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MODELING AND OPTIMIZATION OF THE ACETYLENE PRODUCTION PROCESS IN MATLAB/SIMULINK

Annotatsiya

Ushbu maqolada asetilen (C_2H_2) gazini ishlab chiqarish jarayonini MATLAB dasturining Simulink muhitida modellashtirish va optimallashtirish masalalari ko‘rilgan. Asetilen olish jarayoni kalsiy karbid (CaC_2) va suv (H_2O) o‘rtasidagi ekzotermik kimyoviy reaksiya asosida amalga oshiriladi hamda sanoat amaliyotida muhim ahamiyatga ega. Ushbu tadqiqotda jarayonning matematik modeli tuzilgan bo‘lib, reaksiya kinetikasi Arrenius tenglamasi yordamida ifodalandi. Shuningdek harorat, bosim, reaktivlar konsentratsiyasi va vaqt kabi texnologik parametrlarning asetilen hosil bo‘lish tezligiga ta’siri batafsil tahlil qilindi. Matlab dasturining Simulink muhitida yaratilgan model asosida jarayonning dinamik xatti-harakati o‘rganildi. Turli ish rejimlari solishtirilib, maksimal chiqish va minimal energiya sarfini ta’minlovchi optimal ish rejimi aniqlandi. Olingan natijalar MATLAB/Simulink dasturiy muhitining kimyoviy texnologik jarayonlarni modellashtirish, tahlil qilish va optimallashtirishda samarali hamda ishonchli vosita ekanligini ko‘rsatadi. Ushbu yondashuv ishlab chiqarish jarayonlarini raqamli boshqarishda, xavfsizlikni oshirishda, tajriba xarajatlarini kamaytirishda hamda real sanoat sharoitlarida texnologik qarorlar qabul qilish samaradorligini yaxshilash uchun muhim ilmiy va amaliy asos bo‘lib xizmat qiladi. Ushbu natijalar kelgusida avtomatlashtirilgan boshqaruv tizimlarini ishlab chiqishda qo‘llash imkonini beradi hamda ta’lim jarayonlarida modellashtirish misoli sifatida foydalaniladi va keng qo‘llaniladi.

Kalit so‘zlar

asetilen, MATLAB, Simulink, modellashtirish, optimallashtirish, kimyoviy reaktor.

Аннотация

В данной статье рассмотрены вопросы моделирования и оптимизации процесса производства ацетилена (C_2H_2) в среде Simulink программного комплекса MATLAB. Процесс получения ацетилена осуществляется на основе экзотермической химической реакции между карбидом кальция (CaC_2) и водой (H_2O) и имеет важное значение в промышленной практике. В рамках исследования разработана математическая модель процесса, при этом кинетика реакции описана с использованием уравнения Аррениуса. Кроме того, подробно проанализировано влияние таких технологических параметров, как температура, давление, концентрация реагентов и время, на скорость образования ацетилена. На основе модели, созданной в среде Simulink MATLAB, изучено динамическое поведение процесса. Путём сравнения различных режимов работы был определён оптимальный режим, обеспечивающий максимальный выход продукта при минимальных энергетических затратах. Полученные результаты подтверждают, что программная среда MATLAB/Simulink является эффективным и надёжным инструментом для моделирования, анализа и оптимизации химико-технологических процессов. Предложенный подход служит важной научно-практической основой для цифрового управления производственными процессами, повышения уровня безопасности, снижения экспериментальных затрат, а также повышения эффективности принятия технологических решений в реальных промышленных условиях. Полученные результаты могут быть использованы при разработке автоматизированных систем управления и в

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образовательном процессе в качестве наглядного примера моделирования и широко применяться в практике.

Ключевые слова
ацетилен, MATLAB, Simulink, моделирование, оптимизация, химический реактор.

Abstract
This article addresses the issues of modeling and optimization of the acetylene (C_2H_2) gas production process in the Simulink environment of the MATLAB software. The production of acetylene is based on an exothermic chemical reaction between calcium carbide (CaC_2) and water (H_2O), which plays a significant role in industrial practice. In this study, a mathematical model of the process was developed, and the reaction kinetics were described using the Arrhenius equation. In addition, the effects of key technological parameters such as temperature, pressure, reactant concentration, and time on the rate of acetylene formation were thoroughly analyzed. Based on the model created in the MATLAB Simulink environment, the dynamic behavior of the process was investigated. Various operating modes were compared, and an optimal operating regime ensuring maximum product yield with minimal energy consumption was identified. The obtained results demonstrate that the MATLAB/Simulink software environment is an effective and reliable tool for modeling, analysis, and optimization of chemical engineering processes. This approach provides an important scientific and practical basis for digital control of production processes, enhancing safety, reducing experimental costs, and improving the efficiency of technological decision-making under real industrial conditions. The results can be applied in the development of automated control systems and are widely used as illustrative examples of modeling in the educational process.results demonstrate the effectiveness of MATLAB/Simulink for modeling and optimizing technological processes.

Keywords
acetylene, MATLAB, Simulink, modeling, optimization, chemical reactor.

Introduction

Acetylene gas plays a crucial role in industry and is widely used in various fields such as metallurgy, the chemical industry, and welding processes. In modern industrial conditions, automating the acetylene production process, ensuring operational safety, and reducing energy consumption are among the most pressing challenges. Addressing these issues requires the effective application of mathematical modeling and computer-based simulation, which play a key role in analyzing, optimizing, and improving the efficiency and reliability of acetylene production systems. [1]

The MATLAB and Simulink environments are effective tools for modeling, analyzing, and optimizing technological processes in dynamic mode, providing a convenient and powerful platform for studying process behavior and improving operational efficiency.

Methods

Acetylene is produced through the following reaction:

$$CaC_2+2H_2O \rightarrow C_2H_2+Ca(OH)_2+Q$$

The reaction is exothermic, and an increase in reactor temperature is observed due to the release of heat. Consequently, the efficiency and safety of the process primarily depend on the temperature and reaction rate. [2]

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Mathematical model of the process

The reaction kinetics is expressed by the Arrhenius equation:

$$k(T) = A \cdot e^{\frac{-E}{RT}}$$

here:

- A – pre-exponential coefficient,
- E – activation energy (J/mol),
- R – universal gas constant,
- T – temperature (K).

Time-dependent change of acetylene concentration:

$$\frac{dCc_2 \cdot H_2}{dt} = k(T) \cdot C_{CaC_2}$$

C_{CaC_2} — the concentration of calcium carbide in the reactor is the main parameter that determines the rate of acetylene formation.

Modeling the process in the Simulink environment

The Simulink model consists of the following main blocks:

The initial reactor temperature was assumed to be 298 K, corresponding to ambient conditions.

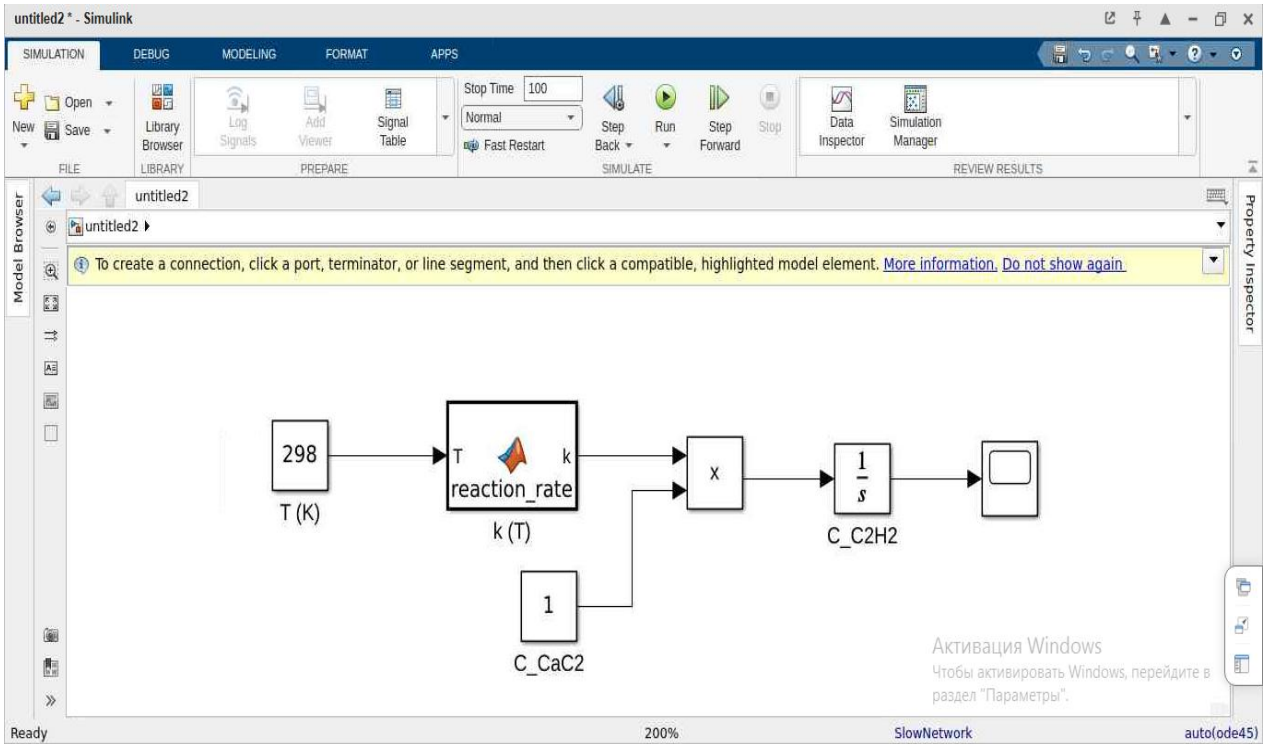


Figure 1. Structure of the Simulink model.

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Results

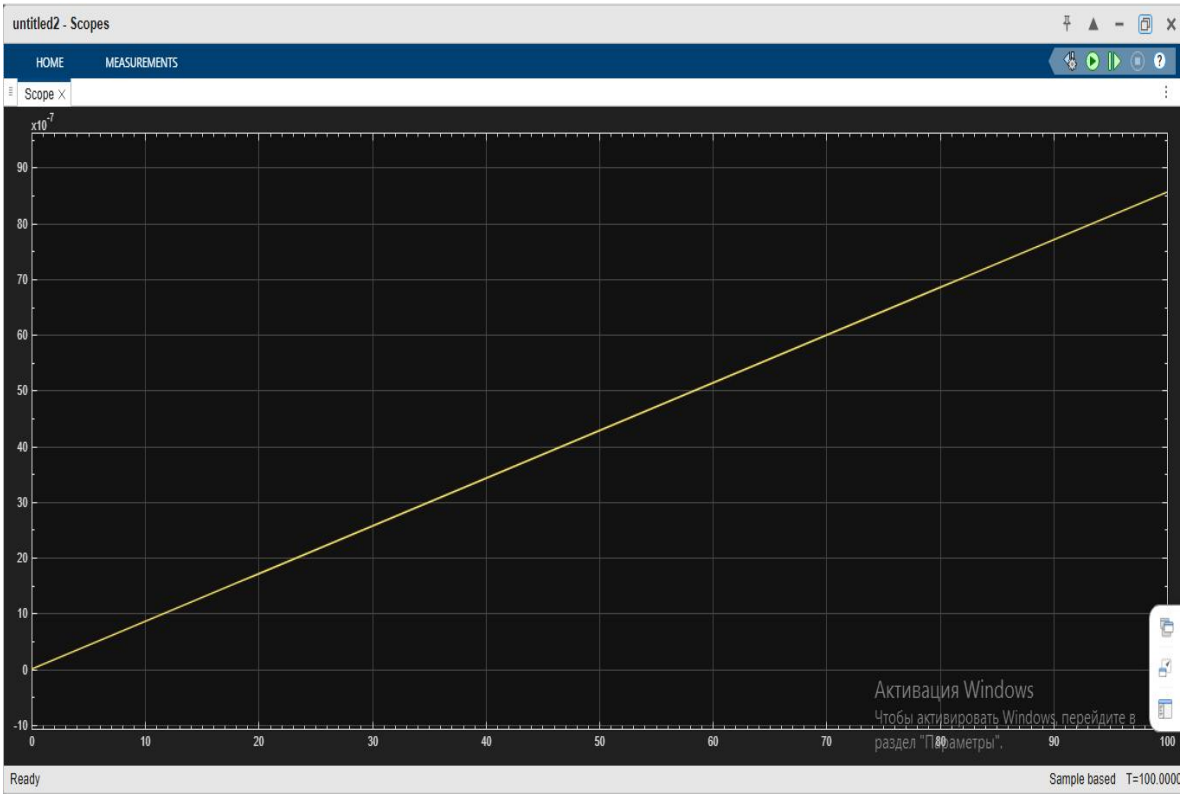


Figure 2. Graph of acetylene concentration increase over time.

According to the simulation results:

The rate of acetylene formation increases with rising temperature

At very high temperatures, the process may transition to an unstable state.

The maximum yield is achieved within the optimal temperature range.

The growth of acetylene concentration over time was observed on the Scope window.

The obtained results indicate that modeling the acetylene production process using the MATLAB/Simulink software environment allows for an in-depth analysis of the process, reduces the number of experiments, and enables the optimization of energy and raw material consumption.

Conclusion

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In this article, the acetylene production process was modeled in the MATLAB/Simulink environment. A Simulink model was created based on the chemical reaction kinetics, the process dynamics were studied, and the acetylene concentration was observed to increase linearly over time. This indicates that the reaction rate is constant and that a steady-state operating mode was assumed in the model. The study results demonstrate the high efficiency of computer simulation in modeling and optimizing technological processes.

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