MODELING AND SIMULATION AFFECT OF BINDER ADDITION RATE ON AMMONIA EMISSION DURING GRANULATION PROCESS

N., Mohamad[1], D., Shafeeq[2], A., Shaaban[3] and M.A., Nurhuda[4]

[1,2]Faculty of Engineering & Technology,
Multimedia University, Jalan Ayer Keroh Lama,
75450 Melaka, Malaysia.

[3]Faculty of Manufacturing Engineering,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia.

[4]Faculty of Electrical Engineering,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia.

Email: [*1]nhidayah.mohamad@gmail.com; [3]azizahs@utem.edu.my

ABSTRACT: This paper presented the modeling and simulation of the ammonia gas released when the urea-based binder solution was sprayed into the fluidized bed granulator. Ammonia gas was detected when heat involved in granulation process of urea-based compound. The binder solution was sprayed into the granulator chamber at rates between 1 and 10 ml/min, in which the amount of ammonia gas release was quantified. The design model based on experimental observation was developed using MATLAB 12b. From simulation result, this model was able to simulate the process of adding binder into granulation chamber. The model had shown a potential to be expanded for whole fluidized bed system and other types of processes.

KEYWORDS: *Fluidized bed granulator (FBG), Ammonia emission, Modeling, Simulation, Urea binder.*

1.0 INTRODUCTION

Computational Fluid Dynamics (CFD) program [1] is commonly used in industry for monitoring the granulation process. It described the particle size distribution of granules and performed good comparison with experimental value. The quality of granules from FBG was improved using multiphase hybrid model [2]. A high accuracy, good generalization ability and effectively reflect the characteristics of each phase of the process.

Urea is commonly used as fertilizer due to high nitrogen content. The fluidized bed granulation (FBG) is an easiest technique to produce urea granules. However ammonia (NH_3) gas was detected during the granulation process. Binder solution added in the FBG during the granule process has been identified for the NH_3 contribution to the atmosphere. The other source of NH_3 gas also came from the evaporation section of the urea synthesis process [3-5]. Figure 1 shows the schematic diagram of FBG.

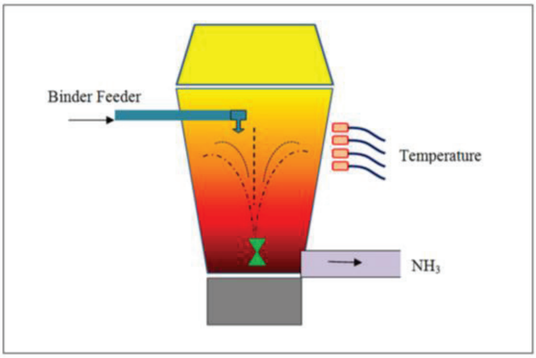

Figure 1: Schematic Diagram of Fluidized Bed Granulator

This paper presented the effect of amount of binder addition towards the NH_3 emission during granulation process of urea. The NH_3 was released as gas during the spraying of urea solution into the fluidized bed. MATLAB 12b was used to create and simulate the model. Hence, reducing the ammonia emission by controlling the process would optimize the energy and generate a greener processing.

2.0 METHODOLOGY

The inlet air temperature was set at 65^0C under a constant humidity of inlet air. The inlet air temperature was monitored throughout the process. Batch size for each run was 10 grams. The granules were collected at regular intervals to measure the growth as the granulation progresses. The binder solution is sprayed onto the fluidizing powder bed using a peristaltic pump. The ammonia gas sensor is used to detect and quantify the gas emission. The spraying parameters were selected based on the minimum ammonium gas released without affecting the quality of the granules. The parameters are used to derive equation and propose a mathematical model for the ammonia emission as a function of the operating conditions [6].

2.1 Development of Binder Addition Rate Simulation Model

Modeling can improve the controlling of FBG [7]. MATLAB12b program is used to develop a model and simulate the input for significant findings. Simulink model to control various parameters of the FBG was developed in MATLAB 12b. This Simulink model was developed using various toolboxes available in the Simulink library such as the power system, power electronics, control system, signal processing toolboxes and from its basic functions. The entire system modeled in Simulink system consisting of the gain blocks, multipliers, constant blocks, adders, constants, sub-systems, the output sinks (scopes), the input sources, state-space models, work-space blocks and others. The developed Simulink model for the control of various parameters of the FBG is shown in Figure 2.

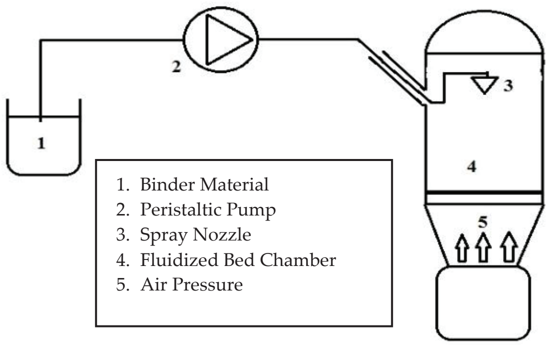

Figure 2: Circuit Diagram for lab scale Fluidized Bed Granulator

The binder material used in this process was the combination of urea, ionized water and starch. The peristaltic pump was used to supply the binder to the spray nozzle. Air was supplied into the chamber from down below to suspend the urea particle onto the air while granulation process was in session. The scope of the modeling and simulation was based solely on previous experiment. Thus, the parameters and the data from the experiment were used to generate graphs using MATLAB 12b. Figure 3 shows the scope, parameters and data flow collected from the experiments.

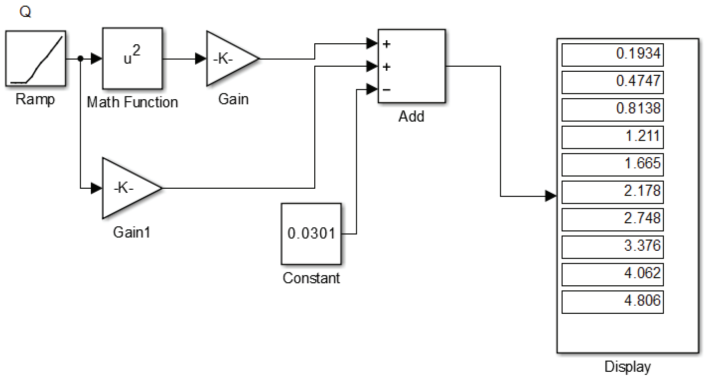

Figure 3: Binder Flow Rate Block Diagram

The model represents the equation;

$$Y = 0.0289X^2 + 0.1946X - 0.0301$$

where Y is the objective function for NH_3 emission and X is the value of binder flow rate. Ramp block represents the X from the equation while Gain blocks are for each value before X. The Constant block is obviously for the value of the constant 0.0301. Math Function block is set to function as 'square'.

Table 1: Manipulated variable: binder flow rate

No	Binder Flow rate (ml/min)	Binder Atomizing Pressure (kg/cm^2)	Inlet Temperature (°C)	Binder Viscosity (µPa.s)	Binder Volume (ml)	Nozzle Size (mm)	Spray Angle	NH_3 Emission (ppm)
1	1	0.5	65	0.236	250	5	90°	0.193
2	2	0.5	65	0.236	250	5	90°	0.475
3	3	0.5	65	0.236	250	5	90°	0.814
4	4	0.5	65	0.236	250	5	90°	1.211
5	5	0.5	65	0.236	250	5	90°	1.665
6	6	0.5	65	0.236	250	5	90°	2.178
7	7	0.5	65	0.236	250	5	90°	2.748
8	8	0.5	65	0.236	250	5	90°	3.376
9	9	0.5	65	0.236	250	5	90°	4.062
10	10	0.5	65	0.236	250	5	90°	4.806

Table 1 shows the parameter used for this model. Other variables remained constant as this model was used to investigate the relationship between binder flow rate and NH_3 emission only. The increment for binder flow rate was 1 ml/min.

Table 2: Manipulated variable: binder volume

No	Binder Flow rate (ml/min)	Binder Atomizing Pressure (kg/cm^2)	Inlet Temperature (^{o}C)	Binder Viscosity (µPa.s)	Binder Volume (ml)	Nozzle Size (mm)	Spray Angle	NH_3 Emission (ppm)
1	8	0.5	65	0.236	25	5	90^o	0.345
2	8	0.5	65	0.236	50	5	90^o	0.812
3	8	0.5	65	0.236	75	5	90^o	1.280
4	8	0.5	65	0.236	100	5	90^o	1.747
5	8	0.5	65	0.236	125	5	90^o	2.215
6	8	0.5	65	0.236	150	5	90^o	2.682
7	8	0.5	65	0.236	175	5	90^o	3.150
8	8	0.5	65	0.236	200	5	90^o	3.617
9	8	0.5	65	0.236	225	5	90^o	4.085
10	8	0.5	65	0.236	250	5	90^o	4.552

Table 2 shows the parameter used for this model. Binder volume was manipulated through the simulation while other variables were kept at constant value. The increment for binder volume was 25 ml and the maximum volume used was 250 ml.

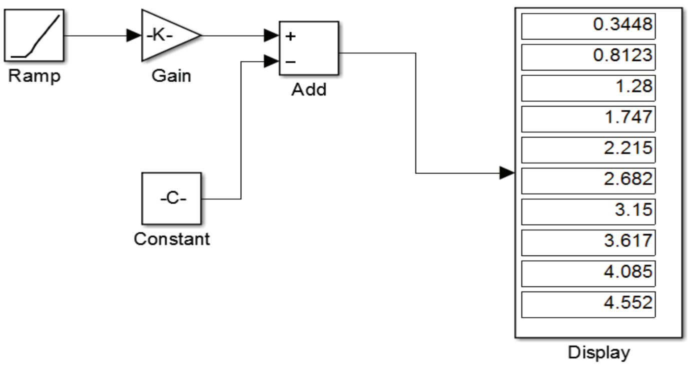

Figure 4: Binder Volume Block Diagram

Binder volume model presented in block diagram is shown in Figure 4. The model represents the mathematical equation of;

$$Y = 0.0187X - 0.1227$$

where Y is NH_3 emission and as in previous model, the Ramp block represents the X value for binder volume. The Display block generated the results of simulation.

3.0 RESULTS AND DISCUSSION

Performance characteristics were observed on the respective scopes based on the simulation input is shown in Figure 5. The curve was plotted in a polynomial form presented the increased of NH_3 emission with every increase of binder flow rate in a very consistent manner.

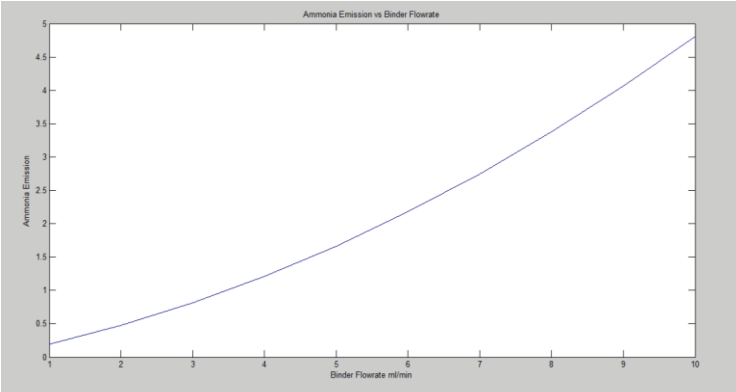

Figure 5: Graph of NH_3 emission against the binder flow rate

Table 3 shows a comparison between simulation and experimental values for binder flow rate. It showed a fluctuation in percentage of error. The error reached as high as 18.750 % and it could go as low as 0.706 %. The maximum error was still considered as very low, hence, the modeling and simulation for this part was similarly approximate.

Table 3: Simulation and experimental data for binder flow rate

No	Binder Flow rate (ml/min)	NH_3 Emission (ppm)simulation	NH_3 Emission (ppm)experiment	Percentage of Error (%)
1	1	0.193	0.200	3.500
2	2	0.475	0.400	18.750
3	3	0.814	0.800	1.750
4	4	1.211	1.300	6.850
5	5	1.665	1.700	2.059
6	6	2.178	2.000	8.900
7	7	2.748	2.800	1.857
8	8	3.376	3.400	0.706
9	9	4.062	4.200	3.286
10	10	4.806	4.700	2.255

The graph in Figure 6 shows a linear relation between binder volume and NH_3 emission. The gas emission increased with the increase of the binder volume.

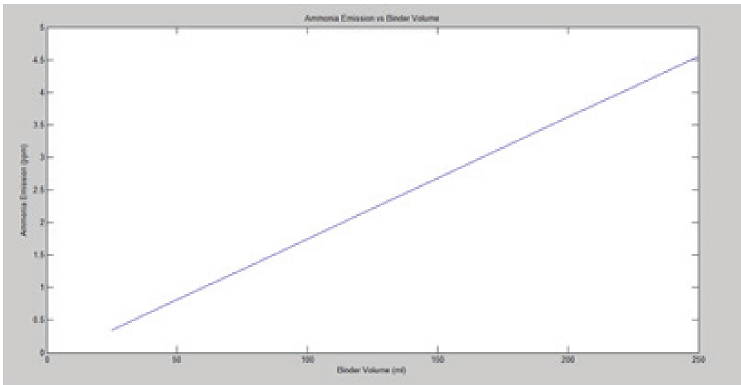

Figure 6: Graph of NH_3 Emission versus binder volume

The experimental and simulation data are shown in Table 4. The error reached as high as 15 % and it was as low as 0.667 %. The maximum error was low, hence, the modeling and simulation for this part was valid.

Table 4: Simulation and experimental data for binder volume

No	Binder Volume (ml)	NH_3 Emission (ppm)simulation	NH_3 Emission (ppm)experiment	Percentage of Error (%)
1	25	0.345	0.3	15.00
2	50	0.812	0.8	1.500
3	75	1.280	1.3	1.538
4	100	1.747	1.6	9.188
5	125	2.215	2.2	0.682
6	150	2.682	2.7	0.667
7	175	3.150	3.1	1.613
8	200	3.617	3.8	4.816
9	250	4.085	4.0	2.125
10	10	4.552	4.6	1.043

4.0 CONCLUSION

Based on the MATLAB 12b code, it is clear that the model variable can be controlled accordingly. The models are to be developed separately based on the parameters involved. Simulations were done in MATLAB 12b and the results are observed on the corresponding scopes. Both results showed that when the amount of liquid binder is reduced, the emissions also decrease at the same rate as the binder flow. Less number of NH_3 emissions is determined when the binder flow rate is reduced. Hence, the modelling and simulation of binder addition in producing urea granules denote an improvement of the experimental result. The simulation model displays the amount of NH_3 released in controllable process parameters with different values of binder volume and binder flow rate. The simulation results have shown that the FBG is a complex process which cannot be predicted or solved analytically. Future study should analyse the possibility of extending the FBG model by adding other process parameters to perform various simulation results. This numerical simulation will play an important role in the model analysis, control and optimization for other FBG process.

ACKNOWLEDGEMENTS

We are grateful to UTeM and the Ministry of Education Malaysia for the technical support and funding the work under the grant scheme code LRGS/2011/FKP/TK02.

REFERENCES

[1] H. Ehlers, A. Liu, H. Räikkönen, J. Hatara, O. Antikainen, S. Airaksinen, J. Heinämäki, H. Lou and J. Yliruusi, "Granule size control and targeting in pulsed spray fluid bed granulation", Int J Pharm, vol. 377, no. 1-2, pp. 9-15, 2009.

[2] N.M. Ghasem, M. A. Hussain, and I. M. Mujtaba, "The use of Simulink block diagram to solve mathematical models and control equations," *Universitas Scientarium*, p. 9, 2003.

[3] M. Potthoff, *Ammonia Emission Reduction in Urea Granulation Plants*. 2012.

[4] S. Lisa, "Studies on effect of process parameters on particle growth in a fluidized bed granulator." M.S. thesis, National Institute of Technology, Rourkela, 2012.

[5] B. Rambali, L. Baert, and D. L. Massart, "Using experimental design to optimize the process parameters in fluidized bed granulation on a semi-full scale," Int J Pharm, vol. 220, no. 1–2, pp. 149-160, Jun. 2001.

[6] H. M. Monayem, "Development of a simulation model for fluidized bed mild gasifier". M.S. thesis, University of New Orleans, USA, 2010.

[7] K. J. Esko, "Intelligent modelling of a fluidized bed granulator used in production of pharmaceuticals," pp. 101-108, 2009.