RESEARCH ON THE THERMAL PYROLYSIS METHOD FOR OBTAINING ETHYLENE FROM METHANE

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Abstract: This article studies the effect of the methane + water vapor ratio on the reaction efficiency in the technology of ethylene production from methane by pyrolysis.

Keywords: ethylene, methane, pyrolysis, water vapor, furnace, reactor, acetylene, oxygen, pyrogas.

In the modern petrochemical industry, one of the important technological directions is the production of high-value products from light hydrocarbons, including ethylene, propylene, hydrogen and methanol. In this regard, methane pyrolysis - the process of converting methane molecules into useful products by decomposition at high temperatures - is the basis for extensive scientific and industrial research. Methane is a cheap, relatively stable and clean source of energy, and the technology of obtaining ethylene from it is one of the most promising methods in terms of environmental and economic aspects.

Methane pyrolysis is carried out in two main directions: thermal and catalytic. In thermal pyrolysis, methane molecules are decomposed under the influence of high temperatures (900–1200°C), resulting in the formation of ethylene (C_2H_4), hydrogen (H_2), acetylene (C_2H_2) and solid carbon (coke). However, this process requires a large amount of energy and product selectivity can be low. Therefore, pyrolysis processes involving catalysts are being intensively studied. Catalysts can be used to lower the pyrolysis temperature, increase product selectivity, reduce coking and improve energy efficiency.

Thermal reactors and their testing

For methane pyrolysis in laboratory conditions, static or flow-type thermal reactors are used. The most commonly used types are:

Batch reactors - the gas mixture is kept in the reactor for a certain time and the reaction process is monitored.

Flow reactors - methane is continuously fed to the reactor and the products are continuously separated.

It is a promising route for producing pure hydrogen from methane, without the release of CO or CO_2. The solid carbon produced is a valuable product for industry.

Ethylene production through methane pyrolysis is an important step in the development of petrochemicals and the hydrogen economy. Laboratory tests, especially using thermal and catalytic pyrolysis reactors, expand the possibilities of obtaining high-value products from methane. The selection of catalysts, optimization of reaction parameters, and analysis using Agilent 7890A chromatography are the main steps in this process.

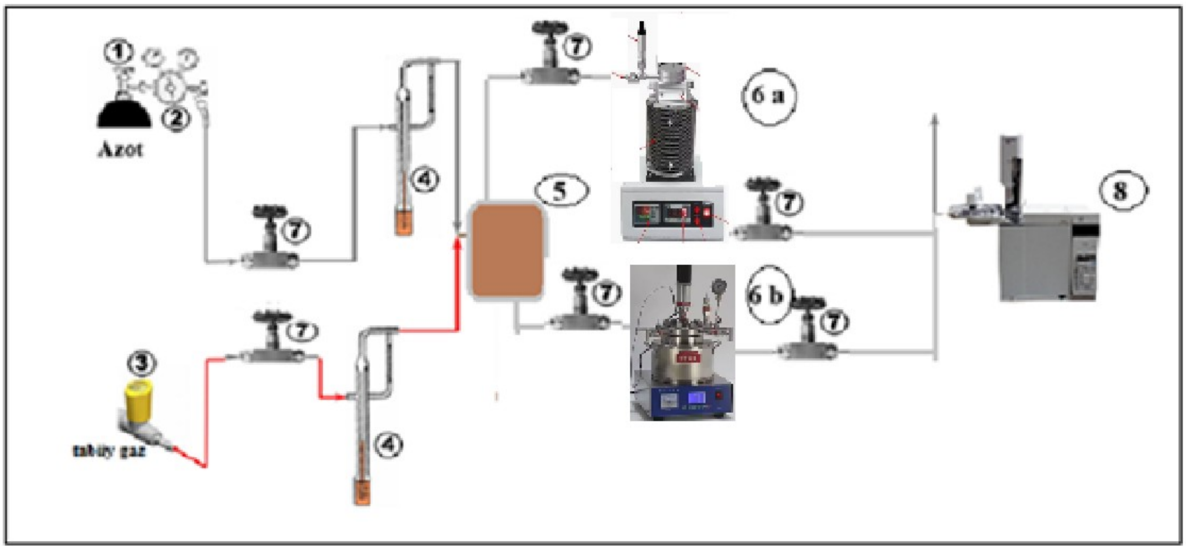

Figure 1. Laboratory device of a thermal reactor for the production of ethylene from methane.

1 – nitrogen cylinder, 2 – reducer, 3 – valve, 4 – rheometers, 7 – straightening tap, 5 – furnace, 6 –a- pyrolysis reactor and b-stationary reactor, 8- 7890A gas chromatograph.

This diagram shows the conversion of methane to ethylene through the pyrolysis process. The main components of the device can be described as follows.

The process begins with a nitrogen cylinder (1). This cylinder supplies nitrogen gas, which is used to fill the system with an inert atmosphere. The gas from the nitrogen cylinder passes through a reducer (2), which reduces the gas pressure to the required level. The gas flow is then controlled by valves (3) and regulating valves (7). These valves play an important role in regulating and directing the gas flow. Rheometers (4) measure the volume of the gas flow, which is necessary for precise control of the process.

In the scheme, methane gas is supplied separately and is introduced into the system through a special path. A mixture of methane and nitrogen is directed to the furnace (5). The furnace provides the high temperature necessary for the process, since the pyrolysis process of ethylene from methane takes place at high temperatures. After the furnace, the reaction continues in reactors (6). Reactors are shown in 2 different types: pyrolysis reactors (6a), stationary reactors (6b).

In general, this device allows the process of ethylene from methane to be carried out efficiently and in a controlled manner in laboratory conditions. Each component performs a specific task at a specific stage of the process, and as a result, the chemical reaction is successfully completed.

Thermal reactors are devices that carry out chemical reactions using heat, and they can be divided into the following main groups:

- Pyrolysis reactors
- Stationary reactors

Each type of reactor is selected according to its characteristics and suitability for use. Pyrolysis and inert reactors are widely studied for methane pyrolysis.

Pyrolysis Reactors

Pyrolysis reactors are reactors based on the decomposition of hydrocarbons under the influence of high temperatures in the absence of oxygen. During the pyrolysis process, methane molecules are broken down and converted into light olefins (ethylene, propylene) and hydrogen gas.

Key features of pyrolysis reactors:

• Operating temperature: 800–1100°C.

• Reaction time: very short (milliseconds).

• High energy requirements.

• Low temperature control required.

• Products may contain many by-products.

Figure 1. High-pressure pyrolysis reactor

High-pressure reactor for supercritical water gas chemical reaction, made of Ni-Base Super-alloy, with excellent absorption strength and oxidation resistance. It can reach 1100 °C with a pressure of up to 4 MPa under oxygen or inert gas. It is an ideal tool for preparing advanced material by hydrothermal method, especially heat treatment sample under high oxygen pressure. An electromagnetic valve is installed on the flange, which allows automatic pressure control. Real-time temperature and pressure monitoring software is also included.

This is a widely used technology on an industrial scale and can work with various raw materials. However, coke (carbon) formation and solid residues on the reactor walls occur.

Stationary Reactors

Stationary reactors are reactors in which the reaction mass is stationary in one place, the flow passes only through the gas or liquid phase, which allows better control of the reaction conditions, unlike pyrolysis.

Characteristics of stationary reactors:

- Temperature: 500–800 °C (may be slightly lower than pyrolysis).
- Operates in the presence of a catalyst (often).
- It is easier to optimize the thermodynamic and kinetic conditions of the reaction.
- The selectivity of the products is higher.

Figure 2. Stationary Reactors

It is a stationary reaction device for high-pressure gas-liquid, liquid-liquid, liquid-solid or gas-liquid-solid three-component chemical reactions in the laboratory.

It is possible to increase the specific selectivity of the products and it is easy to improve the heat and mass transfer conditions. Coke formation is minimal. However, it is important to maintain the catalyst activity and clean the reactor.

Direct production of ethylene from methane is one of the most relevant and promising areas of the modern chemical industry. Ethylene is a very important raw material for industry, from which many products such as polyethylene, vinyl chloride, styrene are obtained. However, the production of ethylene from methane is a thermodynamically and kinetically complex process, requiring high temperatures and special conditions. The role of catalysts in this process is invaluable.

Catalysts are used to increase the reaction rate, increase selectivity and reduce the formation of undesirable by-products. This article provides a detailed analysis of the main catalysts used in the production of ethylene from methane, their properties and efficiency.

Catalytic basis for the production of ethylene from methane

This reaction is endothermic and occurs at high temperatures (900–1100°C). As the temperature increases, the reaction rate increases, but at the same time the thermodynamic stability decreases and many by-products are formed (acetylene, carbon, propane, ethane, etc.). Therefore, it is necessary to increase the selectivity and efficiency not only by temperature, but also by using catalysts.

An ideal catalyst should have the following properties:

- High activity.
- High selectivity (for ethylene product).
- Thermal and chemical stability.
- Resistance to hard coke (C) formation.
- Long service life.

Methane is decomposed into ethylene, methanol, hydrogen and other products by mixing with catalysts in the pyrolysis process. The efficiency of catalysts in this process increases the selectivity of pyrolysis products and improves the energy efficiency of the process. High selectivity in the catalytic pyrolysis of methane helps to reduce energy consumption and allows you to optimize industrial processes. At the same time, controlling the decomposition process of methane with the help of catalysts speeds up the pyrolysis process and ensures the production of more efficient products.

By separating methane from the natural gas composition in a demethanizer column, a high-purity methane fraction is obtained. According to the table, after demethanization, 98–99% pure methane is obtained in the upper stream, which is very important for subsequent chemical processes.

Pyrolysis reactors are reactors based on the decomposition of hydrocarbons under the influence of high temperatures without the participation of oxygen. During the pyrolysis process, methane molecules are broken down and converted into light olefins (ethylene, propylene) and hydrogen gas. Fixed reactors are reactors in which the reaction mass is stationary, the flow passes only through the gas or liquid phase, which, unlike pyrolysis, allows better control of the reaction conditions. Microwave plasma reactor: produces high energy efficiency and a tailored plasma. Widely used in laboratory conditions.

The success of thermal-catalytic processes for the production of ethylene from methane depends on the selection of the right catalyst and its effective use. High activity, large surface area, thermal stability and resistance to coking are the main requirements for catalysts.

From a technological point of view, the continuous or pulsed supply of high-temperature and clean steam leads to optimal results. In the future, the main goal of new pyrolysis technologies will be to increase the energy efficiency of steam, minimize heat losses and maximize product selectivity.

The Agilent 7890A is a modern, multifunctional and highly sensitive gas chromatograph, which is an ideal tool for qualitative and quantitative analysis of products formed during the conversion of methane, ethane and other gases into ethylene and olefins.

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