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INFLUENCE OF SURFACE CONDITION OF TAXIWAYS AND RUNWAYS ON TIME OF AIRCRAFT DEPARTURE

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ABSTRACT

The state of the runway (RWY) under operating conditions, due to the possibility of formation of a layer of water, ice, slush, snow, decreases the friction coefficient of the aircraft landing gear to RWY, and may cause the aviation events. In addition, the condition of taxiways and airport runway affects the taxiing time of aircraft, which during high-traffic hours can lead to additional flight delays. To study the effect of friction coefficient on the runway occupancy time the methodology of collecting statistical data about the time of different types of aircraft spent on runway at various values of the friction coefficient is offered. The method is based on a full-scale experiment. To conduct the experiment as the object of analysis the process of moving the aircraft from the holding position up to reaching the height of 200 meters at Vnukovo airport was chosen. Since the observer cannot control the parameters affecting the object of study during the flight, the friction coefficient is recorded as an input parameter during the experiment and as the response – the time of moving aircraft from holding position up to reaching the height 200 meters after take-off on standard departure procedure. As a result of the experiment, according to the obtained data, a graph of T_{tot} versus friction coefficient was designed. The greatest influence of the friction coefficient is observed when taxiing from the holding position on runway to line-up position.

Key words: Friction coefficient, airport capacity, air traffic control, airspace planning, experiment procedure.

INTRODUCTION

The state of the runway (RWY) under operating conditions, due to the possibility of formation of a layer of water, ice, slush, snow, decreases the friction coefficient K_{fc} of the aircraft landing gear to RWY, and may cause the aviation events. In addition, the condition of taxiways and runways affects the taxiing time of aircraft, which during high-traffic hours can lead to additional flight delays [1, 2].

Regulatory documents prescribe the measuring of the runway friction for the next cases[1]:

1. on dry RWY: they examine the wear of the surface of RWY and define the necessity of its recovering;
2. on wet RWY: they measure the friction coefficient for verifying its acceptable limits;
3. if there is a water layer on the RWY: they check the coefficient when tendency for hydroplaning is possible;
4. on slippery RWY in bad weather conditions it is necessary to perform additional measurements for friction coefficient;

[1] Airport services manual. Part 2: Pavement surface conditions. ICAO DOC 9137-AN/898/ICAO. 4th ed. 2002.

5. on RWY covered with snow, slush or ice: continuous and precise evaluation for friction coefficient is required.

Having the above-mentioned measures conducted provides the runways in use with very good friction conditions and required flight safety even in case the runway is wet. Evaluation and maintenance experience prove that surfaces designed in accordance with all requirements and made of asphalt or cement or concrete meet the criteria listed in DOC 9157- AN/901, 3-rd edition ICAO[2].

As soon as the runway surface condition gets worse, it may affect the aircraft accelerating, decelerating, subsequently influencing the takeoff distance available (TODA), rejecting and landing. The lowering of the friction coefficient also has an effect on directional controllability of aircraft leading to immediate action for correcting to the side of reading level of acceptable crosswind during take-off and landing[3].

Furthermore, friction coefficient reduced may change the time of taxiing on aerodrome and rolling for take-off on the runway. In case of traffic congestion, this may cause additional flight delays [3]. To analyze the influence of the friction coefficient on the time needed to occupy the runway by aircraft an experiment was conducted while statistics of the time of occupying the runway by different types of aircraft and different frictions parameters was chosen.

THE PROCEDURE OF THE EXPERIMENT

The Object of Analysis (OA) was chosen to be the process of movement of an aircraft from the holding position on taxiway up to reaching the height 200 meters after take-off on standard departure procedure at Vnukovo airport.

Object of analysis, in accordance [4, 5] appears as the "black box" with some quantity of input and output (fig. 1).

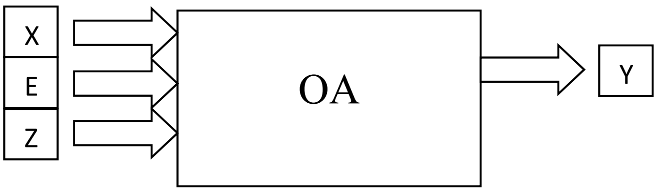

Fig. 1. Block diagram of the analysis object

The figure shows:

- input parameters:
  $X = \|x1, x2, \ldots, xn\|$ – the vector of variable controlled and operated parameters;
  $Z = \|z1, z2, \ldots, zn\|$– the vector of controlled but non-operated parameters;
  $E = \|e1, e2, \ldots, en\|$– the vector of non-controlled and non-operated parameters;
- output parameters:
  $Y = \|y1, y2, \ldots, yn\|$ – the vector of data or quality of the object analyzed. This figure remains dependent variable of the object and also forms feedback of the system to the entering actions. We accept the dependence of feedback on pending variable remains function of feedback, and geometric standpoint of feedback function – is the surface of feedback.

Airport Vnukovo was chosen as the place for the conducting of the experiment. This airport has number three in rating among the Russian Federation airports, after Sheremetyevo and Domodedovo including the quantity of passengers and non-passengers and other kind of flights. The average

[2] Aerodrome Design Manual. Part 1: Runways. ICAO DOC 9157-AN/901 / ICAO. 3 rded. 2006.
[3] Assessment, Measurement and Reporting of Runway Surface Conditions. ICAO circulars CIR 329-AN/191/ ICAO. 2012.

number of passengers at Vnukovo was 15815000 in 2015, and it has more, than 170 directions all over the world. Airport Vnukovo provides more than 170000 flights of Russian and foreign air companies.

There are three passenger terminals and "Vnukovo-Cargo" complex at the airport. The main passenger terminal "Vnukovo-1" contains of "A", "B", "D" terminals. The "Vnukovo-2" is a terminal for VIP flights, special government flights. "Vnukovo-3" terminal services business flights, Moscow government and other special flights including "Roscosmos".

There are 2 intersecting runways at the airport:

- runway 1 – magnetic RWY heading 238° and 158°;
- runway 2 – magnetic RWY heading 193° and 13°.

Considering that during the process of flight operations, the observer cannot change the parameters, which can affect the object of analysis, only passive experiment could be conducted [6]. The friction coefficient will be as a parameter of the Z group. T_{tot} time will be the output parameter. This time is between movements of an aircraft from the holding position on taxiway up to reaching the height 200 meters after take-off on standard departure procedure.

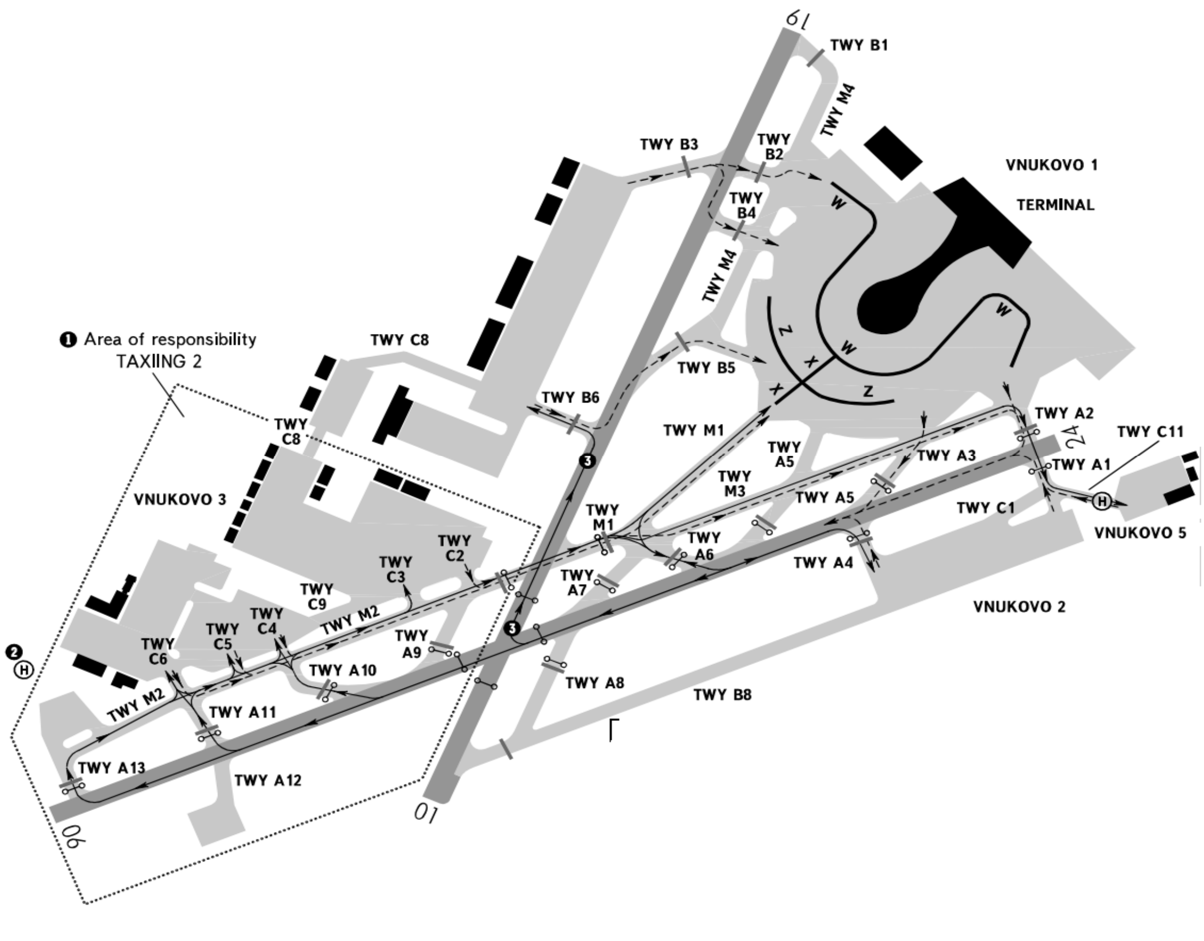

Fig. 2. Map of aerodrome surface movement with an active runway with magnetic heading 238°

For equal conditions during conducting of an experiment, the sample will include only those events that meet the following criteria:

- aircraft types: Airbus A320, Boeing B737, Boeing B767, Boeing B777 and Yakovlev YAK 40;
- active runway with magnetic heading 238°;
- the holding position on taxiway is A2.

As seen from fig. 2, when taxiing from the holding position up to line-up position on taxiway A2, the aircraft has to make an about 90° turn. To perform such a maneuver, it is very important for flight deck crew to consider the friction. For better analysis, the T_{tot} will be divided into several parts:

- T_1 is the time of aircraft taxiing from the holding position to line-up position;
- T_2 is the time between of ATC clearance for departure of aircraft and its starting of take-off run;
- T_3 is the time between starting of take-off run of aircraft and its take-off;
- T_4 is the time between take-off of aircraft and reaching the height of 200 meters.

ANALYSIS OF THE OBTAINED DATA

During the conducting of the experiment, a sample of values of time intervals T_1, T_2, T_3, T_4 and T_{tot} was obtained for different values of the friction coefficient. For each of the aircraft types that meet the requirements of conducting of an experiment, a table was designed. In it, each value of the friction coefficient corresponds to the expectation of time intervals M (T_1), M (T_2), M(T_3), M(T_4) and M(T_{tot}).

Table 1

Expectation of time intervals of taxiing for various values of friction coefficient for aircraft A 320

K_{fc}	T_1	T_2	T_3	T_4	T_{tot}
0.42	1:41:38	0:14:07	0:42:30	0:20:30	2:58:00
0.45	1:46:20	0:11:40	0:28:20	0:16:20	2:42:40
0.5	1:06:00	0:14:00	0:46:00	0:16:00	2:22:00
0.6	1:03:24	0:16:24	0:35:12	0:17:36	2:00:36

Table 2

Expectation of time intervals of taxiing for various values of friction coefficient for aircraft B 737

K_{fc}	T_1	T_2	T_3	T_4	T_{tot}
0.45	1:32:24	0:23:12	0:34:36	0:13:12	2:43:24
0.6	1:19:34	0:13:34	0:32:34	0:21:26	2:27:09

Table 3

Expectation of time intervals of taxiing for various values of friction coefficient for aircraft B 767

K_{fc}	T_1	T_2	T_3	T_4	T_{tot}
0.4	1:34:00	0:11:00	0:42:00	0:38:00	3:05:00
0.42	2:02:00	0:14:00	0:46:00	0:14:00	3:16:00
0.5	1:51:30	0:09:00	0:47:30	0:18:30	3:06:30
0.6	0:47:40	0:15:20	0:40:00	0:17:40	2:00:40

Table 4

Expectation of time intervals of taxiing for various values of friction coefficient for aircraft B 777

K_{fc}	T_1	T_2	T_3	T_4	T_{tot}
0.5	1:00:00	0:44:00	0:31:00	0:10:00	2:25:00
0.55	1:31:30	0:27:30	0:38:00	0:14:00	2:51:00
0.6	1:29:36	0:13:36	0:37:18	0:18:48	2:39:18

Table 5

Expectation of time intervals of taxiing for various values of friction coefficient for aircraft JAK 40

K_{fc}	T_1	T_2	T_3	T_4	T_{tot}
0.4	1:34:00	0:11:00	0:42:00	0:38:00	3:05:00
0.42	2:02:00	0:14:00	0:46:00	0:14:00	3:16:00
0.45	1:28:00	0:09:00	0:40:00	0:49:00	3:06:00
0.5	1:51:30	0:09:00	0:47:30	0:18:30	3:06:30
0.6	0:47:40	0:15:20	0:40:00	0:17:40	2:00:40

Figure 4 shows a graph of T_{tot} versus friction coefficient.

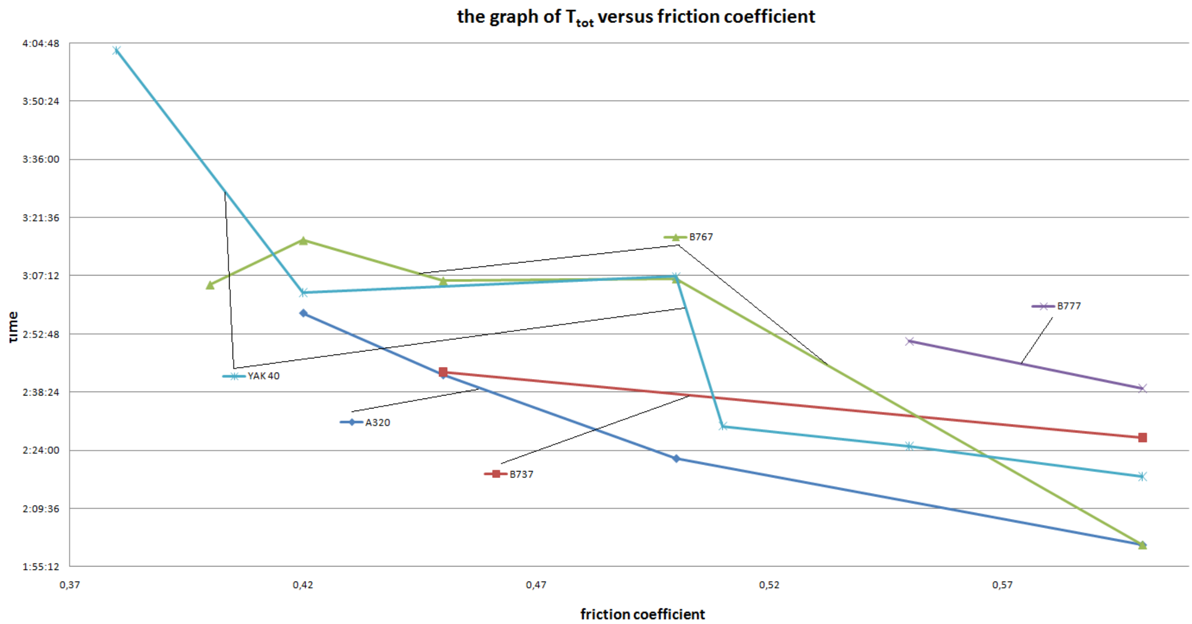

Fig. 4. Graph of T_{tot} versus friction coefficient

As it can be seen from the graph, with an increase in the friction coefficient, T_{tot} decreases. It should be noted that the greatest influence of the friction coefficient is noted when taxiing from the holding position to line-up position. The influence of the friction coefficient on the remaining time intervals is insignificant. Taxiing is carried out on a complex trajectory close to a sinusoidal curve, which can be explained by the second-order dynamic equations. Speed and features of movement on taxiways depend on the condition of the coating. When the surface is dry, the taxiing speed may be higher than when it is wet. This can be explained by the fact that the longitudinal and transverse resistance forces to movement, which determine the longitudinal and ground stability and controllability of the aircraft, have large values on dry surfaces. The speed of the aircraft on the taxiway also depends on the pilot qualification [7–10].

As it can be seen from fig. 2, at Vnukovo airport there are quite a lot of taxiway intersections where the aircraft has to maneuver at large angles. Therefore, the friction coefficient can have a significant impact on taxiing time on the airfield, which in turn should be taken into account, especially during "peak hours" when the intensity movement is the highest. At the same time, the presence of high-speed taxiways used as runway exits and entries, the trajectory of movement along which allows you to perform a maneuver faster than from the taxiways that are perpendicular to the runway. This could significantly increase the capacity of the airport.

It is practically impossible to predict the condition of the runways and taxiways. However, it is possible to accumulate statistics on the friction coefficient in different calendar months. The use of such statistics in flight planning to adjust airport capacity rates will help to reduce flight delays.

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ВЛИЯНИЕ СОСТОЯНИЯ ПОВЕРХНОСТИ РУЛЕЖНЫХ ДОРОЖЕК И ВЗЛЕТНО-ПОСАДОЧНОЙ ПОЛОСЫ НА ВРЕМЯ ВЫЛЕТА ВОЗДУШНЫХ СУДОВ

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Состояние взлетно-посадочной полосы (ВПП) в эксплуатационных условиях, обусловленных возможностью образования на полосе слоя воды, льда, слякоти, снега, приводит к снижению коэффициента сцепления пневматиков шасси самолета с ВПП и может быть причиной авиационных событий. Кроме того, состояние рулежных дорожек и ВПП аэропорта влияет на время руления воздушных судов, что в часы высокой интенсивности воздушного движения может привести к дополнительным задержкам рейсов. Для исследования влияния коэффициента сцепления на время занятости ВПП воздушным судном предлагается методика, заключающаяся в сборе статистических данных по времени нахождения разных типов воздушных судов на ВПП при различных значениях коэффициента сцепления. В основе методики лежит натурный эксперимент. Для проведения эксперимента в качестве объекта исследования был выбран процесс движения воздушного судна от предварительного старта до набора им высоты 200 метров в аэропорту Внуково. Так как при производстве полетов наблюдатель не может управлять параметрами, влияющими на объект исследования, то в ходе эксперимента фиксируется в качестве входного параметра – коэффициент сцепления, в качестве отклика – интервал времени, затраченный воздушным судном при движении от предварительного старта до набора этим воздушным судном высоты 200 метров. В результате эксперимента по полученным данным был построен график зависимости этого интервала от коэффициента сцепления. Наибольшее влияние коэффициента сцепления отмечается при рулении от предварительного старта к исполнительному.

Ключевые слова: коэффициент сцепления, пропускная способность аэропортов, управление воздушным движением, планирование использования воздушного пространства, методика проведения эксперимента.

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