PARTICLE GROWTH AND FILM COATING IN A FLUIDIZED BED GRANULATOR

A REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY (CHEMICAL ENGINEERING)

Submitted by

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2011

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CERTIFICATE

This is to certify that that the work in this thesis report entitled "Particle Growth and Film coating in a Fluidized Bed Granulator**"** **submitted by Satya Sindhu Biswal** in partial fulfillment of the requirements for the degree of Bachelor of Technology in Chemical Engineering, Session 2007-2011 in the department of Chemical Engineering, National Institute of Technology, Rourkela, is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge the matter embodied in the report has not been submitted to any other University /Institute for the award of any degree.

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ACKNOWLEDGEMENT

I wish to express my sincere thanks and gratitude to Prof (Dr.) A. Sahoo for suggesting me the topic and providing me the guidance, motivation and constructive criticism throughout the course of the project.

I thank Prof. (Dr.) R. K. Singh and Prof. (Dr.) H. M. Jena for acting as the project coordinator.

I am grateful to Prof. (Dr.) K. C. Biswal, Head of the Department, Chemical Engineering for providing me the necessary opportunities for the completion of my project. I also thank other staff members of my department for their invaluable help and guidance.

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ABSTRACT

Fluidized bed granulation is a process of converting atomizable liquids eg. Suspension, solution or melts into coarse, granular solids, which is either governed by coating or agglomeration, which depends upon the operating conditions and the physico-chemical properties of the raw material. The main objective of granulation is to improve the flow properties and compression characteristics of the mix, and to prevent segregation of the constituents. It has application in fertilizer, pharmaceutical, food processing, and etc. industries. The effect of various process parameters on the final size and nature of the granular product is always of interest and this has been actively studied by researchers in the past two decades. In this work the granulation of some powder material (calcium carbonate, titanium dioxide, and sugar powder) has to be studied experimentally in a laboratory fluidized bed. Granules are to be produced using water and other materials (sucrose solution and starch solution) as the binder. Effect of granulating liquid flow rate, granulating liquid concentration, fluidizing air flow rate, fluidizing air temperature is to be studied. The present work also aims at fundamentally understanding and precisely determining the effect of different operating conditions on coating quality in a jetting fluidized bed where the coating agent is sprayed as liquid droplets into the bed.

Keywords : Granulator , Fractional Factorial Design , Agglomeration , Coating

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NOMENCLAURE

dp = Average diameter (mm)

M_g^0 = Nozzle gas flow rate (kg/hr)

M_w = Solvent flow rate (kg/hr)

$T_{g,out}$ = Outlet gas temperature (^oC)

X_s= Solid concentration fraction of the solution

W = Weight of powder in the bed (gm)

Rho= Density of powder (gm/cc)

F= Fluidizing air flow rate (Nm^3/hr)

T= Temperature of fluidizing air (^oC)

V= Volume of binder used (ml)

Y= Fractional growth

CHAPTER-1

INTRODUCTION

INTRODUCTION

Fluidized bed granulation is a process in which the liquid products, e.g. suspensions, solutions or melts are converted into granular solids. It is mainly considered as a size enlargement process, during which primary particles are formed into large agglomerates. The process of granulation is either governed by coating or agglomeration, which depends upon the operating conditions. The coating process is mainly utilized for the modification of surface properties of the material, which finds wide application in pharmaceutical industries. The agglomeration serves the purpose of granulating fine powders with the use of binders, thereby reducing explosion risks and dust, to improve the flowing properties and to provide the ease of handling. The liquid to be granulated is sprayed by means of a two-fluid nozzle with pressurized air atomizing the liquids into a fluidized bed composed of hot solid particles. The nozzle may be positioned either above or inside the fluidized bed, leading to rain like wetting process. Particle growth takes place as fine droplets hit the surface of hot fluidized particles and form a layer. In the case of suspensions or solutions, the solvent will be evaporated, leaving behind the deposited solid material as thin solid layers. Therefore, this growth mechanism is called layering or coating usually lead to uniform spherical granules. During agglomeration, large particles or granules are produced by small particles adhering to one another via liquid bridges. The solidification of liquid bridges through drying leads to solid granule formation.

Granulation is an important application in the agrochemical, pharmaceutical, food and mining industries to convert small diameter particles into large diameter agglomerates made up of initial particles.

Reason for size enlargement by coating and agglomeration are:-

>> To improve the handling, flow properties and compression characteristics of the initial powder.

>> To modify he bulk and particle density.

>> To produce a desired particle size distribution.

>> To control the dissolution time.

>> To improve appearance, taste or odour of a particle.

The control of fluidized bed granulation process is very much difficult as it involves wetting, drying and mixing of particles simultaneously. If the liquid is excessive or if it is maldistributed, most of the region of the bed may defluidize and particles stick to each other forming large wet lumps, called wet quenching. While, if excessive particle growth occurs, the minimum fluidization velocity will exceed the operating velocity causing defluidization, called dry quenching. To understand the mechanism of particle growth, the effect of various parameters such as amount of spray liquid, fluidizing gas temperature, fluidizing gas velocity, amount of particles in fluidized bed on the growth rate of particles is studied.

As mentioned earlier, coating can be considered to be a subset of the granulation process when the forces causing the breakup of agglomerates dominate and overwhelm the forces tending to hold particles together.

My objectives in this project are fabrication of the apparatus, coating of different spherical particle, granulation of different powder sample, study of effect of various parameters (amount of binder, flow rate of fluidizing air, temperature of fluidizing air and amount of material taken for granulating) on the growth of granulation.

CHAPTER-2

LITERATURE REVIEW

LITERATURE

2.1. GRANULATION

Granulation is the act or process of forming or crystallizing into grains. Synonym "Agglomeration": Agglomeration processes or in a more general term particle size enlargement technologies are great tools to modify product properties. Agglomeration of powders is widely used to improve physical properties like: wettability, flowability, bulk density and product appearance.

2.2. GRANULATION TECHNIQUES

Two types of granulation technologies are employed, namely, Wet Granulation and Dry Granulation.

Wet Granulation: Wet granulation, the process of adding a liquid solution to powders, is one of the most common ways to granulate. It involves the massing of a mix of dry primary powder particles using a granulating fluid. The fluid contains a solvent which must be volatile so that it can be removed by drying, and be non-toxic. The liquid solution can be either aqueous based or solvent based. Aqueous solutions have the advantage of being safer to deal with than solvents.

Dry Granulation: The dry granulation process is used to form granules without using a liquid solution because the product to be granulated may be sensitive to moisture and heat. Forming granules without moisture requires compacting and densifying the powders. In this process the primary powder particles are aggregated under high pressure.

In fluidized bed granulation, either of two surface layering or agglomeration may lead to granule growth. Agglomeration will occur when a wet particle collides with another particle and is bound by a liquid bridge, that becomes solidified during the subsequent drying period. The drying zone is mostly affected by three process parameters, the bed height, the nozzle gas low rate and the gas temperature in the bed. In practice, if we want surface layering as the desired particle growth mechanism, shallow fluidized beds with a nozzle spraying upwards into the fluidized bed is recommended. Also, an increase in the outlet gas temperature or in the nozzle gas flow rate reduces the formation of agglomerates (Becher and Schlu¨nder, 1998). Granulation experiments were run by spraying a certain amount of a suspension into the fluidized bed of inert material discontinuously. For the suspension fine CaCO3 primary particles with *d*=2 mm diameter were suspended in water and polyvinylpyrrolidone added as binder. This suspension was sprayed on glass spheres of an average diameter of *d*P =700 mm. At the end of one experiment,

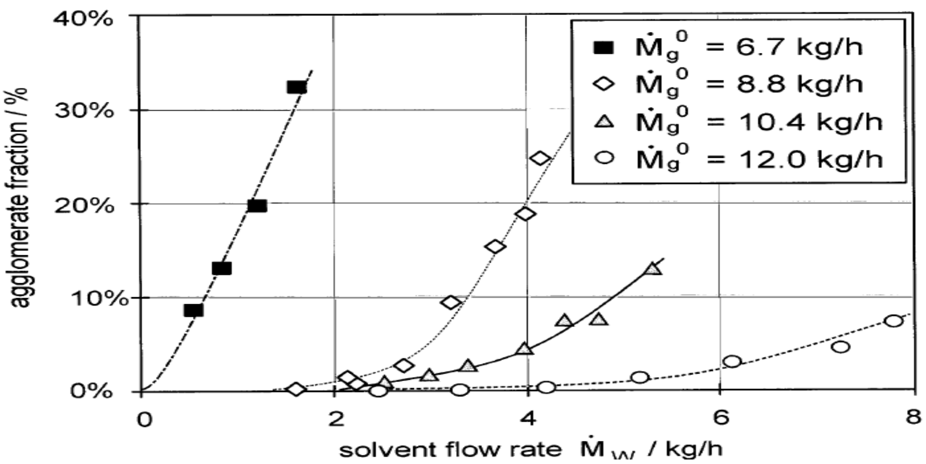

Fig 1 .Particle growth as function of the solvent flow rate for different nozzle gas flow rates.

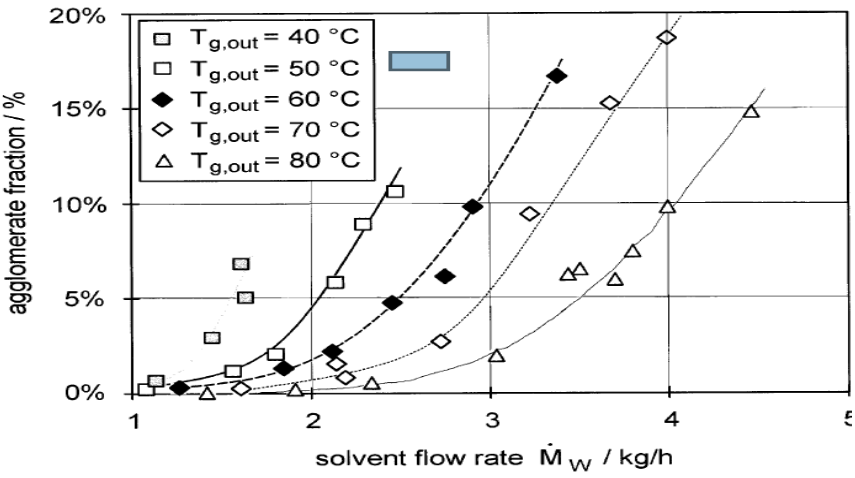

Fig 2 Particle growth as function of the solvent flow rate for different outlet gas temperatures.

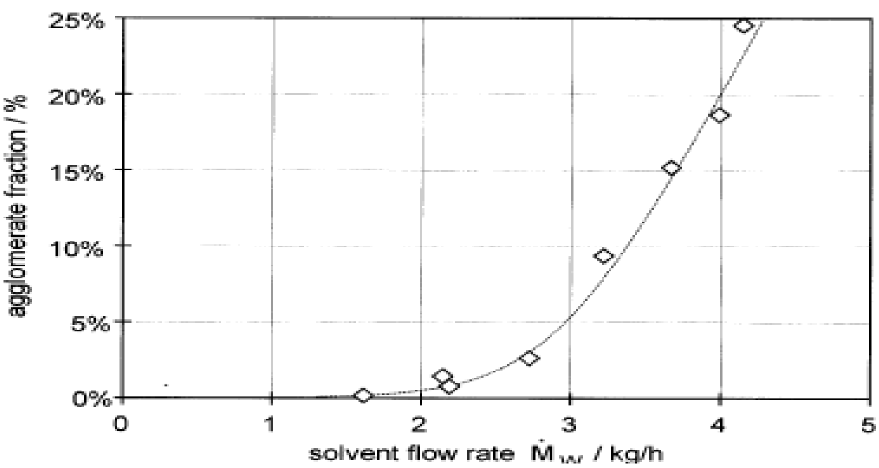

Fig 3 Agglomerate fraction as function of the solvent flow rate.

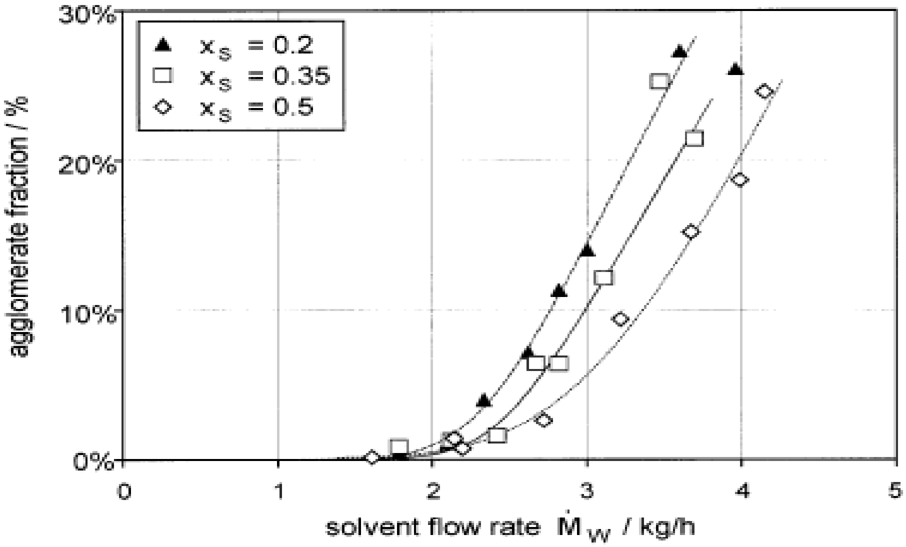

Fig 4 Agglomerate fraction as function of the solvent flow rate for different solid concentrations of the suspension

Becher and Schlu¨nder (1998) concluded that the drying zone is affected by three process parameters, the bed height, the nozzle gas flow rate and the gas temperature in the bed and above the plenum of the bed. In practice, if we want surface layering as the desired particle growth mechanism, shallow fluidized beds with a nozzle spraying upwards into the fluidized bed are recommend. Then, an increase in the outlet gas temperature or in the nozzle gas flow rate reduces the formation of agglomerates.

A series of experiments are carried out batch wise in a fluidized bed granulator with malic acid to understand the growth mechanism and the growth rate of particles with respect to the operating parameters such as the flow rate of the spray solution, temperature and flow rate of the fluidizing air, the concentration of the solution and the seed particle diameter. The increase in concentration of the spray solution or the increase in flow rate is found to increase the growth rate of particles.

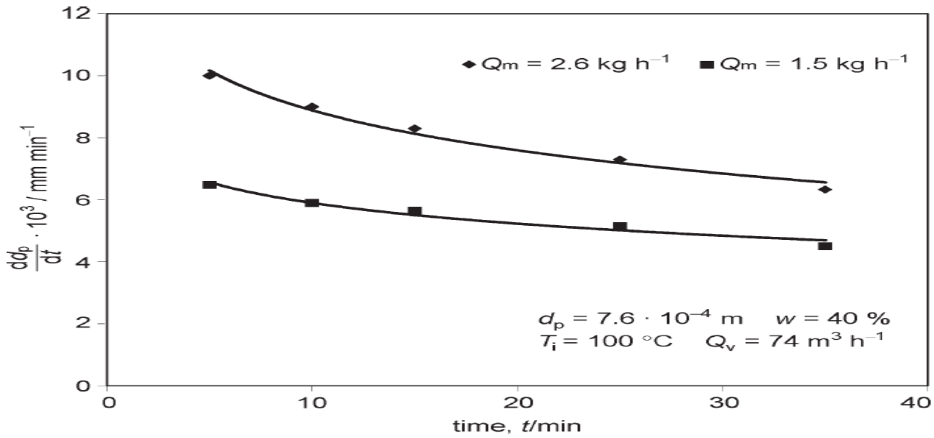

Fig 5.Influence of the flow rate of the spray solution on the growth rate of particles.

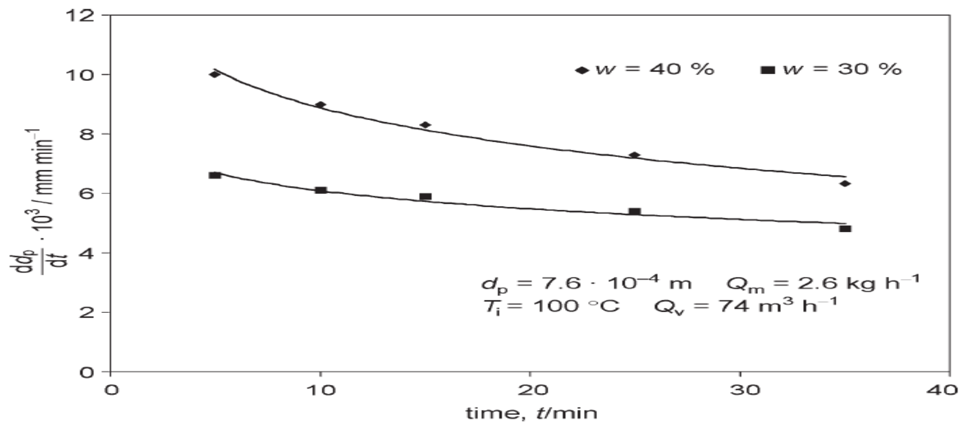

Fig 6.Influence of the initial mass fraction of the spray solution on the growth rate of particles.

Srinivasakannan and Balasubramaniam (2003) concluded that an increase in the flow rate or an increase in the concentration of the spray solution increases the particle growth rate. Neither the increase in the flow rate nor the temperature of the fluidizing air is found to alter the growth rate; however, they facilitate to operate the bed at high liquid flow rates without wet quenching

Fluidization bed agglomeration process is used for size growing process used to improve end properties of powder, which depends on the type of agglomeration process and the operating conditions. Depending upon the nature and amount of binder used, agglomerates have different structures and therefore exhibit different characteristics. Solid particle agglomeration can be achieved if wet quenching and layering are avoided.

Jimenez, Turchiuli and Dumoulin performed experiments by varying different process parameters: inlet temperature of fluidizing air, initial mass of particles, binder solution rate and nozzle air pressure. Spray granulation trials were performed by spraying acacia gum solution over glass beads.

The conclusions that were made are the particle growth is enhanced by increasing the solution feed rate and decreasing the relative nozzle air pressure.

Table 1.Physical properties of initial glass spheres and agglomerated with acacia gum.

Particle	Particle size (micro meter)
Glass	160
P = 1 bar , T = 70^{0}C , M=500gm , S = 6gm/min	585
P = 2 bar	430
P = 3 bar	219
T = 800 C	393
M = 750 gm	517
S = 3 gm/min	371
S = 9 gm/min	630

In the article by Hemati (2003), the coating and granulation of solid particles by aqueous solutions of polymers or inorganic salts has been studied. Agglomeration results by the adhesion of small particles by forming liquid or solid bridges between them, leading to formation of larger particles, called ‘‘agglomerates,’’ of mean diameter at least equal to twice the initial particles diameter. ‘‘Coating’’ or ‘‘onion-ring layering’’ corresponds to the deposition of an ingredient on the entire surface of particles. This study, which deals with the coating and granulation of solid particles by aqueous solutions of polymers or inorganic salts, aims at understanding the effect of process (excess gas velocity, atomizer location, liquid flow rate, and concentration, atomizing air flow rate) and physicochemical related variables (viscosity of solutions, wettability of the liquid on the solid, initial particle mean size, and porosity) on the growth mechanisms.

The experiments are carried out by Hemati (2003) in a batch fluidized bed granulator, which is a Pyrex cylindrical column with a dinner diameter of 0.1 m and height of 0.35 m. The column topped by a conical freeboard, 0.2 m high, inclined at 45j.The air distributor is a stainless steel perforated plate with a porosity of 2%. Before entering in the bed, the fluidizing air flow rate is measured by a rotameter and preheated by an electrical heater. The elutriated particles are collected at the column outlet by a cyclone.

The results were point out as:-

– the increase of air relative humidity, depending on the liquid flow rate and air flow rate, favors agglomeration mechanism especially for values greater than 0.4,

– a decrease of droplet size done by increasing the atomizing air flow rate permits homogeneous coating of the solid surface,

– an increase in the initial size of the particle leads to an enhancement of the layering mechanism especially for values greater than 300 Am,

– the capillary forces are the dominant forces in the granulation process. Thus, increasing the adhesion strength of the solution on the solid surface, i.e., cLVcos h, and using fine particles enhance the growth by agglomeration. In the given operating conditions, the viscosity of the solution has relatively lower effects than the interfacial parameters,

– the spraying of a binder solution on the porous particles is characterized by a non-growth period during which the solute is deposited inside pore volume. After this period, the particles' growth occurs in the same manner as for non-porous particles.

2.3. Fractional Factorial Design:

Full and fractional Factorial Design analysis is common in designed experiments for engineering and scientific applications. In many cases, it is required to consider the factors affecting the production process at two levels. The experimenter would like to determine whether any of these changes affect the results of the production process. The most intuitive approach to study these factors would be to vary the factors of interest in a full factorial design, that is, to try all possible combinations of settings.

With two cube (2^3) Factorial Design Analysis, the correlation will be represented in the following form.

$$Y_{i\,jv} = a_0 + a_1A + a_2B + a_3C + a_{12}AB + a_{13}AC + a_{23}BC + a_{123}ABC \qquad (1)$$

If four or five factors are involved, the complete factorial might involve more than a practical number of experiments. A 2^5 factorial would require 32 experiments. By careful selection of the experimental conditions it is possible with only a fraction of the total experiments required for the complete factorial to determine the main effects by aliasing them with the higher order interactions which are usually not significant.

The eight experiments required for a complete three factor, two level factorial can be used to determine the change required in four, five or under ideal conditions, even in seven experimental variables to obtain the maximum change in the response variable.

As (n-p) factorial design is set up and the p factors not included in the complete 2^{n-p} factorial are aliased with one of the higher order interactions to form a generating contrast.

CHAPTER-3

EXPERIMENTAL SECTION

EXPERIMENTATION

To perform the particle film coating and powder granulating experiment, the experimental set up was fabricated. An air heater was used to heat the incoming fluidized air to desired temperature, temperature sensor was used to regulate the temperature, an air compressor was used to supply air for fluidization. A distributor was used for even distribution of solution from the top and a rotameter was used to regulate the air flow rate. With all these accessories, the experimental set-up was constituted as shown in Fig-7.

Fig.7- Experimental set-up

3.1. PARTS OF EXPERIMENTAL SET-UP

The experimental set-up is consisting of the following parts.

i) The fluidizing column: It is a glass column of dimension: length of 60 cm and diameter of 5 cm.

ii) Temperature sensor: A digital thermal sensor is attached to the main apparatus that shows the temperature of the inlet fluidizing air.

iii) Heater: A heater is provided on the way of fluidize air, which heats the air to desired temperature of operation.

iv) Variac: A variac is also provided that controls the heater.

v) Rotameter: A rotameter of range 0-120 Nm^3/hr is provided that controls the flow of the fluidizing air.

vi) Compressor: An air compressor is present there, which supplies air to the apparatus, which is controlled with the help of a valve.

vii) Distributor: A distributor is placed at the bottom of the column, through which the hot fluidizing air is passed through and evenly distributed over the bed in the coating experiment.

viii) Canvas Cloth: The distributor is replaced by a thin canvas cloth to fluidize powder in the column for granulating experiment.

ix) Sprayer: The binder solution and the coating liquid are sprayed onto the bed from the top of the column through a sprayer and distributor of different sizes (2mm, 3mm, 4mm, and 5mm).

3.2. MATERIAL AND METHODS

For the coating experiment, we took wheat flour as the coating material and the solution was prepared of different concentration and the particles on which coating is done are glass beads, polypropylene balls and black peppers.

For the granulating experiment we took the sucrose solution as the binder and in the bed we took Calcium Carbonate powder, Titanium Dioxide powder and Sugar powder.

The initial average particle size of glass beads is 2.58mm, polypropylene balls are 5mm and black peppers is 3.5mm.

Calcium carbonate powder of average size 15 micron and density 0.7gm/cc, titanium dioxide of average size 25 micron and density 0.77gm/cc and sugar powder of average size 60 micron and density 0.6gm/cc were taken.

For the coating experiment, the sample was taken in the column and its initial size was measured and weighed. Then the heater was switch on and air was supplied into the column from bottom passing through the heater. The desired temperature of the fluidized air is maintained with the help of the sensor. The air is supplied by the compressor and the flow is controlled by the valve and rotameter. First of all the air is passed till the minimum fluidized condition of the bed is attained and then it is used to heat the particles. The coating solution is then passed from the top of the column through distributor onto the hot particles. The flow rate of the fluidizing air is then increased gradually so that coating will take place uniformly. The same condition is maintained for some time and the coating of fluid on the particle is allowed to settle/precipitate on the hot particle. Finally the coated particles are taken out and the sizes are measured.

For the granulation of powder, the distributor taken out and replaced with a canvas cloth. The measured quantity of powder is taken and kept in fluidized condition and the binder from the top is sprayed. The adhesive powder under fluidized condition binds with each other in the presence of binder. The sample is stirred continuously as the powder binds with each other and lumps are formed.

CHAPTER-4

RESULTS AND DISCUSSION

In the first part of our project work, experiment was performed for the coating of the particles by spraying the solution. Three samples were considered (glass beads, polypropylene balls and black pepper) for coating by putting wheat flour into it. And there results are shown in Table 2 for different operating conditions.

Table 2. Effect of various parameters on particle growth in a coating experiment:-

SAMPLE/ PARAMETERS	GLASS BEADS I	GLASS BEADS II	POLYPROPYLENE BALLS	BLACK PEPPER
INITIAL AVG SIZE (mm)	2.58	2.58	5	3.5
WGT OF SAMPLE (gm)	100	100	35	40
FLUIDIZING AIR FLOW RATE (Nm^3/hr)	70	80	70	60
FLUIDIZING AIR TEMP.(^{0}C)	50	60	43	60
BINDER CONC.(gm/ml)	0.428	0.33	0.5	0.5
NEW AVG SIZE (mm)	3	3.2	5.75	4.75

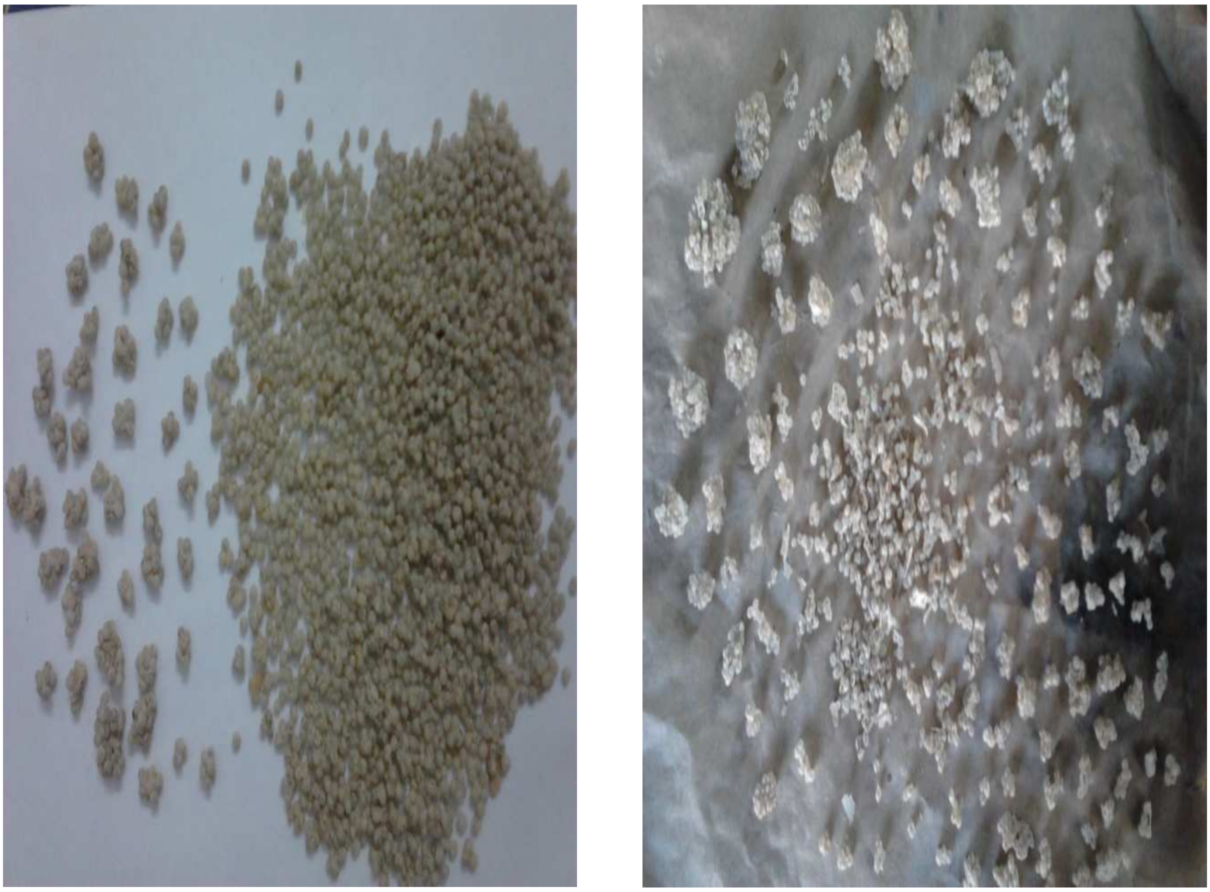

Fig 8.Experimenal result of coating of particle glass beads I and glass beads II

In the granulating experiment, the particle coating was performed by putting the coating solution on the particle. Three different particles were studied in this work and it was observed that the surface properties have great effect over the coating process. The more the shine surface the less is the coating possible. Also the coating is associated with agglomeration, which is broken with the addition of an external source like stirrer. The agglomeration can also be reduced with the limited supply of coating liquid, with the higher fluidizing air flow rate and with the increase of temperature of fluidizing air. A comparison has been made taking glass beads as base material and a graph has been plotted between particle size and time.

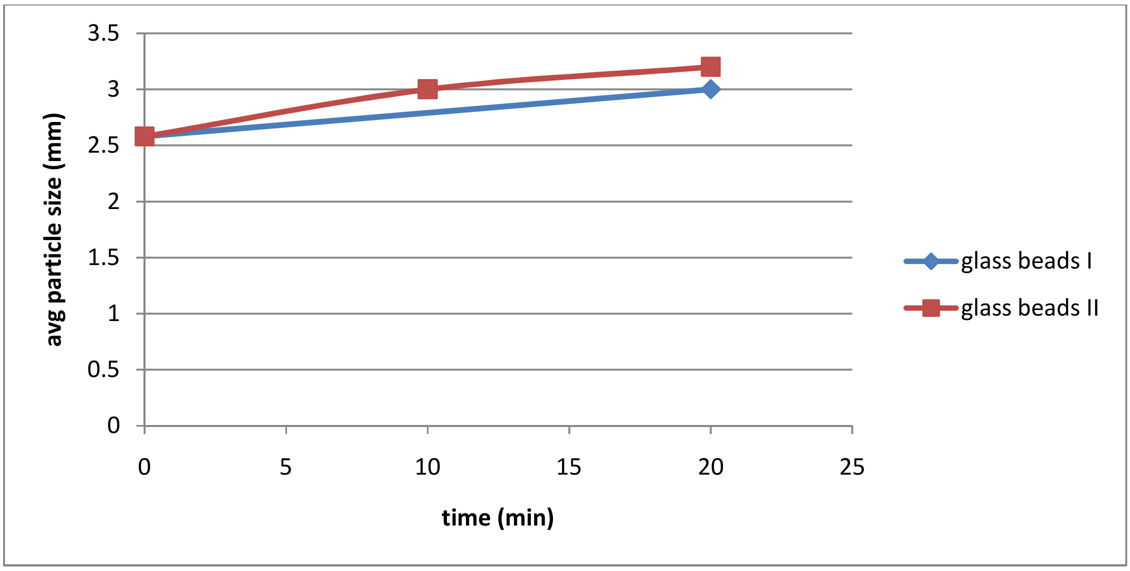

Fig 9.Variation of average particle size against time for different operating conditions for glass bead.

It is easily figure out , the particle growth (coating) rate is more in case of glass beads II, where all the conditions are favoring for less agglomeration and more coating with higher temperature , higher flow rate of fluidizing air and supplying relatively less concentrated coating solution.

In the granulation experiment various parameters like the amount of binder used, the amount of powder taken in the bed for granulation, the temperature and flow rate of the fluidizing air and different powders has been varied and accordingly the particle growth rate has been studied

4.1. Variation of amount of binder:-

Sample: Calcium Carbonate

Table 3.Effect of binder quantity on particle growth in a granulation experiment

Amount of powder(gm)	Density of powder(gm/cc)	Flow rate (Nm^3/hr)	Fluidizing air temp(^0C)	Amount of binder (ml)	Granule size formed(mm)	Fraction growth
30	0.7	45	50	25	17	1133
30	0.7	45	50	15	14	933
30	0.7	45	50	10	9	600

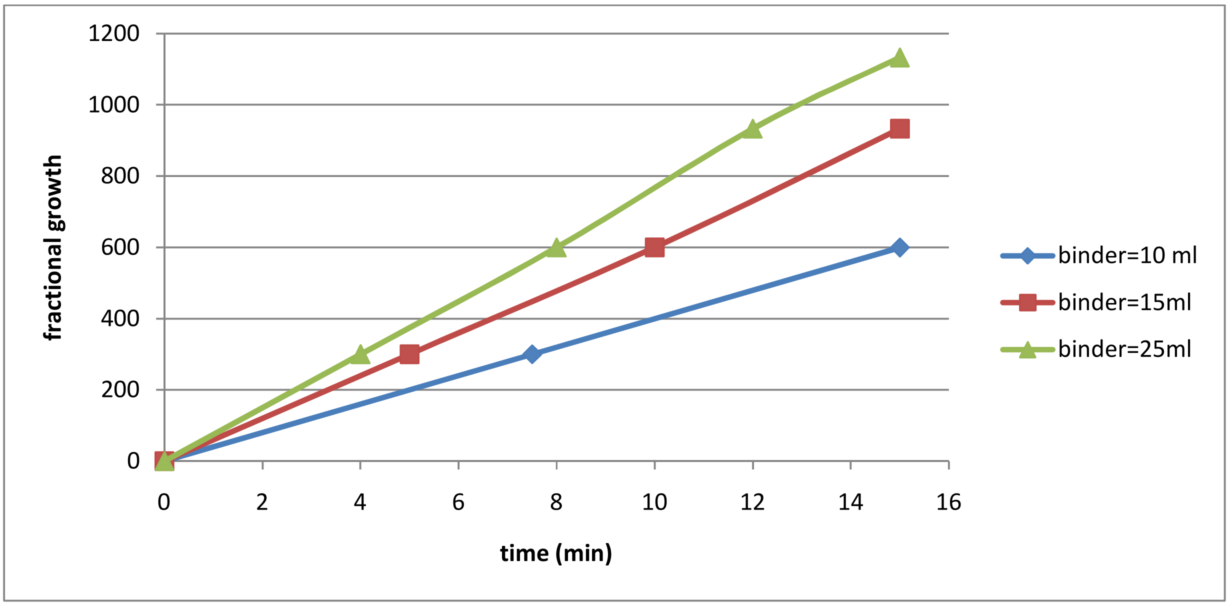

Fig-10: Variation of average particle size against time with varying quantity of binder.

It was observed that more the amount of binder used, more is the fraction of particle growth. It is such because on adding more binder, the powder agglomerates and lumps are formed thus the size is increasing. When less binder is added as in case of third sample , less lump of particle are formed , favoring more granules of regular small sizes.

4.2. Variation of temperature:-

Sample: sugar powder

Table 4.Effect of temperature on particle growth in a granulation experiment

Amount of powder(gm)	Density of powder(gm/cc)	Flow rate (Nm^3/hr)	Fluidizing air temp(^0C)	Amount of binder (ml)	Granule size formed(mm)	Fraction growth
40	0.56	50	50	2	6	100
40	0.56	50	60	2	5.93	98.83
40	0.56	50	70	2	5.8	96.67

In the present work, only the temperature was varied keeping all other parameters constant. The drying period has major role in the granulation process. As the data shows more is the temperature of fluidizing air, better will be the granulation. A graph has been plotted between average particle size and time showing the effect of temperature in Fig.11.

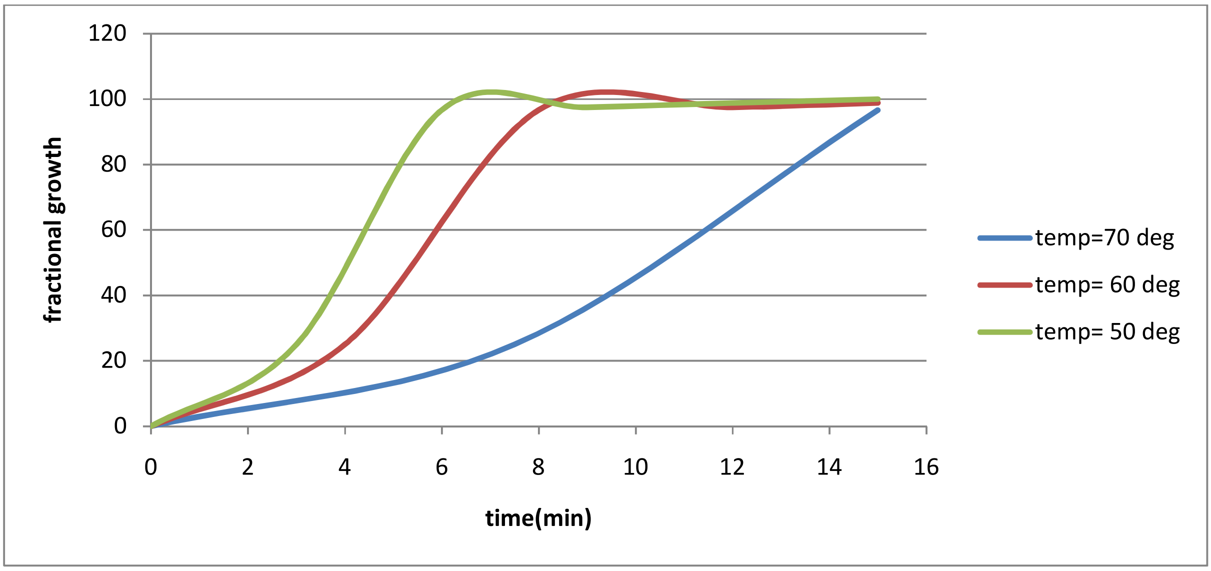

Fig-11: Variation of average particle size against time with temperature

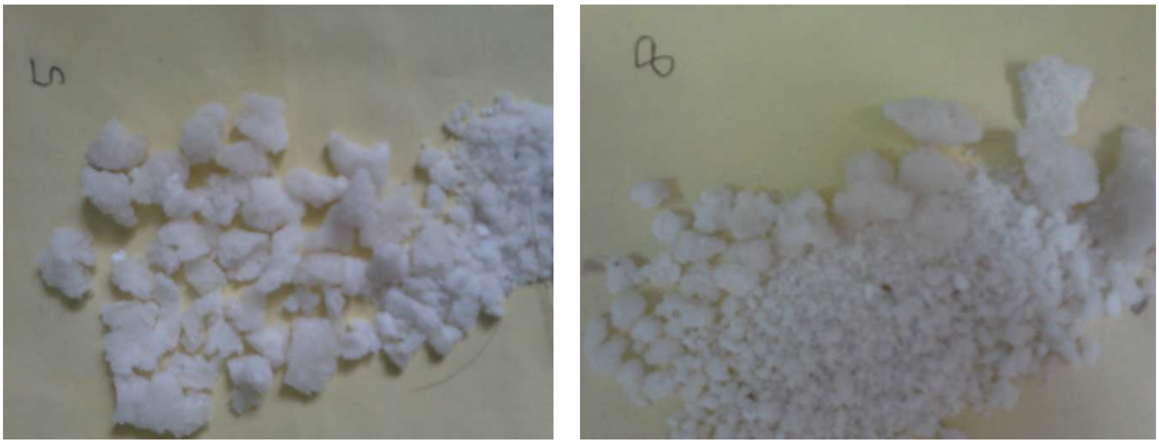

Fig-12: Experimenal result of granulation of sugar powder at a operating temperature of 50 and 70 ^{0}C

It was observed that on increasing the temperature of the inlet fluidizing air, granule growth was promoted .

4.3. Variation of amount of material in the bed:-

Sample: sugar powder

Table 5.Effect of amount of initial material taken on particle growth in a granulation experiment

Amount of powder(gm)	Density of powder(gm/cc)	Flow rate (Nm^3/hr)	Fluidizing air temp(^0C)	Amount of binder (ml)	Granule size formed(mm)	Fraction growth
30	0.56	45	50	5	6.15	102.5
40	0.56	45	50	2	6	100

By increasing the amount of powder in the bed, it was observed that the degree of agglomeration formation is reduced and granulation is increased as for given operating condition if the sample is less, initially they will granulate but later agglomeration will start, so it is profitable to take more powder thus minimize agglomerates.

4.4. Variation of material in the bed:-

Table 6.Effect of various materials taken on particle growth in a granulation experiment

Amount of powder(gm)	Density of powder(gm/cc)	Flow rate (Nm^3/hr)	Fluidizing air temp(^0C)	Amount of binder (ml)	Granule size formed(mm)	Fraction growth
30	0.56	45	50	5	6.15	102.5
30	0.7	45	50	15	14	933.33
30	0.77	45	50	5	2.45	98

By varying different material it was found out that, $CaCO_3$ has good binding property and easily forms agglomerates thus it has higher fractional growth, while TiO_2 has the least agglomeration and produces small sized granules.

4.5. Variation of flow rate of fluidizing air:-

Sample: Calcium Carbonate

Table 7.Effect of fluidizing air flow rate taken on particle growth in a granulation experiment

Amount of powder(gm)	Density of powder(gm/cc)	Flow rate (Nm^3/hr)	Fluidizing air temp(^0C)	Amount of binder (ml)	Granule size formed(mm)	Fraction growth
30	0.7	60	50	15	13	866.67
30	0.7	45	50	15	14	933.33

Here the effect of fluidizing air flow rate over the particle growth was studied. It was observed that on increasing the flow rate, the fraction growth is reducing. This is due to the attrition that takes place among particles under higher flow rates.

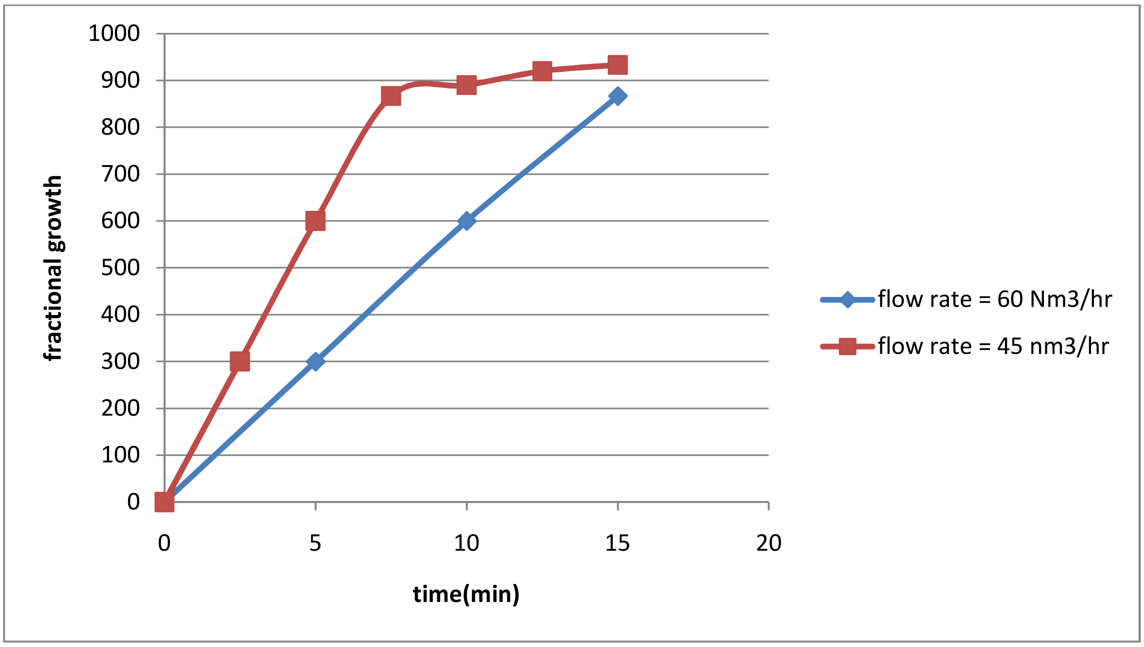

Fig-13: Variation of average particle size against time with fluidizing air flow rates.

The plot in Fig-13, shows that more is the fluidizing air flow rate , smaller will be the size of granules developed , as on increasing velocity , the granules collides among themselves more vigorously and thus large granules and agglomerates breaks up into small particles.

4.6. Statistical Analisis approach for Correlation

After getting all the experimental data's an attempt has been made to develop a statistical correlation showing the effects of various parameters such as weight of material in the column bed , type of material i.e., the density , fluidizing air flow rate , temperature of fluidizing air and the volume of binders sprayed on the fractional growth of granule. The correlation developed is

$$\textbf{Y-cal} = 115.5 + (4)*A + (38)*B + (-24)*C + (-2)*D + (90)*E + (4)*AC + (-2)*BC \quad (2)$$

	Expts.	A	B	C	D=ABC	E=AB	AC	BC	a0	a1	a2	a3	a4	a5	a13	a23
125	1	-	-	-	-	+	+	+								
102	a(de)	+	-	-	+	-	-	+								
112	b(de)	-	+	-	+	-	+	-								
135	ab	+	+	-	-	+	-	-								
118	c(d)	-	-	+	+	+	-	-								
98	ac(e)	+	-	+	-	-	+	-								
105	bc(e)	-	+	+	-	-	-	+								
129	abc(d)	+	+	+	+	+	+	+								
115.5									115.5	4	38	-24	-2	90	4	-2

W	Rho	F	T	V	Y(expt.)	A-effect	B-effect	C-effect	D-effect	E-effect	AC-effect	BC-effect	Y(calc.)	%dev
25	0.56	32	50	10	125	-1	-1	-1	-1	1	1	1	191.5	-53.2
40	0.56	32	70	2	102	1	-1	-1	1	-1	-1	1	7.5	92.64
25	0.77	32	70	2	112	-1	1	-1	1	-1	1	-1	87.5	21.87
40	0.77	32	50	10	135	1	1	-1	-1	1	-1	-1	271.5	-101
25	0.56	60	50	10	118	-1	-1	1	1	1	-1	-1	135.5	-14.8
40	0.56	60	70	2	98	1	-1	1	-1	-1	1	-1	-24.5	125
25	0.77	60	70	2	105	-1	1	1	-1	-1	-1	1	31.5	70
40	0.77	60	50	10	129	1	1	1	1	1	1	1	223.5	-73.2

CHAPTER-5

CONCLUSION

CONCLUSION

In the fluidized bed granulation, the agglomeration and surface layering leads to the growth of granule. Agglomeration occurs when a wet particle collides with another particle and get bound with it by a liquid bridge which solidifies during subsequent drying period.

While coating a material, high dilution of the coating material shows good spreading properties and thus results in even coating on the surface of particles. Also high flow rate and temperature of fluidizing air favors coating of particles rather forming agglomerates.

The granulation experiment have shown the importance of drying zone. The drying zone can be affected by three parameters, namely the bed height, the fluidizing air flow rate and he gas temperature. In practice , if surface layering is the desired mechanism of particle growth, then an increase in the air flow rate and outlet gas temperature can make it done possible as those things reduces the formation of agglomerates. Also the amount of binder provided decides the mechanism of particle growth. With low binder content, fine granules are produced, which turns to big agglomerates on increasing binder amount.

Besides all this there are two more things that have major contribution on deciding the mechanism of particle growth ,i.e. the external force that can be a stirrer or a vibrator which will help to break down the agglomerates into fines and other thing is the fine spraying of binders and coating material. More the fine the droplets, more is fine the granules are and more evenly coating will be carried out.

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