A single solution to the four challenges facing your urea prilling plant

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Summary

Most of the urea plants in the world operate a prill tower; the majority are now several decades old and their capacities have increased by creep to some 120 to 130% of their original design capacity. These plants typically face several problems or challenges: high ammonia and dust emissions from the prilling tower, low prill quality, competition from granules in the market and demand from farmers for additional nutrients for their crops. The solution to all four challenges in one step is the Sandvik Process Systems Rotoformer. This paper explains how the system meets these challenges and also outlines a number of additional benefits.

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1. Introduction

Most of the urea plants in the world operate a prill tower and the majority of these plants are now several decades old and their capacities have increased by creep to some 120 to 130% of their original design capacity. These plants typically are facing several problems or, shall we say, challenges: high ammonia and dust emissions from the prilling tower, low prill quality, market competition from granules and the growing realization by farmers that their crops needs additional nutrients. The solution to all four of these challenges is the Sandvik Process Systems Rotoformer. This paper explains how, and also outlines a number of additional benefits.
2. Existing challenges

2.1 High emissions

In prilling towers the urea melt falls down inside a concrete structure, cooling and crystallizing against a large quantity of upward-moving air. In some prilling towers this air flow is created using fans; in others natural draft is used. However while the draft is created, the air becomes loaded with urea dust particles and ammonia, and is typically emitted into the atmosphere from the top of the prilling tower.

In some cases a dust scrubber is installed on top of or alongside the prilling tower to reduce the urea dust emissions. In a limited number of cases, the dust scrubber is combined with an acid washer to reduce the ammonia emissions. These scrubber systems are only feasible in so-called forced draft prilling towers, where air fans are available. Scrubber systems are not feasible in natural draft prilling towers as the pressure drop over the scrubbers is too high.

The absolute amounts of urea dust and ammonia emissions are directly related to the load on the prilling tower; there exists a linear relation.[1] The relative emission figures can be influenced by the air flow, but one should realize it is not a solution but a dilution of the problem.

2.2 Low prill quality

Increasing the load on a prilling tower can have negative consequences for the prill quality. Higher moisture contents and higher temperatures cause more dust formation and an increased likelihood of caking problems.[2]
Picture 2a/b/c: Different examples of caking of urea prills

Caking can be so severe that the product becomes damaged when it is loaded on trucks or cars. Part of the product will be lost and complaints from customers may follow. So measures need to be taken.
2.3 Competition from granules

The quality of prills is significantly less than that of granules, the main difference being the lower strength and smaller size of prills. Research has shown that once a farmer has used granules, he will not choose prills again, unless the price is lower. Most new urea plants are large scale granulation plants and are located in low feedstock areas; these plants are export driven and will compete – or will compete – with your prills.

2.4 From bulk to specialty products

Your plant is several decades old and is located inland. You have built up a strong relationship with your customers. Your competitors offer their products for a lower price, which they can do as their feedstock costs are very low. To compete on price is very difficult as your plant capacity is lower and your feedstock costs higher.

However your strong relation with your customers is your competitive advantage. More and more farmers are starting to realize that their crop needs more nutrients than just nitrogen (N). Other Primary Macro Nutrients plants need to take in are Phosphates (P) and Potassium (K); others – Carbon (C), Oxygen (O) and Hydrogen (H) – are available through air (via the photosynthesis process) and water. Then there are the Secondary Macro Nutrients Calcium (Ca), Magnesium (Mg) and Sulphur (S) and the Micro Nutrients Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Zinc (Zn), Chloride(Cl), Nickel (Ni), and Molybdenum (Mo), which are also essential for plant growth but required in much smaller quantities. Finally Silicon (Si) and Cobalt (Co) are also beneficial for some plants in even smaller quantities. A deficiency of any single nutrient is enough to limit growth as is indicated in the pictures below.

Figure 1A/B: A plant needs many different nutrients. A deficiency of any single nutrient is enough to limit growth
In general, Nitrogen application efficiencies are very low as between 30 and 50% of the nitrogen supplied to the soil is typically lost to air and water, causing more and more environmental problems. In Canada, for example, urea has become the broadcast fertilizer of choice for many winter wheat growers on the Canadian Prairies, especially since ammonia nitrate fertilizer was removed from the market. The problem, though, with surface applications of urea is that the N is susceptible to ammonia volatilization. The urea molecule, in the presence of moisture and the soil enzyme urease, converts to ammonium carbonate, which can lead to the production of ammonia gas.

![Diagram of nutrient inputs and outputs](image)

**Figure 2: Typically between 30 and 50% of the urea applied is lost to air and water**

Adding slow release substances to your urea prills contributes to higher efficiencies, resulting in less environmental problems and fewer fertilizer product lost and wasted.

Producing specialty fertilizer products based on urea therefore fulfills the need of your customer; these are considered to be higher value products attracting a higher price. The close relationship you have with your customers gives you the competitive advantage and opportunity to produce and sell higher margin specialty products.
3. The solution

The solution to all four of these challenges is the Sandvik Process Systems Rotoformer. Let us explain how.
The figure below shows the flow scheme of the Rotoformer technology.

Figure 3: Sandvik Rotoform pastillation process for urea

The feed to the Rotoform is urea melt with a concentration of 99.6 wt% and in existing urea plants can be branched off from the urea evaporation section downstream of the urea melt pumps.
Urea is introduced under pressure (2-3 barg) in molten form to the drop former. The Rotoform HS (High Speed) drop former, patented by Sandvik, consists of a heated stator and a perforated rotating shell that turns concentrically around the stator to deposit drops of urea across the full width of the belt. The circumferential speed of the Rotoformer is synchronized with the speed of the steel belt cooler ensuring that the drops are deposited on the belt without deformation and, after solidification, results in regular pastilles with an optimum shape.
The rotating shell contains rows of small holes which are sized to deliver the required product size. The heat released during crystallization and cooling is transferred by the stainless steel belt to the cooling water. The cooling water is sprayed against the belt underside, absorbs the heat and is collected in pans, cooled in a cooling system (cooling tower) and returned to the Rotoform units.

Under no circumstances can the cooling water come into contact with the urea product.

The use of formaldehyde is not necessary in this technology to realize pastilles with a high crushing strength. The pastilles are very uniform and additional screening is not needed.

After solidification the pastilles are smoothly released from the steel belt via an oscillating scraper. The product then falls directly onto a conveyor belt for transfer to storage. The section above the moving steel belt is enclosed with a hood and vented to an existing vent system.
There are no large air flows involved in this technology and there is no visible urea dust emission. What ammonia vapors are produced can easily be captured in a simple atmospheric absorber; this results in negligible emissions of ammonia and urea, a unique feature of this technology.

Picture 6: Rotoform skid mounted equipment showing the hood which captures any ammonia and dust emissions
By installing one or more Rotoformer lines in parallel with your prilling tower, the load on your prilling tower will be reduced, leading to lower ammonia and urea dust emissions from your prilling tower and a higher prill quality. For example, when you reduce the load on the prilling tower from 1300 to 1000 mtpd by installing two Rotoformer lines in parallel, the ammonia and dust emission figures reduce by some 23% (300/1300).

Let’s show an imaginative but realistic example how the switch from prills can take place.

The figure on the left side shows the production capacity of a typical urea plant over time. The plant has a design capacity of 1000 mtpd prills and during its first years will be able to increase its actual production to some 1300 mtpd prills, typically by making use of the design margins and by creep debottlenecking technologies. Dust and ammonia emissions from the prilling tower will increase in line with the increase in production as these are linear related.

Figure 5: Production capacity of prills (red) and pastilles (blue) in mtpd versus the age of the plant in years.
So, as plant capacity increases from 1000 mtpd to 1300 mtpd, dust emissions will increase from 100 mg/Nm³ to 130 mg/Nm³ and ammonia emissions from 80 mg/Nm³ to 104 mg/Nm³, as can be seen on the figure on the left. When pastilles are produced the load on the prilling tower will be reduced, as will the dust and ammonia emission figures. In this way one can reach emission figures which are acceptable to local governmental regulations.

Furthermore, while the load on the prilling tower decreases, the prill quality increases. The figure on the left shows that for example after start up of the plant the prill quality was considered good. After increasing the load on the plant and prilling tower the prill quality became problematic. Too much dust, high moisture content, high prill temperatures, low strength and caking troubled the production and sales of the prills. As pastille production reduced the load on the prill tower, the prill quality became good and even excellent again.

Finally if you operate a forced draft prilling tower, the power consumption per ton of urea will reduce by about 9 kWh/mt as the Rotoformer consumes less power than a forced draft prilling tower.

The quality of the pastilles is better than the quality of prills. It is similar and in some aspects even better than the quality of granules. Table 1 provides an overview of the product properties of prills, granules and pastilles.
Table 1: Typical properties prills, granules and pastilles

<table>
<thead>
<tr>
<th></th>
<th>Prills</th>
<th>Granules</th>
<th>Pastilles</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average diameter</td>
<td>1.5…1.9</td>
<td>2…4</td>
<td>2…5</td>
<td>mm</td>
</tr>
<tr>
<td>between</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>0.15-0.30</td>
<td>0.10</td>
<td>0.10</td>
<td>wt%</td>
</tr>
<tr>
<td>Formaldehyde content</td>
<td>0.1-0.3</td>
<td>0.3-0.55</td>
<td>Only when required</td>
<td>wt%</td>
</tr>
<tr>
<td>(in case of export)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>Round with hole</td>
<td>Round</td>
<td>Hamburger</td>
<td></td>
</tr>
<tr>
<td>Crushing strength</td>
<td>12 (1.7 mm)</td>
<td>40 (3 mm)</td>
<td>40-75 (3 mm)</td>
<td>N</td>
</tr>
<tr>
<td>Product temperature</td>
<td>60-80</td>
<td>50-60</td>
<td>40-45</td>
<td>°C</td>
</tr>
</tbody>
</table>

From Table 1 one can conclude that granules and pastilles have some significant advantages over prills: Granules and pastilles can be produced with larger average diameter (which can be specified over a relatively wide range) and are significantly stronger than prills.

For example the strength is similar to the strength of granules even without any formaldehyde. The size of the Rotoformer product is same as for granules, moreover the size can be easily varied between 1 and 5 mm. The pastilles are extremely uniform, even more than granules. It goes without saying that the Rotoformer product quality is significant better than prills. And farmers who have applied the pastilles were very satisfied and were prepared to pay a premium price above prills.

**Picture 8: Farmers prefer pastilles to prills**

With a Rotoformer line, which has a typical capacity of some 130-140 mtpd, it is possible to produce all kinds of specialty urea products in addition to fertilizer grade urea.
The following products have been already produced with a Rotoformer:
- Fertilizer grade urea
- Technical urea for urea-formaldehyde, melamine, ad blue production
- Urea blended with Macro nutrients
- Urea blended with Micro nutrients
- Urea with Ammonium Sulphate
- Ammonium Nitrate
- Ammonium Nitrate derivatives (KCl, Zeolite, AS < 10% and NPK)
- NPK Complex fertilizer from Nitrate & UREA route
- Calcium Nitrate
- Magnesium Nitrate
- Sulphur Bentonite

Please find below the reference list of the Rotoformer technology for urea and fertilizer products

**Table 2: Rotoformer reference list**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PLANT CAPACITY</th>
<th>COMPANY/LOCATION</th>
<th>STATUS</th>
<th>PRODUCT/APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1 Flaker</td>
<td>KEMIRA / Dubai</td>
<td>in operation</td>
<td>Urea + phosphates Fertilizer</td>
</tr>
<tr>
<td>2000</td>
<td>1 Rotoformer</td>
<td>ESSECO / Italy</td>
<td>in operation</td>
<td>Sulphur Bentonite / Fertilizer</td>
</tr>
<tr>
<td>2002</td>
<td>1 Rotoformer</td>
<td>Coogee / AUSTRALIA</td>
<td>in operation</td>
<td>Sulphur Bentonite / Fertilizer</td>
</tr>
<tr>
<td>2004</td>
<td>Pilot unit,</td>
<td>PCS / Tennessee USA</td>
<td>in operation</td>
<td>Fertilizer urea / technical urea</td>
</tr>
<tr>
<td>2005</td>
<td>1 Rotoformer</td>
<td>Coromandel / India</td>
<td>in operation</td>
<td>Sulphur Bentonite / Fertilizer</td>
</tr>
<tr>
<td>Year</td>
<td>Location and Capacity</td>
<td>Additives</td>
<td>Status</td>
<td>Notes</td>
</tr>
<tr>
<td>------</td>
<td>-----------------------</td>
<td>-----------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td>2006</td>
<td>PCS / Georgia USA (300 MTPD)</td>
<td>Technical grade urea</td>
<td>in operation</td>
<td></td>
</tr>
<tr>
<td>2006 till 2009</td>
<td>Zlotniki / Poland (240 MTPD)</td>
<td>Mg-N + CaN / Fertilizer</td>
<td>in operation</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Pilot production unit (125 MTPD)</td>
<td>Urea +10%S; fertilizer urea</td>
<td>Pilot Production</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>ACRON / Velikiy Novgorod / Russia (120 MTPD)</td>
<td>Technical and fertilizer urea</td>
<td>in operation</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Petrobras Sergipe / Brazil (1 Pilot Rotoformer unit + dosing + mixing &amp; grinding)</td>
<td>Urea + additives for urea based fertilizers</td>
<td>under construction</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>AZOMURES Romania (Rotoformer unit + mixing and grinding 200 MTPD)</td>
<td>Ammonium Nitrate with ingredients for fertilizer</td>
<td>under construction</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>AZOMURES Romania (Rotoformer unit + dosing &amp; mixing &amp; grinding 200 MTPD)</td>
<td>NPK with ingredients for fertilizer</td>
<td>under construction</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>SABIC Al Bayroni / KSA (2 Rotoformers 240 MTPD + down stream)</td>
<td>Technical grade urea</td>
<td>under construction</td>
<td></td>
</tr>
</tbody>
</table>

The production process of these specialty urea products is fairly simple and straightforward. In some cases one simply injects a liquid additive in the urea melt, in other cases a blending unit is applied to grind and mix the solid additives in the urea melt.

For example, for urea plus Ammonium Sulphate (AS), urea melt and solid AS are mixed and grinded in two steps in a blending unit, which is a standard packaged unit. Up to 40% wt. AS has been mixed with urea with excellent results.
Figure 8: Flow scheme to produce urea+AS

Picture 9: Blending unit to produce urea/AS
The introduction of specialty urea products can be realized smoothly as one can begin with a single Rotoformer line, which can be brought into and out of production whenever required. When market demand increases, additional lines can be installed in parallel. The pictures below show various specialty urea products.

![Fertilizer urea](image1)
![Urea + sulphur](image2)
![Urea + AS](image3)
![Urea micro nutrients](image4)

**Picture 10a/b/c/d/: Specialty urea products produced with the Rotoformer**

The press release from Aditya Birla Nuvo Limited in India illustrates perfectly the above reasoning.

**ABNL to benefit from higher neem-coated urea provision**

*Feb 13, 2011: Aditya Birla Nuvo Limited (ABNL) has said that its urea business (Indo Gulf Fertilisers division) would benefit from recent liberalization in the production of neem coated urea. In a presentation on its Q3 2010-11 results, the multi-sector company said: “Department of Fertilisers increased the ceiling for Neem Coated Urea from 20% of total production to 35% of total production from January, 2011. Business to benefit from additional production of this value added urea.”*  

The agri-inputs business that largely comprises the fertiliser division boosted its sales by 26% to Rs 347 crore in the third quarter (October-December 2010) of current fiscal from Rs 276 crore in the corresponding period of previous year.

Some other recent quotes:

**IFA says improving micronutrients deficiency can have dramatic impact**

*Feb 16, 2011: The International Fertilizer Industry Association (IFA) has issued a brief highlighting the critical importance of solving the problem of micronutrient malnutrition through both application of micronutrient fertilizers and breeding of micronutrient-fortified crops.*

**Arab Fertilizers, Issue. 58, 2011, Sulphur in crop production in Pakistan, M. Ehsan Akhtar and Ghulam Nabi**

*Similar multi-location experiments were also conducted by NARC on sunflower and brassica n S-deficient oils. The crop response to applied S was up to 10 per cent (Rehmatullah,1992).*


*Zinc has emerged as the most important micronutrient deficient in soils of several countries of the world. About 50% soil samples analysed for available Zn were found deficient in 25 countries including India. A good response to In application has been reported for several crops from all over India. The factors responsible for increase of incidences of Zn deficiency include large Zn removals due to high crop yields and intensive cropping systems, lesser application of organic manures, use of high analysis fertilisers such as urea and DAP in place of ammonium sulphate and single superphosphate, increased*
use of phosphate fertilisers resulting in P-induced Zn deficiency and the use of poor quality irrigation without adequate drainage.

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4. 2010 04 Baeder SPS UreaKnowHow.com Rotoformer applications
5. IFA website