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EFFECT OF $NH_4NO_3.K_2SO_4$ PARTICLE SIZE ON GRANULATION EFFICIENCY IN PRODUCTION OF NPKS USING THE PIPE REACTOR PROCESS

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RESUME

L'effet de la répartition granulométrique de $NH_4NO_3.K_2SO_4$ sur le rendement de granulation d'engrais NPK par le procédé au réacteur tubulaire. Ceci conduit à la conclusion que la répartition granulométrique de NH_4NO_3 n'a rien à faire avec le rendement de granulation, mais la granulation de K_2SO_4 a un effet important sur le contrôle de la production. Cela fournit une analyse théorique sur le point de la théorie de la granulométrie. C'est important pour la conduite de la production d'engrais NPK.

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1. INTRODUCTION

In 1975-1976, TVA of USA invented a cross pipe reactor for application in NPK slurry granulation process. On this basis, French « Société Chimique de la Grande Paroisse - AZF » dual pipe reactor process used in production of DAP, NPK compound fertilizers overcomes the shortcoming of TVA pipe reactor of easy clogging by deposit in the short production cycle [1,2].

In the pipe reactor process, the melting slurry formed by the chemical reactor heat from NH_3, H_3PO_4 and H_2SO_4 reaction is directly used for granulation. The large quantity of chemical reaction heat produced from violent chemical reaction vaporizes the water in the reactor, which is exhausted from the outlet of the reactor to the tail gas of the granulator. When the slurry is fed to the rotating fertilizer bed, the water is vaporized from the product granules. Due to this melting slurry granulation feature, the particle distribution of the raw materials added has very big effects on the granulation in the NPK production.

2. GRANULATION MECHANISM

The melting slurry granulation is always wet granulation. When NPK is produced, the solid phase is the recycled fertilizers along with others such as NH_4NO_3, K_2SO_4, etc. At beginning, the raw materials fed into granulation are loose fine particles. These fine particles become the cores of granules as the granulator rotates. The driving forces making the fine particles to become the core of granulation is the surface tension of the liquid phase, reduction of the total surface free energy of material system and decreasing of the boundary surface between vapor and liquid phases. The particle size changes in many ways after the core is formed. The factors relating to these processes are:

1. The particle size and the other properties of added solid materials.
2. Surface tension and stickiness, etc. of liquid phase.
3. The way of production (continuous or intermittent).

Once the core is formed, the granules for the product grow up in the following ways:

1. Adhesion granulation where the melting slurry aggregates small particles into one.
2. Coating granulation: melting slurry is coated evenly on the surface of the solid particles, water vaporizes quickly. After the granule is crystallized, another coating is put on. This process is repeated again and again and granules grow up gradually.
3. Self-granulation: while being sprayed, small slurry drops dry out before touching solid particles and form granules automatically.

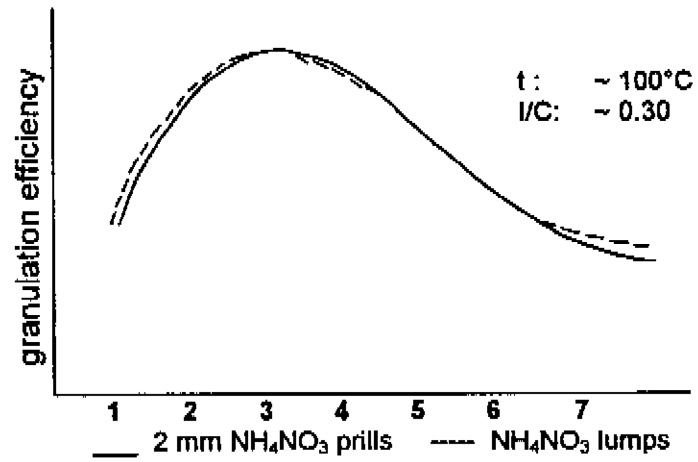
In granulation process, adhesive granulation and coating granulation co-exist and play the leading function. When the particle size distribution range of fresh raw materials such as K_2SO_4, KCl, filler, etc. added is narrow the relative surface area is large. In this case, coating granulation and adhesive granulation occurs easily.

The granules produced are hard and not easy to break. On the contrary, when the range of particle size of solid materials added is wide (bigger portion is in 1 mm and more), due to less capillary force and smaller relative surface area, there is a lot of opportunities of adhesive and coating granulation. However, as the granulator rotates, the strikes between the granules as well as vaporization of water inside granules cause the loose ones to be broken. As a consequence, granulation efficiency will be low.

3. EFFECT OF RAW MATERIAL PARTICLE SIZE ON GRANULATION EFFICIENCY

As mentioned above, the key factors affecting the change of granule size are the particle size of solid materials added to the granulator and their properties, the surface of tension of liquid phase, stickiness of slurry and the way of production. For the AZF dual pipe reactor system, when the product grade (such as NPK 15-15-15 SOP) is fixed, the property of the liquid phase and the way of production are also fixed. In this case, the particle size of solid materials added would play a very important role to granulation ratio at the outlet of the granulator. When NPK 15-15-15s is produced, the solid phase fed to the granulator are NH_4SO_3, K_2SO_4 and recycled fertilizer. The liquid salt in the granulator are the scrubbing liquid (about 40% of water) and the reaction products of H_3PO_4, NH_3 and H_2SO_4. However, production practice proves that the particle size of NH_4NO_3 has no effect on granulation efficiency. The key factor affecting granulation efficiency is the particle size of K_2SO_4, as shown in Figure 1.

Figure 1 - Average dia. of particle dg/mm - Effect of NH_4NO_3 particles size on granulation efficiency



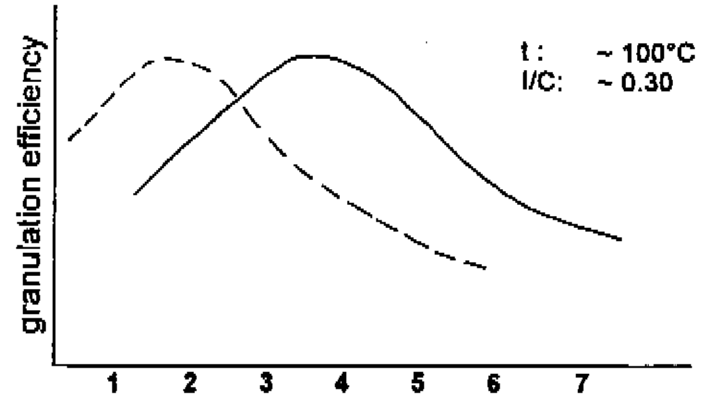
The cause of this phenomenon is the difference of the physical properties between NH_4NO_3 and K_2SO_4. Their physical properties are shown in Table 1.

Table 1 - Physical properties of NH_4NO_3 and K_2SO_4

	NH_4NO_3	K_2SO_4
% Critical relative humidity (30°C)	59.4	96.3
Solubility (120°C)/kg.kg H_2O^{-1}	8.71	0.24
Melting temperature/°C	169.4	

From Table 1, we can see that under the same condition, NH_4NO_3 absorbs much more water than K_2SO_4, and the solubility of NH_4NO_3 is very high. In process of granulation, NH_4NO_3 is dissolved and becomes liquid phase as soon as it is in contact with water from the pipe reactor and fertilizer bed.

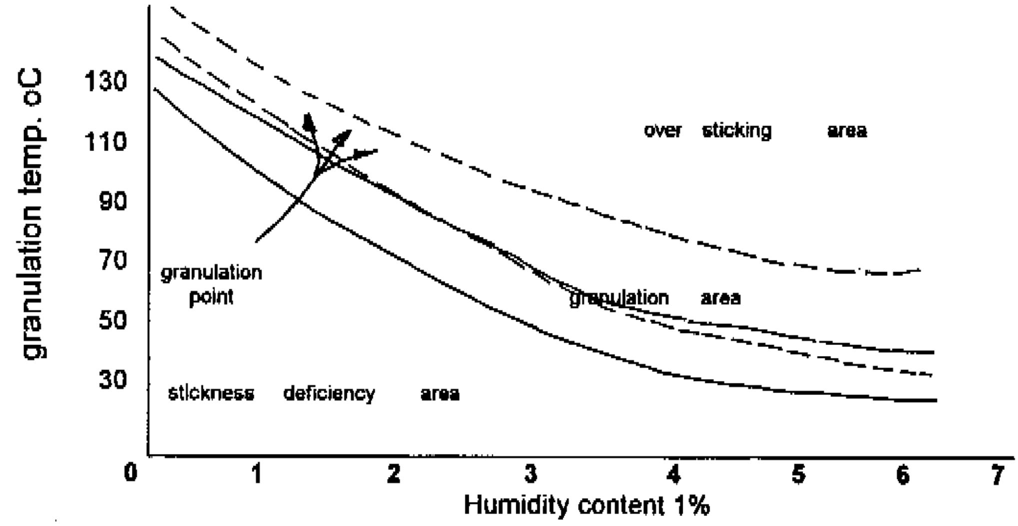
Figure 2 - Average dia. of particle dg/mm - Effect of K_2SO_4 particle size on granulation efficiency



__ K_2SO_4 particle size distribution:	> 1 mm	0.2%
	1 ~ 0.1 mm	97.4%
	< 0.1 mm	2.4%
— K_2SO_4 particle size distribution:	> 1 mm	42.5%
	1 ~ 0.1 mm	55.5%
	< 0.1 mm	2.3%

The particle size of NH_4NO_3 affects only its dissolving speed, not granulation efficiency. The solubility and water absorption ability of K_2SO_4 are weak. When fed into the granulator, it coats or sticks on the surface of granules by means of stickiness of the liquid phase. If the ratio of coarse particles is higher, the tendency of sticking with granules will be weak, only a little of the particles can coat on to the granules. Even if it sticks with other granules, if not being coated on time, the stiffness of the formed granules will be low. It will be broken easily in the subsequent events such as striking and drying. As a consequence, the qualified granules at the outlet of the granulator will be less, which results in changing of granulation curves and make the granulation point moving away from granulation are into sticking deficiency area, see Figure 3.

Figure 3 - Granulation area moving



___ granulation area —— new granulation area

In production, if the problem as mentioned above occurs and not being regulated on time, it will become a vicious circle. The consequences are as follows:

1. K_2O content in product fluctuates greatly, which causes fluctuation of N, P_2O_5 contents and production quality goes out of control.

2. The quantity of recycled materials will increase continuously due to low granulation efficiency, which will cause production system out of control. Consequently, production has to be stopped.

3. Due to increase of recycled materials, the fine powder in the system increases, which, in tum, increases the load of the subsequent process. It makes temperature of recycled materials decrease. The dedusting system and chute will be blocked easily.

According to Figure 3, the only way to solve above mentioned problem is to try to move the granulation point to a new granulation area so as to establish a new granulation balance. There are three means to achieve the objective:

1. To increase the quantity of liquid fed into system, i.e. to increase the ratio between liquid and solids.
2. To increase the quantity of steam fed to the system so as to raise up the temperature of the system and to increase liquid-solid-ratio.
3. If possible, to change product formulation for increasing reaction heat, and/or to increase the load of hot air system.

However, NPK granulation is a complicated process, in practical production, sometimes due to limitation of the existing system itself, the means as mentioned above cannot be used at our will. Even if applied, the result is not as obvious as expected. We must make general consideration on mass balance and heat balance of the whole system, so, it becomes very important to control the particle size distribution of the K_2SO_4 (or KCl) and fillers at the time of raw material purchase.

4. CONCLUSION

From the above theoretical analysis and our practical experience, the conclusion drawn is as follows:

In NPK production, the particle distribution of K_2SO_4 is a key factor for granulation control; whereas the effect of the particle size of NH_4NO_3 is insignificant. The ideal physical property of K_2SO_4 is:

content:	K_2O 50%
particle size:	(free flowing, nature)
less than 1 mm:	≥ 98%
less than 0.1 mm:	≤ 5%
bulk density:	1.30 t/m^3

REFERENCE

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