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Features of Using Liquefied Petroleum Gas with Addition of Dimethyl Ether as Fuel of Car with a Spark-Ignition Engine

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ABSTRACT: The article presents the results of studies of a passenger car with a spark-ignition internal combustion engine running on liquefied petroleum gas (LPG) with the addition of dimethyl ether (DME). Comparative results obtained for the base (gasoline, LPG) and composite gas (DME concentration 5, 10, 15% in LPG) fuels are presented. Based on the work performed on the use of LPG with DME additives as a motor fuel for a spark-ignition engine, it has been established that the upper concentration of DME in LPG is limited by the antiknock resistance of the composite fuel.

KEYWORDS: car, composite gas fuel, diesel and gasoline vehicles, dimethyl ether, the environmental performance of vehicles, LPG- Liquified Petroleum Gas, oil refining, spark ignition.

I. INTRODUCTION

The analysis of the performed scientific and technical developments very clearly shows that the use of alternative motor fuels and energy in the field of transport, in particular road transport, is the most rational and affordable solution to modern energy and environmental problems.

The most modern direction in this area is the use of dimethyl ether (DME) as a motor fuel, which will significantly reduce oil production and refining, increase the use of environmentally friendly alternative motor fuels of non-oil and biological origin, reduce the tension of fuel supply, increase operational, including environmental indicators of vehicles running on this type of fuel. Conversion of diesel and gasoline vehicles to DME power supply in whole or in part with minimal design and regulatory changes solves several environmental problems of transport and this connection is a very urgent task.

II. ANALYSIS OF PUBLICATIONS

In the last decades of the twentieth century, researchers in many countries of the world, especially Austrian, Danish and American, actively carry out scientific and practical work on the use of DME as a substitute for diesel fuel [1, 2, 3].

Most of these scientific works are devoted to the use of DME as an environmentally friendly substitute for diesel fuel (DF) and DME is considered in them as a new, universal, efficient and environmentally friendly motor fuel that does not contain aromatic hydrocarbons, sulphur and is characterized by complete combustion, high cetane number (55-60 versus 40-55 for petroleum diesel fuel) and the absence of soot, nitrogen oxides and carbon dioxide in exhaust gases,

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which is especially important for large metropolitan areas [4, 5, 6].

However, in most of these works, it was found that when using DME as the main fuel (complete replacement of diesel fuel), the control and design of the fuel supply system become more complicated (structural and technological changes in order to compensate for the low heat of combustion and viscosity of DME in comparison with diesel fuel) and several problems arise associated with an unstable diesel engine.

Several scientific works related to the use of a mixture of liquefied petroleum gas (LPG) and DME as a motor fuel for an internal combustion engine (ICE) with spark ignition have been carried out [7, 8, 9, 10].
In these works, it is noted that the use of DME as an additive to LPG leads to some reductions in the values of power and torque of the internal combustion engine compared to the base fuel, as well as a decrease in emissions of harmful substances - carbon monoxide (CO) and hydrocarbon (CH) compared to the base fuel. fuels.

However, at the same time, there are no results of scientific work related to the study of speed and acceleration characteristics and environmental (including greenhouse gas emissions) indicators of vehicles running on LPG with DME additives.

III. PURPOSE AND PROBLEM STATEMENT

Based on the above, the purpose of this work was to study the performance of a passenger car with a spark-ignition engine running on a composite gas fuel (a mixture of LPG and DME).
Description of the comparative properties of fuels, and the experimental car.A comparative analysis is carried out by studying the quality indicators of various investigated fuels (tab. 1).

Table 1.Indicators of various motor fuels under investigation.

Indicators	Fuel					
	Petrol	Dieselfuel	CNG	LPG		DME
Chemicalformula	C_8H_{18}	$C_{15}H_{32}$	CH_4	C_3H_8	C_4H_8	C_2H_6O
Molecularmass	114,5	190	16	44	58	46,07
Elementary composition: C H O	85,5 14,4 0,1	86 13 1	74,6 25,4 —	82 18 —	82 18 —	52,2 13,0 34,8
C: H ratio	5,3	6,62	2,93	4,55	4,55	4,02
Density, g / cm^3 (kg/m^3) liquid phase gas phase	0,720 1,07	0,85 1,23	0,5 0,68	0,509 2,018	0,582 2,703	0,68 (2,1)
Net calorific value, MJ / kg of combustible mixture fuel $d = N_{max}$	44 3,10	42 2,09	49.5 2,63	46,5 3,02	45,5 3,02	28,4 1,06
Ignition temperature (self-ignition), °C	470…530 (220)	290…310 (430)	680…700 (570)	475…580 (520)	475…580 (520)	235 (350)
Flammability limit in air,% lower upper	1,4 7,4	0,6 6,5	5,3 15,0	1,8 9,5	1,8 9,5	3,4 18,0
Excess air ratio suitable: flammable limit maximumpower	0,7…1,1 0,85…0,95	0,9…5,0 1,3…1,5	0,7…1,3 1,05…1,15	0,7…1,2 0,3…1,05	0,7…1,2 0,3…1,05	3,4…34 3,0…4,5

Theoretically required amount of air for complete combustion of fuel, kg / kg	14,85	14,35	17,1	15,2	15,2	9
Octane Number, RON	76-98	-	115-120	100-105		-
Cetanenumber, CN	-	45-55	-	-		55-60

It follows from the above data that at certain concentrations of DME in LPG, the antiknock resistance of the composite gas fuel may change.
In accordance with the World Fuel Charter, the following requirements are imposed on the octane number of motor gasoline or other fuels for an internal combustion engine with spark-ignition (Table 2.)

Table 2.Limiting values of the octane numbers of modern motor gasoline.

Indicatorname	Gasoline brand	Limit value	
		Min.	Maks
Research OctaneNumber	91	91	-
Motor octanenumber	91	82	-
Research OctaneNumber	95	95	-
Motoroctanenumber	95	85	-
Research OctaneNumber	98	98	-
Motoroctanenumber	98	88	-

It is known that DME has a rather high (over 55) cetane number (CN), which is related to the octane number (RON) of gasoline by the following formula:
CN = 60- RON / 2 or CN = (120 - RON) / 2 (1)
Then the RON values of gasoline or motor fuels for an internal combustion engine of spark ignition are determined by the formula:
RON = 120 - 2CN (2)
The results of the performed analytical calculations of changes in the RON of composite gas fuels are presented in the form of a table (Table 3.)

Table 3.The octane number of various motor fuels.

Fuel	The research octane number(RON)	Changing the RON value	Actual RON	Note
LPG	100-105	-	100	Norm
DME	10	-	10	-
LPG 95+DME05	96	4	96	Norm
LPG 90+DME10	91	9	91	Norm
LPG 85+DME15	86,5	13,5	86,5	Limitation

Thus, the maximum concentration of DME in the LPG composition according to the permissible RON value or according to the antiknock resistance of the composite gas fuel is no more than 10%. It should be added that this concentration may slightly change according to the results of experimental studies.
At the same time, a regression equation was obtained, obtained by the least-squares method by calculating the RON of the composite gas fuel, depending on the concentration of DME in the LPG composition.
$RON = -1{,}18K_{DME} + 100{,}6$ (3)
The resulting composite gas fuels (a mixture of LPG and DME) were examined during field tests of a NEXIA III vehicle equipped with a universal power system.

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In the course of field tests, the speed and acceleration indicators (tab. 4) of the NEXIA III car operating on various fuels were obtained using the "KORSUS-DATRON" test complex.

Table 4.Speed and acceleration indicators of the car NEXIA III.

№	Fuel	V_{max}, km/h	Acceleration time to 100 km / h, s
1	PetrolAI-91	179	15.2
2	LNG	178	16.0
3	LPG	176	15.6
4	LPG 95+DME05	174	15.6
5	LPG 90+DME10	177	15.7
6	LPG 85+DME15	166	16.5

IV. RESULTS AND DISCUSSION

The calculated comparative indicators of various motor fuels for the spark-ignition internal combustion engine have been established, which make it possible to carry out further stages of the necessary research.
For the purpose of comparative research on various fuels (gasoline, LNG, LPG, LPG with various DME additives), speed-acceleration indicators (maximum speed, acceleration time up to 100 km / h) were obtained. The results obtained showed close to the results of the base car.

V. CONCLUSION

Based on the work performed on the use of LPG with DME additives as a motor fuel for a spark-ignition engine, it has been established that the upper concentration of DME in LPG is limited by the antiknock resistance of the composite fuel.
The obtained speed and acceleration indicators (maximum speed, acceleration time to 100 km/h) of a passenger car running on a composite gas fuel containing 6-10% DME (SNG90 + DME10) with LPG are practically the same with the results of the base car.

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