

# Airstrip Roughness Simulation to Dynamic and Vibration Analysis For Take off and Land on

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elevation changes across the road, while longitudinal profiles show the roughness of the road.



Fig.1 Road Profile [1, 2]

**Abstract—** Air Passenger is one of the most public transport for a long travel distance that is directly associated with human, so safe factor used in aircraft manufacturing is very important. One of the most important issues in analyzing the motion of an aircraft during flight and landing is passenger comfort that have Dynamics and vibration loading on Aircraft fuselage structures. Obviously, vibrations and dynamic tests on a real model of aircraft is very time consuming and costly and sometimes costs of doing a specific test is more than the rebuild cost of a plane, therefore used simulation environments and Finite element analysis in industry to reduce costs and achieve results in shorter time.

This present paper, Asphalt road surface profiles obtained in favorable circumstances by topography cameras and estimate road roughness such as power spectral density or PSD Function by using Numerical Methods in various error order. This paper can be estimated runway roughness by obtained results Generalizations based on comparison it with ISO Standard.

*Keywords- aircraft; airstrip; road roughness; PSD Function.*

## I. INTRODUCTION

Ever since the invention of modern vehicles, quantification of road roughness has been of great interest. Road profile is a two-dimensional slice of a road surfaces, taken along an imaginary line. Figure.1 shows longitudinal and lateral profiles on a road surface. Profiles taken along a lateral line show the

Profilers are devices used to measure road profiles. There are many types of profilers and they differ by the resolution, the interval of measurements recorded, and the speed at which the profiler is able to take measurements. A profiler works by combining a reference elevation, a height relative to that reference, and longitudinal distance (Michael, 1998) [1]. A device, called a rod and level, forms a basic profiler shown in Figure.2.

The level provides the height reference, and the reading from the rod is the elevation change relative to the reference. The longitudinal measurements between the rod and the level are taken with a tape measure or a laser. The rod and level is a static method because the instruments are not moving when taking measurements.

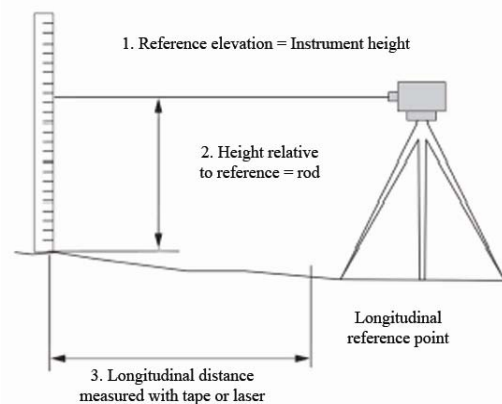


Fig2. Rod and Level [1, 2]

In 1960's, General Motors Research Laboratories developed the inertial profiler that made high-speed profiling possible (Michael, 1998) [1]. An accelerometer mounted on a moving vehicle measures the vertical acceleration. A computer processes the data and with reference to an inertial reference height, the elevation change of the accelerometer in the host vehicle is defined. Combining the accelerometer data, a laser transducer that measures the roughness of the road and the vehicle speed from the speedometer, high-speed profiling is possible. This is significant because the development of the inertial profiler made monitoring large road networks possible.

Even though models have been created to describe road profiles since the early 1970s, only recent technology advancements have allowed gathering comprehensive data to analyze road profile thoroughly. New laser profilers have made it possible to get high speed profiling with high resolution and small sampling intervals. The laser readings coupled with the vertical acceleration data enables estimates of roughness resolution of 0.2 mm and sampling interval of 50 mm (Rouillard, 2001) [3]. It was shown by Perm (1988) [4] that the laser profiler is valid for wavelengths ranging from 0.2 to 33 m. This range corresponds to a wavelength bandwidth at which vehicle vibrations are significant for typical vehicle speeds.

Dodds and Robson (1973) [5] were among the first to conduct extended study of road surfaces. They proposed that typical road surfaces may be considered a homogeneous and isotropic random process with a Gaussian distribution. A single-track power spectral density (PSD) estimate can be used to generate a complete description of a typical road.

It was also shown that the shape of the road data PSD estimates is independent of the road type and is a function of the RMS (root mean square) of road roughness. Heath (1989) [6] proposed a modification to the isotropic roughness assumption of Dodds and Robson (1973) [5]. Heath concluded that the entire roads were not completely homogeneous and only certain sections of roads were found to be homogeneous. Furthermore, Heath (1988) and Rouillard et al. (1996) showed that distribution of typical road surface roughness deviates from the Gaussian distribution and needs further investigation to provide a model for accurate road roughness description [2].

Bruscella et al. (1999) recommended that road surface classification cannot be based on spectral characteristics alone for vehicle simulation. Classification of road profiles is better achieved by using spatial acceleration because transient events are more easily identified in the spatial acceleration domain. A method of separating the non Gaussian and transient characteristics from the Gaussian characteristics of road profile is required [2].

Rouillard et al. (2001) proposed a concept of treating road surface irregularities as two fundamental components: the underlying stationary, i.e., does not change when shifted in time or space, road surface irregularities and the transient events. It was shown that the underlying roughness profile can be described by an offset Rayleigh distribution and was a function of the RMS of the roughness. The transient events,

which are the second fundamental component, were generated by a Gaussian distribution. The mean and standard deviation of this Gaussian distribution were a function of RMS level of the underlying roughness profile (Rouillard, 2001). The two components are combined to characterize a comprehensive representation of road surface irregularities [3].

Bogsjo (2006) proposed a similar concept of treating road surface by separating the irregularities into stationary and non-stationary components. The general roughness is modeled by a stationary Gaussian process. To model the occurrence of unusually rough parts, random irregularities are superimposed to the stationary process at random locations (Bogsjo, 2006) [7]. Two types of irregularities are superimposed: long-wave and short-wave. The long-wave represents the elevation changes due to terrain variations and the short-wave represents the high roughness parts of the road.

Kang et al. (2009) developed a vehicle simulation environment for evaluating durability of the suspension elements. Tire model with its complex nonlinear characteristics has significant impact on the credibility of durability analysis. The proposed method generates an equivalent road profile to compensate for the inadequate tire model. First the method identifies the frequency response function from the road height to spindle force and then back-calculates a road profile. The solution is updated iteratively until it yields the spindle forces close to the measured value. Using this method for back-calculating a road profile, a durability analysis was performed for a suspension component. It was found that the estimated fatigue life using the simulation results agreed well with the estimation based upon the force measurement with only 9% difference between the results (Kang, 2009) [8].

Improvements have been made in the methods for describing the road profiles but little is known about how uncertainties of the road profile affect the results from a vehicle simulation model. Using similar ideas from Rouillard (2001) and Bogsjo (2006), a methodology for creating road profiles by combining different aspects of the road roughness is developed. Using this methodology this thesis studies the effects of varying road profiles on vehicle dynamics simulation [2].

## II. TOPOGRAPHY

In this research and operation used Leica series of total Station TS02 camera (see Figure.3) by details 7 second for Angular accuracy and 2 ppm for length accuracy. Time of work is about 6 hours in a sunny day to take 500 points in distance of 1000 meters.

Errors in these measurements can be divided into the following categories:

1. Human factors: camera isn't a precision balance or have no Proper calibration and measurements error
2. Trabrak error
3. Natural and Environmental conditions

Longitudinal and transverse profiles of the road access points in AutoCAD by using obtained topography data are shown in Figures.4 and 5.



Fig.3 overview of topography camera Leica series of total Station TS02

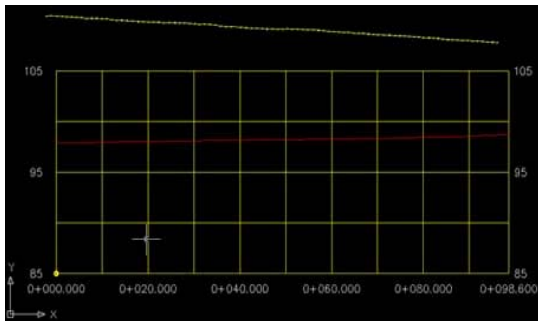


Fig.4 Longitudinal profile of the road access points in AutoCAD

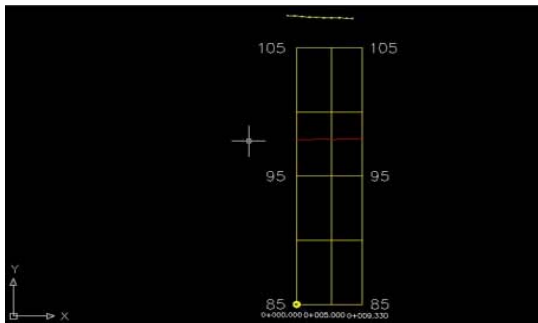


Fig.5 Transverse profile of the road access points in AutoCAD

### III. SURFACE ELEVATION PROFILE

In early attempts to investigate aircraft motion characteristics, excitation from ground in the form of sine waves, step functions or triangular waves are used. While these inputs could provide a basis for comparative evaluation of various designs, they could not serve as a valid basis for studying the actual ride behavior.

The frequency composition of a random function is of importance. It may be established by methods based on the Fourier transform. For instance, after obtaining the surface

profile, one can perform a frequency analysis to make an estimate of the amplitudes for various wavelengths present.

In random vibrations, the mean-square value of amplitude, and not the value of amplitude, is of prime interest since it is associated with the average energy. For harmonic components  $Z_n(x)$  with amplitude  $Z_n$  and wavelength  $L_{wn}$ , it can express as:

$$z_n(x) = z_n \sin\left(\frac{2\pi x}{L_{wn}}\right) = Z_n \sin(\Omega_n x)$$

Where  $\Omega_n = 2\pi/L_{wn}$  is the circular spatial frequency of the harmonic component expressed in rad/m.

The mean-square value of the component  $\bar{Z}_n^2$  is:

$$\bar{z}_n^2 = \frac{1}{L_{wn}} \int_0^{L_{wn}} \left[ Z_n \sin\left(\frac{2\pi x}{L_{wn}}\right) \right]^2 dx = \frac{Z_n^2}{2}$$

Road roughness obtained base on above relations and results from topography points in terms of millimeter such as shown in Figure.6.

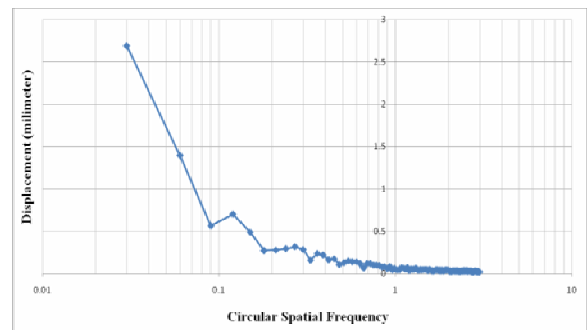


Fig.6 Changes of vertical displacement in terms of circular spatial frequency based on topography's data

In this study, the considered road has a negative slope to the theoretical value of 4 degrees.

### IV. PSD FUNCTION AND EXPAND RESULTS

Attempts by various organizations have been made over the years to classify the roughness of road surfaces. The International Organization for Standardization (ISO) has proposed a road roughness classification (classes A-H) based on the power spectral density [3, 8]. Figure.7 shows the classification proposed by ISO. In the ISO classification the relationships between the power spectral density  $S_g(\Omega)$  and the spatial frequency  $\Omega$  for different classes of road roughness may be approximated by two straight lines with different slopes on a log-log scale, as shown in Figure.7. The relationships are as follows [9, 10 and 11]:

$$\text{For } \Omega \leq \Omega_0 = \frac{1}{2\pi} \text{ cycles/m}$$

$$S_g(\Omega) = S_g(\Omega_0) \times \left(\frac{\Omega}{\Omega_0}\right)^{-N_1}$$

And For  $\Omega > \Omega_0 = \frac{1}{2\pi}$  cycles/m

$$S_g(\Omega) = S_g(\Omega_0) \times \left(\frac{\Omega}{\Omega_0}\right)^{-N_2}$$

The range of values of  $S_g(\Omega_0)$  at a spatial frequency  $\Omega_0 = \frac{1}{2\pi}$  Cycle/m for different classes of road is given in Table.1 and the values of  $N_1$  and  $N_2$  is 2.0 and 1.5 respectively.

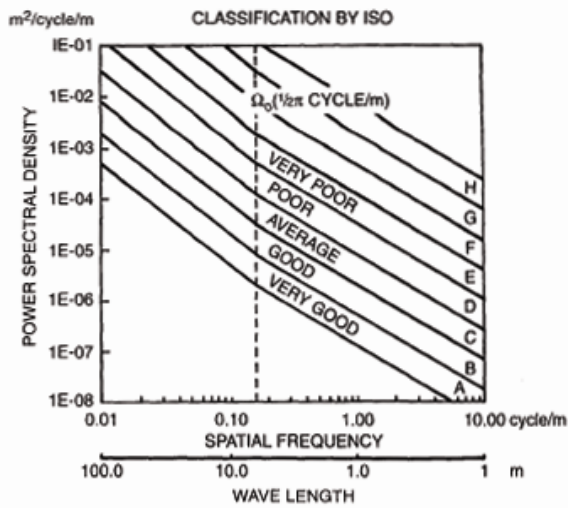


Fig.7 Classification of surface roughness by ISO [9, 12, 13]

Table.1 Classification of Road Roughness Proposed By ISO [9, 12, 14]

Road Class	Degree of Roughness	$S_g(\Omega_0), 10^{-6} m^2 / cycles / m$
	Range	Geometric Mean
A (Very Good)	< 8	4
B (Good)	8 – 32	16
C (Average)	32 – 128	64
D (Poor)	128 – 512	256
E (Very Poor)	512 – 2048	1024
F	2048 – 8192	2048
G	8192 – 32768	4096
H	More than 32768	16384

By using Numerical Integration Method of Simpson for three consecutive topography points and in this calculation order of estimate error is assumed 4 as express below:

$$a = x_0 < x_1 < x_2 < \dots < x_{2n-1} < x_{2n} = b$$

$$\int_{x_{2n-2}}^{x_{2n}} f(x) dx =$$

$$\frac{h}{9} \left\{ f(x_{2n-2}) + 4f(x_{2n-1}) + f(x_{2n}) - \frac{h^5}{90} f^{(4)}(\eta) \right\} h = \frac{b-a}{2n}$$

Hence, you can see obtained Psd displacement for topography points that is in Class Road D in according road classification ISO 2631-1 on Figure.8.

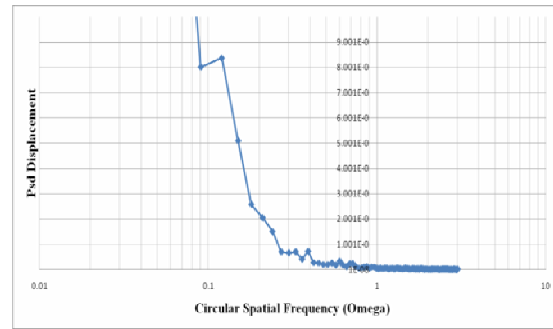


Fig.8 Psd displacement in terms of circular spatial frequency based on topography's data

Is achieved road roughness as PSD Function in a constant speed by using Matlab Code [8, 9] in Road classification A until E in term of spatial frequency [10] as shown in Figure. 9.

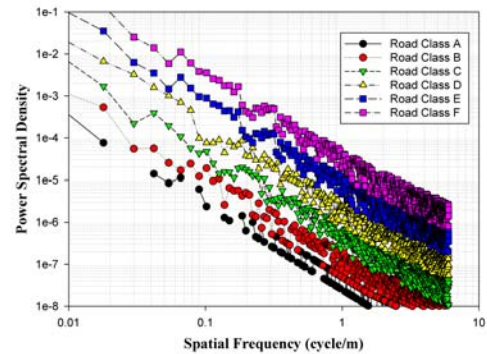


Fig.9 Power Spectral Density in terms of Spatial Frequency in different Road Classification by ISO with Constant speed

Runways with minimal changes of ups and downs displacement in vertical direction of ground will be placed on road class A.

## V. CONCLUSION

Provide real road test and doing dynamic and vibration tests of Aircraft are very costly. Hence, Using virtual environments and test simulations to decrease results time is most important in industrial design.

Based on ISO Road Classification changed vertical displacement in during travel length for all constant motion speed as the least displacement is related to Road class A and Maximum displacement is related to Road class E.

To filtering irregularity surfaces and Approach Road roughness same as sinusoid function, how increase motion speed, this approximated is closer to reality conditions, and so vertical displacement in high speed is more similar to road roughness than in low speed.

Scientific user can optimize various effect parameters by numerical methods or sensitivity analysis easily, because solving problem with numerical methods that can define parametric variables.

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