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METHODS AND TECHNIQUES FOR DETERMINING ADHESION COEFFICIENTS ON AIRFIELD PAVEMENTS

Анотація. У статті проаналізовані найбільш популярні методи визначення коефіцієнта зчеплення в Україні і за кордоном. Наведено їхні переваги й недоліки. Показано порівняння приладів для вимірювання фрикційних властивостей аеродромів. Розглянуто способи визначення коефіцієнта зчеплення поверхні аеродромного покриття.
Ключові слова. коефіцієнт зчеплення, злітно-посадкова смуга, аеродром, метод вимірювання коефіцієнта зчеплення, вимірювальне колесо, деселерометри, повітряне судно, шорсткість, мікропрофіль.

Аннотация. В статье проанализированы наиболее популярные методы определения коэффициента сцепления в Украине и зарубежом. Приведены их достоинства и недостатки. Показано сравнение приборов для измерения фрикционных свойств аэродромов. Рассмотрены способы определения коэффициента сцепления поверхности аэродромного покрытия.
Ключевые слова. коэффициент сцепления, взлетно-посадочная полоса, аэродром, метод измерения коэффициента сцепления, измерительное колесо, деселерометры, воздушное судно, шероховатость, микропрофиль.

Abstract. The most popular methods of determining the coefficient of friction in Ukraine and abroad are analyzed in the given article. Their advantages and disadvantages are given. A comparison of instruments for measuring the frictional properties of airfields is shown. The methods of determining the coefficient of friction of the road surface are considered.
Key words: coefficient of friction, runway, aerodrome, method for measuring the friction coefficient, measuring wheel, decelerometer, aircraft, surface roughness, microprofile.

Introduction

The coefficient of adhesion (CA) of the surface of pavement that determines the measure of its adhesion with the wheels of the vehicle is all over the world the subject of research and production of works directed to measure and increase it on the surface of runways of airfields and road pavements by applying a transverse incision and the use of highly frictional materials in order to improve the safety of aircraft landing as well as transportation.

Pre-landing measurement of adhesion properties of surface coatings with the wheels of aircrafts is currently being implemented at airports all over the world by rolling with a constant skidding of measuring wheels, using mobile (self-propelled or towed) installations.

World experience of measuring the friction coefficient

The world leader in the measurement of the coefficient of friction on airfield pavements is the Swedish company ASFT (Airport Surface Friction Tester). Mobile units of this company are used by more than 200 airports in Europe and America.

All ASFT units contain an electro-hydraulic hoist device of the measuring wheel with a system that ensures its constant downward pressure to the surface. Another competitive product on the world market is towed installation model Skiddometer BV 11 manufactured by the Finnish company «Patria Industries Oyj». It is easy to use by ground personnel, reliable in operation and has been many times recognized at international conferences, exhibitions as the best measuring device in the world. Installations Grip Tester and Mu-Meter of British companies Tradewind Scientific and Specialist Electronic Services, respectively, equipped with electronic measuring systems with computer control also rank high up among other companies. All these installations are usually provided with modern computer systems, data processing and data broadcast to the airport control service in real-time, distance traveled sensors, monitors and printers. There are about two dozen brands of COP meters that have firmly entrenched at the global market (1).

Equipment for measuring the constant friction coefficient

DFT equipment can be used under various weather conditions and in contrast to the previous system for measurement the constant friction coefficient it is compatible with more than 80 vehicles servicing the airport. In addition, new DFT equipment was also attractive in terms of finance.

Figure 1 - Dynamic Friction Tester, (DFT)

Information from both measuring systems (DFD and DFT) is ultimately transmitted to the system of providing information to flight crews (Notice to Airmen System, NOTAM). These data can also be used in air traffic control services to provide pilots with information on the state of the runway and the nominal values of the coefficient of adhesion of the airfield pavement. Pilots take account of these data coupled with certain features of aircrafts for optimization of modes and securing safety during the takeoff and landing of aircrafts. (2)

Measurement of the friction coefficient in Russia

Measurement of the friction coefficient in the Russian Federation is carried out by special devices. These devices include:

- Measuring the friction coefficient AT-EM;
- Aerodrome truck brake ATT-2.

Figure 2 – Friction coefficient measuring device AT-EM

Friction coefficient measuring device AT-EM is used for:

• determination of friction properties of the runway with artificial pavement according to the friction coefficient value, calculated as the average arithmetic value of the ratio of measured values of the longitudinal traction force to the normal reaction, acting at each of the two measuring wheels when electromechanical braking occurs for each of the two MW;

• calculated as the ratio of the measured values of the longitudinal traction force to the normal reaction at each of the two measuring wheels when the electromechanical braking occurs.

• binding of measuring indicators of the friction coefficient to a particular point of measurement on artificial airfield pavements;

• creating an archive of measurement results of the friction coefficient;

• transfer of measurement parameters via a secure radio link to the command and control center (ATC tower), FOD, or AS.

Experience of AT-EM friction coefficient measuring devices in aviation enterprises of CA of Russia has shown that information about the dynamics of change of values $K_{fric.}$ makes it possible for allows the ground services to take timely measures to maintain the surface of artificial runways in operational condition. For example, regular measurement of the friction coefficient and prevention of only ice formation on airfields of class A provides savings of up to 250 - 300 tons of anti-icing chemicals per year (data obtained from the Office of the Federal Air Transport Agency of Airport Operations of Russian Federation).

According to performance and measurement accuracy, the AT-EM friction coefficient measuring device corresponds to the requirements of the ICAO (Doc. №9137-AN/898, 1994), it is cost-effective, which is not typical for friction coefficient measuring devices applied at Russian and foreign aviation enterprises.

Currently, the airfield complex AT-EM (AT-EM - Air Force) is the only friction coefficient measuring device both in Russia and abroad, meeting the requirements of the ICAO (Doc. №9137-AN/898, Part 2, Ch. 5), which can be used to predict the braking performance of aircrafts. (3)

Measurement of the friction coefficient in Ukraine

Ukrainian civil aerodromes have employed for more than 30 years the only national friction coefficient measuring device - towed aerodrome brake trolley ATT-2, which presents a simple implementation of the principle of mechanical braking in the form of a two-wheeled trailer with driving and measuring wheels of different diameters, and this provides constant skidding of the measurement wheel relative to

the drive wheel, equal to the difference quotient of wheels diameter with respect to the larger diameter of the drive wheel. Strain values of the friction coefficient in ATT-2 are amplified and displayed by a galvanometer and registered by the operator who checks the readings. Obviously, such a setting does not currently meet the international standards; it is obsolete and requires replacement. The aerodrome brake truck ATT-2 is designed for calculation of the regulatory friction coefficient to determine the braking conditions of aircraft chassis operated in 50 - 60 years of the last century (4).

The principle of measuring C_f (friction coefficient) by the brake trolley ATT-2 in foreign countries is based on kinematic rigidity of the measuring wheel coupling with the reference one through the driveline and does not maintain a constant measuring mode of the friction coefficient due to the lack of possibilities to keep a predetermined slip rate of the measuring wheels at surface irregularities of the artificial runway (ice, snow, water, pollution, etc.). There is carried out indirect measurement of standard values of the friction coefficient. For these reasons, the error of standard values of the friction coefficient constitutes up to 30% (5).

Of all the devices of this kind the most perfect is the Swedish trolly "Skiddometer BV 11: 2". It is a three-wheeled trailer weighing 360 kg, designed for towing vehicles. The braking effect is created by the movement of the middle measuring wheel with a constant slippage of about 17% under all states of coatings. This allows obtaining the values of friction coefficients proximately to their limit values.

The measured friction coefficients are continuously recorded by the recorder, the paper tape of which is stretched in proportion to the distance traveled. Simultaneously, the integrator automatically calculates mean values of the coefficients for distances predetermined in the device software, and prints them on the paper tape indicating the direction of movement of the trolley (the direction of the runway), the date and time of measurement.

Among other instruments used to assess the conditions of braking on the runway there should be noted mu-meter, designed and manufactured in England. It is a three-wheeled trailer, used for towing cars. Unlike the skiddometer, the braking effect in it is created by the installation of two wheels with a slip angle. The third wheel is used to measure the distance traveled. The resultant in the course of motion force of the side clutch is measured by a hydraulic sensor, and the ratio obtained in such a way is adopted as the longitudinal coefficient of coupling. This principle of

truck operation is less successful, because it allows you to evaluate the lateral grip of tires and does not meet the conditions of hindered movement of the wheel.

In the process of measuring, the coefficient of friction is recorded on the paper tape, stretched proportionally to the distance traveled.

At present, at domestic and foreign airports assessment of braking conditions on the runway, using dynamometric trolleys of type "Skiddometer BV 11: 2" and the mu-meter is carried out by the method of the International Civil Aviation Organization (ICAO), contained in Annex 14 "Aerodromes". In accordance with this, measurements are performed by means of two driveways of the trolley at the speed of 60 km/h on the runway at a distance of about 10 m from the center line. Based on the data obtained they calculate the average values of friction coefficients for each third part of the length and the entire runway.

Imperfection of the existing state of the fleet of vehicles for continuous control of frictional properties of airfield and road coatings is also partly due to the common and necessary for both foreign and national products requirement, impairing their access to the Ukrainian market - mandatory state certification (6).

Methods of determining the friction coefficient of the road surface

Due to the fact that all previous methods present the availability of instruments for measuring the friction coefficient that significantly increases the cost of measurement, the State Enterprise "ROSDORNII" obtained a patent for the method of determining the friction coefficient of the road surface. The authors of the method I question are N. Lushnikov, P. Lushnikov, Yu. Gvozdkov.

The invention can be used to control the geometrical characteristics of coatings in the construction and repair, as well as to determine the coupling properties of the road surface. The method consists in measuring the parameters of the road surface and calculation of the friction coefficient. Initially, they measure the ordinates of the microprofile of the coating surface, according to which they determine the dependence y = f (x), describing the microprofile at a fixed interval. Using this dependence, they determine the length of the curve of the microprofile and parameters K_i of the roughness of the road surface by calculating formulas. The invention makes it possible to simplify and reduce the cost of the measurement method, as well as eliminate the need for wetting the coating. (7).

Method of determining the coefficient of wheel coupling with the surface of artificial coating

The invention relates to measurement methods and is used to assess the state of the surface of the airfield runway, but can also be used to determine the coefficient of friction of road coatings.

The aim of the method offered lies in increasing the accuracy of measurement of friction coefficient of the wheel with the road surface by registering the maximum braking force $R_{break.max}$ between the measuring wheel and the surface of the coating, according to which they calculate the rate of wheel friction with the surface of the artificial pavement with no slip of the measuring wheel.

Solution of the goal set concerning "The method of determining the coefficient of friction of the wheel with the surface of the artificial pavement" is achieved by the fact that using this method the coefficient of wheel friction with the surface of the artificial pavement is determined by the method of braking, when they roll the measuring wheel on the surface of the artificial pavement, the brakes being applied in accordance with the state of the coating surface, wherein the normal force F of the measuring wheel load onto the coating surface is determined.

In the inventive method, regardless of the speed of movement they further determine the braking torque (M), generated by the electromagnetic brake, and the friction torque (Mg) of the measuring wheel with the surface coating. Thereafter, the equality of the braking force moment (M) and the time of friction force (Mg) (M = Mg.) are constantly maintained. At the same time, the maximum braking force $R_{break.max.}$, which is equal to the force of friction $R_{fric.}$ of the measuring wheel with the surface coating, is obtained between the measuring wheel and the surface of the pavement ($R_{break.max} = R_{fric.}$, $R_{fric.} = RK_{fric.}$). The coefficient of friction is calculated by the following formula:

$$K_{fric} = \frac{M_g}{P \cdot R}, \qquad (1)$$

where $K_{fric.}$ - coefficient of friction of the measuring wheel with the surface of pavement;

M - braking torque, generated by the electromagnetic brake or other braking device, N_m;

M_g - friction torque of the measuring wheel with the coating surface N_m;

P - normal load of the measuring wheel on the surface of coating, H;

R_{fric}. – friction force of the measuring wheel with the coating surface, H;

$R_{break.max}$ - maximum braking force between the measuring wheel and the surface of the coating, H;

R - radius of the measuring wheel, m.

The use of this method during its implementation will make it possible to increase the safety of aircraft landing by improving the accuracy of determining the coefficient of friction of the landing gear with the surface of the runway, as well as determine more accurately the state of highways.

Conclusions

Imperfection of the existing state of the fleet of vehicles for continuous control of frictional properties of airfield and coatings has lead to the need for a uniform method of determining the frictional properties of airfield pavements.

On example of the International Baltimore Airport/Washington it was shown that to obtain more accurate data on the friction coefficient, it is necessary to use several devices, which can cover a wider range of information.

Implementation of these methods makes it possible to determine the coefficient of friction at any speed, which allows measuring the coefficient of friction on the runway, on the aircraft parking place, when taxiing, in hangars, on the highways in use at any time (observing all the traffic rules), while maintaining or commissioning new highways, in all turns and a small extension of the coating surface.

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