PROPOSAL FOR FUEL – REGULATORY SYSTEM FOR SMALL TURBOSHAFT ENGINE

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The content of this article is proposal for fuel - regulatory system for small turboshaft engine TS - 20, which is converted into energy unit in the laboratory KKE is needed because the original fuel units - regulatory system are not available. TS - 20 as a power unit will work with gaseous fuel and replace the original mechanical control system of automatic regulation FADEC.

K e y w o r d s: power generating combustion turbine, fuel – regulatory system, regulation, turbin starter TS – 20, FADEC, turboshaft engine.

1 INTRODUCTION

Turboshaft engine TS - 20 located at Department of Power System Engineering (KKE) Faculty of Mechanical Engineering at the University of West Bohemia is the original turbine starter whose free gas turbine is kinematically connected to the rotor starting turboengine starting the engine AL-7F-1, fighter-bomber Su-7BM. A disadvantage of these motors is their short run (50 – 60 sec). For its practical use, in this case, use the engine to study and laboratory conditions, will require a reduction in work mode, thus reducing the resulting performance.

Original components of the fuel - regulatory system TS - 20 are not available, therefore the proposal of suitable assemblies components for the system is needed. The original regulatory system turboshaft engine TS - 20 was mechanical. With respect to the contemporary situation, it is appropriate, therefore, to use motor regulatory system FADEC. FADEC system makes the selection of appropriate components in the system. Another peculiarity compared to the original fuel - regulatory system is that as the fuel, gas will be used LPG**.**

2 ANALYSIS OF FUEL – REGULATORY SYSTEMS FOR SMALL TURBOSHAFT ENGINE TS - 20

The original control of the engine TS - 20 was mechanical. Oil - fuel pump 414AF-3 is assigned to supply oil and fuel to the engine during its operation. The pump has several regulatory elements.

Speed of turbo – compressor are regulated on the basis of measurements of the gas temperature behind gas turbine T_{4c} and afterwards are re-regulated by supplement of gas to the engine. The turbine was burdened when running turbocompressor rotor.

Governing valve of initial pressure in the fuel pump is designed to ensure the supply of fuel in the engine spins depending on the pressure after the compressor p_{2c} with short term increase in the gas temperature to a maximum value given by technical conditions. The control valve consists of a bellows and adjusting screws.[8]

2.1 Fuel – regulatory system for engine MPM 20

Experimental small jet engine MPM 20, located in the laboratory of the Aviation engineering at the Faculty of Aeronautics, is structurally modified turbine starter TS – 20. Fuel regulatory system engine MPM – 20 may be put as example for the proposed fuel - regulatory system.

Parts of fuel - regulatory system: fuel tank, fuel filter, solenoid valve, fuel pump 6223 LUN, fuel filter LUN 7165, fuel - oil unit 414AF-3, flow control valve, solenoid shut-off valve, fuel flow, fuel temperature sensor, flexible connection.

Fuel is supplied to the four fuel nozzles location in the fuel cell turbine starter by fuel - oil pump 414AF - 3, which is electrically powered. The fuel is gasoline B - 70 which is drawn from a special fuel tank containing fuel in the necessary volume to trigger activity.

In the process of starting engine the fuel supply to the combustion chambers is regulated depending on the pressure after the compressor motor control valve p_{2c} of initial fuel pressure, which is located in the aggregate 414AF – 3. Change the value of the initial fuel pressure is controlled alongside with the nature of the accretion pressure when cranking the engine by an adjusting screw valve of initial fuel pressure.

Regulation of output gas temperature T_{4c} of small jet engine is allowed by reducing valve, which is located in the aggregate 414AF - 3. Reduction valve is adjusted by firing of the fuel back to the fuel inlet gear pump unit 414AF-3, by that to the overall fuel supply to the fuel nozzles the engine combustion chamber.

2.2 Measuring chain of the engine MPM 20

Measuring chain consists of the following:

- sensors, transducers,
- bus system (SCXI 20)
- the object itself - MPM 20,
- a central computer with the software and card for collecting and archiving data.

In the measuring chain in Fig. 1 analog and digital sensors have been used. The sensors were connected to the bus system SCXI 1000 with the transduction cards SCXI 1102 and 1303. This system was connected with a computer and by usage of LabVIEW program environment information was processed and appeared as a virtual dashboard for direct monitoring of engine parameters MPM 20.

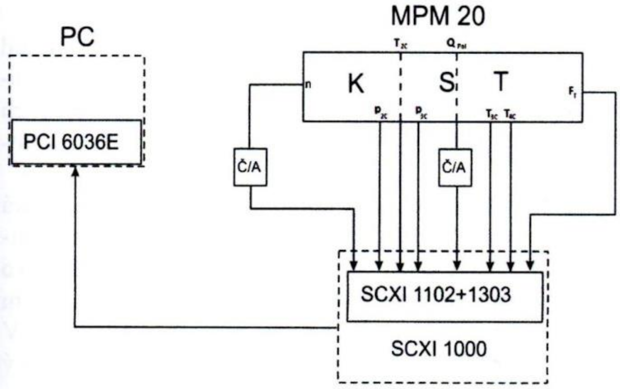

Figure 1 Scheme of the measurement chain

Digital sensors:

- Rotating Vane Flowmeter Hoffmeter to measure fuel flow, which flows through the engine.
- Optical speed sensor Tesla, which is used to sense speed turbo engine.

Analog sensors:

- Differential K thermocouples measuring temperature T_{2c}, T_{3c}, T_{4c}.
- Induction pressure sensor - VEGABAR which senses pressure p_{2c} a p_{3c}.
- Potential sensor thrust.

3 PROPOSAL MODIFICATIONS FUEL – REGULATORY SYSTEM FOR SMALL TURBOSHAFT ENGINE TS – 20

Since the original components of fuel - regulatory system is not available, it is necessary to propose new components for fuel - regulatory system. In this case, the proposal will be affected by fact that turbine starter worked at maximum power and the engine spins a rotor speed of 1000 min^{-1}. short period. Transformed power unit has to work longer time than 60 seconds, but with lower performance.

3.1 Control of turboshaft engines

Characteristics of turboshaft engines depend on the main parameters of the engine, i. e. performance and specific fuel consumption of the engine speed and flight conditions. As in uniflow engine, the flow of characteristics of turboshaft engines depends on the particular configuration and process of control.

The crew controlls the choice of engine work by engine control lever (ECL). In the case of automatic controls, this is performed by autopilot depending on potential external failures. The Control program, dependence configuration n a T_{3c} position POM assign values of controlled variables to individual positions:

$$n = f(\alpha_{POM}) \quad (1)$$

$$T_{3c} = f(\alpha_{POM}) \quad (2)$$

Based on changes in position α_{POM} the regulatory system changing regulatory variables (fuel supply to the combustion chamber Q_{HSK} or changing a geometry nozzle A_5) intends to change the controlled variable (speed at temperatures T_{3c}) under program control, which is programmed in the automatic control system, due to which leads to the change of regime activities aviation turbo-compressor engine (ATCE). After reaching the selected mode ATCE are regulated quantity ATCE maintained at the set value system of automatic regulation. Disorders that affect ATCE are removed by appropriate change of control variables. Each mode of the engine has one control program.

$$n = f(Q_{HSK}) \quad (3)$$

For bischafted engine, turbo engine part is most often regulated fuel flow Q_{HSK} and the controlled variable is the speed n.

$$n_{TK} = f(Q_{HSK}) \quad (4)$$

Free gas turbine connected through gearbox with the propeller, sperr will vary depending on the propeller blade angle of attack φ (propeller load) by the regulatory law:

$$n_{VT} = f(\varphi_v) \quad (5)$$

Engine speed n are readily measured with the necessary static and dynamic stability, in contrast to the measured temperature T_{3c}. When strangulation engine speed decreases continuously throughout the range of operating modes, it clearly defines mode the engine is running.

TS – 20 has two rotors, turbocharger and spare gas turbine. Speed of the turbocharger is controlled by the flow rate of fuel and the free turbine speed can be controlled her burden, as a generator of electricity, which will take its mechanical performance, see equation (6).

$$n_{VT} = f(P_{el.}) \quad (6)$$

To control the fuel flow Q_p control valve LUN 6743 is suitable. Finding the voltage required fo the supply of fuel is possible by applying the regulator - design of internal feedback.

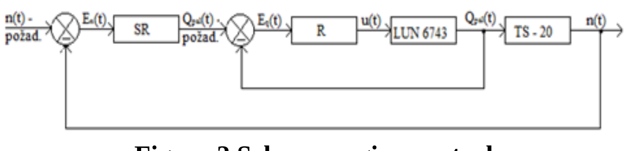

Figure 2 Scheme engine control

3.2 Automatic control system

Engine management systems are designed to set a large number of requirements and also the functionality of the system with regard to program management, location sensors, etc. This makes each system unique. The main advantage of the FADEC system is its flexibility; the digital controller is implemented in the form of software and modifications may be made without a complete replacement of the original controller.

The main tasks of the fuel supply to the engine:

- Manage the amount of fuel supplied to the engine combustion chamber under all engine.
- The system shall ensure the operation of the motor in order to maintain engine speed required by pilot or aircraft controling computer, so that there no exceedance of engine parameters occurs.
- The management system of fuel supply to the engine has limitations for speed rotor shaft, temperatures and pressures to meet the task of protecting. The engine system controlls the other engine subsystems (elimination of air compressor, operation of the outlet nozzle, winding stator vanes, etc.).

Parts of automatic control engines working with gaseous fuel:

- Engine control block.
- Shut-off valve no.1.
- Shut-off valve no.2.
- Gas dosing valve.
- Control block injector.
- Block motor protection.
- Blocks engines control elements that control the geometric parameters of the gas-air channel (inlet guide vane compressor, air valves, forgiveness, etc.).
- Sensors and signaling process parameters of the engines.
- Interconnecting tubing and wiring between the parts of the automatic control engines.
- Devices for vibration control engines.
- Connecting wires of the automatic control system for engine with higher levels of automatic control.
- Algorithms of management and control of engines.
- Technological counter.

The control block management may consist of a single block or be part programmatically - technical means of automatic devices pipeline compressor station.

3.3 Engine control block

Currently used electronic automatic control systems, operating on the basis of digital electronics using microprocessors. Such devices are programmable and reprogrammable and are able to perform complex calculations. Tour operator is used to display operational information and transmitting signals to the operator's management system. Motor encoder signals to proceed through the connecting terminals to the analog digital converter - ADC, transforming the continuous electrical signal to digital (digital) signal.

Digital scan parameters of engines in real time, it is important to create a model and also for automatic control systems in accordance with the requirements of FADEC systems and situational management. Is shown in Fig. 3 basic scheme of digital data collection.

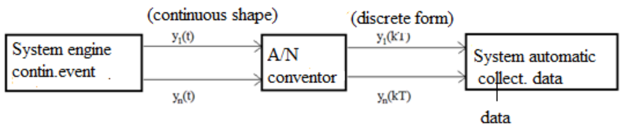

Figure 3 Scheme of digital data collection

The information is processed in the control unit, which goes into ADC. The processing of data occurs in a program that laws are made engine management. As a result created an output signal in the digital to analogue converters transforming into a continuous electrical signal is fed to the connecting terminal of the power mechanism.

3.4 Fuels for transformed aircraft engines.

Fuel is an essential source of energy that is supplied to the engine. Therefore, the fuel placed great demands:

- High heating value and high density, which provides for engines great range and in the terrestrial use of its long-term operation in a defined volume of the fuel tank.
- Security of fuel flow to personnel and the surrounding environment.
- Can be used in a wide range of ambient temperatures (from -60 ° C to +60 ° C).
- High chemical and thermal stability.
- High cooling capacity in the use of fuel as coolant in the cooling system, oil, air and elements of design.
- The use of combustion products as working fluid motor.
- Availability of fuel sources in nature, cost-effective campaign and processing.
- Economic efficiency and security of supply ground infrastructure, storage, loading, etc.

Another important requirement is the fuel that does not disturb the seal material and components. Problem destructive impact of biofuel mixtures of FAME (fatty acid methyl ester) and kerosene Jet A-1 on the rubber seals used in engines had to deal with Ing. Marian Hocko, PhD. Results of half-year follow-up seals in different concentrations FAME fuel mixed with kerosene Jet A-1:[10]

- With increasing concentration of FAME fuel mixed with kerosene Jet A-1, there were intensive moisture causes to be seen as increasing the volume of rubber seals.
- With increasing concentration of FAME fuel mixed with kerosene Jet A-1 and prolonging the duration of action occurs etching (dissolution) of surface structures of rubber seals.

- In the present, there are the most commonly used kerosene as fuel for engines. Jet fuel meet all the requirements. Transformed for aircraft engines they are used in liquid and gaseous fuels, each of which the largest share of natural gas. Nowadays, much attention is paid to the alternative fuels, especially renewable biofuels (biogas, biodiesel, alcohol, etc.), which are used in pure form or blended with conventional fuels.

In Fig. 4 show the fuel system when engine working with gaseous fuel.

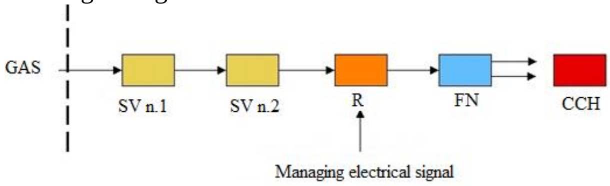

Figure 4 Fuel system for gas

SV – shut-off valve,
FN - fuel nozzle,
R – control system,
CCH– combustion chamber.

3.4 Liquid Propan Gas

LPG is one of the alternative fuels of petroleum origin. The use of liquefied LPG for propulsion engines dates back to 1910, Europe is regarded as LPG mixture of C_3 and C_4 hydrocarbons in the United States is reputed for LPG propane. LPG is a byproduct of oil refining or natural gas. Liquefied gas is stored at a pressure of 1,4 MPa. Thanks to the built infrastructure it is easily available.

Propane and butane are easily liquefied and stored in pressurized containers. These features make it easy to carry fuel, and therefore can be easily transported in cylinders or tanks to end-users. It is easy to strike the right balance mixture of fuel and air, allowing complete combustion. At the same time, LPG is one of the cleanest fuels in the world. It is characterized by a minimal carbon emission footprint and minimum impact on human health. It is a great alternative for the use of traditional fuels. It has very positive impact on reducing emissions from traffic transport. It does not contain a component of corrosion and thus does not degrade components and individual parts or engine design. During production, it is impuried from aggressive substances, mechanical impurities and water in the special cleaning processes. I tis especially popular for its significant price saving operating costs.

3.5 Combustion of Propane – Butane

Propane - Butane (PB) mixture in the liquid phase is a clear, colorless liquid with a specific odor and is readily volatile. It stores the compressed state in tanks and 1,5-times heavier than air. PB diffuses slowly in areas with poor air circulation and thus an increased risk of explosion. [11]

Reaction rate in the combustion process PB depends mainly on:

- temperatures
- pressure
- mixure concentration

Density ratio of propane and butane is 1/4, consequently:

$$\rho_t = (0{,}2 \cdot 2{,}019) + (0{,}8 \cdot 2{,}590) = 2{,}476 \text{ kg/m}^3$$

And then the calorific value of the mixture is:

$$Q_n = (0{,}2 \cdot Q_{n,p}) + (0{,}8 \cdot Q_{n,b}) = (0{,}2 \cdot 92{,}970)$$
$$+ (0{,}8 \cdot 122{,}775) = 116{,}8 \, MJ/m^3$$

PB combustion process can be described by the following oxidation reaction:

$C_3H_8 + 5\ O_2 = 3\ CO_2 + 4\ H_2O$
$C_4H_{10} + 6{,}5\ O_2 = 4\ CO_2 + 5\ H_2O$

The minimum (hypothetically) part of the oxygen needed for combustion of 1 m^3 PB gaseous fuel is:

$$O_{2,\min} = 5 \cdot \frac{C_3H_8}{100} + 6{,}5 \cdot \frac{C_4H_{10}}{100} = 6{,}2$$

Therefore, the minimum amount of air for combustion is 29,5238 $m^3.m^{-3}$.

When using LPG as fuel in aviation there are some basic requirements:

- Fuel tank for PB must be under pressure.
- All parts of the fuel system of the aircraft and engine must be adapted for use PB, fuel pump, fuel nozzles, ignition system.

4 SPECIFIC PROPOSAL FOR FUEL - REGULATORY SYSTEM

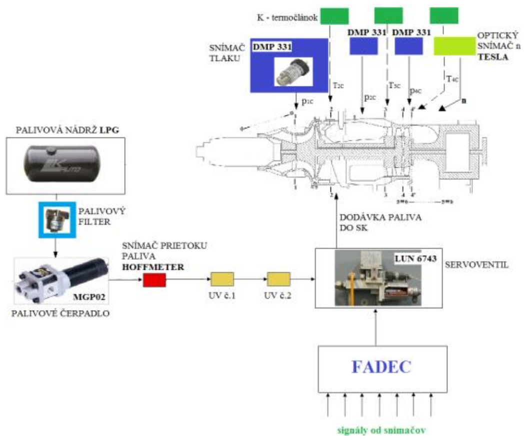

Figure 5 Proposal for fuel – regulatory system

4.1 Fuel tank

In the case of gaseous fuel, for example LPG, it is necessary to use by a reservoir of gas. Tank must be pressurization and hermetically sealed, filling the tank must be pressurized. There can be used tanks that are used in cars, which run on LPG, in Fig. 5. In this case, to a particular type of tank pradajca offers frame and fit the filter, in this case, filter the liquid phase.

Figure 6 Fuel tank for LPG

4.2 Fuel piping

Piping (Pipes, hoses, fasteners such as hose clamps, brackets, elbows, etc.) is used to supply fuel from the fuel tank to the combustion chamber LTKM. Greatest demands are placed on the low-pressure pipe leaks and material should be resistant to the selected fuel.

4.3 Fuel pump

The proposed pump should run when the engine meet the following parameters:

- Minimum pressure at the outlet $p_{v,min}$ = 1,72 MPa.
- The fuel pressure from 1,226 to 1,716 MPa (12,5 to 17,5 kp.cm^{-2}).
- • flow of fuel delivered Q_p = 1,37 l.min^{-1}.
- Pressure control is done throttling valve, so it is advisable to select a pump that has a pressure greater than the required minimum pressure $p_{v,min}$ =1,72 MPa.

4.4 Sensors

When the fuel passes through, it the pump passes through the sensors, fuel flow sensor and pressure sensor. These sensors give information about the pressure and fuel flow, on the basis of which fuel delivery is controlled.

4.4.1 Sensor of fuel flow - Hoffmeter

In proposal of fuel - regulatory system is advantageous to use already proven fuel flow sensor Hoffmeter, serving on the principle of a changing magnetic field, which starts spinning vane flowmeter that is in it. 1 l.min.$^{-1}$ fuel mass flow rate corresponds to the paddle around 50-60 Hz.[5]

4.4.2 Optical speed sensor TESLA

Optical speed sensor is a discrete sensor whose outputs are fed to the input evaluation device. It is a system SCXI 1000 with the transduction cards SCXI 1102 and 1303. This system is able to handle only analog output signals and therefore there are placed discrete sensors digital to analogue converters.between the device and

4.4.3 The pressure sensor

The Department of KKE already purchased pressure sensor - DMP 331, which is used to measure the relative and absolute pressure of liquids, gases and vapors.

Properties DMP 331:

- Range from 10 kPa to 60 MPa.
- Accuracy 0,35 %, 0,5 % (0,25 %, 0,2 %, 0,1%).
- High overload, good linearity, accuracy and stability.
- Intrinsically safe version (Ex) II 1 G Ex ia IIC T4 Ga, (Ex) II 1 D Ex iaD 20 T 85°C.
- Type test TCM 173/94-1905.
- Certified SIL 2 dle IEC 61508 / IEC 61511.

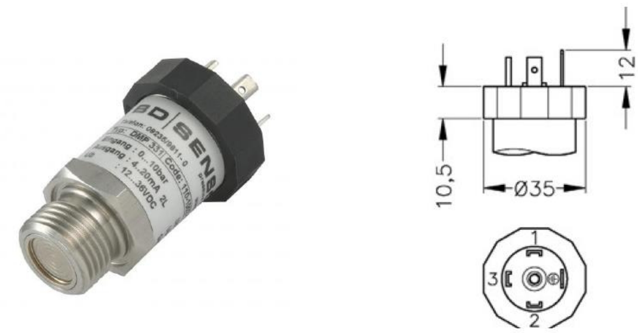

Figure 7 DMP 331

4.5 Servo valve

Control system - to control fuel flow and thus the engine is utilized servo valve (fuel distributor) LUN 6743.

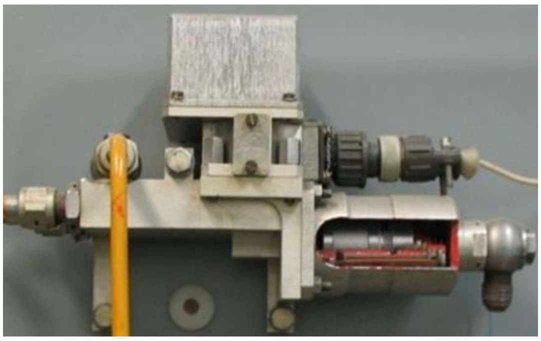

Figure 8 LUN 6743

Safeguards supply of filtered fuel injected to the engine fuel nozzles and further regulates the flow of fuel in the fuel return line from the motor circuit. It follows that, compared with the initial involvement of the fuel supply to the engine, in this case, the branch is regulated returnable fuel system and thus its involvement fuel nozzles will be different.

5 CONCLUSIONS

Proposal for fuel - control system for engine for gaseous fuel type allows the use of small turboshaft engine TS - 20 in laboratory conditions KKE as a power unit for experimental and educational purposes only. The original mechanical control system was replaced in the design of digital systems management - FADEC, which makes a range of new elements of the control system. Theoretical design of fuel - the regulatory system will continue its practical design and verification functionality. In accordance with experiments and further use turboshaft engine TS - 20 energy units as the KKE will be necessary to enter into fuel - the regulatory system and modify individual parts.

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