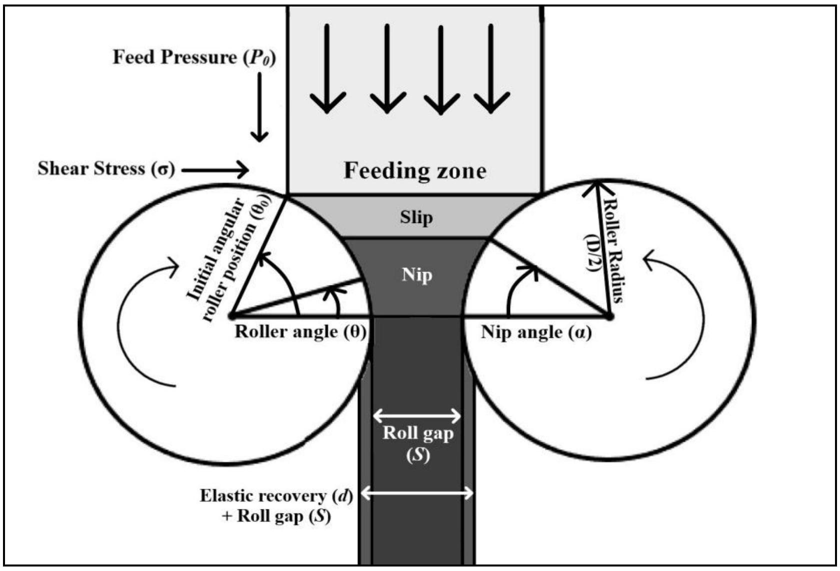

Figure No. 4: Schematic diagram of the roller compaction process

Jenike and Shield (1959) developed powder mechanics theory which later was used by Johanson (1965) to develop a rolling theory for granular solids which explains the calculation of nip angle (α). It is defined as the angle at which the boundary conditions of the rolls and the material change from slip condition to a non-slip condition as shown in Figure No***. 4***. The model proposed by Johanson (1965) (22) is based on a gap controlled roller compactor i.e. automated roller compactor since the roller gap is input for this model and neglects the screw speed. The compaction zones are categorized in as feeding zones, slip region, and nip region. The important points of interest begin from the slip region in which, the particles rearrange on account of the de-aeration system. The effective zone of the slip region depends upon the internal angle of wall friction ($\emptyset_W$) and effective angle of internal friction (δ_E). Pressure exerted by the rolls on the slip region ($\theta > \alpha$) is very low because the rate of mass flow in the slip region is less than the speed of rolls. In the nip region, pressure exerted by the rolls is very high when $\theta \leq \alpha$. This is because there is no slip between the rollers and the material, and the rate of mass flow is equal to the speed of rolls. Most of the compaction takes place in the nip region (16,23). The general model for pressure distribution at the slip and non-slip boundary conditions can be determined using equation 1 and 4.

$$\left(\frac{d\sigma}{d\theta}\right)_{slip} = \frac{4\sigma\,(\pi/2-\theta-\vartheta)\tan\delta_E}{D/2(1+S/D-\cos\theta)[\cot(A-\mu)-\cot(A+\mu)]} \qquad 1$$

Where,

$$A = \frac{\theta+\vartheta+\pi/2}{2} \qquad 2$$

$$2\vartheta = \pi - \sin^{-1}\frac{\sin\emptyset_W}{\sin\delta_E} - \emptyset_w \qquad 3$$

$$\left(\frac{d\sigma}{d\theta}\right)_{nip} = \frac{K\sigma(2\cos\theta-1-S/D)\tan\theta}{D/2(1+S/D-\cos\theta)\cos\theta} \qquad 4$$

At the point of contact between the slip region and the nip region, the stress gradient is equal. Hence, Johanson (1965) proposed that the nip angle can be determined at this point by solving equation 1 and 4:

$$\frac{4(\pi/2-\alpha-\vartheta)\tan\delta_E}{\cot(A-\mu)-\cot(A+\mu)} = \frac{K(2\cos\alpha-1-S/D)\tan\alpha}{\cos\alpha} \qquad 5$$

The peak pressure (P_{max}) applied on the material at the lowest roller gap (S) with roller force (R_f) is expressed as,

$$R_f = \frac{WDP_{max}F}{2} \qquad 6$$

Where, (W) is the roller width (D) is the roller diameter and (F) is an integral over the nip region.

The force factor (F) can be calculated as,

$$F = \int_{\theta=0}^{\theta=\alpha} \left[\frac{(d+S)/D}{d/D+(1+S/D-\cos\theta)\cos\theta}\right]^K \cos\theta \, d\theta \qquad 7$$

Where, (K) is the compressibility factor determined from reciprocal of the slope of the initial linear portion of the logarithmic plot of density as a function of pressure data obtained in uniaxial compaction (23).

Calculation of the nip angle (α) can yield the maximum pressure in the nip region (σ_θ) i.e. when $\theta \leq \alpha$, as:

$$\sigma_\theta = \sigma_\alpha \left[\frac{d/D+(1+S/D-\cos\alpha)\cos\alpha}{d/D+(1+S/D-\cos\theta)\cos\theta}\right]^K \qquad 8$$

On the other hand, the process model proposed by Reynolds (2010) can be used for a manual roller compactor since the input for this model is screw speed and neglects roll gap. Reynolds (2010) model also considers the solid fraction density in the roller gap (γ_G) and not the solid fraction of the final ribbon (γ_R), thus neglecting the elastic recovery of the ribbon (24). Reynolds (2010) theory holds when the ribbon relative density can be evaluated using the true density and envelope density measurements.

Reynolds (2010) explains that the equation 8 is dependent upon a simple power-law relationship between material density and pressure. Thus, the ribbon relative density (γ_R) can be estimated from peak pressure acting on the minimum roller gap as follows,

$$\gamma_R = \gamma_0 P_{max}^{1/K} \qquad 9$$

Where,

γ_0= Pre-compaction material density

Using equations 6, 7 and 9, a concise relation between process parameter, equipment geometry, and powder material properties can be established to the output of the roll compactor in terms of ribbon relative density (γ_R) (24):

$$\gamma_R = \gamma_0 \left(\frac{2R_f}{WD \int_{\theta=0}^{\theta=\alpha} [(S/D)/(((1+S/D-\cos\theta)\cos\theta))]^K \cos\theta d\theta} \right)^{1/K} \quad 10$$

C) Size reduction/Milling:

Size reduction of the compacted ribbon is carried out using an oscillating granulator. Most modern roller compactors are equipped with speed and angle control for operating oscillating granulator. Oscillating granulators are of two main types: pocket shaped and star-shaped as shown in Figure No***. 5***, courtesy of Sundaram M, Uventis Bioscience, Pune.

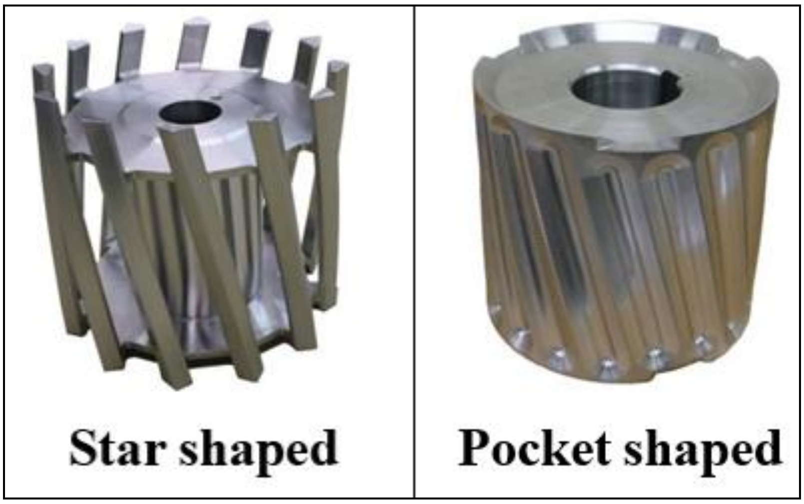

Figure No. 5: Types of oscillating granulators

The material throughput capacity of the oscillating granulator is largely dependent upon the speed of the motor and angle. Increase in the motor speed and angle results in higher abrasion of the granules on the screen mesh, which results in a decrease in median particle size of granules and increased particle size distribution and amount of fines. Effect of the type of granulator i.e. pocket shaped or star-shaped was reported to be insignificant. Only the pocket shaped granulator produced granules with large particle size but higher size distribution than the star-shaped granulator (25).

Kazemi. P et.al used various full factorial designs to observe the effect of compaction force, true density, screen size, and impeller tip speed on granule size (d_{50}) using Alexanderwerk BT 120 roller compactor and an oscillating mill. It was found that milling screen compared to other parameters had a significant impact on the resultant granule size (26). An increase in the milling screen size and ribbon density leads to lower fines generation, higher granule size, and low resident time in the granulator during milling process as demonstrated by Mangal H and Kleinebudde P using 2^2 full factorial design (27). The selection of screen size is the most critical parameter to control the size distribution of resultant particles. Screen with lower pore diameter causes increased abrasion of the granular edged with the screen mesh resulting in an increased amount of fines and creating broader size distribution (25).

Critical Process Parameters (CPPs) in Roll Compaction process:

Identification of CPPs can be a crucial step in the product development process using roll compaction. The material being compacted is heavily affected due to its property, such as elasticity, rigidness, plasticity, and cohesiveness. As important as the property of the material itself, the process parameters of the roll compaction also play an important role in deciding the final property of the ribbon and the resultant granules. The key process parameters that affect the final product, regardless of the material property are best represented in the reference document for QbD by FDA (28). A modification of the same is discussed in Table No**. 1**.

Table No. 1: Critical Process Parameters (CPPs) of Roll Compaction process

Sr. No.	**Process parameter**	**Output material CQA**	**Justification**
1.	Roller compactor type	Ribbon Density Granule Distribution Granule Size Uniformity Granule Flowability	Due to operating principle differences between roller compactors, the ribbon attributes and PSD of milled granules can vary significantly. If the roller compactor type is changed during scale-up or commercialization, the risk should be evaluated.
2.	Deaeration	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	Deaeration is used to enhance the flow of the blend feeding into the roller compactor. Thus, it can impact the uniform

			distribution of the material throughout the ribbon width.
3.	Feed screw speed	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	Feed screw speed, in modern roll compaction machines, is dependent upon the internal feedback system and is often automated. In manual machines, it is controlled in such a way as to achieve the desired roll gap and roll pressure.
4.	Roller surface design	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	Roller surface design may impact the nip angle when the material properties are taken into account. Thus, suitable roller surface design is aimed to achieve the desired compaction zone in roll compactor.
5.	Roller pressure	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	Ribbon density is directly related to roller pressure and, in turn, may impact the PSD, flowability, uniformity, compressibility, and compactibility of the milled granules.
6.	Roller speed	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	The roller speed determines the throughput of the process and is adjusted according to the selected feed screw speed to avoid material build-up. Also, roller speed is inversely related to the dwell time for particle compaction which may impact the ribbon density.
7.	Roller gap	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	According to the Johanson model (22), ribbon density is inversely related to the roller gap and, in turn, it may impact PSD, flowability, uniformity, compressibility, and compactibility of the milled granules.
8.	Mill type	Ribbon Density	The ribbon is formed

		Granule Size Distribution Granule Uniformity Granule Flowability	during the roller compaction step. The type of mill governs the type of attrition and impacts the PSD of the milled granules. A change in the mill type results in altered granules to fines ratio and should be evaluated if changed during scale-up or commercialization.
9.	Mill screen type	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	The mill screen type impacts obtained from the milling step. As discussed earlier, mill screen type can be the primary CPP that affects the granule size distribution, granule uniformity, and granule flowability.
10.	Mill speed and angle	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	The mill speed and angle may impact the PSD of the milled granules which can potentially impact granule uniformity and flowability.
11.	Oscillating granulator design	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	The Oscillating granulator design can apply variable shear to the material based on design. A star-shaped or pocket shaped is used for size reduction and each design has its resultant effect as discussed above.
12.	Mill screen orifice size	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	The ribbon is formed during the roller compaction step. The mill screen orifice size directly impacts PSD which can potentially impact granule uniformity and flowability.
13.	Number of recycles	Ribbon Density Granule Size Distribution Granule Uniformity Granule Flowability	If excessive powder leakage occurs during roller compaction or excessive fines are generated during milling, recycles of the fine particles may be considered. However, the number of recycles may impact the homogeneity of

			granule quality attributes. A pneumatic roll compactor can be used to re-process the non-compacted fines (29).

Process Analytical Techniques (PAT):

The roll compaction process may appear as a simple process with scalability entirely dependent upon trial and error experiments. This type of approach is most commonly used in the industry due to a lack of scalability factors and direct measurement for scale-up elements. The trial and error approach may prove costly, tedious, and inefficient in case of a highly potent or expensive drug molecule where trials cannot be afforded for the development process. Thus, PAT tools find their way into the roll compaction process as a significant way to measure the in-line and on-line evaluation of the raw materials and observe the change in their properties as the process proceeds.

Modern PAT tools utilized in roll compaction enable the observation of the physical properties of the ribbon and the production of the subsequent granules during the roll compaction operation. Food and Drug Administration established Quality by Design (QbD) concept which encompasses on-line monitoring tools for a better understanding of the critical process parameters and critical material attributes (30). On-line monitoring thus enables to establish a robust manufacturing procedure. Table No*. 2* illustrates some of the modern PAT tools.

Table No. 2: Modern PAT tools utilized in the roll compaction process

Sr. No.	**Author**	**Title**	**PAT tool**	**Instrument mechanism**	**Advantage**	**Disadvantage**
1.	M. Yu, A.D. Salman and et.al (31)	Roller compaction: Infrared thermography as a PAT for monitoring powder flow from feeding to	**Infrared thermography**	• Detects the heat generated during compaction on account of pressure applied to the compacted	• Good relation between temperature and thus, density distribution across ribbon width. • Non-	• Inaccuracy in results during dusty operation. • Requires extensive calibration work.

		compaction zone		molecules.	destructive and non-contact technique.	• Expensive.
			X-ray Computer Tomography	• Detects the pattern of motion and speed of powder particles across the compaction zone using X-Ray.	• Powder density distribution determination. • Detection of void spaces. • Identification of resistance zones.	• Nil
2.	Stagner W and et.al (32)	Real-Time Particle Size Analysis Using Focused Beam Reflectance Measurement as a Process Analytical Technology Tool for a Continuous Granulation–Drying–Milling Process	**Focused beam reflectance measurement (FBRM)**	• A laser beam is projected through a sapphire window and when the focused rotating laser beam contacts the particle, light is reflected and propagated back through the probe sapphire window, thus particle size measured by calculating the distance between the edges of the particle.	• Granule size control • Decrease analytical time and cost • Increase material throughput • Minimal maintenance and calibration	• Particles that adhere to the sapphire window tend to be measured multiple times during operation. • False results due to dusty operations.
3.	Kuentz M et.al (33)	Different modes of dynamic image	**Dynamic image analysis system using a xenon flashlight and**	• As the particles pass through the	• Provides images of fast-moving particles	• The in-line sensor system is prone to the

		analysis in monitoring of pharmaceutical dry milling process	**charge-coupled device (CCD) camera**	detecting zone, the xenon flashlight illuminates the particles and a charged-coupled device (CCD) camera acquires images of the fast-moving particles. • XenParTec software analyses the images in real-time to display and store the results.	• Sensitive to differences in size and shape characteristics • Robust on-line PAT tool.	accumulation of particles on the measuring screen, thus reducing the robustness of the system.
4.	McAuliffe M.A.P., O'Mahony G. E., and et.al (34)	The Use of PAT and Off-line Methods for Monitoring of Roller Compacted Ribbon and Granule Properties with a View to Continuous Processing	**Eyecon particle imager**	• The particles are illuminated with red, green, and blue LEDs from different angles. The color on the surface of the particle is captured in an image, and for each pixel, a map of the surface height is built. • Using image gradient data an	• Provides size and shape information in addition to images	• Nil

				ellipse is fitted on the particle edges, and its maximum and minimum diameters are obtained.		
			Multieye (multipoint NIR spectrophotometer)	• A halogen light source and a four-point reflectance probe are used to analyze the ribbon produced from the roller compactor. • An increase in absorbance will correspond with an increase in ribbon density.	• Cost-effective when compared with NIR array or FTIR-based systems • Non-destructive and non-contact technique.	• Nil

Recent technological advancements in roll compactor:

A recent patent invented by Brian K. Jensen and filed by Freund - Vector Corporation, Marion, IA (US) includes a steam injection system in the nip region of the compaction zone (35). This invention claims to improve the compaction or functional characteristic of powdered materials. The resultant compaction is claimed to provide more consistent compression of the powdered material and improve compaction characteristics and reduced compression variability. The steam from a source can be provided from above the rollers or from the side of the rollers. These top steam injection port (s) and side steam injection port (s) function substantially the same to mix with the powder product before compaction so as yield an improved compressed product. Other alternatives to introduce the steam are claimed through feed screw orifice, through rollers using the rotary connection, and through side sintered plug. The resultant compressed sheets are produced with an increase in the moisture content of approximately 1%. The steam compacted API sheet can then by more easily and consistently granulated due to the improved compression characteristics.

CONCLUSION:

Roller compactor is an economical approach to pharmaceutical dry powder compression and granules production. The omission of solvent addition in the compaction material makes the process not only affordable and less time consuming, but also allows the user to skip the analytical procedures that are required for residual solvent analysis. Thus, the resultant product is safe and more stable when compared to the wet granulation technique. The impact of pressure application on the material changes its physical properties that affect the dissolution, disintegration, and compression capabilities as discussed above. This leads to the disadvantages of the roller compaction process. Materials that undergo tremendous pressure between the rolls are required to incorporate a lubricant to avoid any sticking issues that may arrive during production. In the case of knurled rollers, i.e. the rollers with design on the surface, the compaction potency reduced as more and more material gets adhered on its surface. This is especially true when dry binders are incorporated in the formula composition. Pressure application also alters the dissolution profile of the final product when compared to the direct compression technique. Also, the compressibility of the material is reduced due to deformation and fracture generation during the roll compaction process. Inherent properties of the material to be compacted are required to have good compaction properties i.e. material with flexible nature are preferred for consistent compaction and process optimization. Pressure application during the compaction process may lead to segregation of the API from excipients and result into blend uniformity issues post compaction. Thus, the roller compaction process proves although simplified, does require optimization of material and process.

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