Development of tractor gas-diesel modifications

O P Lopatin

Department of thermal engines, automobiles and tractors, Vyatka State Agricultural Academy, 610017, Kirov, October prospect, 133, Russian Federation

E-mail: nirs_vsaa@mail.ru

Abstract. A system for reducing toxicity has been developed that includes the use of compressed natural gas (CNG) and exhaust gas recirculation (EGR) and is intended for both new tractors and those in service. The use of CNG does not require expensive equipment, significant design changes, and re-equipment is possible in specialized workshops of farms and repair and technical enterprises.

Conditions for CNG for gas-cylinder machines in the Russian Federation are regulated in GOST 27577-2000 "Compressed fuel gas for internal combustion engines", which determines its performance indicators. CNG by its properties is suitable for use in cars and tractors. But, like any fuel, gas must be pre-prepared not only for storage in a tractor or car, but also for regulating parameters that affect performance properties. The gas must be stable not only in its component composition, but also in the presence of various impurities. The liquid residue, which is a group of heavy hydrocarbons, such as pentane, in CNG that has not been processed, varies widely. A significant problem when using CNG in automotive equipment is associated with moisture content and drying, since the moisture content of CNG pumped through main pipelines can reach large values. The presence of moisture in CNG for automotive equipment should not be higher than 9 mg/m³. At automobile gas-filling compressor stations, this indicator is necessarily monitored. The moisture in the CNG forms ice jams in the power system [1-6].

A characteristic feature of CNG-powered equipment is the presence of a gas cylinder device. Unified tractors running on CNG with basic diesels of current production in Russia are not sufficiently developed. Since the transfer to CNG equipment requires certain design solutions, the body is also being upgraded to accommodate gas cylinders. For versatility, the tractor is equipped with two equivalent autonomous power systems - CNG and diesel fuel (DF). The unification of power systems contributes to the expansion of the potential data of the workflow with the ability to regulate mixing, energy saturation of tractors and broad final capabilities [7-13].

The CNG power system contains classic equipment for such power systems and includes CNG cylinders with shut-off equipment, gas reducers, a CNG heater connected to the cooling system, a gas dispenser-mixer, a magnetoelectric valve with a filter, a high-pressure fuel pump with a device (HPFP) for remote control of the ignition dose, and connecting gas pipelines. The equipment of the gas supply system is equipped with protection and controls [14-19].

Reliable CNG ignition requires a high temperature or a small suitable pilot charge supply (15-20%). Start-up and idling are provided by DF, and operation under various load conditions and maintaining the necessary power are provided by CNG.
Reduced power when running on CNG can degrade the traction-dynamic and operational data, so a controlled distribution of gas injection into the cylinders is used. This system not only restores power, but, most importantly, guarantees minimal toxic emissions [20-25].

The pilot portion of DF is limited by the stroke of the HPFP rail and dispenser, depending on the HPFP design. Switching to power from DF to CNG and vice versa is performed by a switch. The CNG feed system can contain a diaphragm limiting mechanism that provides cover for the throttle of the mixer-dispenser when the CNG supply is higher than allowed. At the end of CNG, you can quickly switch to full-fledged operation on diesel fuel, which is a very important advantage when the network of gas-filling compressor stations and mobile tankers is not widespread enough. The CNG power system allows for good detonation properties and ensures efficient operation. The rated power on CNG and diesel fuel is the same, which ensures almost constant traction qualities of tractors on CNG [26-33].

Chemical inertia, which characterizes the high octane number of methane (100-105 and 110-115, respectively, according to motor and research methods), allows it to be used at a compression ratio of 12-16. Methane-detonation-resistant among all hydrocarbons is also superior according to this indicator, including isoctane, which serves as a standard for detonation resistance. If the CNG supply system is properly adjusted and functioning, the probability of carbon monoxide and other harmful substances being formed is limited, since methane combustion occurs in poor fuel-air mixtures.

CNG burns almost without carbon formation. Also on CNG, some researchers note an increased service life of the injectors. CNG does not wash off the oil film from the cylinder walls, which improves the lubrication of the rubbing sleeve – upper piston ring pair. CNG almost does not produce varnish deposits and carbon deposits. CNG gives almost no varnish deposits and sludge that reduce the pollution and dilution of the oil, are less common for this reason, adjustment of the various elements [34-41].

**Figure 1.** CNG and EGR powered system on a tractor-mounted engine.

Along with the positive signs of tractors CNG nutrition has some disadvantages. The main drawback of CNG as a motor fuel is 1000 times less than in liquid petroleum fuels, the volume energy supply of 0.034 MJ/dm³ against 31.3 MJ/l in gasoline and 35.6 MJ/l in DF. This is to some extent due to the insufficient number of automatic gas filling compressor stations and their significant distance from the agro-industrial complex [42-50].

Difficulties with starting the engine in the cold season (below 0°C) are explained by the higher ignition temperature and self-ignition of natural gas in relation to gasoline and diesel fuel. It should also be noted the increased requirements for explosion and fire safety. The fire and explosion hazard of gas tractors is ensured by the creation of the most advanced shut-off valves, namely, miniature sensitive sensors that can be installed in all places where gas leaks are likely.
In the Russian Federation, the use of natural gas as a motor fuel, despite its obvious advantages, is at a very low level, which is explained by the following main reasons:

- insufficiently developed infrastructure;
- low consumer demand for a vehicle with gas fuel or the need to organize the production of such vehicles;
- inertia of buyers’ thinking.

Despite this, a mock-up model of the MTZ-80 tractor was created (figure 1) with a power system upgraded to work on CNG with EGR, which has improved environmental indicators and is designed to work in various sectors of the road economy, in the city for the needs of special vehicles, as well as in rooms with limited air exchange and in environmentally extreme conditions; its functional tests were carried out [51-59].

The recirculated gases are cooled in two stages: a liquid heat exchanger (figure 2), where cooling occurs due to heat transfer of the coolant from the tractor cooling system, and an air cooler (figure 3), cooling due to heat transfer to the atmosphere [60-67].

A comprehensive system for reducing toxicity, including the use of regulated EGR and CNG, can be used both on new tractors and on those in service. Installation of the system does not require expensive equipment, significant design changes and can be carried out in the conditions of specialized workshops and repair and technical enterprises.

References
[1] Bhaskar K and Sendilvelan S 2018 Pertanika Journal of Science and Technology 26(3) 1067-80
[2] Chuvashov A N and Chuprakov A I 2019 Journal of Physics: Conf. Series 1399 055085
[3] Marchuk A, Likhanov V A and Lopatin O P 2019 Theoretical and Applied Ecology 3 080-6
[4] Lopatin O P 2020 Journal of Physics: Conf. Series 1515 052004
[5] Jung Y and Bae C 2015 Fuel 161 312-22
[6] Kozlov A N, Anfilatov A A and Chuvashov A N 2019 Journal of Physics: Conf. Series 1399 055051
[7] Likhanov V A and Lopatin O P 2018 IOP Conf. Series: Materials Science and Engineering 457 012011
[8] Anfilatov A A and Chuvashov A N 2020 Journal of Physics: Conf. Series 1515 022035
[9] Skryabin M L 2020 IOP Conf. Series: Earth and Environmental Science 421 072012
[10] Likhanov V A and Lopatin O P 2019 Journal of Physics: Conf. Series 1399 055016
[11] Plianos A and Stobart R K 2011 International Journal of Systems Science 42(2) 263-275
[12] Skryabin M L and Likhanov V A 2020 IOP Conf. Series: Materials Science and Engineering 734 012075
[13] Likhanov V A and Lopatin O P 2019 Journal of Physics: Conf. Series 1399 055020
[14] Fino D and Russo N 2011 Industrial and Engineering Chemistry Research 50(5) 3004-10
[15] Anfilatov A A and Chuvashov A N 2020 Journal of Physics: Conf. Series 1515 042052
[16] Likhanov V A, Lopatin O P and Yurlov A S 2019 Journal of Physics: Conf. Series 1399 055026
[17] Tsolakis A, Torbati R, Megasitis A and Abu-Jrai A 2010 Energy and Fuels 24(1) 302-8
[18] Kopchikov V N and Fominykh A V 2020 Journal of Physics: Conf. Series 1515 042028
[19] Likhanov V A and Lopatin O P 2020 IOP Conf. Series: Earth and Environmental Science 421 072018
[20] Lopatin O P 2020 IOP Conf. Series: Earth and Environmental Science 421 072019
[21] Abd-Elhady M S, Zornet T, Malayeri M R, Müller-Steinhagen H et al. 2011 International Journal of Heat and Mass Transfer 54(4) 838-46
[22] Anfilatov A A and Chuvashov A N 2020 Journal of Physics: Conf. Series 1515 042048
[23] Likhanov V A and Lopatin O P 2020 Journal of Physics: Conf. Series 1515 052002
[24] Abd-Elhady M S, Malayeri M R and Müller-Steinhagen H 2011 Fouling Heat Transfer Engineering 32(3-4) 248-57
[25] Anfilatov A A 2020 Journal of Physics: Conf. Series 1515 042049
[26] Likhanov V A and Lopatin O P 2019 Ecology and Industry of Russia 23(9) 60-5
[27] Jatana G S, Naik S V, Shaver G M and Lucht R F 2014 International Journal of Engine Research 15(7) 773-88
[28] Lopatin O P 2020 Journal of Physics: Conf. Series 1515 042009
[29] Anfilatov A A and Chuvashov A N 2020 Journal of Physics: Conf. Series 1515 042077
[30] Skryabin M L and Likhanov V A 2019 Journal of Physics: Conference Series 1399 044063
[31] Likhanov V A and Lopatin O P 2018 Ecology and Industry of Russia 22(10) 54-9
[32] Chuvashov A N, Chuprakov A I and Anfilatov A A 2020 IOP Conf. Series: Materials Science and Engineering 734 012184
[33] Likhanov V A, Kopchikov V N and Fominykh A V 2020 Journal of Physics: Conf. Series 1515 042026
[34] Romanyuk V, Likhanov V A and Lopatin O P 2018 Theoretical and Applied Ecology 3 27-32
[35] Devetyarov R R and Chuvashov A N 2020 Journal of Physics: Conf. Series 1515 042080
[36] Lopatin O P 2020 Journal of Physics: Conf. Series 1515 042021
[37] Anfilatov A A 2020 Journal of Physics: Conf. Series 1515 042098
[38] Likhanov V A and Lopatin O P 2020 IOP Conf. Series: Materials Science and Engineering 734 012202
[39] Skryabin M L 2020 Journal of Physics: Conf. Series 1515 04283
[40] Arent D J, Wise A and Gelman R 2011 Energy Economics 33(4) 584-93
[41] Likhanov V A, Lopatin O P and Yurlov A S 2020 IOP Conf. Series: Materials Science and Engineering 734 012208
[42] Lif A and Holmberg K 2006 *Advances in Colloid and Interface Science* **123**(126) 231-9
[43] Chuvashev A N and Chuprakov A I 2020 *Journal of Physics: Conf. Series* **1515** 042094
[44] Lopatin O P 2020 *IOP Conf. Series: Materials Science and Engineering* **734** 012199
[45] Skryabin M L and Grebnev A V 2020 *Journal of Physics: Conf. Series* **1515** 052052
[46] Subramanian K A 2011 *Energy Conversion and Management* **52** 849-57
[47] Likhanov V A and Lopatin O P 2020 *Journal of Physics: Conf. Series* **1515** 042008
[48] James C A and Szybist P 2010 *Energy* **35** 1658-64
[49] Likhanov V A and Lopatin O P 2017 *Thermal Engineering* **64**(12) 935-44
[50] Skryabin M L 2020 *Journal of Physics: Conf. Series* **1515** 042107
[51] Rajkumar S Thangaraja J 2019 *Fuel* 101-18
[52] Likhanov V A and Lopatin O P 2020 *Journal of Physics: Conf. Series* **1515** 042019
[53] Likhanov V A and Rossokhin A V 2018 *IOP Conf. Series: Materials Science and Engineering* **457** 012007
[54] Erdiwansyah, Mamat R, Sani M S M et al. 2019 *Energy Reports* **5** 467-79
[55] Vellaiyan S, Subbiah A and Chockalingam P 2019 *Fuel* **237** 1013-20
[56] Likhanov V A and Skryabin M L 2019 *IOP Conf. Series: Earth and Environmental Science* **315** 032045
[57] Kumar A N, Kishore P S, Raju K B et al. 2019 *Environmental Science and Pollution Research* **26**(7) 6652-76
[58] Likhanov V A and Rossokhin A V 2019 *Journal of Physics: Conf. Series* **1399** 044038
[59] Sinyavski V V, Shatrov M G, Dunin A Y et al. 2019 *Periodicals of Engineering and Natural Sciences* **7**(1) 281-6
[60] Al-Esawi N, Qubeissi M A and Kolodnytska R 2019 *Energies* **12**(9) 1804
[61] Likhanov V A and Rossokhin A V 2020 *IOP Conf. Series: Materials Science and Engineering* **734** 012207
[62] Kuszewski H 2019 *Fuel* **235** 1301-8
[63] Likhanov V A, Kozlov A N and Araslanov M I 2020 *IOP Conf. Series: Materials Science and Engineering* **734** 012211
[64] Yesilyurt M K 2019 *Renewable Energy* **132** 649-66
[65] Shah P R, Gaitonde U N and Ganesh A 2018 *Renewable Energy* **115** 685-96
[66] Likhanov V A, Rossokhin A V and Devetyarov R R 2020 *Journal of Physics: Conf. Series* **1515** 042064
[67] Algayyim S J M, Yusaf T, Wandel A P and Hamawand I 2018 *Renewable and Sustainable Energy Reviews* **82** 1195-214