Modeling of Changes in Flow Air Fuel Effected by Changes in Environmental Conditions

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Summary

Software simulation environments are used in design of an aircraft and its systems providing engineers with valuable insight into the behaviour of the proposed systems before they are executed. One of these software tools is MATLAB - Simulink. This simulation software environment can also be used in the design of aircraft fuel systems, for example, in detection of fuel flow changes in the fuel system of an aircraft during the flight of the aircraft by environmental impact.

KEY WORDS
aircraft
aircraft fuel system
modeling
simulation
fuel flow
flying range

INTRODUCTION

For modeling and simulation of flows in an aircraft fuel system, it is necessary to define the elements of the fuel system models and their parameters. The type of the aircraft and its determination defines which tasks will be fulfilled by the fuel system during the flight. Consequently, the requirements result in structural properties of individual components of the fuel systems and the parameters. The object of the proposal is the fuel system for a passenger aircraft with a total weight of 8,618 kg, which is a subject to certification according to JAR-23 FAR-23, RTCA/DO-160, RTCA/DO-178, RTCA/DO-254, and FAR PART 21.

Assuming that these types of aircraft are constructed generally with 4-6 inner tanks and 1-3 engines, a model of a fuel system will consist of four 4fuel tanks and 4 fuel valves. The system will consist of 8 fuel pumps, 4 main and 4 backup. Power of the aircraft will be provided with 2 power units. The cabin will have two crew members with a requirement for the minimum duty for the crew to deal with pump control. The pump control will be executed automatically and manual fuel pump control will be carried out only in emergency situations, in case of failure of a fuel pump. A model of this type of an aircraft fuel system in the MATLAB-Simulink software simulation environment is shown in Figure 1.

MODELLING OF THE FUEL SYSTEM COMPONENTS

For obtaining the maximum accuracy of the results in simulation of activities of the modeled system it is necessary to define the parameters of the tank and fittings in the fuel system as precisely as possible. Any change in the shape, bend or dimension of the fittings can cause major variations in the results. When we only examine the flow of fuel through the fuel pipes and fittings and its dependence on the temperature of fuel or on the flight altitude, then the dimensions and shapes

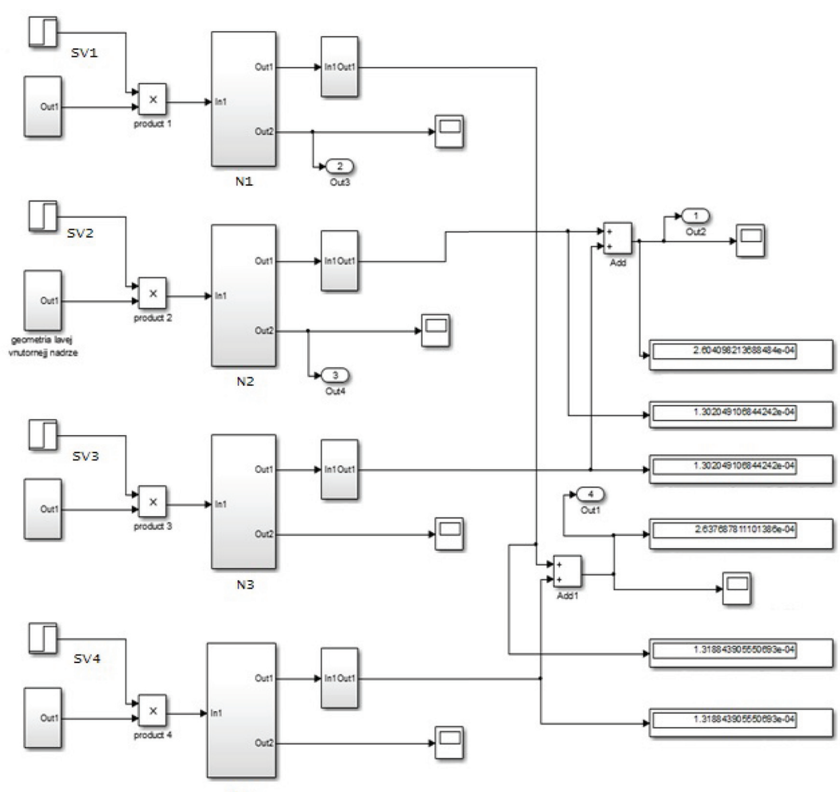

Figure 1. Model of the aircraft fuel system in category up to 8618kg

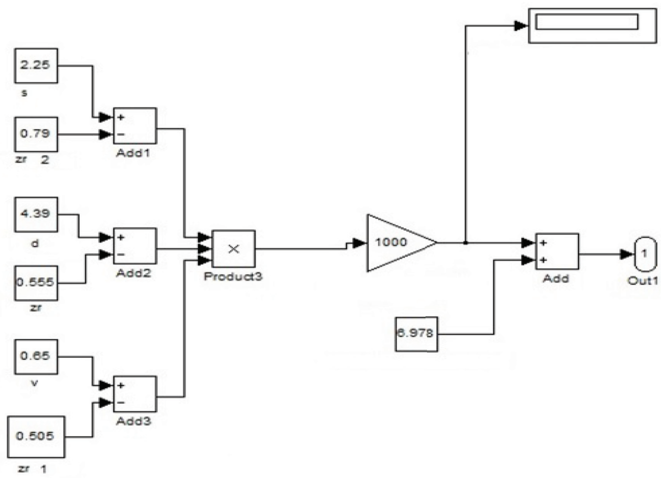

Figure 2. Model of the fuel tank

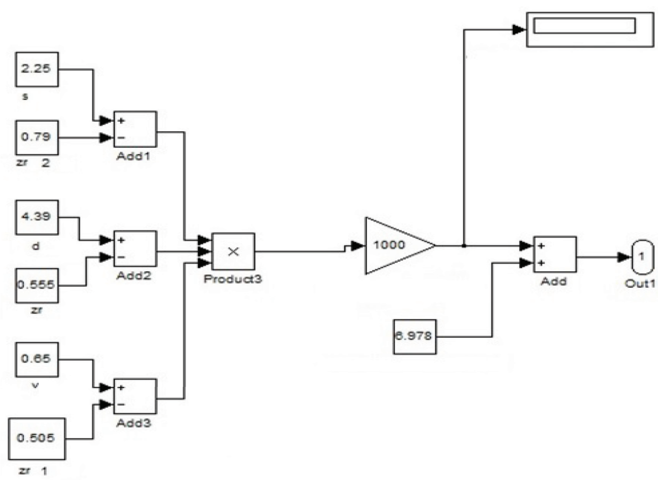

Figure 3. Model for monitoring downstream from the fuel tank

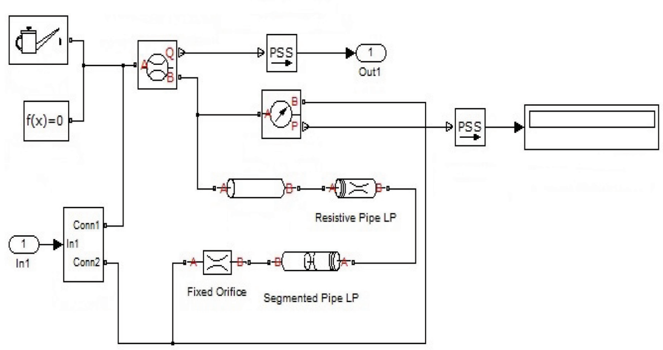

Figure 4. Diagram of fuel lines and fuel pump

Schedule 1. Changes in the fuel flow from the tanks with temperature

Height (m)	Temperature (°C)	Fuel flow of inner tank (m3/s)	Fuel flow of external tank (m3/s)	Flying range of the aircraft (km)
1000	20	0,0001303189	0,0001320041	1169,0021
1150	19	0,0001303019	0,0001320003	1169,1074
1300	18	0,0001302846	0,0001319964	1169,2148
1450	17	0,0001302670	0,0001319924	1169,3241
1600	16	0,0001302491	0,0001319884	1169,4351
1750	15	0,0001302308	0,0001319842	1169,5490
1900	14	0,0001302122	1169,6645	0,0001319800
3000	7	0,0001300717	0,0001319483	1170,5380
6000	-12,5	0,0001296436	0,0001318330	1173,2766

of the fuel tanks are not so significant. In this case the volume of the tank is the most significant factor. However, if we examine the entire fuel system and its operation and the interaction between various elements, it is necessary to pay close attention to the precise defining of parameters, the size and shape of the tanks. The model of the fuel tank is shown in Figure 2.

In the simulation of the system, the operation aviation fuel Jet A-1 of 1,599cm2·s-1viscosity and temperature of 20,00°C. was used. For the closest approximation to the real conditions, the fuel pipes selected are rigid pipes made of metal with the set length to the same value of 3500mm between innerwings and terminal tanks and 2500 mm between innerwing tanks and an engine, the inside diameter of the pipe on 12 mm and the geometric factor on 64 which also determines the shape of the pipe (with a circular cross-section). The corresponding block diagram with the possibility of tracking the discharge of fuel from the fuel tank of an aircraft is shown in Figure 3.

As the fuel pump it is used an axial flow pump with an electric drive. Reference angular speed of the pump was set to 1200rpm, a correction factor of 0.8, the torque of the drive shaft pump 0.4 Nm (Figure 4).

MODELLING OF THE FUEL FLOW CHANGES DEPENDING ON THE TEMPERATURE

Fuel flow measurement is performed for each fuel tank. We should assume the use of the same fuel pumps, and the same performance of a fuel pipe (inner diameter, material) as well as the flow rate and pressure of the fuel in the line (tanks) will be the same (Schedule 1). For a detailed view of the fuel flow from the various tanks of the aircraft is necessary to know in addition to the various flow rates and total flow rates of both inner wing tanks, reservoirs of end wing tanks and also the fuel pressure values in the pipeline from individual tanks (Schedule 2). On the basis of these individual flows it is possible to determine the theoretical flying range of the aircraft. For the simulation the following conditions were selected: the aircraft with the Mach number 0,26, air temperature 20 °C, the speed of sound 314,8 m/s, the speed of the aircraft 87,5 m/s. In the calculation

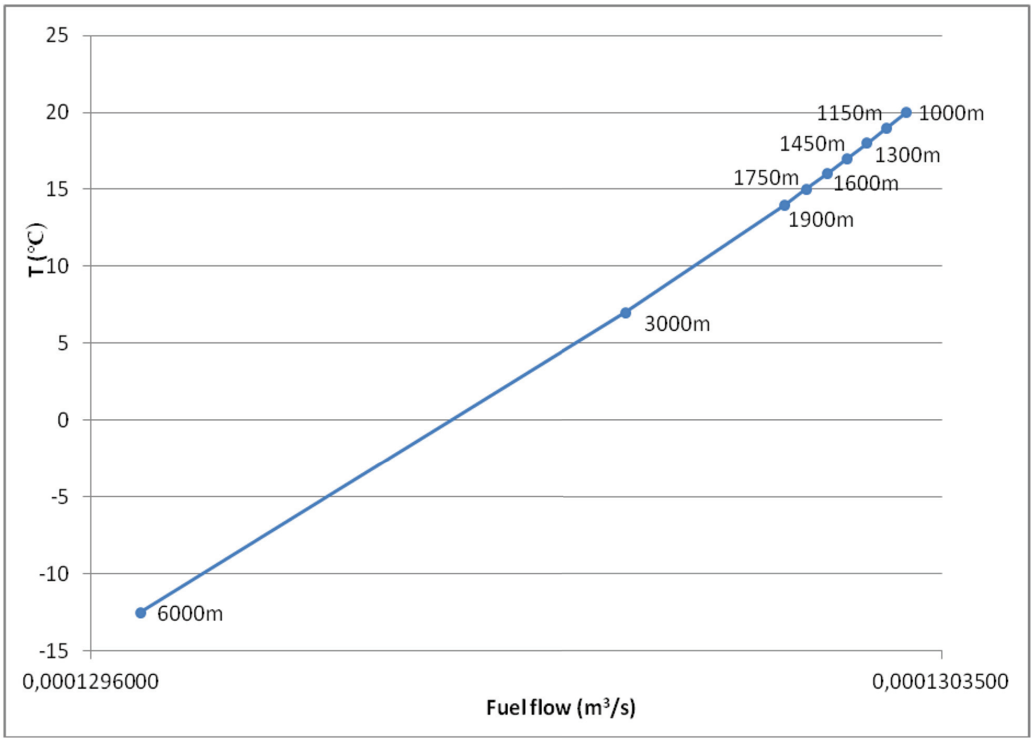

Figure 6. The graph of changes depending on the temperature of the fuel flow and the height of flight

Schedule 2: The fuel flow from the aircraft tanks at the temperature below 20 ° C

Fuel tank	Fuel flow (m3/s)	Fuel pressure in the pipeline (Pa)
Right inner tank	1,3031x10-4	1725914,036
Left inner tank	1,3031x10-4	1725914,036
Right external tank	1,3200x10-4	1693471,979
Left external tank	1,3200x10-4	1693471,979
Inner tanks (total)	2,6063x10-4	1725914,036
External tanks (total)	2,4220x10-4	1693471,979

of the flying range of the aircraft it is possible to issue the straight uniform motion from the following equation:

$$s = \frac{V.v}{Q} \quad (1)$$

where:
V – the volume of the tank in kilograms
v - the speed of the aircraft in Mach
Q - flow (consumption) of the fuel from the tank

CONCLUSION

Simulation program environment of Matlab-Simulink provides valuable insight into the behaviour of the different technical systems. Its use provides valuable insight into the design and aircraft fuel systems. With this tool it is possible to verify the behaviour of the aircraft fuel system and detect changes in the fuel flow from the tank of an aircraft depending on changes in height of the aircraft, i.e., changes in the temperature of the fuel. In the shown case it is the fuel system of a small transport aircraft, which includes 4 fuel tanks, and 2engines. In this simulation and analysis, the temperature changed the value by 32.5 ° C (20 ° to 12.5 ° C), corresponding to the change in the height of the aircraft from 1000 m to 6000 m according to the temperature standard atmosphere model. From the results, which are shown in the simulations we can calculate the total flow and the fuel consumption, the flying range of an aircraft at 20 °C is 1169.002 km and at 16 ° C is 1169.435 km. When changing the height of 6000 m, the flying range is 1,173.276 kilometres. The aim of the simulations performed was to verify the proposed model of fuel systems and at the same time the possibility of the presentation influenced by environmental conditions on their activities.

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