ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1136853

GTD-350 ENGINE POWERED BY LPG – RESEARCH WORK

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Abstract

The paper presents results of comparative tests of exhaust gases toxicity of GTD-350 turboshaft engine powered by Liquefied Petroleum Gas (LPG) and conventional JET-A1 fuel. Structure of GTD-350 engine's test bed was discussed. Because of explosion danger of LPG vapour the test stand was arranged in the open air. Paper comprises specification of LPG supply system, gas injector's construction and visualization of LPG injection. The supply system was based on the newly constructed pressurized injectors. Required LPG operating pressure was obtained by pressurizing LPG tank using nitrogen and LPG-flow was controlled using needle valve. A series of photographs presents shape of fuel streams for new injector supplied by JET-A1 and LPG. Photos of flame torches for multi-hole and conical type injectors fuelled by LPG are inserted as well. A comparative study of carbon monoxide, nitrogen oxides, hydrocarbons and carbon dioxide as well as oxygen concentration for GTD-350 equipped with new injectors fuelled by LPG and standard supplied by Jet-A1 was carried out. The study comprised turbocharger speed range between 40 and 80% of NTS. The exhaust gas temperature comparison for above-mentioned configuration is presented as well. All data shown in presented figures are mean of 6 measurements. All completed tests were carried out for standard GTD-350 engine combustion chamber.

Keywords: *turboshaft engine, Liquefied Petroleum Gas (LPG), toxicity*

1. Introduction

Turbine engines are distinguished, in comparison with piston engines, by a number of advantages particularly useful when used in power units. The disadvantage, which prevents widespread use of them, is high specific fuel consumption of JET-A1a and in consequence – high operating costs. The specialists employed in Institute of Aviation (Warsaw, Poland) undertook some activities to eliminate this obstacle through applying of liquid gas (LPG) used to fuel the turboshaft engine GTD-350, giving wide consideration to environmental aspects.

2. Test bench

As part of research project conducted at Institute of Aviation the test stand equipped with dynamometer for testing of GTD-350 engine was erected, adapted for supply the engine under test with LPG. Due to the high risk of LPG vapour explosion the constructed test bench was placed in the open air. To impose a load to the free power turbine a three-bladed airscrew of aircraft *Mewa* (*Seagull*) was used with a fixed pitch, which provided the correct operation of the engine in established research range. A strong stream of dusty after-airscrew air forced the need of moving engine's air-intake away of the mounting plate.

3. Engine's LPG-fuelling system

Owing to unsuccessful attempts of engine supply using the vane pump a pressurized fuelling system was build. For that purpose, the compressed nitrogen from gas cylinder was fed directly to

LPG-containing tank. Pressure value of LPG in the system used to feeding of injector can be maintained for a period of time necessary for carrying out of research task (approximately 2 hours).

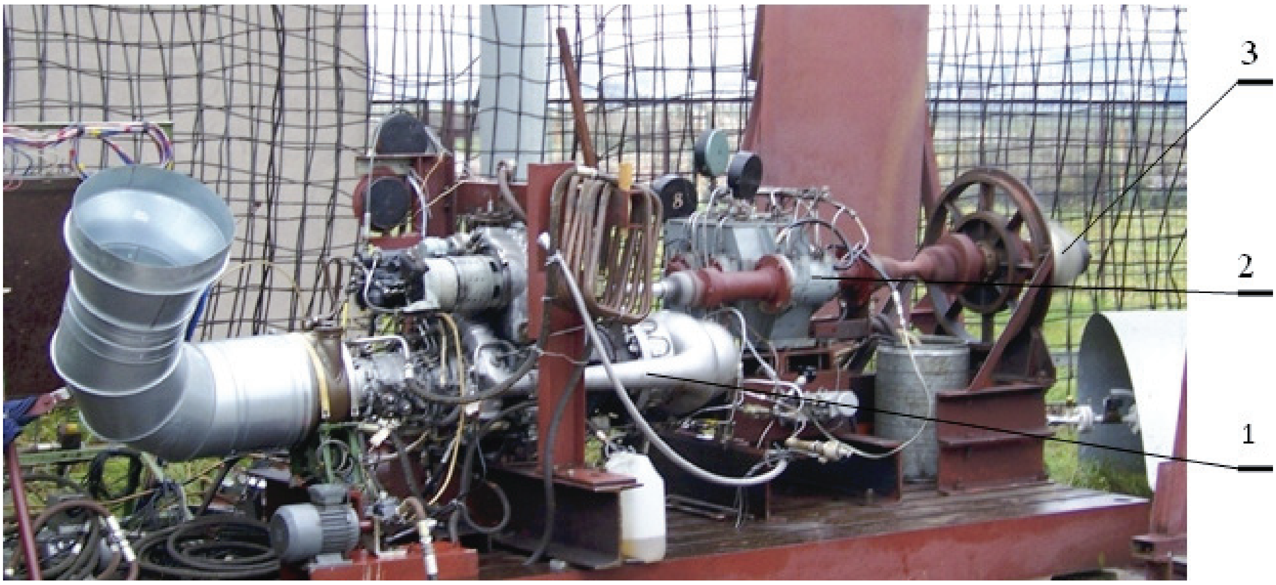

Fig. 1. View of test bench: 1 – GTD-350 engine, 2 – gear, 3 – propeller

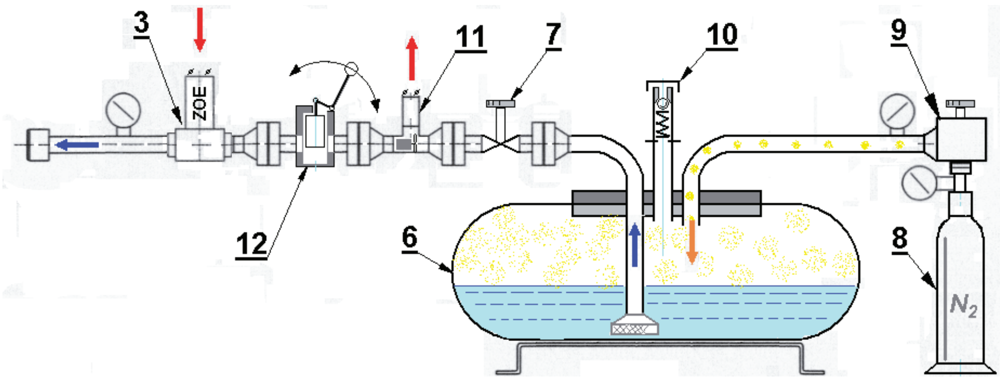

Fig. 2. Schematic diagram of applied LPG pressurized fuelling system: 3 – solenoid cutting off valve, 6 – LPG tank, 7 – cutting off valve, 8 – gas cylinder contained compressed nitrogen, 9 – reducer, 10 – the valve to refuelling of tank, 11 – turbine flow meter, 12 – hand-operated throttle valve

4. Construction and testing work of injectors

The next task was to develop the LPG injectors. For this purpose, new fuel stream forming elements were worked out on the assumption that they should be installable in the original injector housing. In effect, multi-hole and conical type injectors were developed. The multi-hole injector was formed as a sleeve with drilled holes whereas on the surface of conical type a number of small ducts of proper width and depth was nicked to obtain the desired flow cross-section.

The following, presented below, injectors were selected for engine bench tests.

Tab. 1. Summary of test injectors

Type injector	Shape	Dimensions
Conical-type injector No. 1	12 small ducts	0.5 × 0.4 mm
Conical-type injector No. 2	12 small ducts	1.0 × 0.15 mm
Multi-hole injector No. 4	6 holes	⌀0.8 mm
Multi-hole injector No. 5	8 holes	⌀0.7 mm

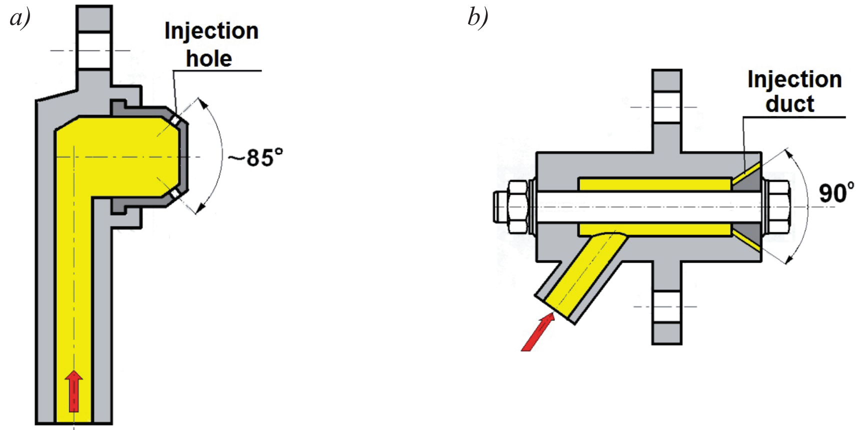

Fig. 3. Alternative designs of multi-hole LPG-injector: modification of original GTD-350 engine's injector (a), and the plate-conical type injector (b)

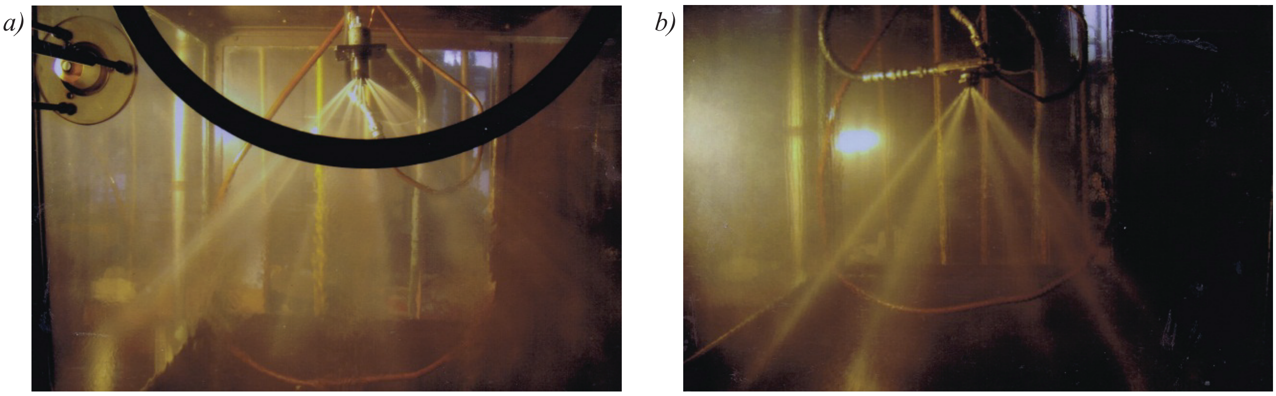

Fig. 4. Shape of kerosene jets acquired at test bed for conical-type No. 2 (a) and multi-hole No. 4 (b) injectors

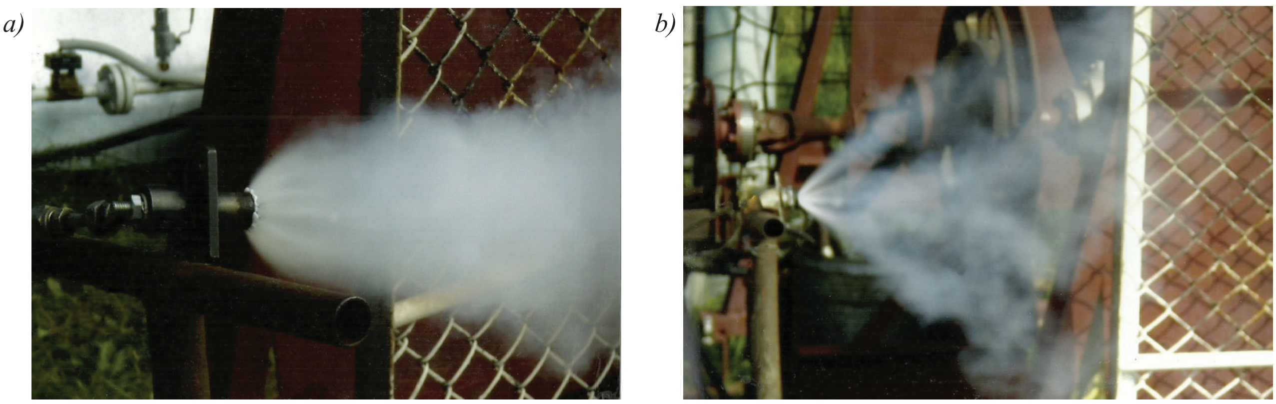

Fig. 5. LPG jets acquired in open air for conical-type No. 2 (a) and multi-hole No. 4 (b) injectors

More advantageous atomization of the fuel was obtained for the cone-type injector. At the photos, representing torches attention should be paid to the flame, which is not divided into separate streams. Unfavourable phenomenon of LPG-solid phase separation at injector's surface was observed when operated at "free" space at the ambient temperature between 10 and 25°C.

5. Engine testing

The procedure for LPG-fuelling of testing engine consisted in removing first of all from engine's working volume all gaseous remainders of volatile LPG-fraction by means of twice carrying out the "cold starting procedure". Next, desired amount of liquid phase of LPG was set up using the

a)

b)


Fig 6. Flame torches of LPG formed for conical-type No. 2(a) and multi-hole No. 4 (b) injectors

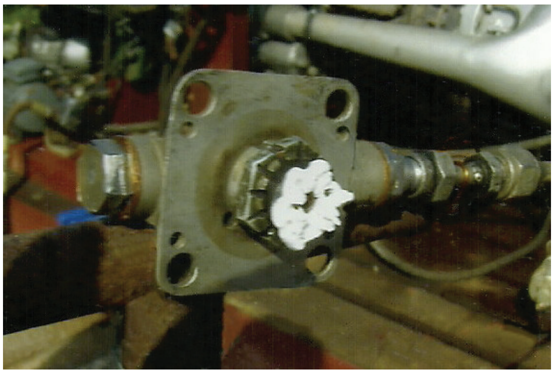

Fig. 7. Superficial deposit of LPG solid phase at conical-type injector No. 2

dosing valve (Fig. 2., item 12), original starting system comprising starting injector and spark plug was activated and finally engine was put in motion using generator/starter. After 9-10 seconds, when the engine reached 17-20% nominal turbocharger speed and about 8-10% nominal low-speed turbine revolutions the liquid fraction of LPG feed was started.

Required speed of turbocharger for the next test point was adjusted by changing the needle position of dosing valve. After stabilization of the engine's operating parameters (about 3-4 minutes), the emissions measurement of exhaust gas was carried out. All achieved and presented below data were averaged from 6 successive measurements. For comparisons, multi-hole injector No. 5 and No. 2 supplied by LPG and original GTD-350 engine's injector fuelled by Jet-A1 were selected.

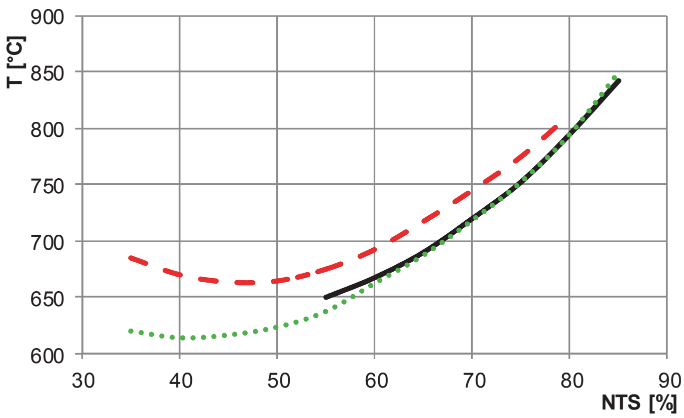

Fig. 8. Exhaust gas temperature in front of turbine: — original injector (JET-A1), – – conical-type injector No. 2 (LPG), • • • multi-hole injector No. 5 (LPG)

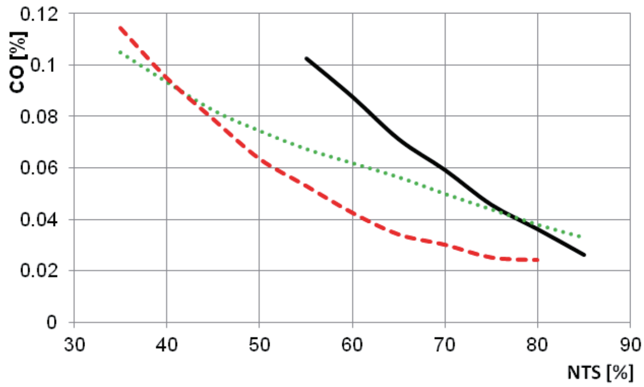

Fig. 9. CO-concentration: — original injector (JET-A1), – – Conical-type injector No. 2 (LPG), • • • multi-hole injector No. 5 (LPG)

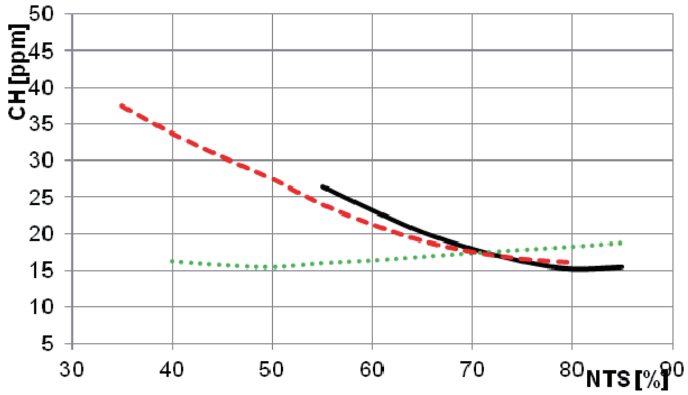

Fig. 10. CH-concentration: — original injector (JET-A1), – – Conical-type injector No. 2 (LPG); • • • multi-hole injector No. 5 (LPG)

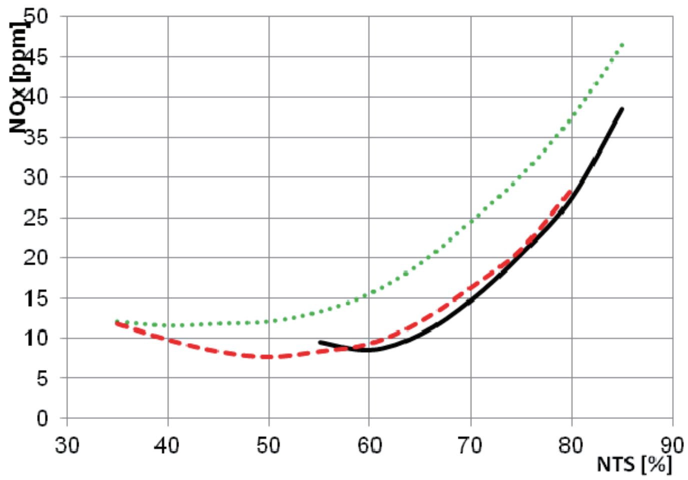

Fig. 11. NO_x-concentration: — original injector (JET-A1), – – Conical-type injector No. 2 (LPG), • • • multi-hole injector No. 5 (LPG)

6. Summary

GTD-350 engine supplied with liquid LPG worked properly in the whole speed range of turbo-charger, reaching comparable values of research parameters as by feeding with JET-A1.

CO and CH concentrations were lower when running on LPG in comparison with Jet-A1.

NO_x concentration was similar to those as by feeding with Jet-A1 fuel.

The results obtained in the course of research works have been achieved without any modification of original combustion chamber.

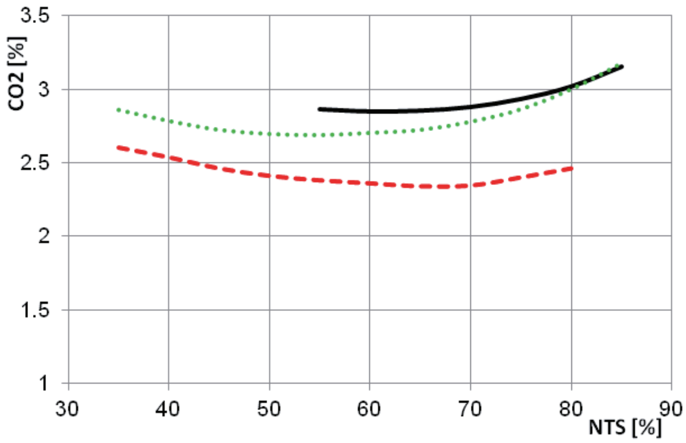

Fig. 12. CO_2-concentration: — original injector (JET-A1), – – Conical-type injector No. 2 (LPG), • • • multi-hole injector No. 5 (LPG)

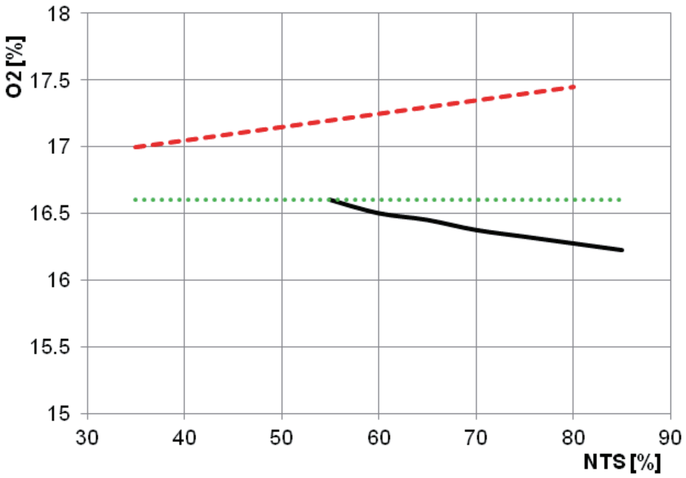

Fig. 13. O_2-concentration: — original injector (JET-A1), – – Conical-type injector No. 2 (LPG), • • • multi-hole injector No. 5 (LPG)

Further research work should be focused on optimization of injectors, supplying system and shape of combustion chamber.

References

[1] Flamme, M., et al., *Low Emission Gas Turbine Combustors Based on Flameless Combustion*, ECM 2003, pp. 25-28, Orleans, France 2003.

[2] Katsuki, M., Hasegawa, T., *The Science and Technology of Combustion in Highly Preheated Air*, Proc. Combust. Inst., No. 27, pp. 3135-3146, 1998.

[3] Magistri, L., Costamagna, P., Massardo, A. F., et al. ., *A Hybrid System Based on a Personal Turbine (5 kW) and a Solid Oxide Fuel Cell Stack. A Flexible and High Efficiency Energy Concept for the Distributed Power Market*, Journal of Engineering for Gas Turbines and Power, No. 124, pp. 850-857, 2002.

[4] Mantzaras, J., Appel, C., Benz, P., *Catalytic Combustion of Methane/Air Mixtures over Platinum. Homogenous Ignition Distances in Channel Flow Configuration*, Proc. Combust. Inst., No. 28, pp. 1349-1357, 2000.

[5] Niedziałek, B., Balicki, W., Gryglewski, W., *Możliwości zastosowania silnika GTD-350 do celów nielotniczych*, Materiały Konfer. Siln. spalin. w zastos. wojskowych, Jurata 2003.