3D Nanostructured Porous Layer of Ammonium Nitrate: Influence of the Moisturizing Method on the Layer's Structure

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The paper deals with the influence of humidifier type and humidification method on structure and quality of porous surface layer of ammonium nitrate granules. Different types of humidifiers are propose and the qualitative characteristics of porous ammonium nitrate for each of them are shown. The structure and quality parameters of porous ammonium nitrate with different mutual direction of movement of granules and humidifier. A method for granules pre-wetting with its heat treatment in vortex granulator is proposed. Obtained data are basis for technique of vortex granulators engineering calculation consisting units of 3-D nanostructured porous surface layer on granule ammonium nitrate obtaining.

Keywords: 3D Nanostructured porous layer, Vortex granulator, Voisturizing

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1. INTRODUCTION

In world practice bulk industrial explosives are mostly manufactured using the special porous ammonium nitrate (PAN) [1-3]. Bulk industrial explosives are widely adopted in blasting operations to replace more dangerous and expensive trinitrotoluene containing industrial explosives. PAN provides a more complete chemical reactions during the explosion due to the greater (compared with an ordinary ammonium nitrate) surface contact with the diesel fuel. With nano-sized porous structure creation on surface and inside of PAN granules it becomes possible to hold diesel fuel (diesel fuel molecule size is 4 nm). Pore system of curvilinear channels can saturate PAN granule diesel fuel in an amount which is sufficient for successful blasting.

PAN is also the base of emulsion industry explosives [4-7].

At present introduction of PAN in production of blasting is limited by lack in Ukraine its own production (up to 80% PAN are purchased in Russia).

The use of vortex granulators for PAN obtaining as a component of industrial explosives such as ANFO (Ammonium Nitrate / Fuel Oil) is a new direction in granulation technology [8]. A distinctive feature of vortex granulators is their versatility, which allows to receive PAN in various ways:

– heat treatment and hydration of granules directly into the granulator;
– preliminary humidification in a separate unit and heat treatment in vortex granulator.

Theoretical description and experimental study of some aspects of granulation in vortex granulators is given in a list of works, which describe the hydrodynamics of flows traffic [9, 10], granules classification and separation processes [11], environmental aspects of development unit of utilizing modules for production waste [12-14], hydrodynamic and thermodynamic conditions for PAN obtaining [15, 16].

2. DESCRIPTION OF OBJECT AND METHODS OF RESEARCH
3. RESULTS AND DISCUSSIONS

Comparative characteristics of granules surface structure is presented in fig. 2.

Experimental studies highlight in the structure of ammonium nitrate granules such types of pores [15]:
- cracks;
- chips;
- caverns;
- channels.

Regardless of humidification method on granule’s surface typical sectors, that are shown in fig.3, are formed. The ratio between the areas of these sectors for each humidification method is different. The more uniform the initial contact of granules with a humidifier, the smaller nonporous surface area and a large surface area with deep pores.

Fig. 2 – The structure of ammonium nitrate granules: a – surface layer of dry granule (ammonium nitrate before humidification); b – surface layer of granule after humidification and heat treatment; c – granule after humidification and heat treatment with diesel fuel at surface and in pores.

Table 1 – Effect of humidification method on granule’s structure and quality (humectant – water, thermodynamic and hydrodynamic characteristics of granulator operation according to [8])

<table>
<thead>
<tr>
<th>Humidification method</th>
<th>Strength, kg / granule</th>
<th>Absorption capacity, %</th>
<th>Holding capacity, %</th>
<th>Relative area of porous surface, %</th>
<th>Relative depth of porous layer, the layer depth mm / radius granule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidifier dispersing in granulator:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– top supply in device center</td>
<td>0,45</td>
<td>7,9</td>
<td>6,2</td>
<td>68</td>
<td>0,1-0,15</td>
</tr>
<tr>
<td>– top supply of humidifier in peripheral areas (directly on surface of vortex fluidized bed)</td>
<td>0,45</td>
<td>8</td>
<td>6,5</td>
<td>74</td>
<td>0,1-0,15</td>
</tr>
<tr>
<td>– horizontal supply in fluidized bed</td>
<td>0,43</td>
<td>8,1</td>
<td>7,3</td>
<td>79</td>
<td>0,15-0,25</td>
</tr>
<tr>
<td>– bottom supply in device center</td>
<td>0,43</td>
<td>8,1</td>
<td>6,8</td>
<td>72</td>
<td>0,1-0,2</td>
</tr>
<tr>
<td>– bottom supply in peripheral areas (directly on surface of vortex fluidized bed)</td>
<td>0,4</td>
<td>8,2</td>
<td>8,1</td>
<td>84</td>
<td>0,2-0,3</td>
</tr>
<tr>
<td>Pre-wetting by methods [17, 18]</td>
<td>0,4</td>
<td>8,3</td>
<td>9,6</td>
<td>91</td>
<td>0,3-0,4</td>
</tr>
</tbody>
</table>

In top humidifier supply of humidifier in peripheral areas of device granule’s contact evenness with liquid increases and nanoscale porous areas, formed on the surface and within the granules, appears. These areas have mixed structure: pores are combined with small cracks that were formed due the partial excess moisture on granule’s surface.

When horizontal supply of humidifier in granule’s fluidized bed and lower supply of humidifier to device’s center nanoscale porous layer has prevailing spread on granule’s surface and inside it. In this case the pores are located only on surface, the structure is

![Image](image-url)
dominated by straight channels granules (fig. 5), which don’t hold effectively diesel fuel.

When bottom supply of humidifier in granulator’s peripheral areas relative nanoscale porous layer is increased compared with other methods of humidifier supplying. In this case the pores in nanoscale layer have small depth, which reduces the ability to retain granules diesel. In the porous layer structure curved channels begin to appear (fig. 6).

Analysis of obtained research results allowed us to offer new ways to produce granules with porous structure [17, 18], which allows to reduce the influence of destabilizing factors on formation of nano-sized porous surface layer. In the base of developed improved granules humidification process methods with predetermined amount of moisture before it enters the vortex weighted layer and the beginning of exposure to high temperature vortex flow of coolant. This solution allows the simultaneous occurrence of drying and pore formation process, helps to reduce granules residence time in the fluidized bed to necessary minimum and granules strength increasing without destroying the internal crystalline structure.

If the granulators constriction has an element for granules humidification before entering in the working chamber via the latter conditions for uniform application of liquid material onto the granules surface. The granules that are moistened in this manner, has deep pores, high relative surface porous. In structure of porous layer curved channels are dominated, which increase granules ability to hold diesel fuel.

The results of studies concerning the influence the humidifier type to granule’s quality are given in Table 2. These results show that at almost equal value absorption capacity is depending on humidifier type, the granules have different holding capacity. This can be explained by the fact that different humidifier types are base for formation of various pores types with straight or tortuous channels. This conclusion can be taken as a starting assumption for further study nanoscale porous layer structure in different humidifiers types.

The granules absorption capacity is caused by pore’s characteristics and size, the holding capacity is caused by grain size and degree of their destruction. The research results also show that the humidifier type affects only to the absorption and holding capacity of granules. Strength of granules depends upon the granulator thermodynamic operation mode and granules drying time.

Microstructure and granulometric structure analysis of granules with porous surface layer showed that the increase the holding capacity value occurs only due to formation of developed pore structure and not due to expense of granules destruction.
Table 2 – The influence of humidifier type on granules quality (pre-wetting by method [17, 18], thermodynamic and hydrodynamic characteristics of granulator operation – according to [8])

<table>
<thead>
<tr>
<th>Type of humidifier</th>
<th>Strength, kg/ granule</th>
<th>Absorption capacity, %</th>
<th>Holding capacity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.4</td>
<td>8.3</td>
<td>9.6</td>
</tr>
<tr>
<td>Solution of ammonium nitrate</td>
<td>0.4</td>
<td>8.4</td>
<td>10.1</td>
</tr>
<tr>
<td>Solution of ammonium nitrate and carbamide</td>
<td>0.4</td>
<td>8.5</td>
<td>11</td>
</tr>
<tr>
<td>Solution of ammonium nitrate, carbamide and lauryl sulfate sodium</td>
<td>0.42</td>
<td>8.5</td>
<td>11.4</td>
</tr>
</tbody>
</table>

4. CONCLUSIONS AND RECOMMENDATIONS

Results of research allow to choose the optimal dispersant location (when humidifier dispersed directly into a vortex granulator), or the most effective conditions prior granules humidification. Comparative indicators of granules depending on humidifier type allow to state that hydration with nitrogenous fertilizer solutions with addition of surfactants is much more efficient than water hydration.

When using the expanded PAN heat treatment after detonation reaction industrial of slowing down as a result of defects in the crystal structure of the granules (the expansion of education-atoms in a crystal). In the obtained PAN samples through the use of new technology and lowering the temperature of the process, in the center of the nucleus after drying are air bubbles, which stop-top reaction proper detonation of industrial explosives detonation.

Experiments data are the basis of optimization selection granules humidification method (place of granules income to granulator, area of application of humidifier, humidification method, etc.). Among the future research challenges – impact assessment of humidifier and coolant temperature on quality of porous surface layer.

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3-D наноструктурний пористий слой аміачної селітри: вплив способа увлажнения на структуру слоя

А.Є. Артюхов, В.І. Склабинский

Стаття посвячена вивченню впливу способу увлажнения на структуру і якість пористого поверхневого слоя гранул аміачної селітри. Предложено різні типи увлажнителя і показані качественнов характеристики пористой аміачної селітри для кожного з них. Ісследовано структуру і показатели качества пористой аміачної селітри при різних взаємних напрямках руху гранул і увлажнителя. Предложен способе препарировального увлажнения гранул що термообработкой в вихровом грануляторе. Полученные данные являются основой для создания методики инженерного расчета вихревых грануляторов в составе установок получения 3-D наноструктурного пористого поверхностного слоя на грануле аміачної селітри.

Ключевые слова: 3D Наноструктурированный Пористый слой, Вихревой гранулятор, Увлажнение

3D наноструктурный пористий шар аміачної селітри: вплив способу зволоження на структуру шару

А.Є. Артюхов, В.І. Склабинский

Стаття присвячена вивченню впливу способу зволоження на структуру і якість пористого поверхневого шару гранул аміачної селітри. Запропоновано різні типи зволожувачів і показані якісні характеристики пористої аміачної селітри для кожного з них. Досліджено структуру та показники якості пористої аміачної селітри при різному взаємному напрямку руху гранул і зволожувача. Запропоновано способ зволоження гранул з їх термообработкою в вихровому грануляторі. Отримані дані є основою для створення методики інженерного розрахунку вихрових грануляторів в складі установок отримання 3-D наноструктурного пористого поверхневого шару на гранулах аміачної селітри.

Ключові слова: 3D Наноструктурований Пористий Шар, Вихровий Гранулятор, Зволоження
REFERENCES