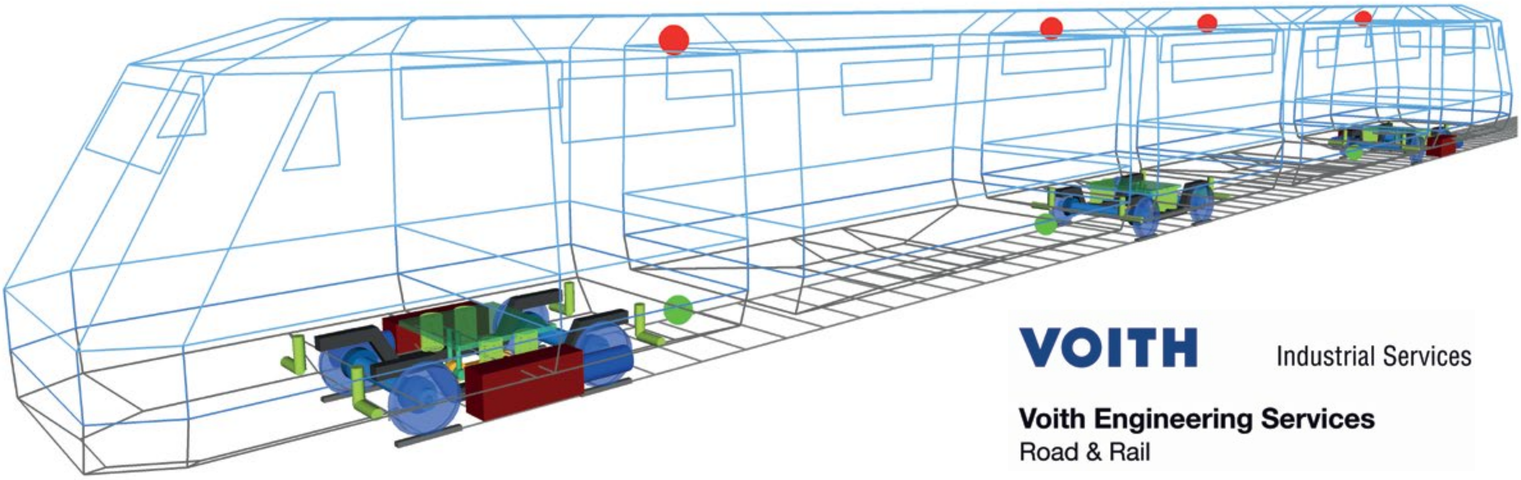
Assessment of Stochastic Track Irregularities for Tram Tracks



Multi-body simulation (MBS) is an important part in railway vehicle development. With the help of MBS, prognosis on derailment safety, stability, driving dynamics and riding comfort are possible. For getting realistic results, the modeling of the track is an essential piece of the modeling process.

TRACK AND TRACK IRREGULARITIES IN MBS

In MBS of rail vehicles, it is essential to model the track as realistically as possible. The best way to integrate a track into MBS is to use measured track data. Often such measured data are not available during the development process. So, it is necessary to create synthetic track data. Therefore, a method to assess stochastic track irregularities from standards, which describe track quality levels, will be suggested.

ITEMS DESCRIBING STOCHASTIC TRACK IRREGULARITIES

In rail vehicle engineering, there are two possibilities for expressing stochastic track irregularities mathematically. Both possibilities are shown in Fig. 1. The first method describes track irregularities in relation to right and left rail using vertical and lateral coordinates (see Fig. 1 picture on top). The second method uses four coordinates to characterize track irregularities in relation to the center point of the track (see Fig. 1 picture on bottom). These so-called track related irregularities will be used in this article because they are commonly used in rail vehicle engineering.

TRACK IRREGULARITIES IN SUPERSTRUCTURE ENGINEERING AND VEHICLE ENGINEERING

The track quality levels from standards are defined as single values $x_{\max}$ which describe the maximum valid deviation to the ideal value. These values are useful in superstructure engineering but, they are not suitable for MBS.

In vehicle engineering, oscillation amplitudes and frequencies are the primary concern. These properties of track irregularities are characterized with the help of power spectral densities (PSD). Fig. 2 illustrates some PSD curves.

"In MBS of rail vehicles it is essential to model the track as realistically as possible."

To assess track irregularities from standards for use in MBS, it is necessary to create a connection between track irregularities in superstructure engineering and track irregularities in railway vehicle engineering.

Such a connection can be related with an essential property of a PSD, as the following equation shows.

$$\sigma^2 = \int_{F_1}^{F_2} \Phi(F)dF$$

The variance of a signal is equal to the surface underneath the graph of the signal's PSD. In literature, many PSD functions $\Phi(F)$ can be found [1], [2]. Most of them are characterized in a similar way: the parameter Φ_{i} describes the level of the PSD and a term $f(\ldots)$ characterizes the shape of the PSD.

$$\Phi(F) = \Phi_{\mathrm{i}} \cdot f(\ldots)$$

The terms $f(\ldots)$ from literature are based on measured track data, so they can be used to assess synthetic track irregularities. So,

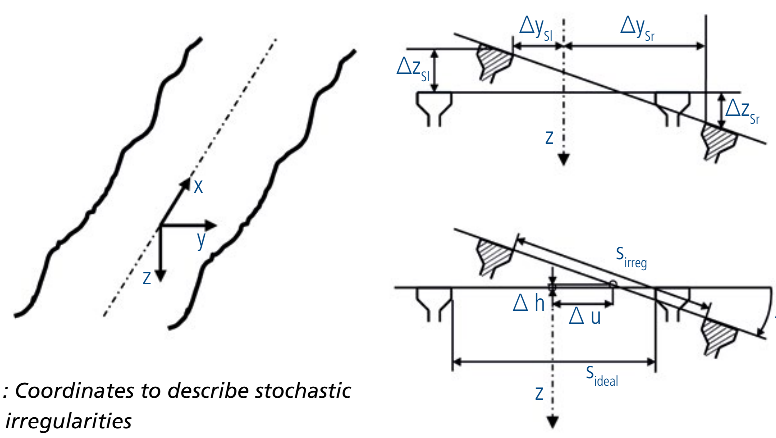


Fig. 1: Coordinates to describe stochastic track irregularities

it is appropiate to calculate the parameter Φ_i based on track quality values from standards. The essential assumption that stochastic track irregularities are uniform distributions leads to the following equation:

$$x_{\max} \approx 3\sigma$$

Ths equation implies that the maximum allowed value $x_{\max}$ is nearly equal to the triple standard deviation, which corresponds to a 99.7 % confidence interval. All valid measurement values are normally considered to fall into this interval. A connection between maximum value $x_{\max}$ and PSD can be formulated.

$$\left(\frac{x_{\max}}{3}\right)^2 = \int_{F_1}^{F_2} \Phi_i \cdot f(\ldots)dF$$

By solving the equation for Φ_i, the connection between track irregularities in superstructure engineering and track irregularities in railway vehicle engineering is created.

$$\Phi_i = \frac{\left(\frac{x_{\max}}{3}\right)^2}{\int_{F_1}^{F_2} f(\ldots)dF}$$

Fig. 3 shows track irregularities which are calculated with a maximum allowed deviation value of 5 mm. The different graphs are based on different parameters in the term $f(\ldots)$. Both shown track irregularities are calculated with the same vector of random phases. This can easily be done with the Simpack excitation element 108.

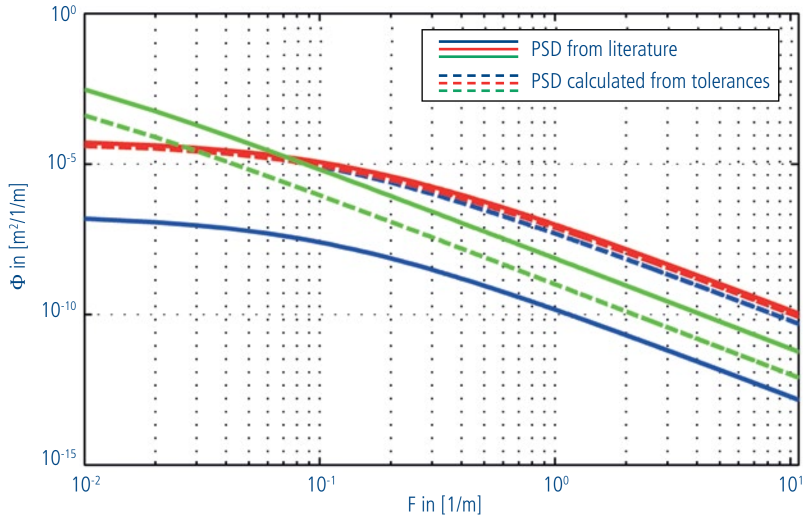


Fig. 2: PSD for different track qualities of Δu

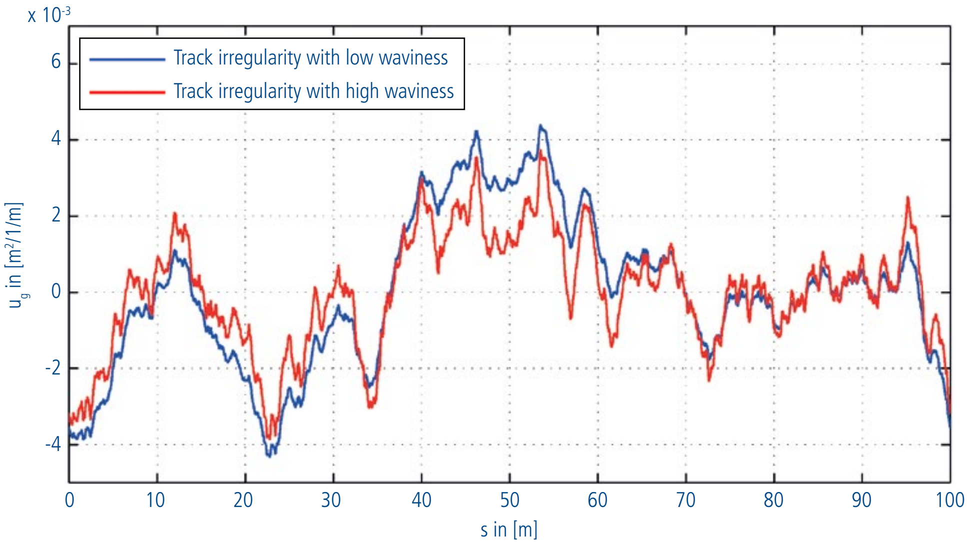


Fig. 3: Example of track irregularities calculated with maximum allowed level 5 mm

IMPLEMENTATION IN MBS PROGRAM SIMPACK

To avoid the need for multiple programs to calculate the value Φ_i and to integrate the resulting track irregularities in MBS, it is useful to implement the whole calculation in the MBS program SIMPACK.

Therefore, SIMPACK Pre offers the possibility to create user-defined scripts and programs by means of the Scripting Manager. The programmer can implement graphical user interfaces (GUI) which can be used by the operator to define user specific data. The program runs within SIMPACK Pre.

"SIMPACK Pre offers the possibility to create user-defined scripts and programs by means of the Scripting Manager."

So, a complex script was programmed whereby track irregularities can be calculated from track quality levels in standards. The term $f(\ldots)$ is predefined, only some significant parameters can be specified by the user. Additionally, a whole load case table can be created. Based on a complete vehicle model, different tracks can be automatically modeled with this script. Also, the implementation of track irregularities on these tracks is automatically possible in all ways SIMPACK Pre allows. The script also allows an automatic solver start to calculate the created models. All needed information are retrieved by GUIs. Fig. 4 shows what such a GUI looks like. Modeling process of tracks, calculation of track irregularities in different ways, and solving is combined into one script.

REMARK

This article is based on a diploma thesis which emerged at Voith Engineering Services GmbH Road & Rail in cooperation with TU Dresden.

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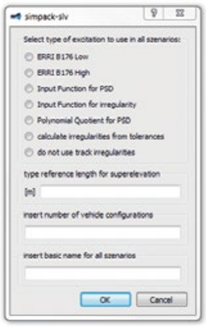

Fig. 4: Example GUI