Łukasz Semkło
Politechnika Poznańska
Instytut Energetyki Cieplnej
Zakład Inżynierii Lotniczej
lukasz.semklo@put.poznan.pl

Agnieszka Wróblewska
Politechnika Poznańska
Instytut Energetyki Cieplnej
Zakład Inżynierii Lotniczej
agnieszka.wroblewska@put.poznan.pl

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Comparative analysis of the friction coefficient of various airport pavements

Abstract: The parameter defined as the coefficient of friction is one of the basic parameters that are responsible for the characteristics of the surface on which vehicles (cars, aircraft) travel. The coefficient of friction is very important as it is responsible for the safety and reliability of the pavement. The paper below presents general issues concerning the friction force and its influence on the movement of aircraft on airport pavements. The requirements for the assessment of the friction coefficient were also discussed. Based on the results of tests carried out at four airports, an analysis of the decrease in the value of the friction coefficient was performed.

Keywords: Friction; Runway; ASFT

Introduction

Nowadays, where there is a need for fast and safe travel, aviation plays a significant role. This applies both to the transport of people and goods as well as to the military aspect of airspace defense. Maintaining security is an essential element of the functioning of the airport.

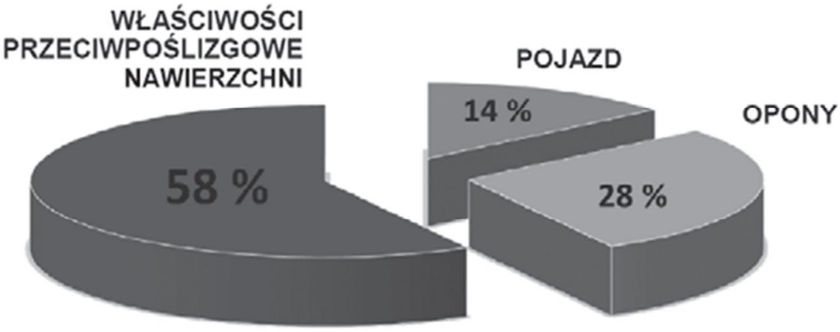
Under the Act of July 3, 2002, on aviation law, an airport is a separate area on land, water, or other surfaces, wholly or in part, intended for take-offs, landings, and surface or surface movement of aircraft, together with those located within its borders, such as buildings and construction equipment of a permanent nature, entered in the register of airports. A crucial part of the airport is the so-called Movement Area. This area is used for take-offs, landings, and ground movement of aircraft, including: Maneuvering area, i.e., the part of the airport used for take-offs, landings, and ground movement of aircraft without aprons and containing: taxiways and a runways. The runway consists of: a runway, shoulder, edge light zone, and exit exits of taxiways [Journal Laws of 2020, item 1970].

The anti-slip properties of the surface, which are characterized by the coefficient of friction, play a significant role, because, by ensuring the best parameters of surface roughness, the level of traffic safety increases. Therefore, it is essential to periodically check the coefficient of friction on surfaces on which aircraft and various types of vehicles move. Therefore, in this work, it was checked how the coefficient of friction changed over time on selected sections of the surface.

The authors' study focuses on providing an analysis of the findings from measurements of the surface friction coefficient of chosen sections at four airports located in our country.

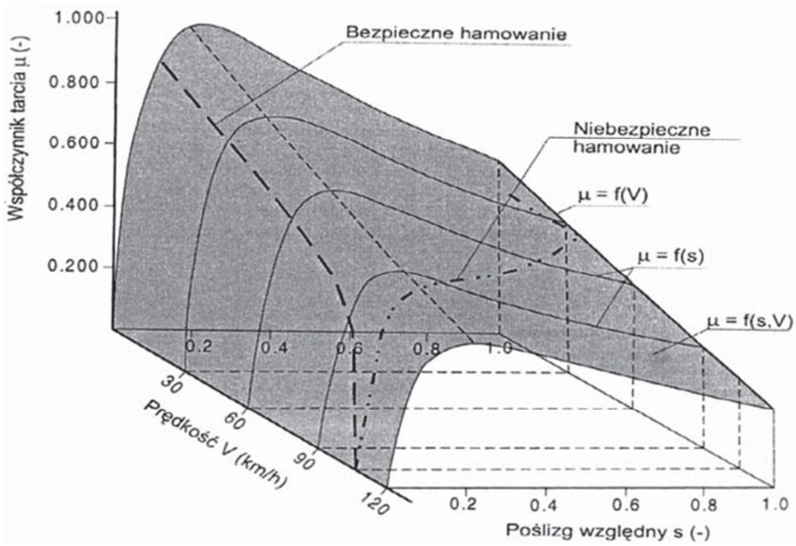
The research concerns only runways because the functional elements of the airport, such as the taxiway, have been analyzed before [Semkło & Wróblewska 2022]. The work aims to evaluate the properties of the tested surfaces in terms of the value of the coefficient of friction. The authors of the paper want to analyze how the value of the friction coefficient at the examined airports changed over the period under study.

The coefficient of friction is the ratio of the resultant friction forces generated between the braked wheel of the measuring device and the surface on which it moves to the pressure of the wheel on the surface [Łądkiewicz-Krochmal 2020]. The main factors affecting the length of the braking distance are shown in Figure **1**.



1. Main factors influencing the braking distance [Korzanowski 2017]

The measurement of surface roughness, i.e., the determination of the friction coefficient, consists in simulating the occurrence of a slip condition on a wet surface, i.e., from the point of view of vehicle wheel adhesion, the most unfavorable phenomenon. This is important because the higher the coefficient of friction, the more effective the braking, and the shorter the distance needed to stop the car or aircraft. The dependence of the friction coefficient on the speed and the amount (degree) of slip is shown in Figure **2**.



2. Spatial function of the friction coefficient depending on the speed and the size (degree) of slip [Sandecki 2017]

When braking, a braking torque is generated, which is transferred to the circumference of the wheel, which in turn creates a braking force between the tire and the road surface. [Iwanowski and Wojciechowski 2016]. The surface texture, which is directly related to the coefficient of friction, has a significant impact here. The anti-skid properties of the surface at the time of friction between the aircraft tire and the ground are very dependent on the texture of the surface [Doc. 9137 ICAO... 2002]. Small irregularities whose amplitude is below 0.5 mm are called microtextures. It is responsible for breaking the thin water film on the wet surface and creating a dry contact zone at the contact point between the tire and the road surface and ensuring proper friction between the wheel and the road surface as a result of intermolecular interaction. On the other hand, irregularities whose wavelength is in the range of 0.5 mm to 50 mm are called macrostructure. These unevennesses are caused by protruding aggregate grains [Łądkiewicz-Krochmal 2020, Bukowski 2017].

Methodology

The tests were carried out using specialized equipment shown in Figures **3** and **4**. These devices measure continuously. Friction coefficient measurements are carried out using a device called an ASFT (Airport Surface Friction Tester), which can be mounted on a trailer or directly on the vehicle. An example of an ASFT device mounted on a trailer could be the ASFT T-10 (Figure **3**) towed behind a vehicle. The ASFT device mounted on the vehicle is shown in Figure **4**.

3. ASFT T-10 trailer [Wesołowski et al 2018]

4. ASFT CSR device [Pożarycki et al. 2019]

Detailed research methodology is specified in: doc. 9137 AN/898 Airport Service Manual, Part 2-Pavement Surface Conditions, issued by the International Civil Aviation Organization (ICAO); ICAO Annex 14 to the Convention on International Civil Aviation; AC 150/5320-12C, issued by the Federal Aviation Administration (FAA); and Polish defense standard NO-17-A501:2015 Airport Pavements. Roughness test. All these standards describe the same measurement method. Table **1** presents a table from the ICAO Annex 14 guidelines specifying the braking performance in relation to a given value of the coefficient of friction.

Tab. 1. Evaluation of braking efficiency based on the value of the friction coefficient [ICAO Annex 14 … 2013]

Friction coefficient value from field measurements	Evaluation of an effective braking	Code number
0,40 and more	good	5
0,39–0,36	average to good	4
0,35–0,30	average	3
0,29–0,26	average to bad	2
0,25and less	bad	1

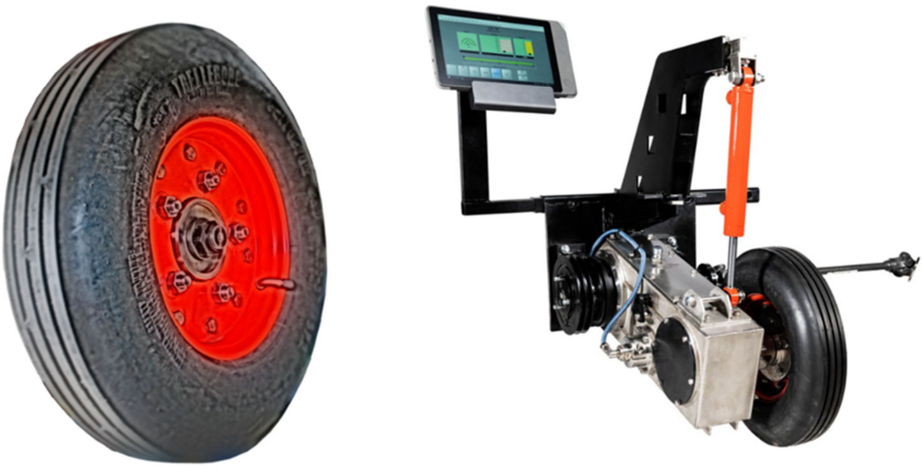
The above parameters refer to the surface during the so-called winter season, when its roads are covered with compacted snow and ice. The "good" rating means that the pilot landing on this surface will not encounter major difficulties in maintaining the direction during landing or braking [Iwanowski and Wojciechowski 2016]. ICAO Annex 14 and the defense standard NO-17-A501:2015 distinguish two limit levels of the friction coefficient when testing the roughness of airport pavements.

According to the requirements in the above-mentioned documents, the coefficient of friction for a runway must be assessed separately for each 1/3 of its length. To report to aeronautical information services, these parts are named A, B, and C, respectively, and it is recommended that used airport pavements be periodically inspected. The frequency of friction coefficient measurements should be set at a level that allows the functional elements of the aerodrome to be identified in terms of the minimum values of the coefficient of friction in order to take corrective action. Measurements should be carried out whenever there is a risk that the runway surface may be unusable due to bad weather conditions. In addition, measurements should be carried out at least once every three months. The periodicity of measurements is also related to the type of aircraft accepted by a given airport, the type of airport pavement, weather conditions, rules for using the pavement, and the number of air operations [Iwanowski and Wojciechowski 2016].

When conducting friction coefficient tests for different types of airport pavements, it can be observed that their results often differ from each other. This is because all the tested airport pavements differ in terms of structure, condition, and age. The measurement results are also affected by other factors, such as surface cleanliness, the amount of water supplied, the type of tire used, or the speed at which the vehicle was moving. For the measurement to be carried out correctly, the tested airport surface must not, or at least should not, contain any contamination. A foreign body that gets between the measuring wheel and the surface has a lubricating effect, thanks to which the obtained coefficient of friction is lower than expected. Examples include dust, fine sand, or an oil-derived substance. On the other hand, a change in the amount of water fed (a film with a thickness of 1 mm is required) during the measurement of a given airport surface affects the anti-slip conditions, which change as a result of this action.

The test speeds for the anti-skid properties of the surface are predetermined. Different speeds of the measuring device will give different coefficients of friction results. This is because the coefficient of friction varies with speed. The coefficient of friction also changes with the change in speed of the objects moving between them. Both devices mentioned above enable continuous linear measurement of the coefficient of friction between the airport pavement and the aircraft's reference wheel at a speed of 65 or 95 km/h. They have a water tank and a mechanism that allows you to wet the surface to obtain the required thickness of the water film, which is not less than 1 mm [Wesołowski et al. 2018]. The variety of measuring devices is also associated with the special measuring tires used in them. Two types of tires are most commonly used for the measurement: UNITESTER T520 for testing with a water film and ASTM E1551 for testing without a water film (Figure **5a**). Tires are mounted on a measuring device (Figure **5b**).

a) b)

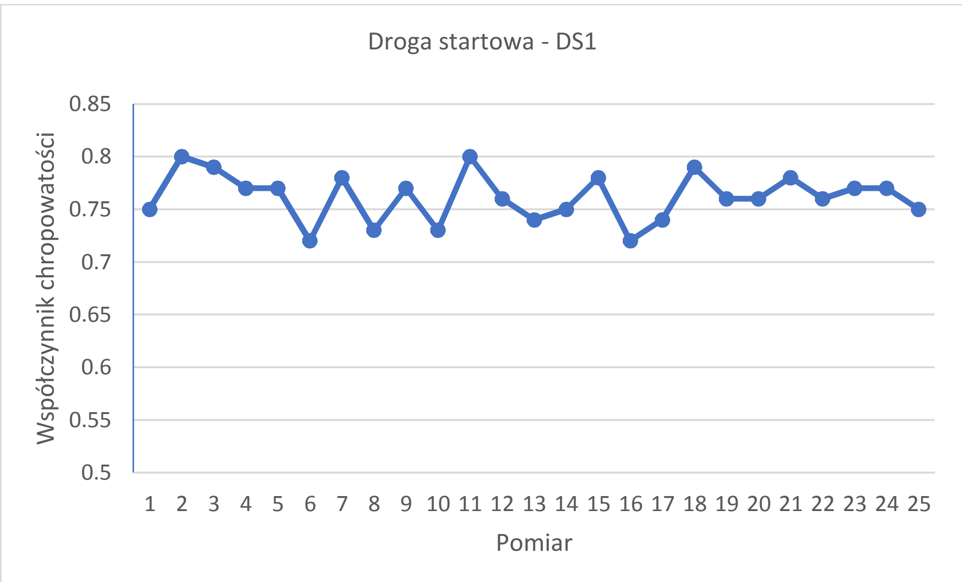


5. a) Unisester T520 measuring tyre; b) measuring device [source: https://gfte.se/products]

Research results

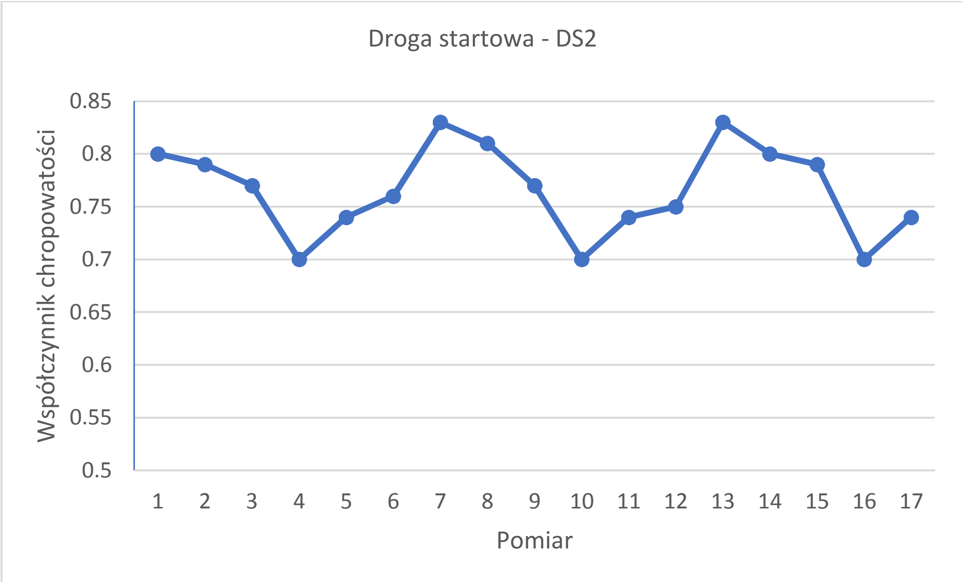
The measurement of the coefficient of friction was carried out for a runway surface made of cement concrete. The length of the tested section was 200 meters. The technical condition of all objects on which the measurements were carried out can be assessed as very good. The coefficient of friction of the surface was measured with the application of a water film under the measuring wheel at a speed of 95 km/h on selected sections. Figures 6–9 show the results of the measurement values at four selected airports.

In Figure **6**, it can be seen that the values of the coefficient of friction are kept between 0.7 and 0.8. Therefore, the value of the coefficient is stable thanks to continuous repairs, so that the condition of the runway surface is at the best possible level.



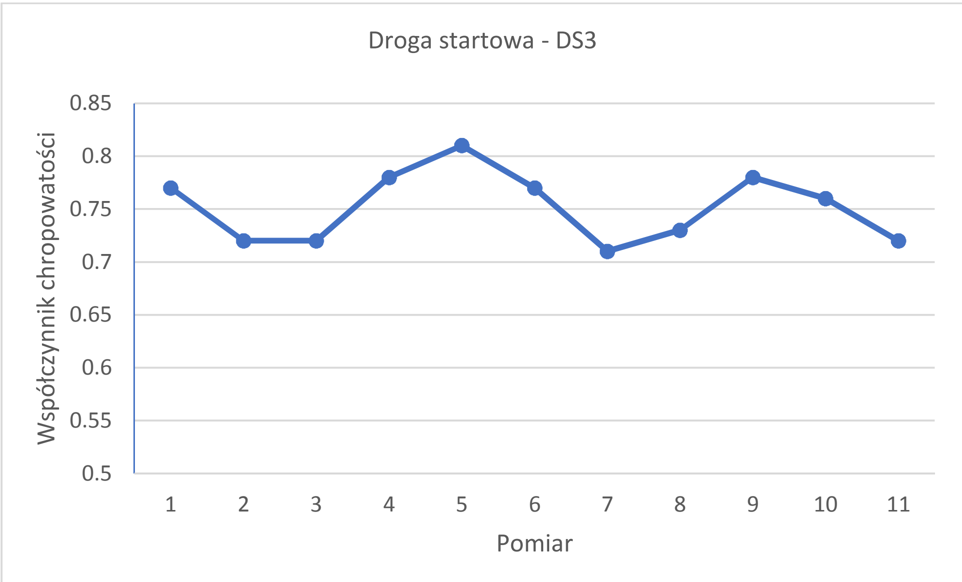
6. The course of variation of the friction coefficient determined for the surface of the runway marked DS1 at a speed of 95 km/h and with a water film

Figure **7** shows the measurement results for the second airport. Here, the values are in the range of 0.7–0.83. The discrepancy is greater than runway 1, but still, runway 2 performs very satisfactorily.



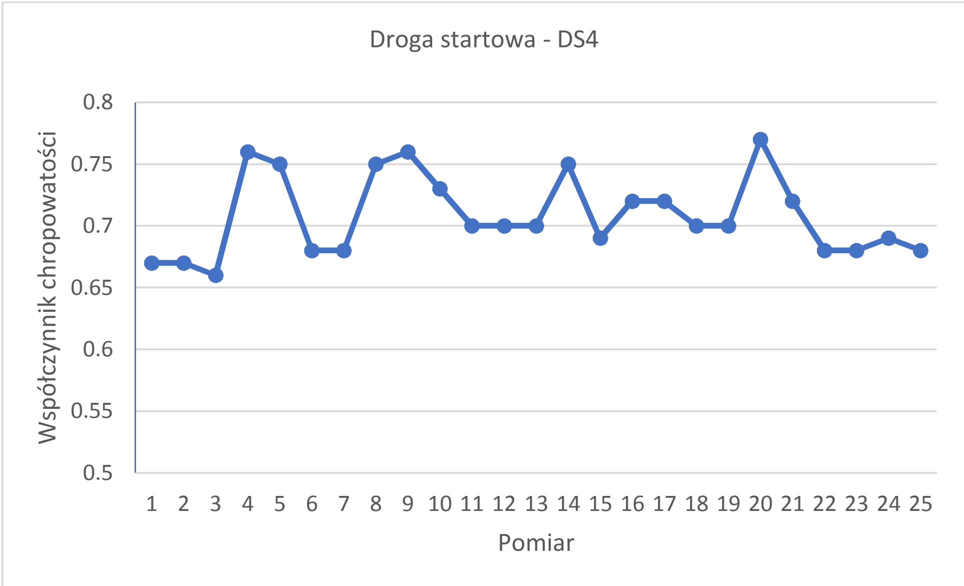
7. The course of variation of the friction coefficient determined for the surface of the runway marked DS2 at the speed of 95 km/h and with a water film

The results presented in Figure **8** coincide with the results presented for runways 1 and 2. The range for DS3 is also between 0.7 and 0.82. It can be said that runway number 3 is also maintained in a very good technical condition as the previous two runways (DS1 and DS2).



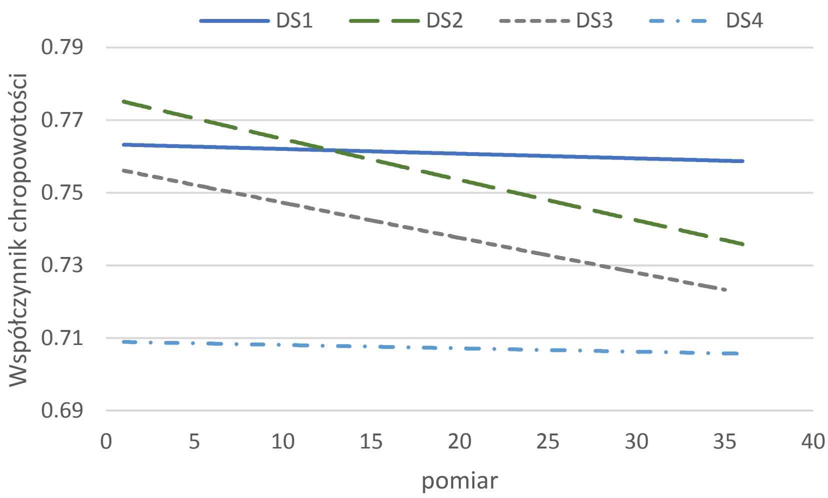
8. The course of variation of the friction coefficient determined for the surface of the runway marked DS3 at the speed of 95 km/h and with a water film

The situation in the case of runway number 4, shown in Figure **9**, is slightly different. It can be observed, comparing the previous results for the remaining runways, that the minimum value of thecoefficient of friction oscillates around 0.65. However, the maximum value does not exceed 0.77. This may be due to the fact that Airport 4 has a much higher traffic load than the other airports.



9. The course of variation of the friction coefficient determined for the surface of the runway marked DS4 at a speed of 95 km/h and with a water film

The results obtained from the conducted tests show some oscillations when it comes to the values of the results obtained. Therefore, trend lines were introduced to better compare all the runways studied. The cumulative analysis is shown in Figure **10**. Thanks to such a combination, it can be observed that all runways were worn out in the examined period. Consumption varies depending on the frequency of air operations and the take-off weight of the aircraft.



10. Trend line for runways DS1 - DS4

Summary

The paper presents the results of friction coefficient measurements, which were carried out on runway surfaces. Measurements made at four airports located in our country were taken into account. The tests presented in the work were carried out on concrete surfaces with water fed under the measuring wheel. The tests were carried out at a speed of 95 km/h.

The results of these measurements proved that the value of the coefficient of friction changes with the time of use of given airfield pavements. The results of the friction coefficient from individual airports were within the standards described in the paper. This means that safety in these facilities is ensured in this aspect.

In addition to the results of the tests of the friction coefficient of airport pavements, the paper also describes the factors that affect this coefficient. These included: the type of surface, the presence of contamination, the amount of water fed during the test, and the speed of the measurement.

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