ABOUT TIRE -RUNWAY FRICTION MEASUREMENTS

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***Abstract**: The paper reveal some aspects and proposals for improving the statistical learn of the measured friction coefficient values, research on the effect of climatic parameters(humidity, temperature of the contact surface) on the friction coefficient.*

Keywords: *friction, coefficient, measurements, tire-runway friction*

1. Introduction

The measured values of the tyre-runway friction coefficient are the only objective information regarding the condition of the runway surface, the other aspects are subjective (appreciation, estimation of contamination by the personnel performing the runway surface condition inspection).

Thus, measurements of friction coefficients are valuable information, especially in contaminant combination situations, when evaluating the increase and degradation of friction characteristics standards, [1].

2. Background

Various types of continuous friction measuring equipment are used around the world to measure the coefficient of friction on the runway surface. Inevitably, the criteria for design objective level, maintenance planning level and minimum level depend on the type of equipment used.

Strict legislative requirements for friction coefficient measuring equipment prevent the introduction of new systems, suggesting that a more general approach would be more practical.

3. Preparation of the experiment/ simulation and procedures

3.1 Input data and test conditions

In the measurements made, an ASFT T5 type equipment was used, [2].

SFT(Surface friction tester) is a high-tech, electromechanical-hydraulic integrated aviation ground equipment, composed of a mechanical transmission system, hydraulic system, computerized measurement and control system, and electrical control system.

Figure 1: *System,* [3]- *SFT*

[1] Easy Access Rules for Aerodromes (Regulation (EU) No 139/2014), ADR.OPS.C.010 Maintenance of pavements, other ground surfaces and drainage, Revision from June 2023

[2] Use of Continuous friction measurement equipment to predict runway condition rating on unpaved runways. Transp. Res. Rec. J. Transp. Tingle, J.S.; Norwood, G.J.; Cotter, B. Res. Board 2017

[3] Manual ASFT Industries AB , 2020, Computer System Description, Techniques , ASFT Trailers (T-10 or T-5)

Figure 2: *Surface friction tester type T5-ASFT*

The measurements were made after the calibration of the equipment and the setting of the necessary primary data: the configuration of the runway in service and the data related to the measurements: travel speed, measurement length, self-wetting, ice presence, direction (of the runway), type of measurement (ICAO, [4]).

3.2. Procedure

The measuring speed is 96 km/h. Under the action of the hydraulic system, the measuring wheel generates a pressure of 140 kg against the ground. The friction (F_f)
between the measuring wheel and the runway surface forms an equal and opposite direction force on the transmission chain through the action of torque, and the resultant force (F) can be obtained by calculation. The calculation schematic for SFT is shown in Figure 3 and equations (1), (2).

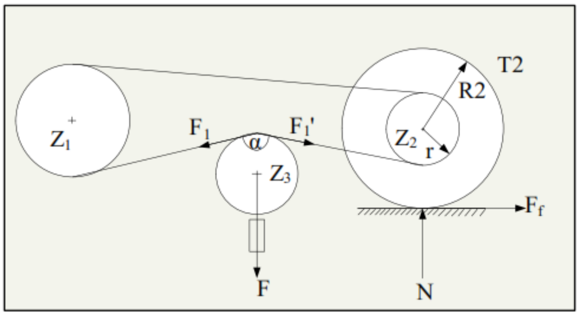

Figure 3: *ASFT T5 working principle diagram, [5]*

Starting from the balance of couples, applying the cosine theorem results :

$$F_f = \frac{F_r}{R_2 \sqrt{2(1+\cos\alpha)}} = kF \qquad (1)$$

The expression used by equipment to calculate the friction coefficient, [6]:

$$\mu = F_f / F_N \approx 7.29 \times 10^{-4} kF \qquad (2)$$

3.3 Output data

Output data, [7]**,** are: the measured friction coefficients, distance, speed, air temperature and the temperature of the measuring surface.

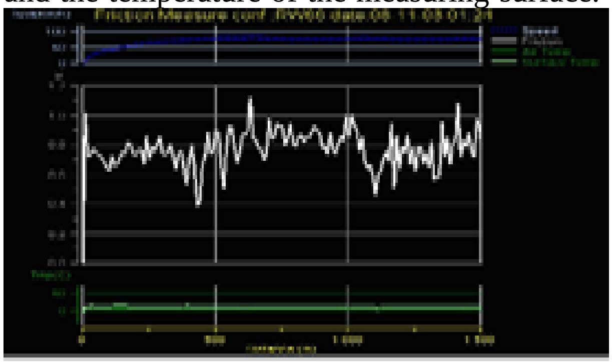

Figure 4: *Examples of measurement results (graphical)*

3.4. Analysis and interpretation of measurement results obtained

3.4.1 Comparative analysis of friction coefficient data - runway surface condition

The centralization and interpretation of the data on the friction coefficient related to the areas where the measurements were made generated the following representation (**fig.5**) :

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[4] ICAO Annex 14: Aerodromes - volume I: "Design and technical operation of aerodromes" (4th edition 2004, with subsequent amendments 2022);

[5] Estimation for Runway Friction Coefficient Based on Multi-Sensor Information Fusion and Model Correlation, School of Mechanical Engineering,2020 – figure 12

[6] Estimation for Runway Friction Coefficient Based on Multi-Sensor Information Fusion and Model Correlation, School of Mechanical Engineering,2020– equation (16) (17)

[7] CAP 683 The Assessment of Runway Surface Friction Characteristics, Civil Aviation Authority UK, 2022

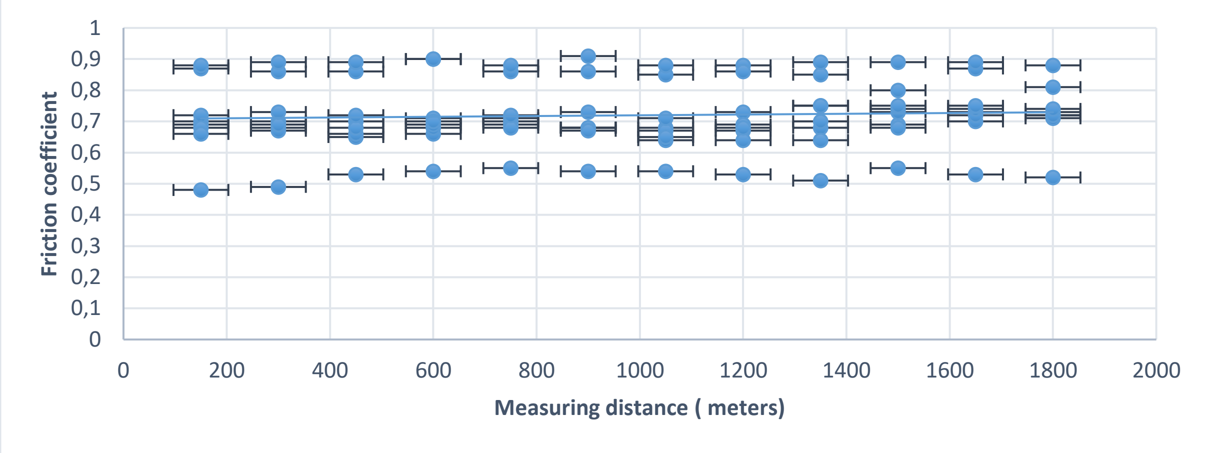

Figure 5: *Distribution of friction coefficients in measurement areas*

It is observed that in the areas between 1000 meters - 1600 meters and 200 meters - 600 meters referring to the northern threshold of the runway on which measurements were made, the variation of friction coefficient is from 0.41 to 0.92, a rather large range.
According to colected data the friction coefficient does not have a normal distibution.

3.4.2 Analysis of the measured values of the coefficient of friction - the speed of movement of the equipment
Following the centralization of the data obtained from the measurements, the following simulation resulted (**fig.6**) :

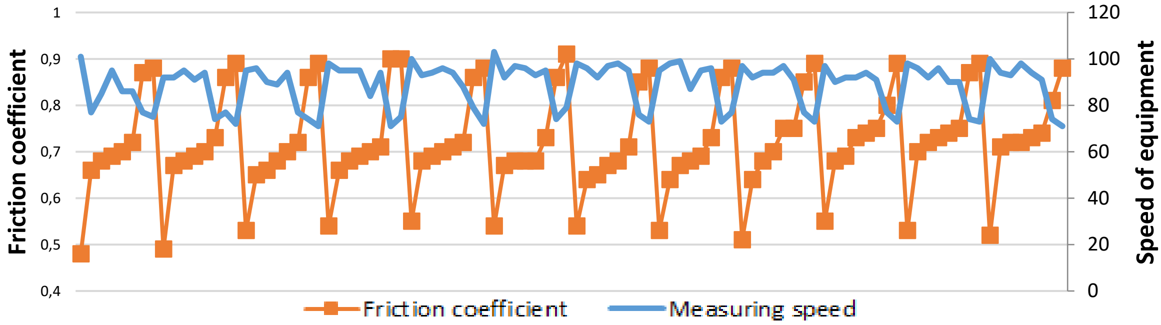

Figure 6: *Distribution of friction coefficients with speed*

The variation is observed: high speed - low friction coefficient and low speed - high friction coefficient. The lack of uniformity, of a normal distribution of the friction coefficient with the speed can also be generated by the climatic conditions and the measurement environment.

3.4.3 Statistical analysis , [8], *of the measured values of the friction coefficient*

The coefficient of friction between two surfaces is expressed in the form of an interval, they are constantly influenced by
the nature of the contact. If the data were not affected by random errors, they should
have the same distribution as the allure. The simulation resulted in the following representation:

[8] Estimation of the Friction Behaviour of Rubber on Wet Rough Road, and Its Application to Tyre Wet Skid Resistance, Using Numerical Simulation. Zhang, L.; Wang, R.; Zhou, H.; Wang, G. Symmetry 2022

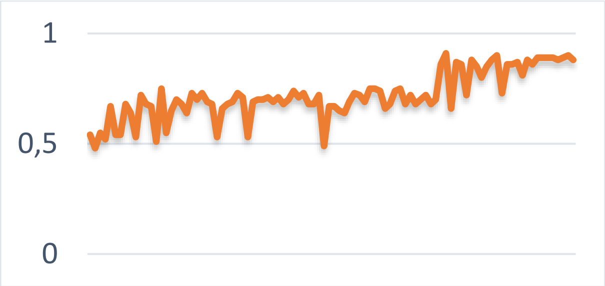

Figure 7: *Distribution of the measured friction coefficients*

On the analyzed data there are differences of 5% and 10% regarding the normal distribution, which would imply that the data in the range: 0.40 - 0.60 are insufficient (more measurements are needed) or/and the variation of up to 10% is given by the influence of external factors (moving speed, surface contamination, etc.)

4. Conclusions and proposals

4.1. The resulting conclusions are that damage on macrotexture significantly influence the friction coefficient on the surface and the braking distance occur.

Thus, a detailed analysis is needed regarding the tire-runway contact parameters, the influence of the degree of wear of the tire on the friction coefficient and the use of the coefficients measured at the runway in determining the classification characteristics of the contact surface.

4.2. The studies on runway friction focused more on the part of the surface structure (macrotexture, roughness) and less on the influence of temperature and humidity on the friction coefficient measurement system.As a consequence, it is considered necessary and it is proposed to deepen the study of the influence of climatic factors on the coefficient of friction at the runway.

4.3 A large part of the measurements shows a behavior similar to the Gaussian normal distribution function.

It is proposed as a research direction the statistical study of the friction coefficient values measured in relation to the errors (generated by various factors) and their statistical influence in the case of the friction coefficient distribution.

4.4 The friction coefficient data obtained does not have a normal distribution and it is needed that research should be done to correctly evaluate the degree of influence of the various parameters.

4.5 Following the analysis carried out and a with the information presented, it is proposed to study the effect of the transverse slope of the track on the coefficient of friction

5. General considerations regarding the research carried out

Considering that the objective of the friction measuring devices is to report the sliding friction, the dynamic influences of winter contaminants in the form of liquid (water) or particles introduce errors in the reported friction values. These dynamic, adverse effects contribute differently to the friction values reported for different device types the sliding friction force depends on the sliding speed and the displacement speed, while adhesion and hysteresis are the main friction mechanisms.

Surface contact temperature has a significant influence on the efficiency of the two key mechanisms responsible for producing tire adhesion: molecular adhesion and indentation. The effectiveness of the adhesion is greatly influenced by the surface temperature, while the effectiveness of the indentation strongly depends on the core (modulus of elasticity and hardness of the materials) and, to a lesser extent, on the surface temperature.

Subsequent to these aspects, there are processes that involve more detailed research. For example, rolling friction versus sliding friction in the case of running on a flexible runway, the dynamic influences of contaminants in the form of liquid (water, slush, snow) or particles that introduce errors in the measured friction values, the structure of the bearing surface, molecular adhesion, hysteresis, indentation, external environmental factors, etc.

The possibility of using mathematical models in the case of research, models that correctly describe the interdependence of
variables, the analysis of statistical data within the analyzed tribosystems.

6. References

1. ICAO-4th edition 2004, with subsequent amendments 2022, *Annex 14: Aerodromes - volume I: "Design and technical operation of aerodromes*"
2. Civil Aviation Authority UK, 2022 *CAP 683 The Assessment of Runway Surface Friction Characteristics*
3. Zhang, L.; Wang, R.; Zhou, H.; Wang, G. Symmetry 2022- *Estimation of the Friction Behaviour of Rubber on Wet Rough Road, and Its Application to Tyre Wet Skid Resistance, Using Numerical Simulation*
4. Misagh Ketabdari, Emanuele Toraldo, Maurizio Crispino ,30 october 2020 *Assessing the impact of the slopes on runway drainage capacity based on wheel/path surface adhesion conditions*
5. Transp. Res. Rec. J. Transp. Tingle, J.S.; Norwood, G.J.; Cotter, B. Res. Board 2017, *Use of Continuous friction measurement equipment to predict runway condition rating on unpaved runways*.
6. ASFT Industries AB , 2020, *Computer System Description*, *Techniques* , *ASFT Trailers* (T-10 or T-5)

7.Regulation (EU) No 139/2014, *Easy Access Rules for Aerodromes, ADR.OPS.C.010 Maintenance of pavements, other ground surfaces and drainage*, Revision from June 2023