THE METHANOL CONVERSION AUTOMOBILE REACTOR LABORATORY TESTS RESULTS

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Summary. The given results of the bench tests of the automobile methanol conversion reactor are suggested for a minibus. The effect of a number of engine regime indicators on the reactor's efficiency has been evaluated. Fig.2, Sources 21.

Key words: motor, reactor, methanol, conversion.

INTRODUCTION

Most forecasts on the development of energy and transport mention that piston internal combustion engines will in future keep playing a leading role on the transport. Predominant types of the power plant vehicles are the internal combustion engines (ICE) using oil fuel. The main consumer of gasoline and diesel fuel is the road transport.

When using the oil rationally, it will remain the most important source of energy for a long time. However, its resources are not limitless, and now one needs to search for some other alternative sources of raw materials for the production of motor fuels, which himmotological properties enhance the engine's efficiency and reduce the toxic emissions of the exhausted gases [1, 2, 3]. The use of methanol as the primary fuel and gasoline additive has confirmed the effectiveness of its impact on the operation of engines [4, 5, 6]. However, it revealed such drawbacks of methanol as: difficulty in starting a cold engine, vapor locks in the power supply system at increased temperatures, the complexity of a homogeneous mixture in the cylinders, increased engine wear and reduced oil life [7]. It is possible to overcome the above mentioned drawbacks by using the method of hydrogen gas through methanol conversion on board the vehicle with the utilization of the exhaust gases heat (EG) [8-13].

RESEARCH OBJECT

The main objective of the tests was to determine the thermal characteristics of the automotive methanol conversion system developed at the Chair of ICE of the East Ukrainian National Volodymyr Dahl University [14, 15, 16].

The research problem is to determine the dependence of the degree of methanol conversion on the temperature, exhaust flow, and engine operation. To assess the technical and operational characteristics of the reactor (fig. 1) of the automotive conversion of methanol [18] one need to know the amount of disposable exhaust heat to heat the reaction chamber to the optimum temperature of the catalyst at a given flow of methanol.

The tests were conducted in the laboratory of internal combustion engines of the Institute of Engineering (machine – building problems) Sciences of Ukraine on the bench engine 4CH9,2/9,2 (four-cycle), equipped with the conversion of methanol system and the reactor shell and tube type with a bulk catalyst. The engine was used as a source of heating fluid (EG) and worked on gasoline. Methanol conversion products (MCP) via analyzer were released into the atmosphere.

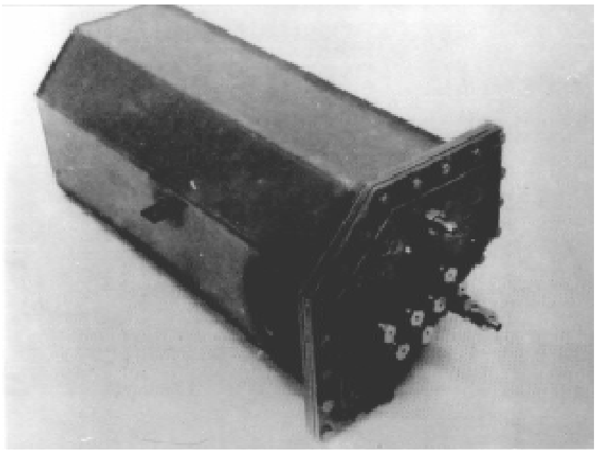

Fig. 1. The general scheme of the methanol conversion reactor

Fig. 2 shows a schematic diagram of the methanol conversion system to power the engine MCP. Liquid methanol from the tank 9 is pumped 8 into the evaporator drive 7. Vaporized methanol was fed into the superheater 4, where it reached the temperature required for the conversion process. After that, the vapors of methanol were directed to the catalytic reactor 5, where they were converted into the hydrogen-containing gas.

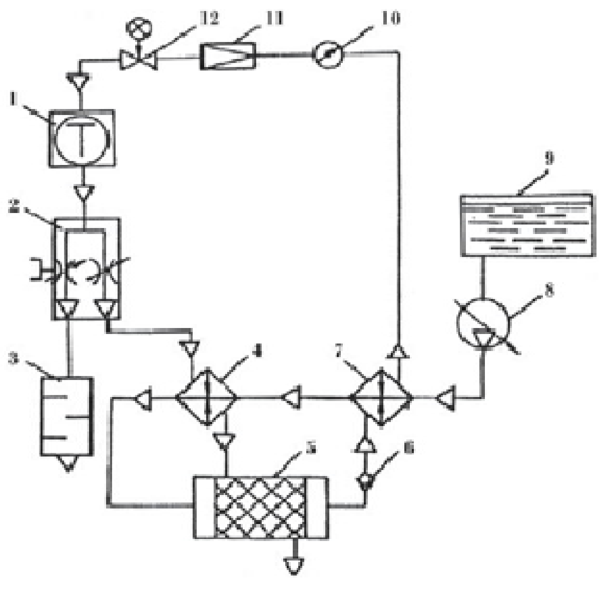

Fig. 2. The scheme of the automobile methanol conversion system

Converted gas mixture passed through the shell side of the evaporator drive 7, giving away the heat for the process of evaporation of liquid methanol. Evaporator pressure was controlled by a manometer 10.

The return valve 6, located between the reactor 5 and the evaporator 7, prevented any MCP back into the working space of the reactor with the engine off. The pressure reducing valve 11 regulated the level of pressure on the MCP set on the entrance of the engine cylinders 1. The solenoid valve 12 shut off the converted products into the engine when it was stopped.

To realize the endothermic dissociation of methanol, the heat of the engine exhaust gases is utilized. From the engine the exhaust gases from the engine were fed to the distributor 2, from where depending on the thermal conditions of the reactor they were directed entirely to the superheater 4 and reactor 5 or partially recirculated around the above mentioned three devices through the muffler out to the atmosphere.

The bench tests of the conversion system showed that the application of the system of the heat flows (EG) regulation by means of the throttle through the bypass channel protected the catalyst from overheating [17].

The tests of the reactor included the following steps:

-installation and tightness of the reactor, including the heating and after cooling;

- preparation and loading of catalyst, its activation and training;

- test of the activity and selectivity of the catalyst by varying the temperature in the reaction chamber, the engine operation, space velocity of the methanol;

- grading of the reactor and the ICE exhaust engines;

- control of the EG heat flow through the reactor;

- analysis of the MCP composition.

The parameters of the engine, the exhaust gas flow and temperature in the exhaust engine were defined with the engine at steady-state conditions of the European driving cycle, warm-up and load-on.

The temperature state of the reactor was estimated by using thermocouples installed in the cavity shell side (exhaust gases inlet and outlet in the reactor), and in the catalyst tubes of the reaction chamber. To control the exhaust gas temperature in the reactor and MCP flexible cable-type thermoelectric converters TCK-1,5 (1,5 mm in diameter) have been used.

The catalyst loaded into the reactor amounted to 2,25 L with bulk density of 3,3 kg/l, the water contents in the initial methanol were 2,5% by weight. The Institute of Organic Chemistry of the Russian Academy of Science developed a catalyst based on intermetallic compounds (IMC), which was a mixture of intermetallic $LaNi_3Co_2H_4$ hydride and nickel metal binder in the following ratio: intermetallic hydride - 66 ... 80%, nickel - 20 ... 34% by weight.

Since in the beginning of the work there was an effect of the gradual development of IMC catalyst, to reduce its period the training and the activation of the catalyst by blowing inert gases (helium, argon), and then with hydrogen at a space velocity of 2500 h^{-1} has been carried out.

RESULTS OF RESEARCH

The activation took place at both ambient temperature and when the catalyst was heated to 250 ... 360^{0}C. To prevent the air going into the reaction chamber, during the reactor cooling there was an inert gas passing through it with a low flow (0,3 – 0,5 l/min), and instead of blowdown the reaction chamber was cooled in a static mode under the pressure of inert gas, for which the inlet and outlet valves had been installed. To maintain the temperature of the catalyst the reactor was provided with the changed mode of the engine or by restarting some of the exhaust gases past the reactor and through the bypass channel [19]. Pre-evaporation of methanol was carried out in the evaporator coil of 6 m (8 mm in diameter) wound around the exhaust pipe of the engine and shielded with a foil. Methanol feed to the reactor was realized by an autonomous gear pump with an electric drive. Methanol consumption ranged from 2,42 to 6 l/h that corresponded to a space velocity of methanol vapors 1100 – 4000 h^{-1}. Once the reactor was heated, a temperature at the length of the reactor tubes with the smallest possible gradient was maintained due to the periodical restart of the exhaust gases through the bypass.

Experimental data have shown that the methanol conversion reactor is extremely inertial. Thus, the heating time of the reaction chamber with the idling engine to the temperature that ensures the conversion of 65% with the methanol consumption of 2 kg/h, varies from 15 to 20 minutes.

The further tests have shown a low degree of conversion (50%), that's why an autopsy of the reactor reaction chamber was performed. The need for visual control of the catalyst was explained by the presence of a significant amount of MCP catalyst dust. Catalyst wear took place in the area of the exhaust gases inlet, characterized by high temperatures and significant dynamic effects from exhaust flow, resulting in vibration.

When the engine is stopped and the main feedline of the MCP is switched off, and when the reactor is cooled, the pressure in it is lower than the atmospheric one which results in creating conditions when air and moisture get into the reaction chamber and further poisoning of the catalyst if there is no proper tightness.

Once the reactor was recharged and the catalyst was activated with hydrogen, the tests of the system of heat flows regulation were continued for such modes of engine: n = 1800 min^{-1}, M_t = 49 Nm and n = 2000 min^{-1}, M_t = 78,5 Nm with a variation of the methanol consumption according to the scheme "3-6-3 kg/hour." The maximum temperature of the catalyst was maintained in the range 380 ... 420^{0}C by letting some of the exhaust gases go through the bypass. In alternating mode of the methanol fed to the reactor, the time needed to restore the temperature of the catalyst layer was not more than 10 ... 15 min with a smooth regulation of EG flow through the bypass.

The contents of the target (H_2 and CO) and by-products of methanol conversion were determined by chromatograph "Gazohrom-3101." According to the chromatographic analysis of the reaction, there were no by-products, such as methyl formate and dimethyl ether in the reaction products (see table 1). It should be noted that the water contents in MCP were less than in the original methanol, which indicates that the reaction was going with CO conversion with steam and carbon dioxide emission. Gaseous MCP consisted mainly of CO and H_2 at a high, up to 93% conversion rate of methanol. Methane was formed in small quantities.

Table 1. The methanol conversion automobile reactor laboratory tests results

Mode of ICE		Temperature of EG in the shell side cavity of reactor, °C	The space velocity of methanol vapors, h^{-1}	Methanol conversion products composition, % rev.					
n, min^{-1}	M_t, Nm			H_2	CO	CO_2	CH_4	CH_3OH	H_2O
1750	48,1	253	1625	53,1	31,1	6,9	1,2	7,2	0,4
1750	48,1	269	0	49,7	35,1	10,6	-	-	-
2000	XX	249	1700	64,9	30,1	4,9	-	-	-
2000	84,4	257	1500	60,0	38,1	0,4	1,5	-	-

Applying of tendered positioners with padding negative feedbacks on movement, pressure, temperature, power etc., possessing a number of advantages as contrasted to used earlier, namely: by absence of a static error of regulation; by a fast response time, regulator performance; by absence of self-oscillations in a broad band of change of parameters, that is favorable has an effect for durability of drives and results in reduction a dynamic error of regulation on 20 %, transient period on 50%, and increase of accuracy of positioning.

Outgoing from above-stated, it is possible to draw a conclusion, that the reviewed drives on the basis of controlled valves - amplifiers due to high static and response characteristics are perspective for applying in pneumatic drives of mechanical systems.

During the experiment a qualitative picture of the heat exchanges between the engine's EG and the reactor reaction chamber has been obtained, as well as some features of the behavior of the catalyst of intermetallic compounds when heated by exhaust gases heat have been identified. Thus, it was found that when the catalyst was activated and trained, and when it worked for 6 hours as a bench engine (with vibration, changed heat flows), its abrasion occurred.

This leads to the effect that the catalyst is constantly taken away from the reaction chamber to the MCP and the need to install the filters with pores of at least 4…6 mm at the reactor outlet.

The developed supply system of the MCP engine provides only a partial conversion of methanol and can be a source of on-board hydrogen-containing additive to the traditional fuel [20].

This additive is an effective way to improve the dynamics of combustion in gasoline engines, because of the homogenizing of the hydrogen, gas and air mixture, where the hydrogen acts as an igniter (promoter). It provides an efficient engine operation with a deep depletion of the fuel and air mixture and a sharp reduction in toxic emissions. The greatest impact on the workflow has a relatively small additive MCP 25 ... 30% by weight in the total fuel. The savings of the mixed fuel (by weight) at low loads of the engine amounts in this cases 17 ... 35% compared to gasoline [21].

CONCLUSIONS

1. These features of the methanol conversion reactor in terms of bench tests and the physical picture of a number of processes allow to eliminate the detected defects and to find the ways for further research on improving the process of the heat exchange and reactor design.

2. The studies have shown that the time for cooling and heating of the reactor is much longer than the time for changing the modes of engine operation (especially when driving on the urban cycle), that's why the reactor in thermochemical regeneration system can be considered as a static element, and the system controlling the heat flows can be used for controlling of the temperature level that does not exceed the maximum allowed for this type of catalyst.

3. There are two ways to increase the degree of methanol conversion: either to raise the temperature of the exhaust gases by additional combustion of some fuel, or to reduce the heat losses in the shell side of the reactor cavity by means of intensification of heat exchange (the creation of a boiling layer, the porous battery, by using the heat pipes, etc.).

4. The studies have confirmed the effectiveness of use of MCP as a fuel to improve fuel economy. Further efforts should be focused on creating effective low-temperature catalysts of methanol conversion on the porous carrier and the designs of heat exchangers.

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РЕЗУЛЬТАТЫ СТЕНДОВЫХ ИСПЫТАНИЙ АВТОМОБИЛЬНОГО РЕАКТОРА КОНВЕРСИИ МЕТАНОЛА

Виталий Баранов

Аннотация. Приведены результаты стендовых испытаний автомобильного реактора конверсии метанола, разработанного для микроавтобуса. Оценено влияние ряда режимных показателей работы двигателя на производительность реактора.

Ключевые слова: двигатель, реактор, метанол, конверсия.