Improvement ideas for Urea Reactor Internals

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Abstract
In order to increase the urea conversion in the urea reactor, we propose the following measures: Adding internal components, changing the material flow direction, increasing gas-liquid contact etc. In this way the back mixing is reduced and conversion ratio of CO_2 to urea is increased.

1. Introduction

The CO_2 conversion in a urea reactor is the key factor influencing all kind of consumption figures of a urea plant and stable running of a total recycle urea plant. To increase the CO_2 conversion, we did install swirl plates and perforated plates to increase the mixing degree of gas and liquid and decrease back mixing.

In the bottom-up flow process of a urea reactor, besides the rapid formation of ammonium carbamate a gradual dehydration to urea takes place. In this process, with the formation reaction of urea, the concentration mixture of urea and water increases, while concentration mixture of carbamate and ammonia liquid, gas, CO_2 decreases, thus, the upper material density is higher than that of the lower part. So there appears the situation where high density material sink relatively, and those low density material flow upwards relatively. This phenomenon is called back mixing of material, which causes that the products (urea and water) in the urea reactor decreases, the reaction driving force reduces, and the reaction rate of formation of urea from ammonium dehydration reduces. Meanwhile back mixing also causes that the unreacted material rises to the top of the tower, and this part of material stays only shortly in the reactor. So back mixing decreases the CO_2 conversion ratio of the urea synthesis reaction.

The upper density of material is higher than subjacent density, which is one of the main reasons for back mixing, and the way to solve this problem is to change the flow direction of material. The reason for designing the material to enter the reactor at the bottom part and to exit at the upper part is to boost adequately the mixing reaction of CO_2 gas and liquid phase. If the material enters at the upper part and get out at the subjacent part, there will appear several bad effects, that is to say, accumulation of CO_2 gas and inactive gas in the top of tower, dead ends, insufficient mixing, small liquid phase space. For this, the author gives the following suggestions:

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2. Add internal parts

We can change the flow direction of material by adding an internal part to reduce back mixing, as indicated in figure 1.

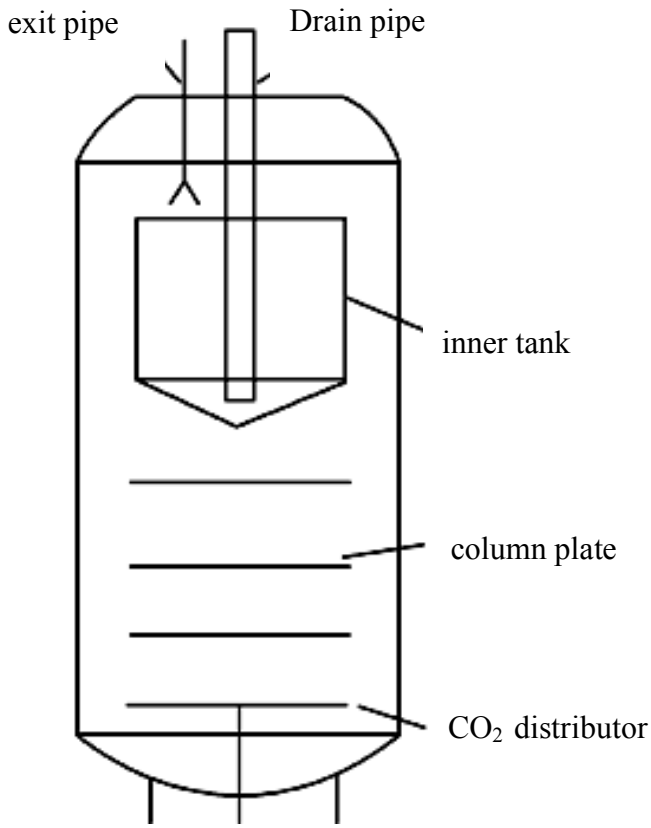

Figure 1: Urea reactor internals

The reaction rate of ammonium carbamate formation is comparatively quick, the factor deciding its reaction speed is the degree of gas-liquid mixing, the swirl plate at the lower part of the urea reactor can foster gas-liquid preliminary mixing, resulting in most of the ammonium carbamate formation. The perforated plates in the upper part reduce returning material above and below the plate and at the same time further promote the gas-liquid mixing and accelerate the residual carbamate formation reaction rate.

2. Add one CO_2 distributor

Like the gas distributor in the bottom part of the medium pressure absorption tower, it also can be imagined to let CO_2 enter the reactor dispersedly via a distributor (like figure 1), to form bubbles. At the beginning of CO_2 entry, make CO_2 mix with liquid phase as much as possible, increase the reaction speed, reduce the range of low temperature at the lower part of synthesis tower, speed up the reaction, and reduce or delete the swirl plate. Because of slow speed of material in tower, the swirl plate cannot bring very good mixing effect. As well as the function of CO_2 distributor, use perforated plate to replace swirl plate to boost gas-liquid mixture and decrease backmixing, and we can open more pores at the lower column plate.

3. Install inner tank at the upper part

As shown in Figure 1, the installation of a cylinder, half height of synthesis tower height, 1/3 volume of reactor. The spacing between inner cylinder and the wall of the column is of 100 mm, the cone-shape at the lower part is closed, and the lower part of discharging tube of synthesis tower (adding division plate to prevent foreign matter) is close to the conical bottom.

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After the material gets into the tower through the lower part, pass the column plates and then gets into the inner tank and annulus between the tower walls, and then get to the top of urea synthesis tower, where the ammonium carbamate formation reaction is mostly completed. The speed of material in annulus is faster than its original speed, a high degree of turbulence, mixing, urea conversion more complete, and back-mixing phenomenon decreases with the increase of the ratio of height to diameter. To let material in annulus get into the inner tank well-distributed, to avoid bias current at the top edge of the inner tank, one should try to locate the top of the inner tank as close as possible to the top of the tower to reduce the gas phase space that may appear, and we open eight semicircle orifice, radius 50mm, which all have the same horizontal level on the wall of top of the inner tank.

When material comes into the inner tank, ammonium carbamate formation reaction and residual gas CO_2 is not the main contradiction for increasing conversion ratio. After material getting into the inner cylinder, the reaction is mainly ammonium dehydration into urea reaction, and the material moves from top to bottom, with the dehydration reaction, the density of the material increases accordingly, when the material reaches the conical bottom of the inner parts, urea content is the highest, having the maximum density. As the density of material is big at the lower part and small at the upper part, back mixing will be less. In addition to unreacted material with low density, slow speed flowing downward, these also lengthen time of staying in the tower and are helpful to increase the CO_2 conversion ratio. The function of bell mouth is not only to reduce waste of the material at the lower part of the inner parts[1], but also to avoid appearing dead zones above or under the inner parts.
Material is lead out through drainpipe and the bottom of the inner parts.
According to experience, the temperature of material in tower increases gradually, the reason in theory is that, urea and water generated make the boiling point increase[2], lower saturation vapor pressure of material in tower, vapor liquefied into ammonia, ammonium, and heat release of ammonia gas liquefaction and ammonium carbamate formation reaction are more than absorption of heat of urea formation reaction, resulting in material temperature gradually increased. Materials inside the cylinder flow downward, gas stagnation in the upper part, so during the flow and reaction, temperature will be lower, so we can control temperature of top of inner tank as the highest temperature of urea tower, in order to improve the dehydration reaction speed.

4. Install exit pipe at the top of tower

Accumulation of inert gas is a question worthy of consideration. At the upper part of the inner part, the inert gas in material can overflow and accumulate, even if the content is small and some can be brought out of the tower though discharge pipe as it can dissolve into the liquid phase under high pressure, however the accumulation is inevitable. Gaseous inert phase leads to a decrease of the level of the inner part, and the availability of capacity of urea synthesis tower decreases. We can install an escape-pipe at the top of tower, taking the statistics measured by radioactive level gauge installed at the upper part of urea synthesis tower, as parameter, to discharge inert gas through the adjusting valve of escape-pipe to adjust the level of synthesis tower automatically. We can discharge the gas into the middle pressure or the tail gas absorption tower according to its composition.

Translator notes:
This is a Technical Paper originating from our Chinese partner: www.Ureanet.cn. The paper was original in Chinese language and it is translated and interpreted into English with care and as much as reasonable possible accuracy, all to the best of our abilities

[1] Not clear what is meant from the original translation
[2] Original translation mentions decrease