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Effects of Number of Motors on Viscosity and Cooling Rate during Prilling Process

Ahmet Ozan Gezerman (Corresponding author), Burcu Didem Çorbacıoğlu
Yildiz Technical University, Department of Chemical Engineering, Istanbul, Turkey
Tel: + 90 532 653 85 05 Email: ahmet_ozan@yahoo.com

Abstract

The prilling process is the most commonly used final stage operation in the granulated product industry today. During storage after prilling, the storage temperature can cause re-crystallization, phase changes, and other undesirable reactions. This paper considers an ammonium nitrate manufacturing process and investigates how the cooling rate increases with an increase in the number of cooling motors that are used in the prilling system, along with the effects on viscosity.

Keywords: Viscosity, Prilling, Ammonium nitrate, Cooling motor

1. Introduction

The prilling process is one of the most preferred granulation methods for granulated product processing. Because of their low investment cost and ability to control the particulate diameter and shape during the granulation process, manufacturers prefer prilling systems.

Prilling systems use a prilling bucket to create prill particulate. The rotating speed of the prilling bucket makes it easy to check the diameter of the particulate using the solution thrown from the prilling bucket. The thrown solution moves downward from the prilling tower based on its temperature and weight. When prilled ammonium nitrate particulates move downward, they are cooled by cooling motors that are placed equal distances apart. There have been several studies on the cooling and prilling processes for solutions with different chemical compositions. In contrast to the studies in the literature, this paper investigates how an increase in the number of cooling motors and a change in the direction of rotation affect the cooling rate and viscosity.

2. Assumptions and calculations

In order to calculate the motor power required to cool the ammonium nitrate, its "enthalpy" needs to be known:

$$\Delta H = C_p \times \Delta T$$

for 97% ammonium nitrate(NH_4NO_3), 0.5% HNO_3 (55%, by weight), 0.5% anhydrous NH_3, and 2% H_2O, where

$\Delta H_{(NH_4NO_3)} = 5808\ {}^{cal}/_{mol}$,
$Cp_{(NH_4NO_3)} = 0.484\ {}^{cal}/_{g\ ℃}$

$$Q = Q_h = m \times C_p \times \Delta T$$

$Q = heat\ transfer$

$m = mass\ of\ NH_4NO_3$

$C_p = specific\ heat\ of\ NH_4NO_3\ at\ 25\ ℃$

$\Delta T = temperature\ difference$

For 100 t/h,

$$Q = \left(100\ {}^{t}/_{h}\right) \times \left(0.484\ {}^{cal}/_{g℃}\right) \times (175℃ - 125℃)$$

$$Q = 56.25\ kW$$

$$Q_h = h \times A \times \Delta T \quad [6]$$

$Q_h = heat\ transfer\ by\ convection$

$h = 0.149\ {}^{cal}/_{s \times m^2 \times ℃}$, $(heat\ transfer\ coefficient\ by\ convection\ for\ NH_4NO_3)$,

$A = m^2, (cylindrical\ area)$

$$56.25\ kW = \left(0.149\ {}^{cal}/_{s \times m^2 \times ℃}\right) \times A \times (175\ ℃ - 125\ ℃)$$

$$A = 2516\ m^2 = 2 \times \pi \times r \times h$$

$$r \times h = 400\ m^2$$

As a first assumption, if $r = 10\ m, h = 40\ m$, the effects of the prilling height on the cooling rate can be described as follows:

$${(T_1 - T_2)}/{(N \times z)}$$

$T_1 = initial\ temperature\ of\ fertilizer\ at\ the\ prilling\ tower$

$T_2 = final\ temperature\ of\ fertilizer\ at\ the\ prilling\ tower$

$N = number\ of\ cooling\ motors$

$z = height\ of\ the\ prilling\ tower$

$${(175\ ℃ - 25\ ℃)}/{(4\ motors \times 40\ m)} = 0.9375\ \ {℃}/{motor \times m}$$

3. Prilling height

For a four-motor system,

$${(175\ ℃ - 25\ ℃)}/{(4\ motors \times (40 - z)m)} = 0.9375\ \ {℃}/{motor \times m}$$

With this formulation, the prilling heights obtained for a four-motor system for which a phase transition occurs between temperatures of 175 °C and 25 °C are shown in the first columns of Tables 1.

For a six motor system,

$${(175\ ℃ - 25\ ℃)}/{(6\ motors \times (40 - z)m)} = 0.9375\ \ {℃}/{motor \times m}$$

With this formulation, the prilling heights obtained for a six-motor system for which a phase transition occurs between temperatures of 175 °C and 25 °C are shown in the first columns of Table 2.

4. Viscosity

The viscosity of ammonium nitrate, in centipoise, is approximately given by the following:

$$\log_{10} \eta = \frac{530}{T} - 0.550$$

The viscosity values of ammonium nitrate are found in the second columns of Tables 1 and 2.

5. Retention time

$$h = V_0^2 + {}^1/_2\, g t^2$$

The size of the prilling bucket is important because it affects the cooling rate. For a diameter of 30 cm and rotating speed of 160 rpm, the throwing rate can be calculated as follows:

$$2 \times 3.14 \times 30 = 188.4\ cm$$

$$V_o = 160\ {}^{rotations}/_{min} \times (188.4\ {}^{cm}/_{rotation}) \times \left({}^{1\ min}/_{60\ s}\right) = (502.4\ {}^{cm}/_{s}) \times \left({}^{1\ m}/_{100\ cm}\right)$$

$$V_o = 5.024\ {}^{m}/_{s}$$

$$h = (5.024\ {}^{m}/_{s})t - ({}^{1}/_{2}) \times (9.81\ {}^{m}/_{s^2}) \times t^2$$

Using this equality, the retention times can be calculated for the temperatures (175 °C, 125 °C, 84.5°C, and 32°C) at which the phase transitions occur (the fourth columns in Tables 1 and 2).

6. Results and discussion

Although the temperature of an ammonium nitrate solution during the prilling process is estimated in the literature, the relationships between the prilling height, temperature, and viscosity have not been given.

During the cooling stage of the ammonium nitrate manufacturing process, it is possible to see that ammonium nitrate has four different crystal constructions: cubic, tetragonal, alpha-rhombic, and beta-rhombic. In the cooling stage, if the temperature decreases at the prilling tower exit, the ammonium nitrate particulates become stable. This paper considers the effect of the cooling process on the stabilized phase transitions of ammonium nitrate. First, the viscosity, height, temperature, and time parameters are calculated using the cooling rate with four cooling motors (Table 1, Figure 1). Next, the same calculations are performed for the cooling rate with six cooling motors (Table 2, Figure 2). In this way, the phase transitions are completed in the prilling process.

Moreover, it is inferred from the calculations performed for the four-motor and six- motor system comparison that in the four-motor system the ammonium nitrate particles do not completed their phase transition when they exit the prilling tower. According to the calculations, this distance is 2.53 m. Thus, the beta-rhombic crystal structure, which is considered to be the last phase transition under room temperature conditions (25 °C, 1 atm), did not occur in the four-motor system.

The six-motor system is similar to the four-motor system, but the crystal structure and phase transitions occur over a shorter time and distance (Table 2). Therefore, the six-motor system has an important effect on the cooling rate of ammonium nitrate particles.

7. Conclusion

In contrast to the literature, this paper considered the prilling process used in an ammonium nitrate factory and investigated the effects of the number of cooling motors on the cooling rate for the ammonium nitrate with the goal of improving the available conditions and suggesting alternative low-cost solutions. Based on the results, instead of using four motors placed at equal distances apart, it was found that it would be beneficial to use six motors to cool the ammonium nitrate, with the additional two motors placed in opposite directions to each other. This ensured the completion of undesired reactions because of the storage temperature, along with complete phase transitions.

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References

Bals E., Breedt, J., Goosen, A.L., Spiteri, W.L., (2004),Porous Prilled Ammonium Nitrate*, Patent No: EP 0648528* B2

Booth, D.H., Vinyard, V.C.,(1967), Density and Viscosity of Ammonium Nitrate, Ammonium Nitrate–Potassium Chloride and Ammonium Nitrate—Ammonium Phosphate Melts*, Journal of Applied Chemistry,*1967, vol. 17(3), pp. 86-88

Derbentli, T.,,(1996), *Muhendislik Yaklasimi ile Termodinamik*. , (1st ed.). Istanbul: Literature, (Chapter 3)

Gezerman, A.O., Çorbacıoğlu, B.D., (2011),A New Approach to Cooling and Prilling during Fertilizer Manufacture, *International journal of Chemistry*, vol. 3(2), pp.158-168

Irshad, U., Sharif, M.N., Khan, R.U., Rizvi, Z.H., Granulation of Urea in a Pan Granulator,,(2009), *Journal of Quality and Technology Management*, vol. 5(1), pp. 56-66

Jacobsen, R.T, Lemmon, E.W., Penoncello, S.G., Shan, Z., Wright, N.T.,(2000), *Thermophysical Properties of Fluids and Materials*, Idaho: E- Publishing Inc. pp. 140-152

Kakac, S., Yuncu, H.,(1999), *Temel Isi Transferi,* Ankara: Bilim, (Bolum 6)

Kucuksahin, F.,(1989), *Teknik Formuller*. (1st ed.). Istanbul: Beta, (Chapter 5)
Kweeder, A.J., Shirley, A.R., Cochran, K.D., Holt, T.G.,(2010), Prilling Method, *Patent No: EP 2260935 A1*

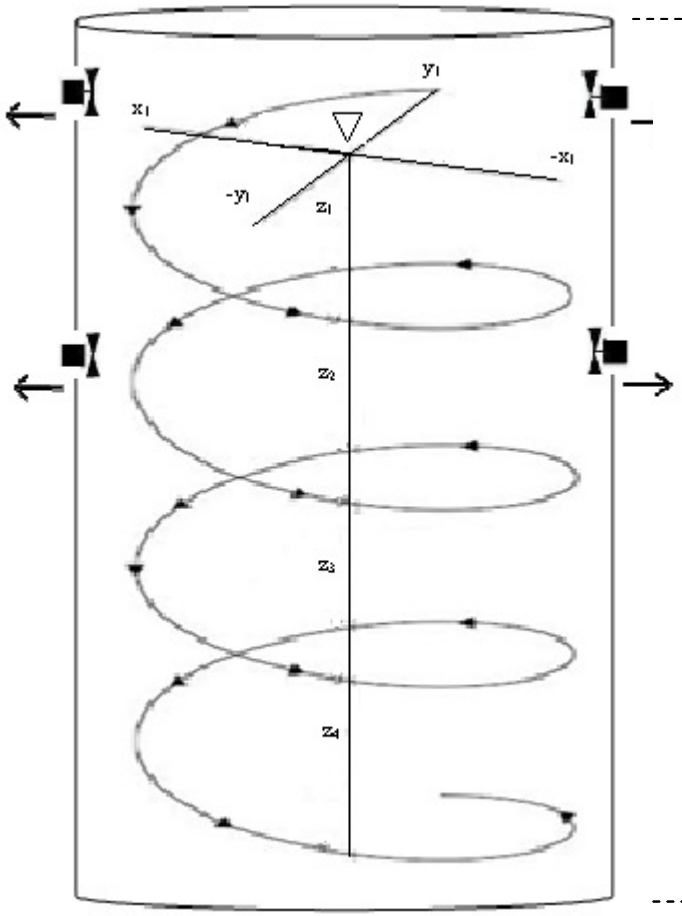
Theoret, A., Sandorfy, C., (1964),Infrared Spectra and Crystalline Phase Transitions of Ammonium Nitrate, *Canadian Journal of Chemistry*, vol. 42(4), pp.57-62

Table 1. Calculated parameters for four-motor system used in prilling process

Prilling height (z-m)	Viscosity (cp)	Temperature ($^{\circ}C$)	Retention Time (s)	Crystal structure (phase transition)
40	4.29	175	4.61	Cubic
26	4.29–6.04	175–125	2.33	Cubic–tetragonal
13.33	6.04	125	1.65	Tetragonal
2.53	6.04–8.56	125–84.5	0.718	Tetragonal–alpha-rhombic
10.8	8.56	84.5	1.48	Alpha-rhombic
18.04	8.56–15.40	84.5–32	1.91	Alpha-rhombic–beta-rhombic

Table 2. Calculated parameters of a six motors system in prilling process

Prilling height (z-m)	Viscosity (cp)	Temperature ($^{\circ}C$)	Retention Time (s)	Crystal structure (phase transition)
40	4.29	175	4.61	Cubic
31.1	4.29–6.04	175–125	2.51	Cubic–tetragonal
8.88	6.04	125	1.345	Tetragonal
1.68	6.04–8.56	125–84.5	0.58	Tetragonal–alpha-rhombic
7.2	8.56	84.5	1.21	Alpha-rhombic
9.33	8.56–15.40	84.5–32	1.37	Alpha-rhombic–beta-rhombic



Cubic

(40 m; 175 °C; 4.61 s)

Cubic–Tetragonal

(26 m;175–125 °C; 2.33 s)

Tetragonal

(13.3 m; 125 °C; 1.65 s)

Tetragonal –Alpha-rhombic

(2.53 m; 125–84.5 °C; 1.48 s)

Figure 1. Prilling process with four-motor system

A six-motor system

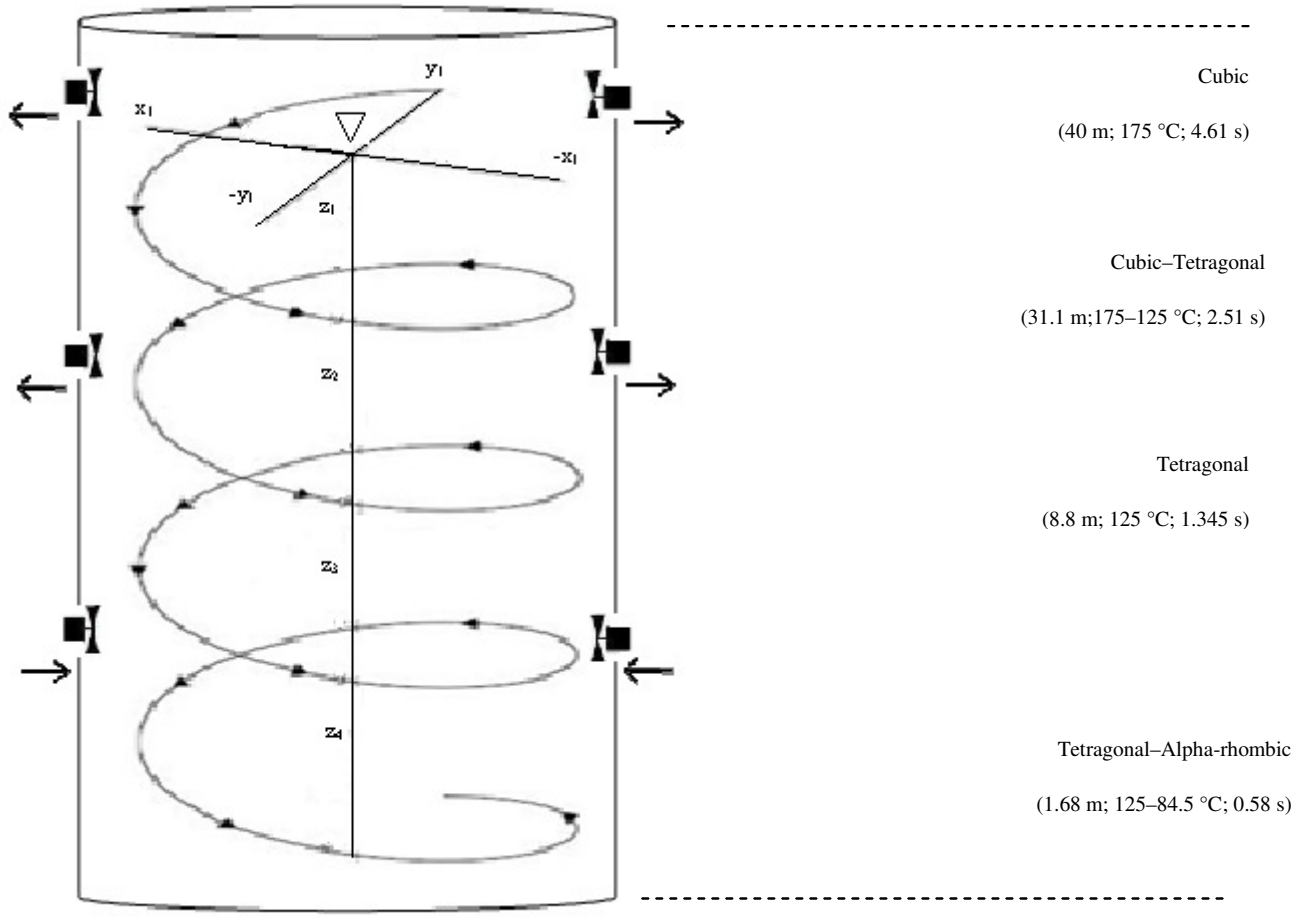


Figure 2. Prilling process with six-motor system

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