A STUDY ON ROUGHNESS EVALUATION OF K AERODROME'S RUNWAY

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Abstract

This paper studies on roughness evaluation of airfield pavement using ICAO's and spectral density estimation method. Thereby, the results of roughness evaluation to the K aerodrome's runway were given through the measured data of pavement surface elevation. The results have been evaluated by 2 methods show that the roughness of K airport is good compared to the current regulations.

Keywords: *Roughness; runway; spectral density estimation; Boeing bump index (BBI).*

1. Introduction

Airfield pavement roughness is one of the most important criteria that significantly affects the quality of airport surface operations. In Vietnam, this criterion has been normally estimated by deviation between the bottom of 3 m (5 m) [2] straight-edge and the pavement surface for checking and taking over the works. Vietnam standard "TCVN 8753:2011 - Aerodrome - General Requirements for Design and Operations" has criteria of airfield pavement roughness evaluation which are recommended by International Civil Aviation Organization (ICAO) standard [4] to create the base of applying this method. In addition, the method of spectral density estimation has been applied for evaluating airfield pavement roughness in many countries such as Russia, US and EU [11] for generally evaluating the roughness of the airfield surface which are considered random processes. This paper would use the two above methods to apply the determination of the roughness of the airfield pavements in Vietnam through the measured data along the runway of K aerodrome.

2. Basis of some methods for evaluating airport pavement roughness

2.1. Runway roughness evaluation by ICAO, FAA's method

According to ICAO's method for evaluating the roughness of airport pavement, the isolated irregularities are defined by the maximum height or depth over distance of longitudinal profile with specified lengths from 3 to 60 m (Table 1).

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Table 1. Acceptable values of irregular height according to longitudinal profile

Surface irregularity	Minimum acceptable length of irregularity (m)								
	3	6	9	12	15	20	30	45	60
Maximum surface irregularity (height or depth) (cm)	3	3.5	4	5	5.5	6	6.5	8	10
Temporary acceptable surface irregularity (height or depth) (cm)	3.5	5.5	6.5	7.5	8	9	11	13	15

With that basis, ICAO and FAA have developed a diagram [3] to check runway roughness on the acceptable, temporary acceptable, excessive and unacceptable zones.

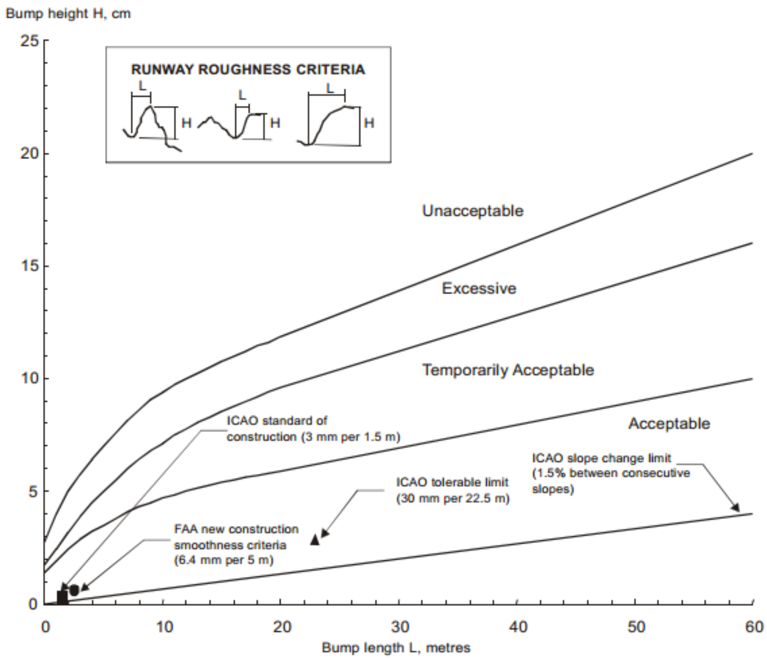

Figure 1. The diagram for evaluating the airport pavement roughness by ICAO, FAA

From the ICAO's recommendations and practical researches [7], the Federal Aviation Administration (FAA) has developed the ProFAA20 program to determine runway roughness by Boeing Bump Index (BBI). From that software, the calculated values include: shape of longitudinal profile, BBI, IRI, bump height and bump length of profile, amplitude of vertical oscillations of the aircraft (such as B727-200, DC-9, DC-10) during movement on runway, taxiway with different speeds…

2.2. Airport pavement roughness evaluation using spectral density estimation method

According to runway roughness evaluation by the spectral density estimation method, the airfield pavement elevations are considered as random values. The pavement surface is divided into longitudinal profile $P(t)$, which is a random process to consist of three different components: macroprofile $M(t)$, microprofile $q(t)$ and surface groove $\psi(t)$ [1]:

$$P(t) = M(t) + q(t) + \psi(t) \tag{1}$$

In three components above, microprofiles $q(t)$ with wavelengths of 1-80m are the main kinematic disturbing factor when aircrafts move on the pavement surface. At the same time, microprofile is the subject research for evaluating the effect of the roughness on the airplane dynamic load. The properties of microprofile as a stationary random process are exhausted by the following statistical estimates: mathematical expectation, variance, correlation function, and spectral density.

The spectral density and the correlation function are related to each other by the Fourier transform according to following expressions [8, 12]:

$$R(\tau) = \frac{1}{2\pi}\int_{-\infty}^{\infty} S(\omega)e^{i\omega\tau}d\omega \tag{2}$$

$$S(\omega) = \int_{-\infty}^{\infty} R(\tau)e^{-i\omega\tau}d\tau \tag{3}$$

where $R(\tau)$ is the correlation function of examined stationary random process, τ is correlation interval, $S(\omega)$ is spectral density estimation, ω is spatial frequency.

In current practice of statistical processing in random processes, two main groups of methods are used: parametric and nonparametric.

The nonparametric methods:

- Periodogram method is a method which is developed and widely used in the early years of the 20th century, but the accuracy of the estimation is not high. For improving its accuracy, with the advent of high-speed digital computers and the implementation of the Fast Fourier Transform, scientists have introduced computational algorithms on the base of periodogram method. If we only have applied pure algorithms to calculate, the accuracy of the assessment is significantly reduced. To overcome this disadvantage, algorithms were devised by Barlett and Welch on the basis of the Periodogram method.

+ The Bartlett's periodogram [5]: The algorithm is estimation method which is based on dividing the implementation length [0 L] into n intervals of length L_0 and applied (3) for each of these intervals, then we obtain n estimates of the spectral density.

+ The Welch's method of modified periodogram [9]: This method differs from Bartlett's method which is the calculation segment divided into small intervals with overlapping intervals in the range from 50% to 65% L_0.

When comparing the two methods above, Bartlett's method was not possible to obtain general theoretical recommendations on the choice of the values of n and L_0, since the optimal value of L_0 is not only used to depend on the type of the sought spectral density, but also on the specific issue which has been being solved. Welch's not only modified the basic scheme of the Bartlett's segmentation and averaged by using overlapping segments, but also implemented the application of the data windows (Hann and Hamming). Therefore, Welch's estimations have been highly convergent and most widely used in the nonparametric methods [10].

The parametric methods:

Most famous methods in this group include: classical method and Burg's. Burg's algorithm is one of the earliest and most well-known algorithms about the autoregressive spectral estimation (or called the "Maximum Entropy Algorithm"). Burg's algorithm has some positive features: high resolution in the analysis of short signals, guaranteed stability of the calculated shaping filter and minimization of prediction error forward and backward. In addition, using this method, there is no need to calibrate the estimated points, thus minimizing the bias of the obtained results. The disadvantage of Burg's method [6] is that if the input signal has a periodic component, the estimate would decrease the accuracy; however, this component is completely absent when estimating the roughness of airfield pavement.

When analyzing spectrum, the received result is normally a large number of averaged points. Therefore, in order to apply in different problems, it is necessary to make approximations by mathematical equations. In the roughness evaluation field of road and airport pavement surface, spectral density estimation is permissible to apply the following simple expression [8, 12]:

$$S(\omega) = \frac{C}{\omega^2} \tag{4}$$

where C is spectral density level (rad.m).

Parameter C can be used to compare and evaluate the roughness of airfield pavement. In some studies with elevation data at airports in Russia and Vietnam [10, 12]. The C coefficient changes from $1 \cdot 10^{-6}$ to $20 \cdot 10^{-6}$, the C coefficient is lower, the pavement surface is more smooth.

3. Roughness evaluation of K airport pavement by FAA's method and spectral density estimation method

To measure pavement surface elevation and evaluate the roughness, we apply the following methods: direct and indirect, in which equipment can be used such as: Walking Profilers; Inertial Profilers; level surveying, laser measuring device, accelerometer, gyroscope... Airport runways are "busy places"; therefore, nowadays the most convenient way to measure the roughness is instruments directly mounted on cars such as: Lightweight Inertial Profiler; High speed Inertial Profiler.

However, in Vietnam, the purchase of modern equipment is still restricted, so the application of classical methods has been still applied. On that basis, for evaluating roughness, runway surface elevations of K aerodrome are measured by level surveying with measuring step of 0.5 m and 3 profiles along the runway from the H0-200 to H0+812 shown in Figure 2.

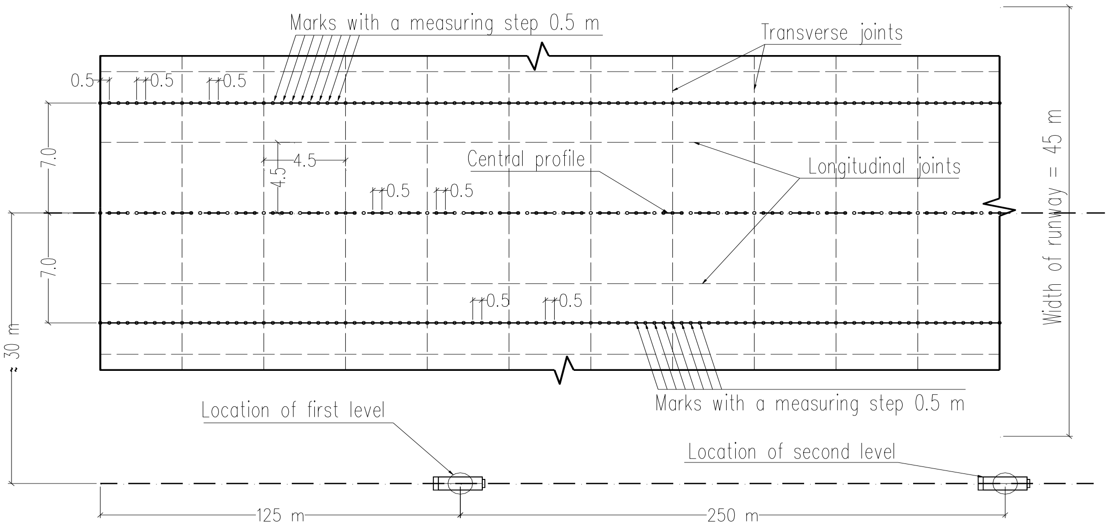

Figure 2. Geometric leveling of the runway of aerodrome K

3.1. Runway roughness evaluation by FAA's method using ProFAA20 software

The modules of longitudinal profile elevation for runway roughness evaluation in ProFAA software are designated by the three-letter extension "pro". Different formats are used by distinct equipment manufacturers. The software includes a conversion utility program that called "Convert Profile Format" to convert the most common profile data formats (ERD, ASTM, Text) to that required by ProFAA20 [3].

The elevation measured of K airport runway with step 0.5 m in longitudinal profile is converted file.txt to file.pro with the length by feet and the height by inches. At that time, each elevation point will be tested by the program to find out the maximum bump height corresponding to the wavelength of longitudinal profile, and checked with the allowed BBI value.

The results of runway pavement roughness estimation by ProFAA20 software are shown in Figure 3, in which the longitudinal profile is shown in part a, on that basis, BBI index is determined in part b. From the indicated results, the segments at the coordinate position from 597.5 m to 607.5 m are BBI index > 1 (excessive zones) [3, 7], in which, at the position 602.5 m there is BBI max of 1,058, with a height of roughness of 123.98 mm on wavelength of 33.3 m. Nevertheless, this level of runway pavement roughness ensures safety operation on it.

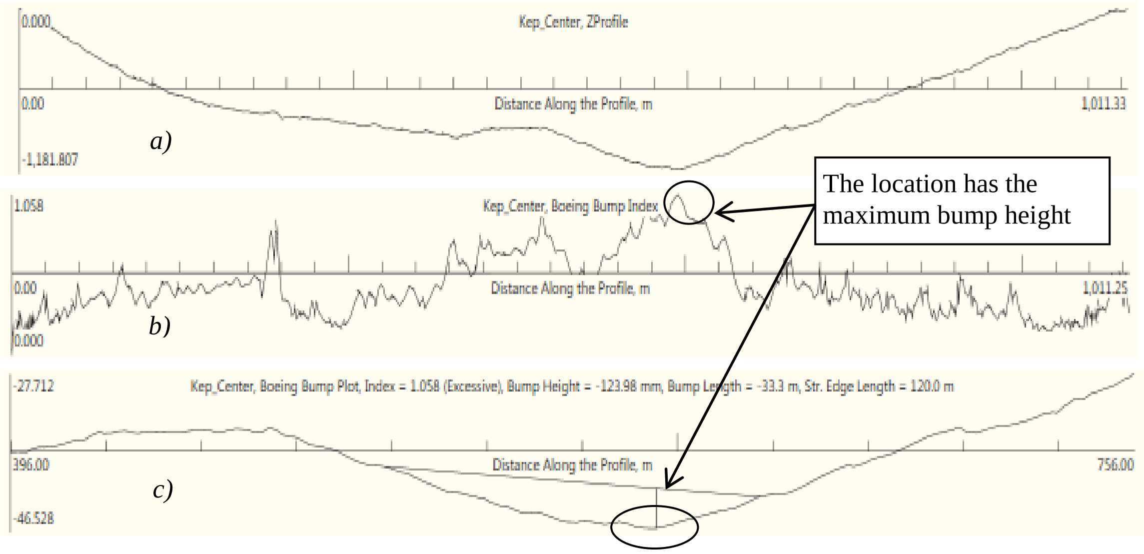

Figure 3. Results of K runway pavement roughness evaluation by ProFAA20 software

3.2. Roughness estimation of runway pavement by spectral density estimation method

Welch's periodogram and the Burg's autoregressive spectral estimation method are used for spectral density estimation of runway profile. These two methods give high accuracy results, and are widely used in the field of analysis and estimation of spectral density.

Spectral density estimation of runway elevations is determined by the program written in the Matlab programming language. The following results have been received:

Investigated surface and longitudinal profiles obtained as a result of leveling are shown in Figure 4.

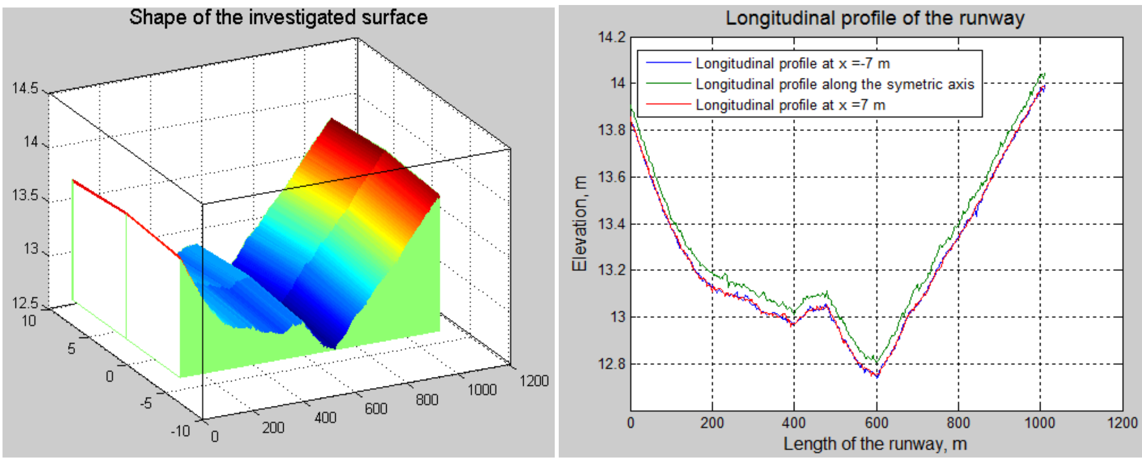

Figure 4. Results of description of measured profiles

Through the program, we have been gotten results of spectral density level of runway profiles shown in Table 2:

Table 2. Results of spectral density level of K runway

Spectral density estimation method	Spectral density level of runway elevations, C ($m \cdot rad$)		
	Profile at X = -7m	Central profile	Profile at X = +7m
Burg's method	$4.2523 \cdot 10^{-6}$	$4.7895 \cdot 10^{-6}$	$3.9789 \cdot 10^{-6}$
Welch's method with k = 2	$3.8512 \cdot 10^{-6}$	$3.9479 \cdot 10^{-6}$	$3.8208 \cdot 10^{-6}$
Welch's method with k # 2	$3.9183 \cdot 10^{-6}$	$4.0751 \cdot 10^{-6}$	$3.8758 \cdot 10^{-6}$

Spectral density estimations of central profiles shown in Figure 5:

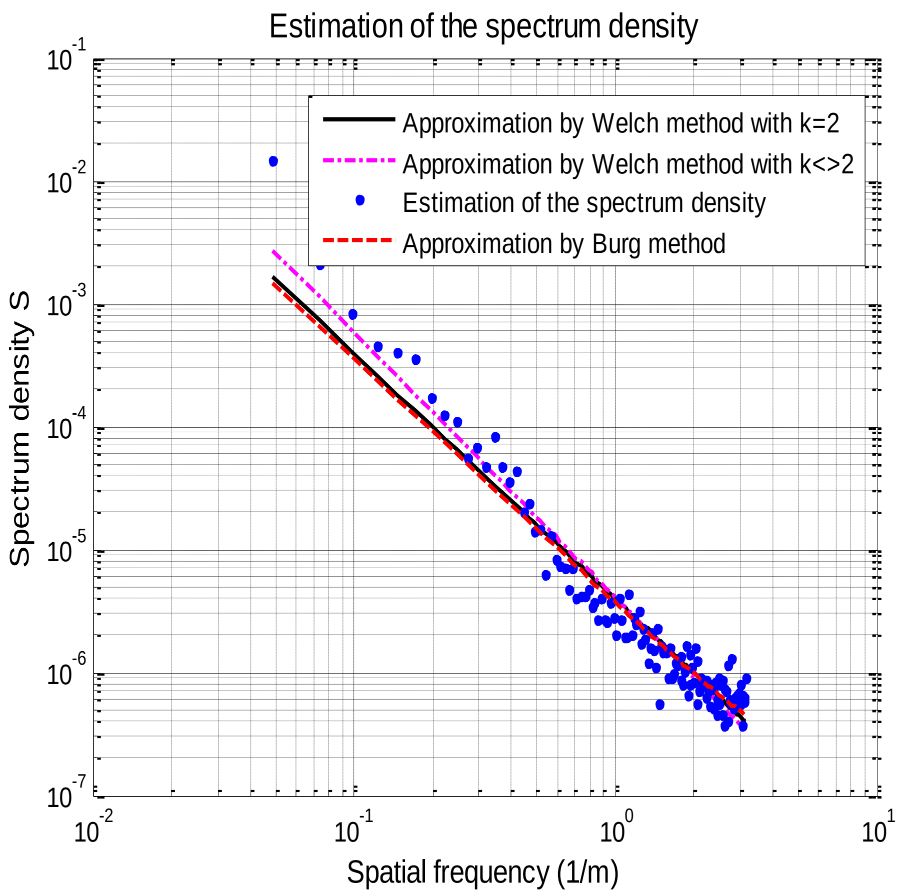

Figure 5. Spectral density estimation of runway elevations

Based on the obtained results, the spectral density level C of the elevations of K runway pavement surface varies from $3.8208 \cdot 10^{-6}$ to $4.7895 \cdot 10^{-6}$. This level has indicated the good roughness of the K runway pavement surface compared with other airports in Vietnam and Russia which was evaluated and published in [10].

4. Conclusions

- The airport pavement surface roughness can be estimated by different methods such as: BBI of ICAO, FAA, or spectral density estimation method. These methods give comparative similar results, and can be completely applied for conditions in Vietnam.

- K aerodrome pavement which is estimated has a good level of roughness, due to the runway surface repair and upgrading have been completed to ensure the operation of new aircrafts.

- By the parameters of spectral density level, dynamic coefficient while moving of plane wheels on the pavement surface with random elevation can be determined [13]. At the same time, using ProFAA software can evaluate the effect coefficient of standard aircraft wheel load B727-200; DC-10 [3, 7].

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NGHIÊN CỨU ĐÁNH GIÁ ĐỘ BẰNG PHẲNG MẶT ĐƯỜNG CẤT HẠ CÁNH SÂN BAY K

Tóm tắt: *Bài báo nghiên cứu ứng dụng phương pháp của ICAO, FAA và phương pháp ước lượng mật độ phổ cao độ mặt đường để đánh giá độ bằng phẳng mặt đường sân bay. Qua đó đưa ra kết quả đánh giá độ bằng phẳng mặt đường cất hạ cánh cho sân bay K qua các số liệu cao độ mặt đường đo được. Kết quả đánh giá theo 2 phương pháp chỉ ra mức độ bằng phẳng của sân bay K ở mức tốt so với các quy định hiện hành.*

Từ khóa: Độ bằng phẳng; đường cất hạ cánh; ước lượng mật độ phổ; chỉ số Boeing bump.

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