The investigation of fixed nitrogen catalytic processes for technologies of dual-purpose materials production

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The paper is dedicated to investigation of fixed nitrogen catalytic processes and related technologies of dual-purpose materials production. The appropriated technologies of ammonia, nitric acid methanol production are considered. The development of novel axial-radial part of ammonia reactor with high-effective special plate heat exchanger is considered too.

Key words: fixed nitrogen technologies, catalytic processes, ammonia synthesis.

Introduction

The significant contribution into theoretical bases of multi-branch chemical technology was done with chemical schools-of-thought of NTU "KhPI", that were founded by prominent scientists in chemical technology, such as academicians Orlov E.I., Atroshchenko V.I., Budnikov P.P., Berezhnoi A.S. Their names are included into "5000 World Prominent Personalities" encyclopedia.

In chemical industries there are 86% of catalytic processes. Catalysts enhance and increase the efficiency of the processes. A number of our University scientists investigations are dedicated to development and implementation of catalysts into different processes. Such works were granted by State Prize in science and technical branch.

Chemical industries produce a lot of dual-purpose materials such as ammonia, nitric acid, mineral fertilizers.

Paper's Body

The ammonia (NH_3) production is carried out with small, medium and large ammonia plants and consists of 8 basic technological stages that includes 7 catalytic processes.

The basic process is ammonia synthesis from nitrogen – hydrogen gas mixture on iron catalyst CA-I in ammonia synthesis column.

The development and creation of novel axial – radial type catalyst basket with diameters 1000-2000 mm with inner plate heat exchanger demanded the mathematical model development for ammonia synthesis process and connected heat exchange between hot and cold streams of synthesis gas.

The response rate W_{kin} of ammonia synthesis process ($N_2 + 3H_2 = 2NH_3 + 112kJ$) was according Tjomkin – Smirnov – Morozov kinetic equation with taking into account conversion rate, fugitiveness of components and constant A that considers the catalyst poisoning with acidic mixtures (H_2O, CO, CO_2).

The calculation of catalyst grain useful surface for grains 1-3 mm and 7-10 mm was carried out basing on Dayson and Seaton equation.

The mathematical model was developed on the base of heat and mass balances of catalyst layer. This model describes ammonia synthesis process and heat and mass transfer processes in reactor with axial and radial catalyst baskets.

With use of software developed appropriate calculations let to define the ammonia synthesis rate, plant capacity, pressure drop through catalyst layers, ammonia content in initial mixture and after catalyst layer, critical reactor sensivity parameter for estimation of autothermal mode of reactor duty.

The developed axial–radial baskets with plate heat exchangers were manufactured in "Pavlogradchemmash" enterprise 42 units were manufactured and installed at plants in Grodno, Chirchik, Vakhsh, Vanadzor (Kirovakan), Navoi etc.

Designed plate heat exchangers show high effective duty in autothermal mode of reactors and let to increase the ammonia output by 18%.

In Ukraine the total ammonia production capacity is 6,2 MMt NH_3 per annum with plants of capacity 1300-1420 tons per day.

Theoretical energy consumption of such plants is 5,3 Gcal/t NH_3, but for Ukraine this figure is 10,0Gcal/t. It is 20-30% more than for ammonia plants abroad.

So the investigations directed on energy consumption decreasing are very actual for ammonia synthesis plants of AM project with capacity 1300 t NH_3 per day.

In modern ammonia synthesis plants big part of natural gas losses occurs at methane (CH_4) catalytic conversion stage and at two stage catalytic conversion of carbon oxide (II).

To estimate the possible decreasing of steam losses for low temperature conversion of carbon oxide (II) according to reaction

$$CO + H_2O = CO_2 + H_2 + 41{,}14kJ$$

the experimental investigation were carried out for CO conversion at units of high pressure (4,3 MPa) with reactor volume $V=15cm^3$ at 500^0C and catalyst grains 1-3mm and 7-10mm.

Conclusions

Investigations carried out show that decreasing of regalement ratio (0,44:1)"steam/gas" $n = V_{H2O} : V_{gas} =(0{,}2\div0{,}5)$" increases the methanol (CH_3OH) not significantly together with NH_3 synthesis from 0,14% vol to 0,18%vol at $t = 240^0C$.

So the ratio decreasing to n = 0,3871 causes the saving of steam ΔG = 157,5 kg/t NH_3 or 0,109 Gcal/t NH_3 for ammonia plant AM-1420 with capacity 1420 t NH_3 per day. The content of carbon oxide is 0,46% vol.

Similar it is possible to decrease steam consumption at medium temperature conversion of carbon oxide (CO) and decrease ammonia output on ammonia plants.

Ammonia is the basic product for production processes of diluted nitric acid HNO_3 (50-56%).

Concentrated nitric acid is produced by concentration of nitric acid with use of magnesium nitrate $Mg(NO_3)_2$.

Nitric acid is dual-purpose product that uses for mineral fertilizers production and for explosive materials production.