Optimization of a complex of technological equipment for aircraft processing

Anatoly Konovalov[1*], *Alexander* Skripko[1], and *Ivan* Kvaschin[1]

[1]Don State Technical University, 1, Gagarin Square, Rostov-on-Don, 344000, Russia

Abstract. When icing, aerodynamic surfaces of the aircraft, negative changes in the impact of the air flow on them occur, which leads to a noticeable drop in wing lift, a decrease in the efficiency of the rudders, a decrease in the aircraft and loss of control. In order to optimize the complex of technological equipment for anti-icing treatment of the aircraft, the necessary studies of materials and methods of anti-icing treatment of aircraft were carried out, based on the KNO-AERO-MA complex, designed for processing (washing, anti-icing protection) of the outer surfaces of aircraft, due to the existing pumping equipment in the system of collecting and returning the spent solution. The essence of the filtering technology is to clean solutions from harmful impurities through a special porous medium, the so-called filter. The created simplified model of a high-speed pressure vertical filter made it possible to study one or more filter links of the filter column. According to the research results, in order to optimize the technological equipment complex during aircraft anti-icing treatment, in the system of collecting and returning spent solutions for repeated anti-icing treatment of aircraft, it is recommended to use a high-speed pressure vertical granular filter. The introduction of such a system will allow servicing several aircraft simultaneously, significantly reduce the cost price and improve the environmental friendliness of this technological process. Keywords: icing, aircraft aerodynamic surfaces, optimization of the technological equipment complex, aircraft anti-icing treatment, system of collecting and returning spent solution, filtration technologies, high-speed pressure vertical granular filter, reduce the cost price, improve the environmental friendliness of the process.

1 Introduction

Aircraft aerodynamic surfaces (elevators and rudders, wings, ailerons) are sometimes subject to icing, which leads to a negative change in the effect of the air flow on them. As a result, there is a noticeable drop in wing lift, the efficiency of the rudders decreases - the aircraft descends and loses control. Icing of pressure receivers or angle of attack sensors leads to the failure of the corresponding instruments and then control of the specified altitude will become extremely difficult, the use of the autopilot is excluded.

* Corresponding author: a-v-k-57@mail.ru

In aircraft, during flight, standard anti-icing systems are provided, during the operation of which important structural elements are heated by a flow of hot air from the engines or electric heating elements. Anti-icing treatment at airports is intended for takeoffs of aircraft, that is, during the runway run and climb, and when flying at an altitude of over 10 thousand meters, when the outside temperature is always – 50 degrees, it does not matter.

During long flights of the aircraft, the fuel in the tanks located in the wing sometimes cools down to -20 degrees, and after its landing the wing can remain "frozen" for a long time. With increased air humidity, moisture condenses on its lower surface, capable of rapid freezing. If it does not have time to melt before the next flight, then anti-icing treatment is carried out in the summer!

The purpose of the work: Optimize the set of technological equipment for anti-icing treatment of the aircraft.

2 Materials and methods

In Soviet times, the treatment was carried out on the basis of a ZIL or MAZ vehicle with an old jet engine from an airplane installed. A stream of hot air was created, which cleared ice and snow, then the airplane was sprayed with "Arktika" anti-icing liquid from a hose (Figure 1).

Fig. 1. MAZ car with an old jet engine from an airplane installed.

In the post-Soviet period, Elephant machines from the Danish company Vestergaard (Figure 2) began to be used. Instead of a jet engine, they are equipped with tanks with hot water and various anti-icing liquids. The technology of mixing in the required proportions depends on weather conditions. The resulting liquid, through a sprayer at the end of the boom, gets onto the aircraft. The operator is engaged in the processing process from the cabin or an open cradle, but in a chemical protection suit (https://1prof.ru/product/protivoobledenitelnye-mashiny-vestergaard-elephant-beta-15/).

Fig. 2. Elephant machines from the Danish company Vestergaard.

There are 4 types of liquids:

1) "Orange" sticky liquid (type I) is used under pressure, hot (60-80 degrees), to remove ice and snow, for de-icing. The stream moves from the leading edge of the wing back and from the end of the wing to the fuselage, at an angle of 45 degrees, while the liquid flows towards the center of the wing, which reduces its consumption.

2) "Green" liquid (type IV) has a thick consistency, but is not heated or diluted with water. It is prepared on the basis of propylene glycol or ethylene glycol, is poisonous, is rarely used. During the treatment, the pilots turn off the cabin air conditioning system. Such a liquid is anti-icing and prevents ice from sticking during takeoff and climb, and then completely "blown off" from the aircraft before reaching an altitude of 300 meters. After that, the standard POS of the aircraft comes into play.

3) "Transparent" liquid (type II) is the same in purpose as liquid (type IV), but has a shorter "shelf life" (holdovertime), now it is almost not used.

4) "Yellow" liquid (type III) is universal, it melts ice and prevents the formation of new. It is more often used for small propeller-driven slow-moving aircraft, when the speed at the moment of takeoff from the runway is not less than 100 knots.

The shelf life of the liquid is the time during which its protective properties are preserved (holdovertime). After treatment, the aircraft must take off no later than a certain period (9 - 160) minutes, depending on the weather. Usually, airports have devices that analyze the intensity of snowfall and automatically calculate the duration of treatment with type IV liquid.

Research on the optimization of the technological equipment complex for anti-icing treatment of aircraft was carried out on the basis of the KNO-AERO-MA complex designed for treatment (washing, anti-icing protection) of the outer surfaces of aircraft (Figure 3).

Fig. 3. KNO-AERO-MA complex for processing (washing, anti-icing protection) of external surfaces of aircraft.

The KNO-AERO-MA complex is used on the ground, before the flight, to remove frozen precipitation and prevent it from appearing on critical surfaces of the aircraft before takeoff. Anti-icing treatment is caused by the negative impact of frozen precipitation on the aerodynamic properties of the aircraft surfaces (https://ctg.su/produkciya/oborudovanie/obrabotka-samolyotov-aerodromnogo-transporta-i-snegoochistiteley/oborudovanie-dlya-obrabotki-samolyotov).

The complex includes: a deicer, trays, tanks and pumping equipment for the system for collecting and returning the spent solution.

The problem of collecting and returning the spent solution after anti-icing treatment is very relevant today. The introduction of such a system allows to significantly reduce the cost and improve the environmental friendliness of this technological process.

External treatment of aircraft is carried out by specialized companies, using a powerful "Karcher" designed for hydrodynamic cleaning of aircraft surfaces.

The complex has several tanks. A cleaning solution is added to one tank, and purified water to the other.

3 Results

Optimization of the technological equipment complex for aircraft anti-icing treatment consists in the correct choice of technology for preparing purified water in the system for collecting and returning waste solutions for repeated anti-icing treatment of aircraft.

Technologies for preparing purified water in the system for collecting and returning waste liquid for its reuse include various methods and techniques [1].

The mechanical filtration method is the most relevant and is widely used in advanced domestic water treatment complexes and installations.

The filtration process is based on the process of passing the purified liquid through a porous layer of filter material in order to retain impurities of a certain size. The filtration process allows for coarse and fine cleaning, removing various contaminants, including silt, sand, small solid particles several microns in size.

The essence of the filtration technology is to purify solutions from harmful impurities through a special porous medium. The filtrate performance and the service life of the filter depend on the quality of this medium. The permissible content of impurities in water is ensured by the planned replacement of the filter element before the end of its service life.

The filter resource depends on the characteristics and volumes of the liquid being purified [2, 3].

Existing filters differ significantly in design, throughput, power consumption and the technologies used. When choosing an effective filter, you need to know what and how we need to purify the working fluid.

According to the research results, preference remains with granular filters for purifying liquids, solutions, etc. Such filters are divided into pressure and non-pressure.

Preference in the process of purifying liquids belongs to pressure filters with granular loading.

The filter material of these filters are natural and artificial materials. Natural filter materials include: sand, expanded clay, gravel, anthracite, etc. Artificial filter materials include: lavsan, polystyrene, nitron, etc.

Pressure rapid filters [2] are a steel body 2 (Figure 4), designed for operation at a pressure of 0.6 MPa. Such filters are placed vertically to increase the filtering surface. Filtration occurs in the direction - from top to bottom. The filtration rate of liquids is from 4 to 17 m/h. The filtration time depends on the quality and condition of the cylindrical filter elements 5, as well as the quality of the liquid being purified.

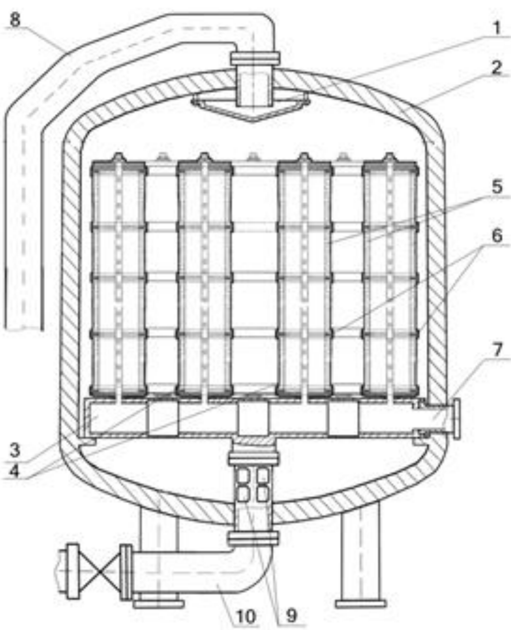

Fig. 4. Pressure rapid vertical filter.

The purified liquid enters through the inlet – 8 into the centrally located funnel, facing the wide end upwards – 1, to the required filling level of the filter housing 2. The filtrate passes through the filter columns consisting of cylindrical filter elements 5, then through the perforated coupling pipe 4 enters the collector 3 for collecting and removing the filtrate, and then goes to the outlet 7.

The proposed filter is washed with "reverse flow". The purified liquid is fed through the filtrate outlet 7, along the collector 3, through the perforated coupling pipe 4, to the filter elements 5, washing out the sediments formed during the filter operation in the pore channels and on the filter surface. The collected dirt gets into the dirt collector 9, then into the dirt removal system 10.

In order to select the optimal option for using the proposed pressure high-speed filter in technological equipment complexes for aircraft anti-icing, with minimal material costs, preliminary studies of the quality of the filtration process were carried out. To solve the assigned research tasks, a model of a high-speed pressure vertical filter was created (Figure 5), which made it possible to study one or several cylindrical filter elements of the filter column.

Fig. 5. Model of a high-speed vertical pressure filter.

Based on the results of the conducted research, the temporary technical characteristics of the operation of the proposed high-speed pressure filter for the complex of technological equipment for aircraft anti-icing treatment were identified, which are given in Table 1.

Table 1. Temporary technical characteristics of the high-speed pressure filter operation.

Loading material	Grain size of loading , mm	Heterogeneity coefficient (maximum)	Filtration speed, m/h	Flushing intensity, h/p·m2	
				aquatic	air
Quartz sand	0.8-1.8	1.8	11	7	16
	1.5-2.5	2	14	7	21
Crushed anthracite	0.8-1.8	1.8	11	7	14
	1.5-2.5	2	14	7	18
Note: the gravel supporting layers have not been investigated.					

4 Discussion

When selecting granular material for the manufacture of filter elements, it is important to consider the type of suspensions to be filtered. For example, salt solutions and most acids are filtered using fine quartz sand, which does not dissolve in the filtered medium, in the complete absence of a chemical bond.

It is recommended to filter alkaline liquids through crushed marble or pure limestone.

Liquids containing resins are best filtered using coarsely ground charcoal. It should be noted that the process of cleaning liquids from resins is also due to the phenomenon of adsorption.

Sand filters are the best option for cleaning liquids with granular materials.

5 Conclusion

Considering that the aerodynamic surfaces of an aircraft (elevator and rudder, wing, ailerons) are sometimes subject to icing, which leads to a negative change in the impact of the air flow on them, materials and methods for anti-icing treatment of aircraft were studied. Preferences in the conducted research on optimization of the technological equipment complex for anti-icing treatment of aircraft were given to the KNO-AERO-MA complex intended for processing (washing, anti-icing protection) of the outer surfaces of aircraft due to the existing pumping equipment in the system of collecting and returning the spent solution. Optimization of the technological equipment complex for anti-icing treatment of aircraft consists in the correct choice of the technology for preparing purified liquid in the system of collecting and returning the spent solutions for repeated anti-icing treatment of aircraft. The essence of the filtration technology consists in cleaning solutions from harmful impurities through a special porous medium, the so-called filter. To solve the set research tasks, a simplified model of a high-speed pressure vertical filter was created, which made it possible to study one or more filter links of the filter column. Based on the research results, the time technical characteristics of the proposed high-speed pressure vertical granular filter for the technological equipment complex for anti-icing treatment of aircraft were identified. The implementation of such a system will allow servicing several aircraft simultaneously, significantly reducing the cost price and increasing the environmental friendliness of this technological process.

References

1. B. N. Lyagushka, A. P. Levchenko, Water treatment: a textbook for universities (Moscow State University Publishing House, Moscow, 1996)
2. A. V. Konovalov, M. A. Konovalov, Theory and practice of using high-speed pressure vertical filters to improve the efficiency of water purification, p. 104: ill. - Bibliography: pp. 100-103 (FGBOU VO RGUPS, Rostov-on-Don, 2016)
3. V. I. Korenevsky, G.V. Korenevsky, A.V. Konovalov, Polymer concrete filters in the water treatment and sanitation complex. High technologies on the threshold of the XXI century (SKNC VSh, Rostov-on-Don, 2000)