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DESIGN OF A UREA GRANULATOR WITH ENERGY OPTIMIZATION

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Abstract*— Urea granules are one of the popular fertilizers among synthetic fertilizer industry. Its main function is to provide nitrogen which enhances leaf growth on plant. Urea granules are produced from the process of granulation. Granulation process is divided to wet and dry granulation. Generally, there are two type of dry granulator which is slugger and roller compactor. Roller compactor or also known as roll press is using two counter rotating rolls to compact raw material such as powder to become ribbons or granules. If ribbons instead of granules are produced from compaction, milling will be used to produce granules. It is difficult obtain a numerical result of the process due to the variety of parameters. Therefore, this work will only consider the parameters which are related to feeder system and roller. The parameters include the feeding rate of feeder, roller force, roller pressure, and roller gap size. While powder flow to roller from feeder, overfeeding may occurs. Overfeeding is harmful because it will cause motor failure. To overcome this problem, the function of roller needs to be improved. The roller will be modified and hence, a new design will be produced.

***Keywords*—Urea granulation; Roller compactor; Granules.**

I. INTRODUCTION

Fertilizer is a material that is used as a supplementary nutrient provided to plants for better plant growth. Synthetic fertilizers are inorganic fertilizers formulated in appropriate concentrations and combinations supplied to the three main nutrients for a plenty of crops and growing environment. N (nitrogen) is to improve the growing of leaf and also forms proteins and chlorophyll. For P (phosphorus), it enhances the growing of root, flower, and fruit. K (potassium) helps in the root growth and the growing of stem, and also the production of proteins [1].

Usually the most common synthetic fertilizers found in market are ammonia (82% nitrogen), NPK combinations, and urea (46% nitrogen). Urea is an extremely soluble organic chemical compound. Synthetic urea which is often used as fertilizer can be manufactured in liquid or solid form [2].

The synthesis of urea includes the matching of ammonia and carbon dioxide at high pressure to become ammonium carbamate which is then dehydrated with the aid of heat to form urea and water [3].

The urea fertilizer found in market is in granules form. The urea granules are manufactured through the process of granulation. This study is under the project of OneBAJA which is initiated by Petronas. The leader from UTeM of this project is Profesor Madya Dr. Azizah Binti Shaaban. The project is divided to two main groups which are urea granules and process. In this study, the main focus is on the mechanism of granulator so it is under the process group instead of urea granules group.

A numerical knowledge of the roll press process has proved hard to be gained due to the complexity of the feeding material properties and the variety of operating parameters [4]. It is impossible to have the mathematical value of the whole process system in a single study. Therefore, in this paper, only few of those parameters will be studied. One of the important systems in roll press process is the feeding system [5]. In the feeding system, overfeeding or underfeeding may occur where overfeeding is more harmful because it will cause the machine to overload [6]. The purpose of the experimental work of this paper is to optimize the compaction system with improving the function of roller.

The two main components that will be studied in this project are roller and feeder system in roller compactor. The parameters that will be studied for roller is the pressure applied at raw material, roller gap size, and the force exerted. For feeder, only the parameter of feeding rate will be studied. The co-relationship between roller and feeder will be concerned as well.

II. INTRODUCTION OF GRANULATION PROCESS

Granules are made from the granulation process which primary powder particles are made to adhere to form bigger, multiparticle entities. The importances of granules are to prevent segregation of formed powder mix and also to control the particle size distribution. There are two kind of granulation process found in current market which is wet and dry granulation process. Wet granulation is a process that is using fluid to make raw material which is either in powder or liquid solution form fed become granules. The granulation fluid is normally mix with binder to ensure the particle adhesion once the granule is dry. Dry granulation is where the raw material which is in powder is aggregated under high pressure [7].

Generally, there are two types of dry granulation tools which are slugger and roller compactor. The product of slugger is large slugs after powder is compressed. Roller compactor compresses uniformly mixed powders through two roller press to form ribbons. Roller compactor is favored than slugger due to several factors which are greater production capacity, more control over operating parameters, simplifier and continuous processing [6].

III. MECHANISM OF ROLLER COMPACTOR

The mechanism of roller compactor will be discussed. Raw material such as powder is fed between two counter rotating rollers from feeder system. The powder is brought towards the gap between rollers by friction between the raw material and roller surface. The powder is compacted into ribbons with high pressure of rollers [8]. In this section, de-aeration is introduced so that compaction occurs when the relative movement ceases between powder and roll surface, and powder is gripped [9]. De-aeration is needed due to the difficulties of air hidden in the slip zone of compaction to leave the section [8]. The ribbons needed to be broken to the required granules size by milling [6]. Then, granules will pass through a screen to be separated from oversized granules, undersized granules or fines and desired sized granules. Only desired sized will be taken out as product whereas oversized granules and fines will be returned to feeder for reprocess. The returning process is known as recycle system.

Currently there are two types of roller compactors that are different in the gap system. They are fixed and movable rolls. The distance between the rollers in the fixed rolls compactor is constant throughout the whole compaction process. For this type of roller compactor, the geometrical dimensions of the ribbons formed are identical but the porosity may vary due to the fluctuating mass flow. On the other hand, the movable rolls type roller compactor, it has one fixed roll and one mobile roll. The pressure that acts on powder between rolls is from the force of hydraulic cylinder. The hydraulic force allows the mobile roll to move horizontally depending on the desired gap size which is according to the feeding rate and pressure [6].

IV. Components of Roller Compactor

Basically, there are four main components in roller compactor which are the feeder system, rollers, milling, and screen. Here, only two out of four components, which are the feeder system and rollers, will be discussed because this project is mainly concern on the two components.

There are three different types of feeder systems which are gravity transport, single screw feeder and double screw feeder. The reason that plenty type of feeder system existed is because of the amount of powder fed must be constant and fed continuously. Gravity feeder is used when the powder features are dense and free flow. However, for the powder that is light, single or double feeder will be used to increase the flow ability [6].

Except feeder system, there are varieties of rollers as well. Different roller type will have different type of product. Dense sheets are formed by smooth or fluted rolls whereas briquettes are formed by pocket rolls [8].

During compaction, the roller is divided to three region which are slip region, nip region, and extrusion region. Slip region, also known as feeding zone is a place that powder slipping at the roll surface. The speed of the powder is always lower than the speed of the tangential speed of the rolls so that relative slip occurs [9]. Compaction zone which is the nip region is the region where the powder trapped between the two same speed counter rotating rollers. Nip angle is the limit between slip and nip region. Extrusion region which is also the release zone is a place that product release from rollers [6].

V. Advantages of Roller Compactor

Roll compactor is favoured in plenty of industry due to several advantages. It is used to process physically or chemically moisture-sensitive materials because it does not need a liquid binder which means the whole process is without wet condition. Besides, it does not need any drying stage and hence it is suitable for compounds that either have a low melting point or degrade rapidly upon heating [10].

It has conceptual simplicity and low operating cost process [8]. This is because it is a continuous process, running at a intermediate densification speeds, capable to handle poor flowability powder and requiring low amounts of energy because no evaporation of granulation liquids is needed [11]. Another advantages is the granules obtained from roll press granulation are dust free products. This is due to the increase of the bulk density because of the pressure applied by the rollers. During transport, handling, storage or processing, the formation of dust is not desired because the dust may dangerous if they are toxic or even explosive [12]. The particle hardness can be adjusted to suit the product needs [13].

VI. Parameters Introduced in Roller Compactor

One of the specialties of roller compactor is the various parameters on the mechanism. It can only work in optimum condition when all the parameters co-operate properly. Basically, the main four components that contribute variety of parameters are feed, roller, roll gap, and properties of material fed which is powder.

Feed speed must be optimized to ensure continuous feeding and homogeneous compaction. Roll speed is important where it will affect the compaction. The pressure of roller is one of the important parameters as well where compaction does not occur when pressure is too low; over compaction will occur if pressure is too high [6]. Other parameters that contribute from roller are roller width, diameter, torque, and force.

Roll gap must be controlled to obtain compacts of the same quality when throughput is different [8]. At the same time, the parameters of nip gap, nip angle, and working zone width is related to roll gap. The nip angle must be adequately large so that a better compaction can be achieved [9]. On the other hand, properties of powder contribute the parameters such as powder density, and stress-strain relationship. The density of the ribbon, which is the formation of powder from compaction, is a quality parameter since it decides the granules flowability and recompactibility. The density of ribbon is related to porosity and solid fraction. Generally, the bigger the ribbon density, the smaller the quantity of fines formed from compaction and hence, the better the flowability of the formed granules [11].

VII. Experimental Works Conducted by Researcher

A study on how the feeder affects the quality of compactors is done by P. Guigon and O. Simon [8]. In the same year, they conducted a laboratory work to obtain the relationship of feeder and powder-packing properties on the stress applied on the compact in the roll gap. The stress is measured by two piezoelectric transducers.

In earlier decade, J. R. Johanson [14] has developed a powder mechanics model that enable the roll surface pressure, torque and separating force of the rolls to be predicted from physical characteristics of the powder and the dimensions of the rollers. An equation is used by J. Hilden et al. [15] to estimate the peak local ribbon stress as a function of roll force, radius, and width. The equation is the result from combination of some mechanical mathematical treatments with certain phenomenological trends. It is including instrumented rolls and other useful trends.

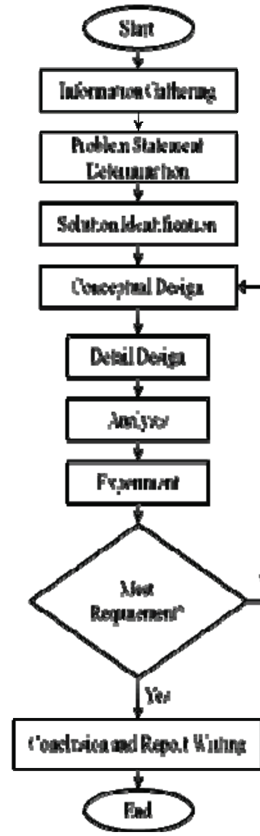
To figure out the parameters such as nip region and friction, many experimental works need to be done to obtain the parameters mentioned. However, the study of K. A. Yehia [12] stated that all those experimental works can be skipped when a single test where the granules are rolled with a small compactor prototype is conducted. Another way to reduce the number experimental works is with the aid of software. The finite element method (FEM) is found to be the most suitable way because it incorporated sufficient information about powder behaviour, geometry and frictional conditions. This method enables simulation with computers which will then decrease cost, time, and optimize the tool [5]. A. Michrafy et al. [4] is using FEM to conduct a modelling with two different feeding conditions which are fixed feed pressure and fixed feed velocity. The simulation of fixed feed pressure shows a constant maximum principal stress and density across the roller gap. On the other hand, the result from simulation of foxed feed velocity shows that the stress over roller gap centre is higher and is lower at the sides.

Normally in the theory, the throughput capacity is determined by pressure of feeder without including roller speed and flow speed properties of the bulk material. In the study of K. Sommer and G. Hauser [16] found that it is necessary to have more advanced modelling technique and more sophisticated material model to enable better matching between theory and experiment.

VIII. METHODOLOGY

Fig. 1 shows the flowchart of the methodology flow. The first thing to do in this project is information gathering. Plenty of method can be used to gather information such as reading book, searching journal, accessing internet and also asking expert by visiting. After adequate information is collected, literature can be done. At the same time, problem statement can be determined as well since a general knowledge on the project is reviewed.

After problem statement is obtained, a preferable solution will be indentified. Since the title of this project is about optimization of mechanism, the solution made must be related to improvement on the machine. Therefore, a new design idea must be generated to achieve the objective of this project.



1 **Figure 1**. Overview on the flow of methodology

New design idea will bring out conceptual design of a product, or more accurately for this project, conceptual design of a mechanism will be built. After certain process in conceptual design, a detail design draft with full dimension will be produced. A detail drawing will be done with CAD such as CATIA according to the detail design. Simulation will be introduced to the drawing with software such as ADAM to analysis whether the mechanism meet the requirement or not. When simulation is success, an experiment will be conducted to examine the feasibility of the mechanism.

A prototype with calculated and simulated parameters will be built to assist in the experimental work. The functionality of the prototype will be examined to ensure it meets the requirement of this project. After that, a report will be prepared according to all the process done and data collected throughout the whole project. However, if the experiment does not meet requirement, new design idea need to be generated again and the following process will need to be repeated.

IX. CONCEPTUAL DESIGN

Only the feeder and roller system will be taken into consideration in this project due to the variety parameters of the roller compactor. The roller compactor process can only be deeply studied when the region need to be focused is small. After a better understanding on the parameters is obtained, a preferable solution will be identified and hence, a general concept idea will be identified to achieve a new concept design. Several steps which are general concept design, functional decomposition, component decomposition, concept selection, and parametric design are needed for approach of new concept design.

A. General concept design

To prevent overfeeding from the feeding system, there should have a prevention system on the slip region of the roller. To do this, a modification on the roller system can be done. The general concept design of this project is based on movable roll type roller compactor which is mentioned in literature review. When overfeeding occurs, the floating roll will be moved further from the fixed roll to make the gap size bigger and so that the flow rate of powder or ribbon will be higher.

To make it become an automation system, Programmable Logic Controller (PLC) will be used. PLC is an electronic computer device to perform automation of electromechanical process. An example of PLC circuit is shown in Figure 8. When both of the switches PB1 and PB2 are pushed, motor will rotate and cylinder will extend after the time of the timer set reached.

With the aid of PLC, the acting force of the hydraulic cylinder will be depending to the rotation speed of roller. When rollers are stuck due to the overfeeding of feeder detected, the roll gap will be adjusted to larger size. A general concept design draft is shown in Fig. 2.

B. Functional decomposition

A chart which is simplifying the function of automation movable roll system is shown in Fig. 3. Basically, the functions of the system designed are to prevent overfeeding of the feeder, to make sure rollers compact with relevant pressure, and provide suitable gap size throughout the whole process.

C. Component decomposition

The detail components of the new design of roller compaction are shown in Fig. 4. There are two rolls which one is fixed and another is floating roll. Then, a hydraulic cylinder to provide compacting force which is connected to hydraulic system circuit to make it an automation system is included as well.

X. Conclusion

From the plenty of activities that done for this project, an overall planning on the project was done. The future work will be done according to the planning which is represented in flow chart form. Through information gathering, a clearer picture and idea on the process of roller compactor was obtained. Therefore, optimization of granulator mechanism can be done with roller system modification. Several of parameters used in the process which are pressure, roller gap, force, and feeding rate were determined. The problem statement related to the roller compaction was made. Useful methodology which is referring to problem statement and scope was identified.

Acknowledgment

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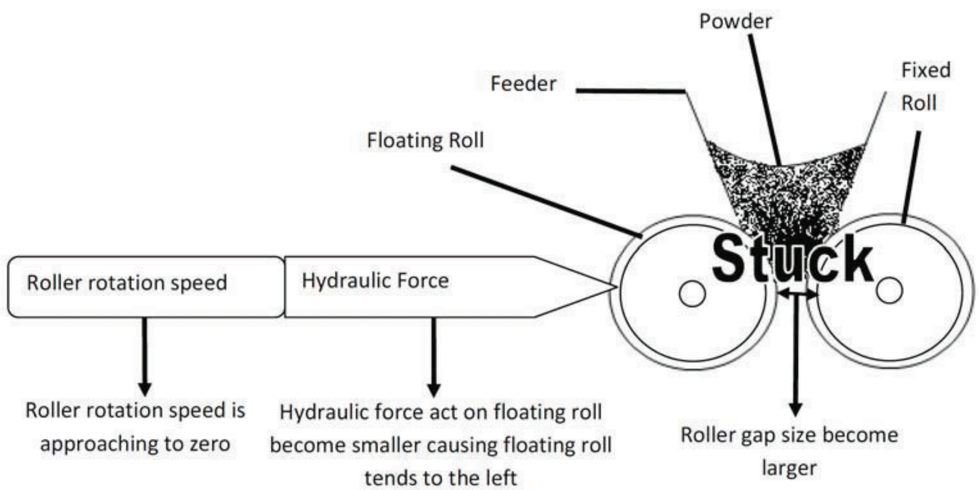

Figure 2. General concept design draft of automation movable roll system

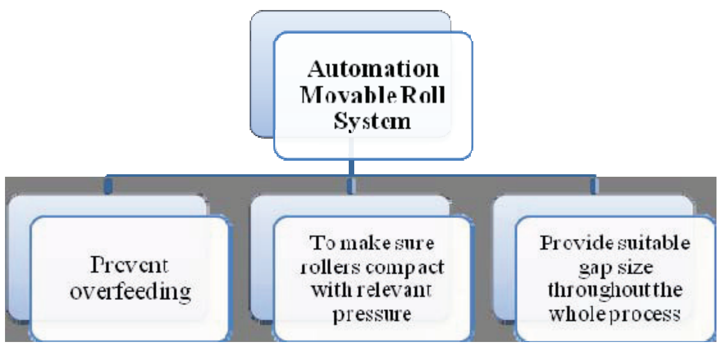

Figure 3. Functional decomposition of automation movable roll system

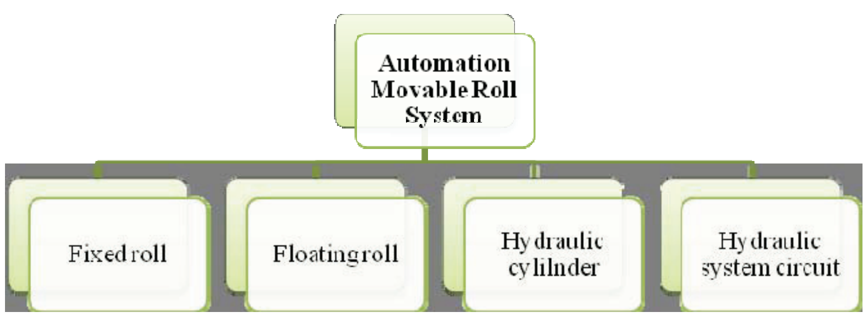

Figure 4. Component decomposition of automation movable roll system