Journal of the University of Chemical Technology and Metallurgy, 42, 3, 2007, 265-268

EFFECT OF SEEDING OPERATION ON THE DYNAMIC STRENGTH OF UREA PRILLS IN PETROCHEMICAL PLANTS

Bahman ZareNezhad

Department of Chemical and Petroleum Engineering,
Shiraz University of Technology,
P.O. Box 71555-313, Modarres Blvd., Shiraz, Iran
E-mail: zarenezhad@yahoo.com

Received 30 January 2007
Accepted 12 June 2007

ABSTRACT

The effect of seeding operation on the dynamic strength of urea prills is investigated in a large scale urea production unit of a petrochemical plant. According to the experimental results the mean dynamic strength of 88 $\%_{mass}$ well above the recommended value of 85 $\%_{mass}$ can be obtained if a seed composition of 450 ppmw with the mean seed size of 20 μm is used for seeding operation. A semi empirical correlation for description of the seeding process is also presented. The predicted prill dynamic strength is always within ± 2.2 % of the measured value.

Keywords: seeding, dynamic strength, urea, prill, petrochemical plant.

INTRODUCTION

Urea has the highest nitrogen content of all solid nitrogenous fertilizers in common use. (46.4 % N). It therefore has the lowest transportation costs per unit of nitrogen nutrient [1]. In the final stage of urea production process in a petrochemical plant, the concentrated (99.7 %) urea melt is fed to the prilling device (e.g. rotating bucket/shower type spray head) located at the top of the prilling tower. Liquid droplets are formed which solidify and cool on free fall through the tower against a forced or natural up-draft of ambient air. The product is removed from the tower base to a conveyor belt using a rotating rake. Cooling to ambient temperature and screening may be used before the product is finally transferred to storage. Normally mean prill diameters range from 1.6-2.2 mm for prilling operations [2].

Although prilled urea is by nature more brittle than many other granular fertilizers, practice has shown that urea prills, too, are suitable for bulk transport, provided that they posses the proper physical properties [3]. When we change from bagged to bulk handling and shipping, it does not take long until we experience severe dust formation of low-grade urea. Large dust clouds develops especially during loading and unloading of ocean going bulk carriers which covers the ship, crew and surrounding area with a blanket of white dust. Current environmental legislation prohibits such operations [2, 3]. In addition, prills must posses sufficient mechanical strength in order to assure a low caking tendency after storage and handling [4,5]. Poor dynamic strength leads to disintegration and dust formation and thus as pointed out earlier to increased caking [6-8].

The problem of poor dynamic strength of urea prills can be alleviated by proper prilling and seeding so as to prevent subcooling of the urea prills [9]. There are very limited information regarding seeding operation in large scale urea plants. In this work the effect of seeding operation on the dynamic strength of urea prills is investigated in a petrochemical complex.

EXPERIMENTAL

All experiments are carried out in a large scale urea plant with the capacity of 1500 MTPD [10]. The prilling tower was 60 m long with the inner diameter of 17 m. The temperature and moisture content of urea melt entering at the top of prilling tower were 140°C and 0.4 $\%_{mass}$ respectively. The bucket rotational speed was set at 4 Hz to produce droplets with the mean size of 1.7 mm and CV of 15 % (CV % = σ / L_m X100, where L_m = mean seed size, [μm] and σ = standard deviation).

A series of experiments are carried out at different operating conditions in an industrial scale urea production unit with the PFD shown in Fig. 1.

The urea seeds were first milled to obtain a powder mixture with a given mean seed size and then the resulting mixture was injected into the cooling air through special louvers at the height of 6 m from the bottom of prilling tower. The rate of cooling air was always kept constant at 49500 kg/h to keep the prill moisture content at the bottom of the tower at minimum possible amount [10]. It should be noted that the cooling air flow is countercurrent with respect to the falling urea melt such that the maximum number of collisions between ascending urea seeds and descending urea droplets occurs. The collected solidified urea prills at the bottom of the tower were completely dried and sieved by an 8 mesh US standard screen for separation of 2 mm prills. The dynamic strength is then measured by shooting 2 mm prills with a velocity of about 20 m/s against a metal plate by means of compressed air and determining the mass percentage of unbroken prills [2]. These types of experiments were repeated at different ranges of seed compositions [expressed in terms of ppmw: weight of seeds per total weight of (seeds + urea melt)X10[6]] and seed sizes. The details of all experimental runs are shown in Table 1.

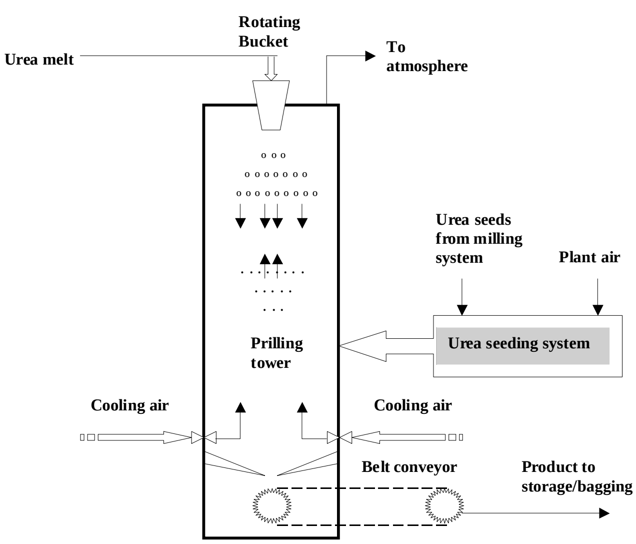

Fig. 1. Schematic diagram of an urea pilling unit equipped with the seeding system.

RESULTS AND DISCUSSION

The measured mean dynamic strength of urea prills at seed compositions of 100 and 450 ppmw and mean seed size of 20 μm are compared together for different observations in Fig 2. As shown on it the mean dynamic strength has been improved significantly from 55 $\%_{mass}$ to 88 $\%_{mass}$ as the seeding concentration increases. At a seed concentration of 100 ppmw, there is a large deviation around the measured mean dynamic strength of 55 $\%_{mass}$, while for a 450 ppmw seed concentration the deviation around the higher mean value of 88 $\%_{mass}$ is much smaller. In fact at low seed concentrations, the melt droplets are subjected to complete or partial subcooling as they descend the tower. So, depending on the degree of subcooling the measured dynamic strength is not always the same and shows a relatively large deviation around a mean value. The prill subcooling can be significantly prevented at higher seed concentration of 450 ppmw such that a more uniform dynamic strength is obtained as shown in Fig. 2. In this case the mean dynamic strength of 88 $\%_{mass}$ is well above the recommended value of 85 $\%_{mass}$ [2] for the given operating condition.

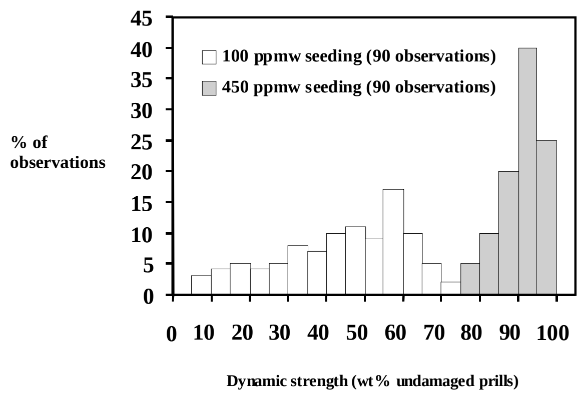

Fig. 2. Effect of seed concentration on the dynamic strength of urea prills at mean seed size of 20 μm.

Table 1. Ranges of run conditions for investigating the effect of seeding operation.

Run number	Seed concentration, ppmw	Seed size, μm
R1-R6	50, 100, 150, 200, 250, 300, 350, 400, 450	20
R7-R12	50, 100, 150, 200, 250, 300, 350, 400, 450	50
R13-R18	50, 100, 150, 200, 250, 300, 350, 400, 450	80
R19-R24	50, 100, 150, 200, 250, 300, 350, 400, 450	110
R25-R30	50, 100, 150, 200, 250, 300, 350, 400, 450	140

The effect of seeding concentration on the prill dynamic strength at different mean seed size is shown in Fig. 3. As shown the minimum dynamic strength is obtained when no seeding is performed. At a seed size of 20 μm, a threefold increase in seed concentration from 100 to 300 ppmw leads to a 42 % increase in prill dynamic strength. In fact the prill dynamic strength increases substantially with an increase in the number of successful collisions between seed crystals and the urea melt droplets. As shown, the mean seed size has also a considerable effect on the prill dynamic strength. According to this figure at a fixed seed concentration of 450 ppmw, the dynamic strength increases substantially from 40.8 $\%_{mass}$ to 87.5 $\%_{mass}$ as the mean seed size decreases from 140 μm to 20 μm. At a fixed seed rate, the number of seed particles increases as the mean seed size decreases. This leads to more effective collisions before complete solidification of prill external surface. Therefore the proper milling of urea seeds down to 20 μm before entering the tower is very useful such that the maximum dynamic strength is obtained with less urea seeds. According to this figure the maximum dynamic strength of urea prills can be obtained if a seed composition of 450 ppmw with the mean seed size of 20 μm is used for urea plant.

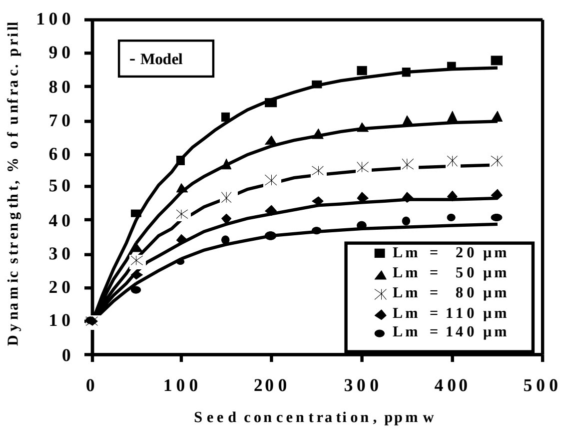

Fig. 3. Comparison of the measured and predicted urea dynamic strength at different operating conditions.

The trend of measured dynamic strength versus seeding concentration at a constant seed size shown in Fig. 3 can be well described by the following first order differential equation:

$$\frac{dD}{dS} = -k_1(D - D_f) \quad (1)$$

with boundary condition:

$D = D_o$ at $S = 0$, where

D = dynamic strength of prilled urea, $\%_{mass}$ of unfractured prills;

D_f = maximum theoretical dynamic strength at S = “ for a given L_m;

D_o= dynamic strength of prilled urea at no seeding condition;

k_1 = parameter in Eq. 1, $ppmw^{-1}$

S = seed concentration, ppmw.

It is assumed that at very high seed concentration, the D_f is just a function of L_m and can be written as:

$$\frac{dD_f}{dL_m} = -k_2(D_f - D_o) \quad (2)$$

with boundary condition $D_f = D_{fm}$ at $L_m = 0$, where

k_2 = parameter in Eq. 2, μm^{-1};

L_m = mean seed size, μm;

D_{fm} = maximum dynamic strength for $L_m = 0$, $\%_{mass}$ of unfractured prills.

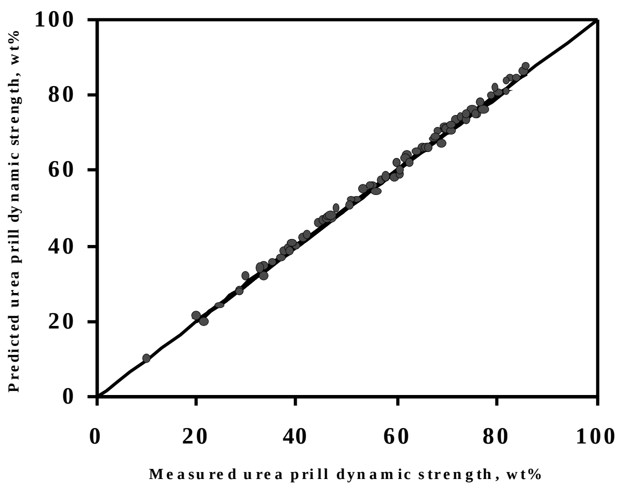

Fig. 4. Comparison of the predicted and measured urea prill dynamic strength.

The analytical solutions of Eqs. 1 and 2 can be written as follows:

$$\ln(1-\frac{D-D_o}{D_f-D_o})=-k_1S \quad (3)$$

$$\ln(\frac{D_f-D_o}{D_{fm}-D_o})=-k_2L_m \quad (4)$$

The parameters k_1 and k_2 determined by linear regression analysis of experimental data at 95 % confidence limits through Eqs. 3 and 4 are 0.01 ± 0.0003 and 0.008 ± 0.0001, respectively.

Combining Eqs. 3 and 4 it is:

$$\frac{D-D_o}{D_{fm}-D_o}=[1-\exp(-k_1S)]\exp(-k_2L_m) \quad (5)$$

For the present case, the values of parameters namely, D_o = 10 %, D_{fm} = 100 %, k_1 = 0.01 and k_2 = 0.008 can be used in Eq. 5 such that:

$$D=10+90[1-\exp(-0.01S)]\exp(-0.008L_m) \quad (6)$$

The predicted results according to Eq. 6 are within ± 2.2 % of the measured value as shown in Fig. 4.

CONCLUSIONS

The results of present investigation confirm that the dynamic strength of urea prills can be increased significantly by seeding operation. Experimental measurements suggest that the effect of seed concentration on the prill dynamic strength is more significant at lower seed sizes. Thus the proper operation of milling system to attain the seed size smaller than 50 μm is quite important. It is found that the maximum dynamic strength of 90 % well above the recommended value of 85 % could be obtained if a seed composition of 450 ppmw with the mean seed size of 20 μm is used for urea plant. A semiempirical correlation is also presented for description of the seeding operation. Comparison of the measured and predicted urea dynamic strength indicates that the trend of data is well described by the proposed approach.

Acknowledgements

The author would like to thank the National Petrochemical Company of Iran for providing the full financial support.

REFERENCES

1. Ullmann's Encyclopedia of Industrial Chemistry, 7th ed., John Wiley & Sons, 2005.
2. Stamicarbon Urea Symposium, Conference Proceedings, Netherlands, 1998.
3. D. Gerald, North American Fertilizer Capacity Data, Tennessee Valley Authority, USA, 2003.
4. A. Basit, Revamp experience of 1725 MTPD urea plant, IFA Technical Conference, Morocco, 1998.
5. B. ZareNezhad, Effects of Process Variables on the Caking Tendency of Prilled Urea in the Warehouse of Urea Production Plants, J. Univ. Chem. Technol. Met. (Sofia), **42**, 1, 2007.
6. Y.A. Ibrahim, Products Quality Improvement on Urea Prills, IFA Technical Conference, Hague, Netherlands, 1992.
7. AL. Shoals, North American Fertilizer Capacity Data, Tennessee Valley Authority, 1991.
8. B. ZareNezhad, Controlling the Rate of Caking in the Urea Warehouse, Research Report, National Petrochemical Company, Iran, 2003.
9. European Fertilizer Manufacturers Association, Production of Urea and Urea ammonium Nitrate, v. 5, 1997.
10. B. ZareNezhad, Static and Dynamic Strength of Prilled Urea in Petrochemical Plants, Research Report, NIOC, 2004.