As a result of the decomposition application, the conversion unit controlling task is realized as obtaining and distributing values of temperature tasks depending on the possible concentration of methane in both the converted and the process gas.

Coordination complies with certain rules for obtaining and redistributing tasks for temperature of the converted gas semi-finished product at the outlets from the furnace chambers of the tube furnace, depending on the state of the whole stage of process gas preparation. Based on the technical and economic characteristics of the conversion process, a mathematical statement of the controlling the conversion unit task was developed. This was done taking into account the potential hazard of the conversion unit (this is one of the most potentially dangerous units on the ammonia synthesis unit) [3].

CONCLUSIONS

The paper analyzes the potentially dangerous technological process from the point of view of creating a control system in real time, its main features and risk factors highlighted. The control goal analysis in terms of the overall cost-effectiveness of the workshop allowed determining the priorities of the goals, as a result of which one of them is replaced by a priority regulatory restriction. Based on the other two goals – formalize the control criterion. As a result, a multi-purpose approach with conflicting control goals is reduced to a single-criterion, and a conversion unit control task is formalized as a hierarchical single-criterion optimal control task. The results of the decomposition of the overall control task allowed the transition to a hierarchical, multilevel real-time control system for this object.

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AN INTELLIGENT SYSTEM FOR CHOOSING A METHOD OF GAS PURIFICATION BASED ON FUZZY LOGIC

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ІНТЕЛЕКТУАЛЬНА СИСТЕМА ДЛЯ ВИБОРУ МЕТОДУ ОЧИЩЕННЯ ГАЗУ НА БАЗІ НЕЧІТКОЇ ЛОГІКИ

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ИНТЕЛЛЕКТУАЛЬНАЯ СИСТЕМА ДЛЯ ВЫБОРА МЕТОДА ОЧИСТКИ ГАЗА НА ОСНОВЕ НЕЧЕТКОЙ ЛОГИКИ

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At present, environmental problems related to air pollution cannot be solved without the use of simulation tools that allow the design of waste gas purification processes based on the fundamental theory of heat and mass transfer together with verified kinetic data and equilibrium properties. In addition, today there are many methods for cleaning air from pollutants such as nitrogen and sulfur oxides. The integration of computer tools on the basis of fundamental laws and intelligent tools for making decisions on choosing the most effective cleaning methods depending on the composition and parameters of the exhaust gases of industrial enterprises is an urgent task.

Keywords: *intelligent system, modeling, gas purification, nitrogen oxides, fuzzy logic*

В настоящее время экологические проблемы, связанные с загрязнением воздуха, не могут быть решены без использования инструментов моделирования, которые позволяют разрабатывать процессы очистки отработавших газов на основе фундаментальной теории тепломассопереноса вместе с проверенными кинетическими данными и равновесными свойствами. Кроме того, сегодня существует множество методов очистки воздуха от загрязняющих веществ, таких как оксиды азота и серы. Интеграция компьютерных инструментов на основе фундаментальных законов и интеллектуальных инструментов для принятия решений о выборе наиболее эффективных методов очистки в зависимости от состава и параметров выхлопных газов промышленных предприятий является актуальной задачей.

Ключевые слова: *интеллектуальная система, моделирование, газоочистка, оксиды азота, нечеткая логика*

На даний час екологічні проблеми, пов'язані із забрудненням повітря, не можуть бути вирішені без використання імітаційних інструментів, що дозволяють проектувати процеси очищення відпрацьованих газів на основі фундаментальної теорії теплопередачі та маси разом із перевіреними кінетичними даними та рівноважними властивостями. Крім того, сьогодні існує безліч методів очищення повітря від забруднюючих речовин, таких як оксиди азоту та сірки. Інтеграція комп'ютерних інструментів на основі фундаментальних законів та інтелектуальних інструментів для прийняття рішень щодо вибору найбільш ефективних методів очищення залежно від складу та параметрів вихлопних газів промислових підприємств є нагальним завданням.

Ключові слова: *інтелектуальна система, моделювання, очищення газу, оксиди азоту, нечітка логіка*

We made attempts to create such a system earlier [1-3, 6-8]. It should be noted that over the past twenty years, many software tools have been developed both for solving various problems of chemical technology on the one hand, and intelligent methods and tools on the other [4, 5]. In this paper, it is proposed to combine the traditional approach to modeling gas purification processes with modern fuzzy inference system.

The developed intelligent system is shown in Fig. 1. The main task that this system helps to solve is the choice of the most effective method for purifying exhaust gases from nitrogen and sulphur oxides. The Subsystem implies two sets of rules to select relevant purification methods for two impurities NOx and SOx. In the paper a computer implementation of the system is presented together with the relevant illustrative examples. The system allows to design of the waste gas purification processes and is based on the fundamental theory of heat and mass transfer together with verified kinetic data and equilibrium properties. Fuzzy logic approach has been used to implement the intelligent components. These components were applied mainly for selecting appropriate purification methods. The knowledge base contains more than 50 rules for choosing cleaning methods. Among the methods used for the gas purification from NO_x there is a variety of those composed of several process units. In the work, mathematical models for different process units have been developed. The mathematical model of an industrial unit for gas cleaning from nitrogen oxides takes into account both different kinetic schemes (from one-two equations up to the full kinetic scheme including 11 equations) and the type of the reaction description (equilibrium or non-equilibrium reactions). Three subsystems consisting of the program modules for the calculation of the gas purification processes have been developed:

1. Program modules for the *absorption-oxidation methods* of gas purification from NO_x. The absorption-oxidation methods include absorption of nitrogen oxides by water or by water solutions of nitric acid. These methods are applied to purify exhaust gases which have a high degree of oxidability and contain more than 40 % of nitrogen oxides.

2. Program modules for the *absorption-reduction methods* of gas purification from NO_x. The absorption-reduction methods include purification by solutions of carbamide, by solutions of sulphite natrium and thiosulphuric ammonium. These methods are applied to purify gases containing nitrogen oxides in a wide concentration range.

3. Program modules for *the simple reactive absorption methods* of gas purification from NO_x. These methods include waste gas purification by solutions of natrium carbonate and natrium hydroxide, by solutions of sulphuric acid and by solutions of organic absorbers.

The choice of a purification method is based on the following factors:

- Cleaning degree;
- Initial concentration of nitrogen oxides;
- Oxidability degree of nitrogen oxides;
- Temperature of the purified gas;
- Volume of the purified gas;
- Presence of other impurities (e.g. SO_2, dust);
- Possibility of commodity output.

These factors and the structure of the mathematical description determine a range of validity of each method and allow correct decision when choosing a purification method.

To develop the mathematical models of a gas purification process from nitrogen oxides it is necessary to determine a number of physicochemical properties of the components included in the selected reaction scheme. The more components of a reacting mixture are taken into account in the model, the larger number of parameters is required to describe their transport phenomena. Therefore we developed the following databases for the calculation of the physicochemical parameters:

- the caloric and equilibrium database covering the presence of strong electrolytes in the fluid phase and supercritical components in the gas phase;
- the database of the kinetics equations for complex reaction systems (gas-phase or liquid-phase reaction or heterogeneous reaction in both phases);
- the database of the mass transfer coefficients for the modelling of the two-phase multi-component mass transfer.

Consider the example of choosing a cleaning method using the NOx example based on the fuzzy logic approach. The user interface provides an interaction with the databases and knowledge bases when solving the simulation tasks. For uncertain factors, ranges of possible values were determined, as shown in Table 1.

Table 1. The range factor values for NO_x-purification methods

No.	Factors	Low	Medium	High
1	Initial concentration of NO_x, %	0.15…0.6	0.5…2.5	1.5…10.0
2	Cleaning degree, %	20…60	50…80	70…100
3	Temperature of the purified gas, C	0…300	200…400	300…500

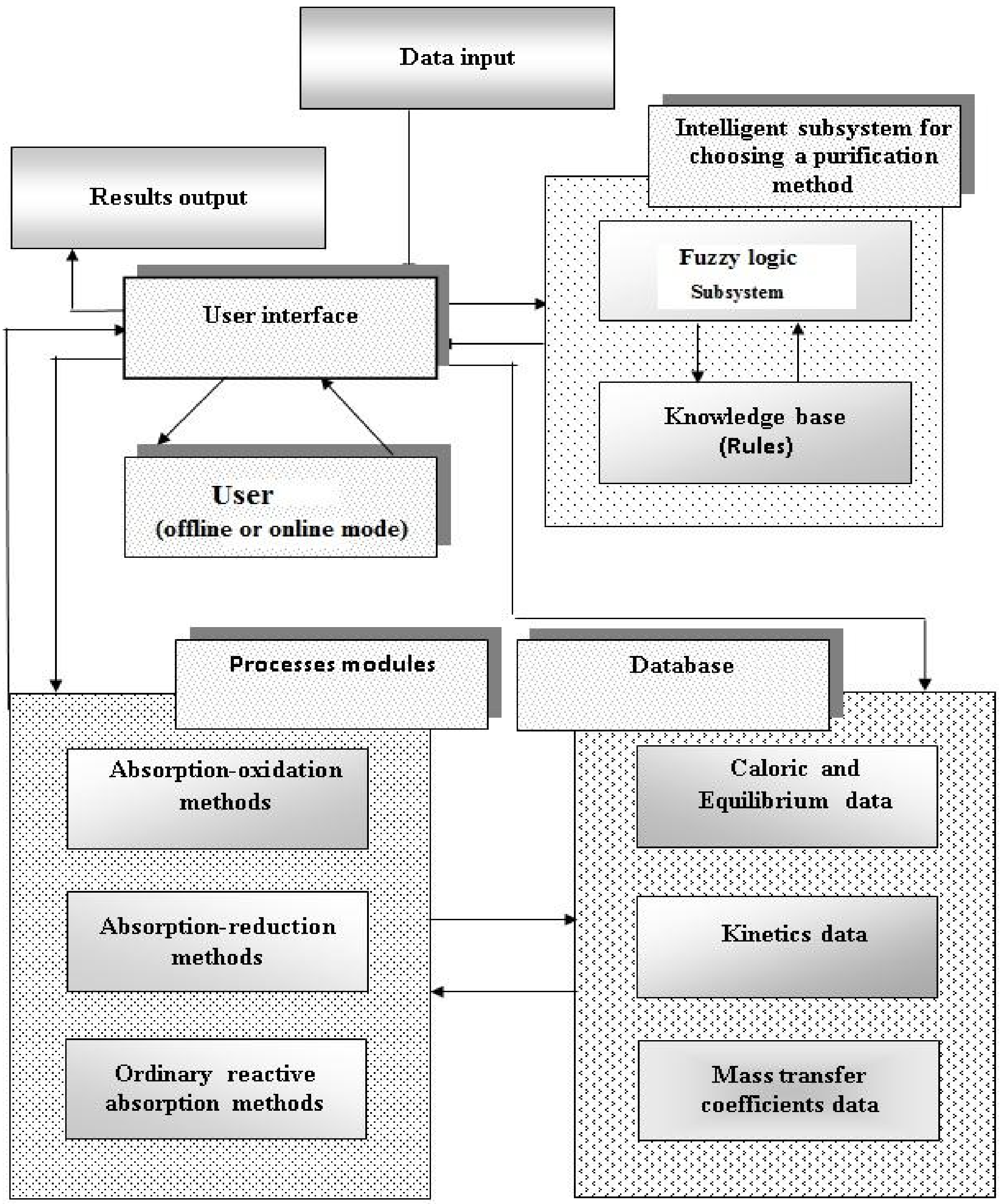

Fig. 1. The structure of the Intelligent System for choosing waste gas purification methods

As it was mentioned above, to accomplish the tasks of waste gas purification from nitrogen oxides, three groups of methods are used. For each method, certain rules have been developed, and these rules define a choice of one of the groups of methods. In addition, during the development of the rules, the following factor values were taken into account:

- presence of admixtures;
- production of commodity output.

These factors can take two values: "yes" (1) or "no" (0). The estimation of data on the purification methods by experts-technologists resulted in the rules for choosing a type of the purification method. These rules constitute the knowledge base of the system.

The rules are available in the system in two forms: the usual one (“If-Then”), and as the binary tables (e.g. rules for choosing the absorption-oxidation methods in Table 2).

Table 2. The rules for choosing the absorption-oxidation methods of gas purification from NO_x

Cleaning degree			Initial concentration			Temperature			Presence of admixtures		Commodity output available		Total pressure			Oxidability degree		
L	M	H	L	M	H	L	M	H	yes	no	yes	no	L	M	H	L	M	H
0	1	0	0	1	0	1	0	0	0	1	0	1	0	1	0	0	1	0
0	0	1	0	0	1	0	1	0	0	1	1	0	0	0	1	0	0	1

The rules-based algorithm of taking decisions can be described as follows:

Step 1. Determine a type of the technological process according to the rules “If-Then”.

Step 2. Carry out the ranking of the initial data similarly to Table 1, but this time in the range of values which correspond to the parameters for given group of the methods.

Step 3. Choose the purification method according to the rules in tables, presented in the binary form.

A type of the method was selected at the first step of the algorithm according to the certain rule provided by technologists. For the group of the absorption-reduction purification methods this rule is as follows:

<u>Rule:</u>
IF the required degree of purification is 60-95%
AND initial concentration of NO_x is 0.2-0.8%
AND average temperature is not more than 333 K
AND average pressure is not more than 0.11 MPa
AND degree of oxidability is 50-100%
THEN **absorption-reduction methods** have to be used.

The knowledge base was built in Fuzzy Logic Matlab. Having the type of the technological process determined according to these rules, at the next step the purification method is to be chosen. To do that, it is necessary to carry out the ranking of the initial data for absorption-reduction purification methods, as shown in Table 3.

Table 3. The range values of the factors for absorption-reduction purification methods from NO_x

No.	Factors	Low	Medium	High
1	Initial concentration of NO_x, %	0.2…0.3	0.3…0.5	0.5…0.8
2	Cleaning degree, %	60…65	65…75	75…95
3	Temperature of the purified gas, K	293…298	298…333	-
4	Total pressure, MPa	0.1…0.11	-	-
5	Oxidability degree, %	50…60	60…80	80…100

The next step is fuzzification of input variables in accordance with table 3 using the program Fuzzy Logic Matlab. For each parameter (Table 3), the corresponding linguistic variables with three values are set: low, medium and high. In the program, they are set in the form of fuzzy Gaussian membership functions, which are shown in Fig.2.

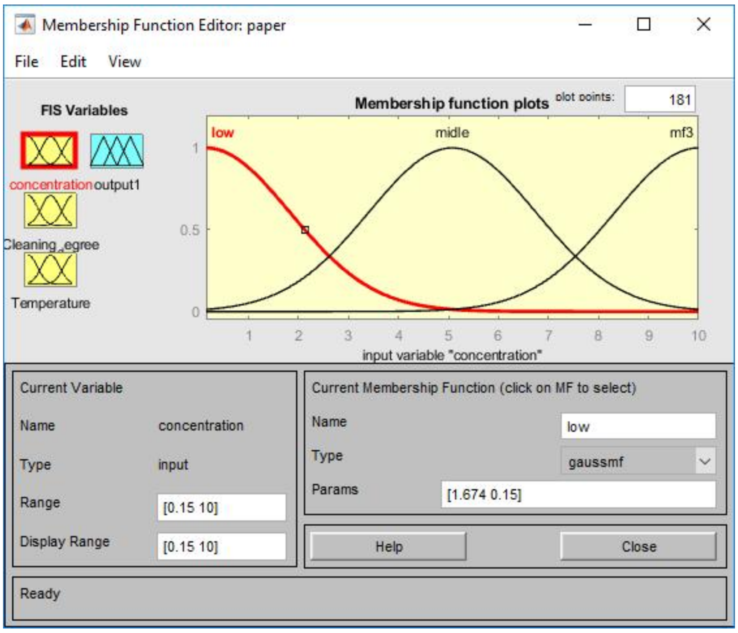

Fig. 2. The setting membership function for the initial concentration

The output variable in the fuzzy inference system will be the number of the most commonly used method for cleaning the database. Therefore, the membership function in the form of a trapezoid was chosen for the output variable (Fig. 3).

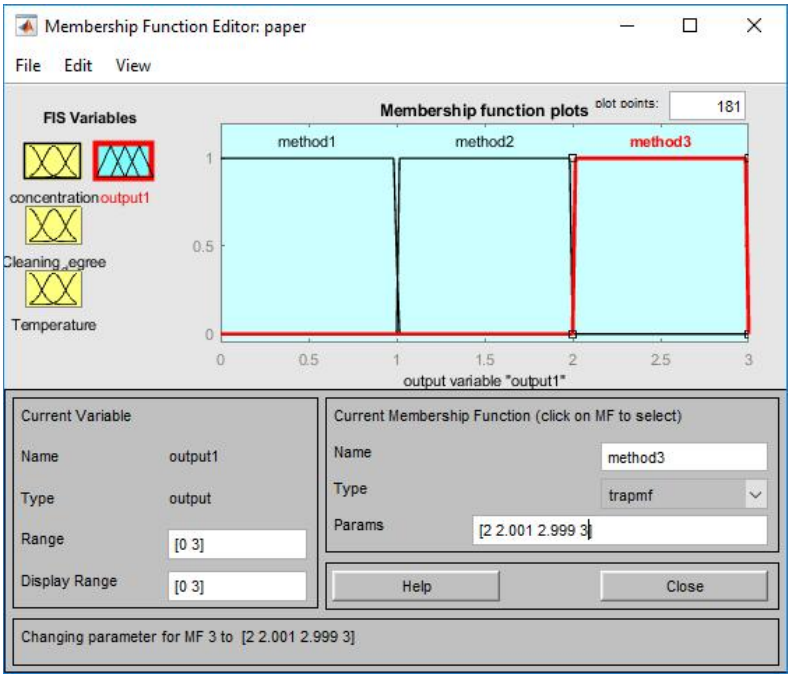

Fig. 3. The setting membership function for a purification method

At the next step it is necessary to select the purification method according to the rules shown in the binary format in Table 2.

As an illustrative example, the solution of the problem of choosing a purification method is presented here. Input data are:

- Cleaning degree - 90%;
- Initial concentration of nitrogen oxides 0.2;
- Oxidability degree of nitrogen oxides 50%;
- Temperature of the purified gas 318…323 K;
- Presence of other impurities SO_2;
- Possibility of commodity output Yes - $(NH_4)_2SO_4$.

The problem was solved with using proposed system. The most approriate method is found to be the purification by the solutions of carbamide $(NH_2)_2CO$.

From absorption-reduction methods of absorption of nitrogen oxides, the method with the usage of an absorbent based on solution of carbamide is of primary interest. Using this absorbent, nitrogen oxides are deoxidised to ecologically safe elementary nitrogen. Ammonium salts are accumulated in the solution, and they are easily utilised as nitrogen-containing manures. The degree of absorption of nitrogen oxides by the carbamide absorbent at the single stage of absorption reaches 75…80%. This allows synthesis of technological scheme of purification of industrial waste gases that ensures maximally allowable concentration of NO_x in gas exhausts.

CONCLUSIONS

The proposed Intelligent System can provide the several different variants of purification methods taking into account the economic and technical aspects. It can be used in the context of feasibility studies, basic design of absorption plants, etc. It reduces the investment risks because of the variant analysis of the plants. The developed models are valid for a wide range of input and process variables. This allows to achieve a range of application that meets the requirements to NO_x (SO_x) removal from industrial exhausts. The proposed tool can be used to solve important problems of the environmental protection.

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