ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0010.2377

IN-FLIGHT TESTING OF THE SUSCEPTIBILITY TO ICING OF THE INDUCTION SYSTEM OF THE ROTAX 582 ENGINE

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Abstract

In many publications relating to the problem of icing of aircraft piston engines with carburettors charts are published indicating that icing may occur even at ambient temperatures above 20°C with a relative humidity as low as below 30%. Studies on the icing of aircraft engines started after the First World War, and later they were continued in the interwar period and during World War II and shortly thereafter. The subject was primarily combat aircraft engines, in many cases differ in design of engine induction systems currently used in aviation. This article presents the results of flight test conducted to verify the susceptibility to icing of a typical induction system of the engine of the ultralight aircraft UL-JIH Sedláček "Kolibřík". During the research several flights, 13 of which were analysed, were conducted in autumn 2011. As an example, results obtained during a flight from an airfield Konopiska near Czestochowa to an airfield Lgota Murowana near Zawiercie made on September 24, 2011 were described. Relating ambient temperature values and relative humidity recorded during the considered flight to the icing diagrams presented in different sources show that the flight took place in conditions of a minor icing risk at the phase of flight and at a major risk during descent. However, the pilot did not notice icing symptoms of the air piston engine induction system.

Keywords: *aircraft powerplant, piston engine, carburettor, icing*

1. Introduction

The first known research results concerning aviation piston engine icing date back to the 1940s, however, already after World War I the problem was noticed and attempts were made to solve it. The main interest was focused on typical induction systems of high-powered engines used in combat planes. After World War II, studies were conducted on induction engine systems used in sports and tourist planes.

A likelihood of occurrence of icing of elements of induction systems of aircraft piston engines even in relatively high ambient temperatures results from the possibility of overlapping the consequences of the following phenomena:

1. A stream of humid air hitting the elements of the induction system, which causes cooling and freezing on their surfaces drops of water, included in the air. A layer of ice can be created on air scoops, screens installed in the inlets, induction system walls, air filters, components of the heating air valves. A particular risk occurs during a snowfall, sleet, a flight in clouds and during rain at ambient temperatures below +5°C especially if ice is visible on the cabin windows or airframe elements. High rate of speed of ice layer growth can be observed at temperatures of about -4°C with cooled drops of water. This type of icing does not pose any

danger at very low ambient temperatures because relative humidity is then quite small and moisture in the air appears as crystals of ice, which can go through the engine inlet system without disrupting the engine work. Icing of this type is present in all kinds of aviation piston engines, the ones with a carburettor as well as low-pressure and direct injection engines.

2. Condensation of water vapour in the air and freezing due to lowering temperatures during a local reduction of temperature as a result of a local increase of flow velocity in throats. This phenomenon can occur even at relatively high temperatures of the air in conditions of partial opening of the throats typical for engine operation range close to idling and cruise phase. For throttle, icing visible occurrence of moisture in the air is not necessary (i.e. in the form of fog, clouds, precipitation, etc.) Ice appears in the throttle throat and right behind it and also directly on the throttle and the induction channel panels in their vicinity. The rate of the ice layer growth depends in this case on air humidity and the size of throttle valve opening wherein a longer operation of the engine poses the danger of a complete suppression of airflow and the engine stall. Icing of this kind, called throttle icing or carburettors icing occurs in all kinds of piston engines – those with carburettors and direct injection engines (on the throttles regulating airflow).
3. Lowering the temperature of air-fuel mixture to the temperature of freezing water as a result of absorbing heat from the air and walls of the flow channel, which is necessary to evaporate fuel. The phenomenon usually occurs together with throttle icing. Ice sets on carburettor elements and inlet manifold placed after the fuel nozzle. Heavy icing connected with the process of fuel evaporating occurs even at temperatures over +30°C at 50% of relative humidity and higher. It poses the biggest danger in engines with float carburettors in which the throttle valves are placed after the fuel nozzle and it is smaller in engines with pressure carburettors. In direct fuel injection engines this type of icing does not occur. In low-pressure fuel injection engines, usually at the point of induction channel where it is realized, takes place channel wall heating as a result of absorbing heat from the engine cylinder; and in engines with the carburettor placed behind the compressor this type of icing can occur during a start of a cold engine in winter conditions.

2. Measuring system

For research was used an ultralight two seater tourist airplane UL-JIH Sedláček „Kolibřik powered by two stroke naturally aspirated two cylinder piston engine Rotax 582 developing maximum output of up to 5,500 rpm. The engine is equipped with an induction system with two carburettors Bing Type 54 type supplying the mixture to each cylinder separately.

Each carburettor is mounted to the cylinder with a rubber transitional cornet and a hose clamp. Before the carburettor is mounted, a surface air filter shaped like frustum of cone. The carburettor Bing 54 is a float-type slide throttle carburettor and in terms of its structure and operating principles, they are similar to carburettors used in motorcycles.

The measuring system used during the research was modified on the basis of an analysis of previously obtained results and in the final stage, it comprised of elements used for measuring temperatures and relative air humidity and flight altitude.

During flights, temperature measurements were made with the use of thermocouples/ like *TP-201K-1b-600-2.5* manufactured by Czaki Thermo-Product connected to Oticon recorder whose measuring inserts were placed in one of the carburettors in the following places (Fig. 1):

- in front of the carburettor inlet in the air filter (T1),
- at the bottom part of the carburettor flow channel behind the slide throttle, just behind the idle jet (T2),
- at the top part of the carburettor flow channel, 10 mm off the wall (T3),
- at the outer wall of the carburettor flow channel, at 2:00 hours (T4),
- at the axis of the carburettor flow channel, behind the slide throttle (T6),

- at the outer wall of the carburettor flow channel, at 6:00 hours (T7),
- thermocouple T5 was attached to the airframe and was used for measuring ambient air temperature.

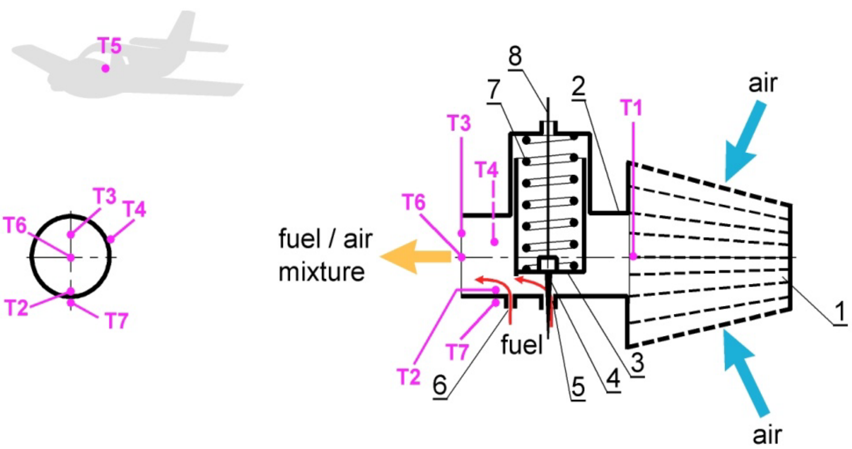

Fig. 1. The diagram showing locations of thermocouples used during the in-flight tests: 1 – air filter, 2 – carburettor body, 3 – slide throttle, 4 – needle, 5 – main jet, 6 – idle jet, 7 – slide throttle spring, 8 – slide throttle-controlling bowden, T1...T7 - thermocouples

Visualization of temperature distribution was made by means of programs *MagdeTech* and *Excel*.

The flight altitude was recorded with a GPS recorder *Garmin* and later visualized with the use of programs *SeeYou* and *QuickRoute*

Relative air humidity and temperature at landing fields were estimated on the basis of data from meteorological stations; moreover, during some flight relative humidity and temperature were recorded by means of an electronic recorder *Lascar EL-USB- USB-2-LCD*.

The engine operating ranges were estimated on the basis of the rev-counter and the position of the control lever and they were not registered automatically.

During flight, special attention was paid to the possibility of occurrence of engine icing symptoms.

3. Analysis of the results

During the research several flights, 13 of which were analysed, were conducted in autumn 2011.

As an example, results obtained during a flight from an airfield Konopiska near Czestochowa to an airfield Lgota Murowana near Zawiercie made on September 24, 2011 were described. The flight was performed in sunny conditions with sky cover 1/8. The temperature at the take-off airfield was +18^{o} C and relative humidity changed within the range of 35-45%.

The temperature recordings acquired during the flight and the flight altitude profile are shown in Fig. 2.

The record of parameters shown in the picture corresponds to the engine operating parameters on the ground before take-off (segment A), in the air (segment B) and on the ground after landing (segment C).

On starting the data recording, before starting the engine, thermocouples positioned inside and at the walls of the engine induction system indicated greater temperatures than the ambient temperature. The reason for this is the early start of the engine, causing heating of its components. After stopping the engine, part of the heat, which is emitted by its elements, causes elevated temperatures in the engine induction system in relation to ambient air temperature.

Immediately after the engine is started a noticeable rise of temperature values is noticeable with the biggest drop (of 20°C as compared to the output value) the rapid decrease in the

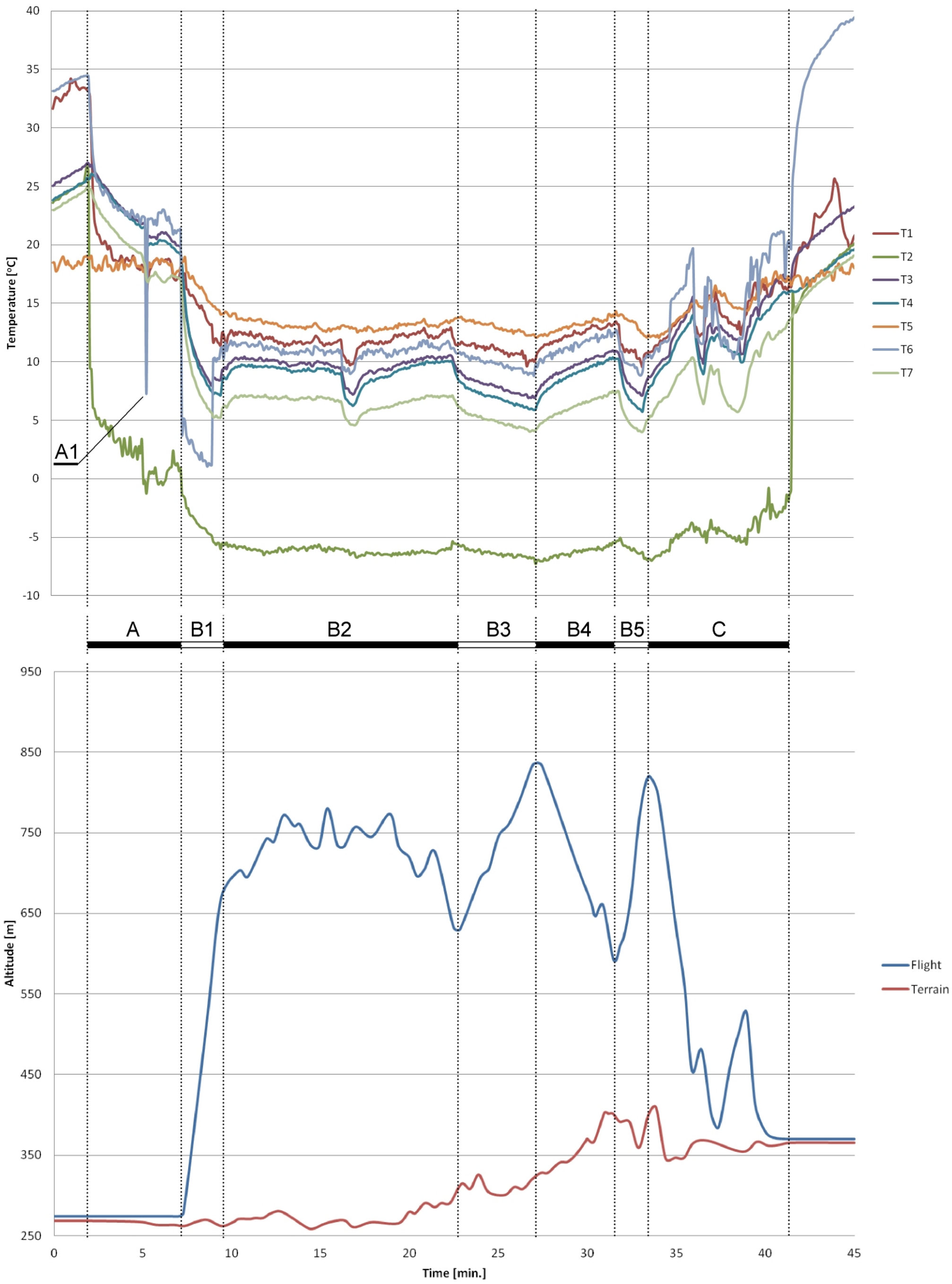

Fig. 2. Visualization of temperature and flight altitude changes in flight from Konopiska to Lgota Murowana on September 24, 2011

temperatures measured by sensors inside the flow channel, with the biggest drop (of 20°C as compared to the output value) is noticeable for thermocouple T2, places where in the zone where the fuel evaporates sucked from the idle jet. When the engine is idling range at a speed of 2,200 ... 3,000 rpm a further decrease in the value of all temperatures occurs and the temperature value T2 reaches 0°C. Full opening of the throttle during tests on the engine before the take-off (point A1) causes a rapid drop of temperature (of 15°C) of the mixture of the carburettor channel (T6) as a result of evaporation of a large amount of fuel from the main jet at the carburettor piston and much smaller – around 2 ... 3°C – drops in the value of other temperatures measured behind the engine slide throttle. After reducing the range of the engine to idle at the time of taxiing for take-off, the temperature values return to the previous state.

At the start of and during the climb (segment B1), with the engine running on maximum scope at full throttle, a further drop in temperatures occurs resulting from atmospheric temperature decreasing with altitude, but mainly due to the evaporation of a large amount of fuel delivered by the main jet of the carburettor.

At the stage of proceeding to horizontal flight the temperature values after the throttle are estimated at -6°C (T2), +1ºC (T6), +8°C (T3). Simultaneously, a fall in the temperature of the carburettor walls to +8°C for T4 and + 5°C for T7 can be observed.

Closing the throttle and reducing the engine speed to 5,200…5,500 rpm during a flight at a relatively constant altitude (segment B2) caused an increase in all temperature values except temperature T2, which remained within the limits of -6... -7°C. Changes in their values noticeable in later phases of flight are connected with necessity of bypassing field obstacles (segments B3 and B6) and airport control zone at Pyrzowice (segment B4). At this time changes in throttle opening corresponding to movements of the lever engine control causing changes of fuel amount supplied form the main jet are clearly noticeable in the temperature change of mixture and carburettor walls, but the T2 temperature values change within small limits.

Reducing the power during descent, approach to landing and landing at the airfield at Lgota Murowana and taxiing (segment C) results in temperature increase wherein the temperature T2 until the end of the operation of the engine assumes negative values. Only after stopping the engine causes a rapid increase of all measured temperatures with the highest estimated values of the thermocouple/thermocouple T6 is by most thermocouple T6, which is most affected by heat from the warmed elements during engine elements work.

4. Summary

Relating ambient temperature values and relative humidity recorded during the considered flight to the icing diagrams presented in different sources; show that the flight took place in conditions of a minor icing risk at the phase of flight and at a major risk during descent. However, the pilot did not notice icing symptoms of the air piston engine induction system. The lack of icing is due to the ″motorcycle″ origin of Bing Type 54 carburettor, in which the throttle is located before the main sprayer and not behind it like in most ″classic″ air float-type carburettors. The temperature of the air-fuel mixture at the bottom of the carburettor flow channel, behind the throttle, had a negative value during the whole flight. In spite of the relative humidity of the air was sufficient for icing formation, induction channel panels were not cooled to 0ºC and the icing was not possible. In the case of a classic carburettor, the throttle encircled by a mixture of temperature value of -6ºC could be cooled down to a temperature allowing for ice formation on its surface.

It could be concluded that diagrams used for estimating the level of icing danger should be treated as an aid just for indication of the icing danger level. Nevertheless, it is absolutely crucial to obey recommendations included in instructions of use for certain aircraft and their power units because icing is closely connected with configuration of particular induction systems, type of carburettor and the used anti-icing systems.

Acknowledgments

The authors dedicate this work to memory of Mr Artur Gudaniec. Mr Artur Gudaniec performed all the in-flight tests in the course of his post-graduate education in the MUT. Mr Artur Gudaniec was a great enthusiast of aviation and an aircraft as well as a paraglide pilot. He died at the paraglide disaster on May the 31st 2015 during aerobatic manoeuvre at the aerodrome Rudniki by Czestochowa.

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