Granulation of Urea in a Pan Granulator

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Abstract

Urea granulation is favored over prilling due to the problems associated with prilling. Tumbling agglomeration technique is employed in pan granulator. Product with wide size range can be produced by playing with only few parameters like binders (water and urea solution), ratio of binders, rpm of pan, granulation time and angle of inclination. Urea granulation is studied at laboratory scale using pan granulator. Water and urea solutions of different concentrations are employed as binder. Results reveal that concentration of urea solution is proportional to rate of granulation. A threshold quantity of binder is required for optimum granulation yield. Speed of the pan is inversely proportional to the rate of granulation. Granulation yield is also proportional to time of granulation however it becomes critical at a certain point. Angle of inclination of the pan has no significant effect on the granulation yield

***Key Words**: Fertilizer, Granulation, Pan Granulator, Prilling, Urea*

Introduction

Commercially, fertilizer urea can be purchased as prills or as a granulated material. Depending upon the degree of recycling of the unconverted ammonia and carbon dioxide, the processes of production of urea are, Once Through Process, Partial Recycle Process and Total Recycle Process.

Prills are small round aggregates that are artificially prepared. Prilling is a process by which solid particulates are produced from molten urea. Molten urea is sprayed from the top of prill tower. Surface tension causes the liquid to adopt a spherical shape as this result in the smallest surface area to volume ratio. As these droplets fall through a counter-current air flow, they cool and solidify into spherical particles (Fayed and Otten, 1984).

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Prill tower can be classified into two categories on the basis of draft used which are Natural draft Tower and Forced/Induced draft Tower. The prilling tower is a reinforced concrete structure with cylindrical wall. The tower includes the spinning basket room in the tower top and the product scrapper located in the tower bottom. Windows for air inlet and outlet are located on the bottom and the top end of the wall respectively. The evaporation section, the elevator and stairs are located in a side structure made of steel (Abdul Rauf et al, 2008).

Production of prills from molten urea solution involves number of problems that can not only spoil the product quality but in some cases can make the process highly undesirable in aspects of physical and chemical properties of the product. Main problems in the operation of prilling that are common in Urea Industry are moisture, biuret content, prill size, crushing and impact strength, caking of prills and urea dust losses (Abdul Rauf et al, 2008).

Prill size becomes crucial for some application those require slow dissociation of fertilizer in the soul hence focusing attention on high crushing strength and larger size fertilizer urea. Production of larger size urea prills requires very tall prilling tower if strength is considered not an issue and purpose can be achieved by just increasing size. This will result in high capital investment and operation will be problematic as well. Also standardized product can be achieved by prill tower i.e. falling in narrow range of size. Due to these problems urea granulation is favoured over prilling.

Selecting a suitable agglomeration technique for urea industry has won wide attention in modern days due to increased population of the world that resulted in increased demand of crops to meet the need. The key question in this regard is what must be the method of agglomeration that caters to the needs of customers and abilities of industries? A dynamic research is vital for comprehensive answer to this. Prills are usually produced by dropping liquid urea from a "prilling tower" while drying the product. The prills formed are smaller and softer substance than other materials commonly used in fertilizer blends. Urea can be manufactured as granules. Granules are larger, harder, and more resistant to moisture. As a result, granulated urea has become a more suitable material for fertilizer blends. Commercial granulation of urea is done by the processes; Fluidized Bed Granulation, Spouted Bed Granulation (*Fertiliser Production Technology Manual*, 1968).

The manufacture of prills is rapidly decreasing owing to both environmental problems and product quality as compared to granules. Generally, both crushing and impact strength of the prill is much less than for granule. This cause many problems in handling both at the plant and in shipping (Kirk Othmer, 1998). Granulation is more popular than prilling in those countries that are very much particular about their environment. There are two granulation methods, drum granulation and pan granulation (Macketta, 1997). In drum granulation, solid are built up in layers on a seed granules in a rotating drum granulator/cooler approximately 14ft in diameter. Pan granulator also forms the product in a layering process, but different equipment is used (Macketta, 1997). Pan granulator is a suitable equipment to use for urea granulation and granulation is done by using tumbling agglomeration technique. Product with wide size range can be produced by playing with few parameters which are the focus of this work. The values of the parameters determine the size range of product, output, bulk density and spread of sizes.

Urea granulation and prilling systems consist of particles of a wide range of sizes and it is necessary to be able to give a quantitative indication of the mean size and of the spread of sizes. The result of a size analysis can most conveniently be represented by mean of a cumulative mass fraction curve, in which the proportion of particles smaller than a certain size is plotted against that size. The particle size, the size analysis are obtained as a series of steps, each step representing the proportion of particles lying within a certain small range of size. From this cumulative size distribution plot is made (Richard and Backurst, 2002).

Commercially available urea products Bubber Sher Urea, Tara Urea and Engro Urea are characterized for size distribution for both forms i.e. prills and granules using cumulative size distribution charts. Cumulative distribution charts are shown as figure 1, figure 2 and figure 3 for Bubber Sher Urea, Tara Urea and Engro Urea. Particle size is greater for granules than prills and size distribution is well illustrated by following the charts.

Figure 1: Cumulative Distribution Plot for Bubber Sher Urea

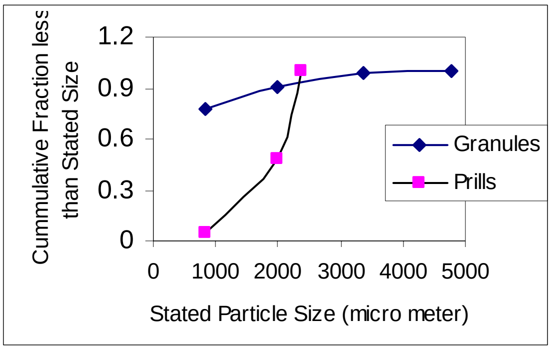


Figure 2: Cumulative Distribution Plot for Tara Urea

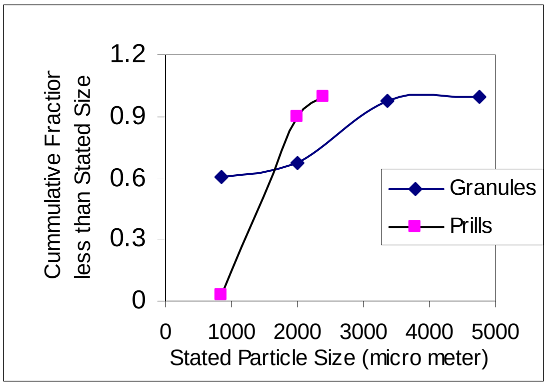
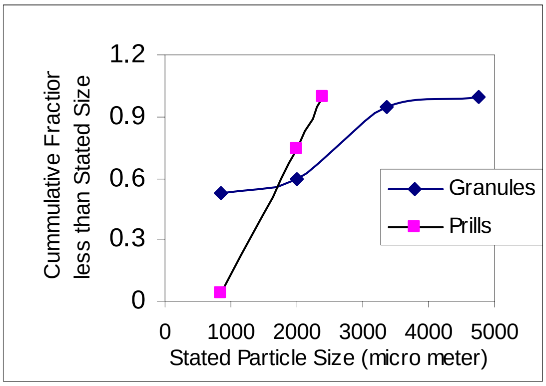


Figure 3: Cumulative Distribution Plot for Engro Urea



The Hydro-Agri process is used in the majority of newly installed plants that are producing granules in U.S.A. This process was developed by NSM of Holland many years ago. They have no plant size limitation and design a single-train unit for production over 3000MTD. The C&I Girdler drum system has been very successful, but cannot compete in today's market because of restrictions in the train size. Toyo has successfully developed a spout-fluid technology. Stamicarbon also working on a fluid-bed large-scale single-train plant that is somewhat similar to the Hydro-Agri design (Kirk Othmer, 1998).

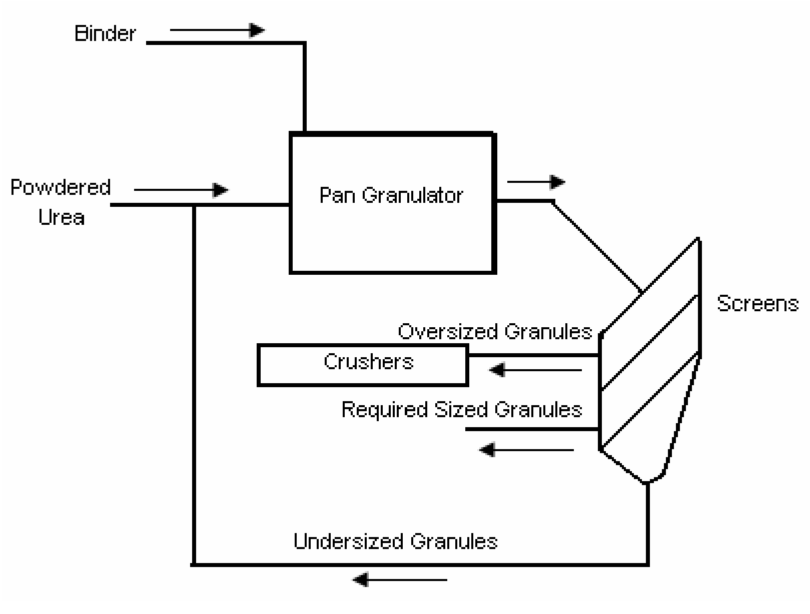
Urea granulation is studied experimentally in this work. Factors affecting granulation are studied such as rpm of pan, granulation time, concentration of binder, ratio of binder and angle of inclination of the pan.

Experimental Work

Granulation of urea was done in the laboratory using pan granulator. A schematic diagram for urea granulation is shown below as figure 4. The granulator consists of a rotating pan with adjustable speed motor. The pan diameter is 46.5 cm and depth is 16 cm. The pan can hold up to 1.5 kg of charge depending upon the density of the charge. Spray nozzle distributes fine mist of binder. Powder and solution flow continuously at predefined rate. The slope degree of its pan can be adjusted from 40° to 55°.

The pan revolves at a certain angle with the horizontal plane driven by the motor. The powder will rise along with the revolving pan under the friction between the powder and the pan, on the other hand, the powder will fall down under the function of its gravity. At the same time, the powder moves to the pan edge because of the centrifugal force. The powder material rolls in a certain trace under the function of these three forces. It gradually attains the required size (Kirk Othmer, 1998). Product is withdrawn and classified using standard sieves (US ASTM MESH SCREENS) and oversized is sent to crusher and undersized is recycled. Bulk density of the product of required size is determined. Standard deviation of whole product and granulation yield are also calculated.

Figure 4: Schematics of the Granulation

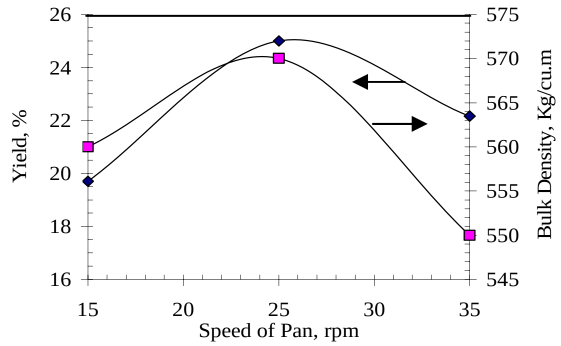


Results and Discussions

1. Effect of RPM

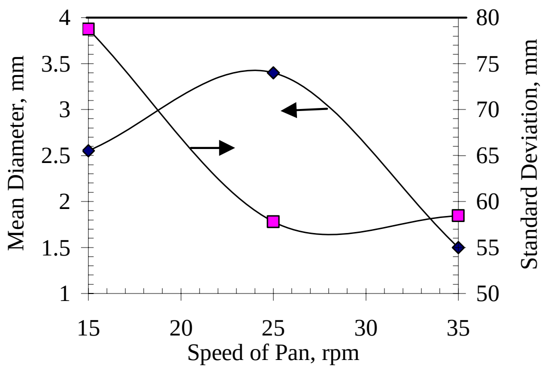
Effect of rpm has a very pronounced effect on the amount of urea granulated as shown by figure 5. As the speed of the pan increases, the amount of granules formed decreases significantly. During the course of granulation, collision between granules themselves, also with the wall of the pan, and with doctor knife take place. At high speed collision becomes savior and it breaks the granules. At low speed of pan outer most granules loose contact with the wall of the pan depending on the balance between gravitational and centrifugal forces and cause breakage of themselves and other granules as well. Both bulk density and granulation yield show increasing trend up to 25rpm and then decrease. Thus granulation yield is maximum at 25rpm. Maximum also is the bulk density. Hence, the storage volume required will be lower. Consequently the optimum speed of pan granulator emerges out to be at 25rpm.

Figure 5: Effect of Speed of pan on yield and bulk density.



Effect of rpm of pan on mean particle diameter and standard deviation is shown in figure 6. Mean particle diameter increases with increase in rpm of pan granulator up to 25rpm. Beyond this speed, particle diameter decreases. Standard deviation is also minimum at 25rpm thus converging the focus of optimality on the speed.

Figure 6: Effect of speed of pan on mean diameter (d_{50}) and standard deviation.

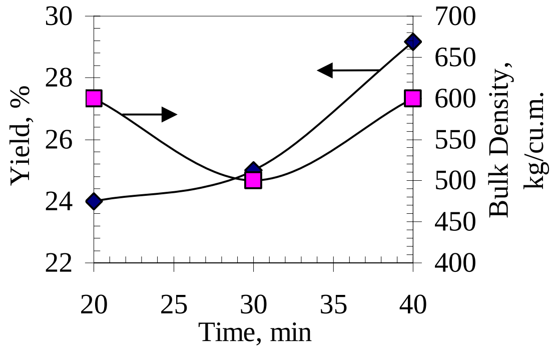


So, there exists a certain critical speed of pan which is favorable for the granulation of urea. Thus the product obtained falls in a narrower range of size and more product of required size is obtained for that critical speed.

2. Effect of the Granulation Time

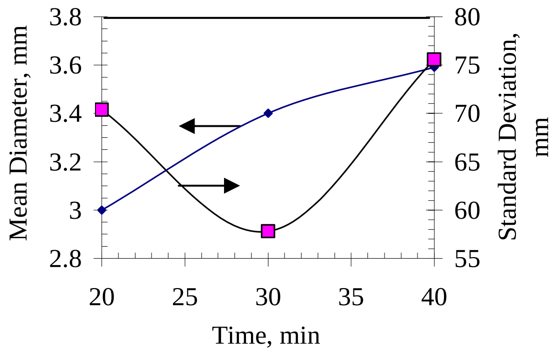
Effect of time of granulation on yield (%) and bulk density is shown in figure 7. Bulk density first decreases and beyond 30 min. granulation time, it shows ascendancy in trend. An increase in the bulk density with increase in granulation time supports the fact that more desirable product is formed. Thus quality of the product is higher. Meanwhile the granulation yield (%) also goes on increasing. Thus both quality as well as %yield are improved but half an hour time is optimum because of minimum standard deviation and acceptable mean particle diameter (d_{50}).

Figure 7: Effect of time of granulation over granulation yield and bulk density.



Effect of time of granulation on mean particle diameter and standard deviation is shown in figure 8. By increasing the time of granulation, mean diameter of the product (granules) increases. At the same instant, the standard deviation is much less which indicates optimum granulation time is 30 min. When granulation time is increased beyond 30 min, standard deviation shows optimality on half hour granulation period.

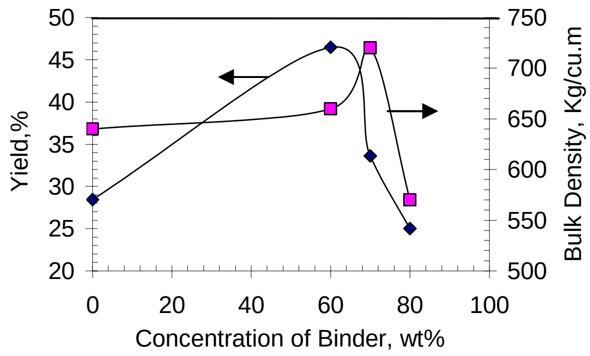
Figure 8: Effect of time of granulation on mean diameter (d_{50}) and standard deviation



3. *Effect of Concentration of Binder*

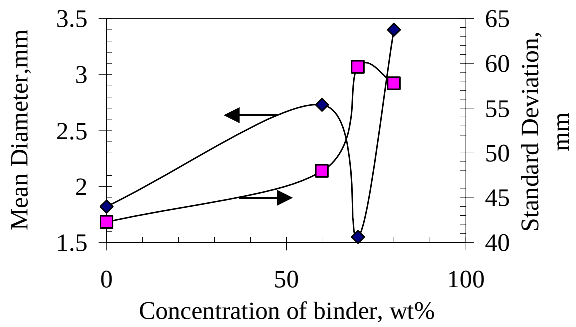
Different chemicals that can be used for binding during granulation are water, urea solutions of different concentrations, molten urea and Polyurethane. Because of high melting point of urea (135^{o}C) it can not be used as it readily solidifies at ambient temperature. It has been evident from the experiments (Figure 9) that operation using water gives much less granules than using urea solution. Also as the concentration of the urea solution rises, the quantity of urea granules increases depending upon the binding strength of urea solutions increases with increase in urea concentration. Effect of concentration of binder on granulation yield and bulk density is shown in figure 9. The %yield is maximum at 60% concentration of binder. The bulk density also shows on increase after enhancing concentration of binder emerges to be 60%.

Figure 9: Effect of concentration of binder on yield and bulk density.



Standard deviation increases while concentration of binder is increased from 0 to 60% but increasing trend is not sharp as shown in figure 10. The mean particle diameter is also acceptable at this concentration of binder. Mean diameter is increasing smoothly till 60% concentration of binder but at 70% concentration it sharply falls. Then it shoots up for 80% concentration that indicates that result on 70% concentration does not represent the actual trend.

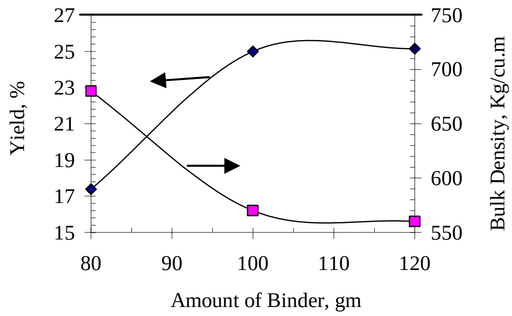
Figure 10: Effect of Concentration of Urea Solution on Efficiency of Granulation



4. Effect of Ratio of Binder

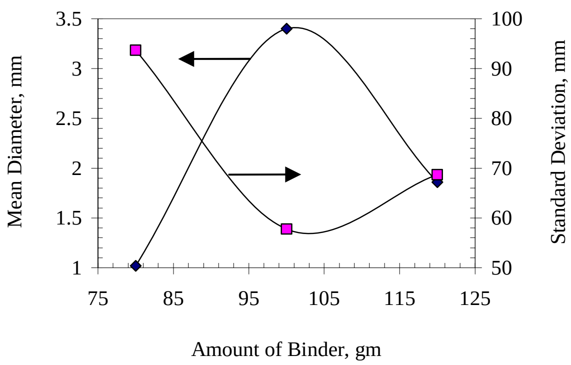
As for as the ratio of chemical used i.e. water and urea solution of different concentrations is concerned it is evident from the experiments that initially with the increase of the ratio of binder used, the amount of urea agglomerated or granulated increased but with more increase, in the ratio it showed the reverse effect. It means a definite proportion of binder and urea powder is needed for granulation. Because when ratio increases it yields very soft granules that break during the process. Though bulk density is not maximum at 1:5 for binder and charge respectively but % granulation yield is maximum as shown in figure 11. Figure 11 is plotted using charge is constant (500gm) and varying amount of binder to change the ratio.

Figure 11: Effect of amount of binder on yield and bulk density.



Mean particle diameter increases when amount of binder is increased up to 100 g (1:5) and then decreases beyond that amount as shown in figure 12. At 100g (1:5) amount of binder, standard deviation is also minimum reflecting optimality of 100 gm amount of binder. Consequently this ratio of binder (1:5) comes out to be optimum.

Figure 12: Effect of amount of binder used on mean diameter (d_{50}) and standard deviation.



5. *Effect of Inclination of Pan*

Experiments were performed for different inclinations of the pan within the operational constraints of the equipment (40^o-55^o) but there is no significant effect observed on the granulation yield.

Conclusions

Urea granulation is studied in a pan granulator by varying different operating parameter. The product is characterized. It can be concluded that the size of the product and the yield decrease with increase in the rpm above a critical value. Optimality of granulation emerges out at 25 rpm in this particular case.

Time of granulation has a significant effect on the spreadness of the size distribution of product. Although the yield is relatively less at optimum time (30 min.) of granulation in this case but product lies in acceptable size range.

Yield, bulk density and spread of product are in acceptable limits at 60% concentration of the urea solution. Product quality is seriously affected by the urea solution concentration in the binder.

At 1:5 of charge to binder, the yield is maximum with minimum standard deviation reflecting optimality of this ratio. Except the angle of inclination; all other parameters affect the quality of the granules thus the conditions need to be optimized.

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