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Railhunt – An interactive tool for hunting stability analysis of a railway carbody

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Abstract

In this study, a simulation tool - Railhunt was developed using App Designer toolbox of MATLAB software to study the hunting stability of a railway vehicle. The fundamental architecture of the GUI is presented. Features to facilitate user friendly experience of the tool are described. Benefits of having a specialized simulation tool would allow the researchers and engineers to perform design studies on railway vehicles efficiently with automated formulation of dynamic equations at the backend.

Keywords: Rail vehicle stability, lateral-dynamics, railway dynamics, railway carbody.

1 Introduction

Around the globe, rail transport is commonly used to move populous, and freight. Over the recent years, safe and comfortable high-speed operation has been a key objective in the rail industry. To achieve this, extensive simulations are essential to design, and operate rail vehicles. Wheelset hunting is a common instability caused due to curved profile of wheels. During hunting, sustained periodic oscillations of wheelset are observed, which causes excessive vibration, and derailment. Hunting stability is quantified by critical speed, which is the maximum speed, beyond which hunting oscillations are observed. Vibrations emerging from wheel rail, eventually transmits to car body, therefore hunting analysis have remained a key interest for engineers, and researchers. A schematic of the carbody system is shown in Figure 1. As a result, several studies have reported hunting stability of rail vehicles. For instance, hunting frequency of a high-speed rail vehicle was investigated using a 17 degree of freedom (DOF) model [1], wherein a nonlinear creep force model was used for wheel-rail contact. Kumar et. al. [2] presented a 31DOF model to study the response of a high-speed railway vehicle. In another study, effects of vehicle parameters on a two-axle truck model with nonlinear yaw dampers was studied by Ahmadian et. al. [3]. Similarly, hunting analysis, and critical speeds of a 21 DOF carbody system moving on a curved track was published by Cheng et. al. [4]. Apart from academic literature, commercial simulation tools such as Adams Rail [5], NUCARS [6], etc. as well as research software DAP 3D [7], Sigma/SAMS [8], etc are frequently used for railway dynamics.

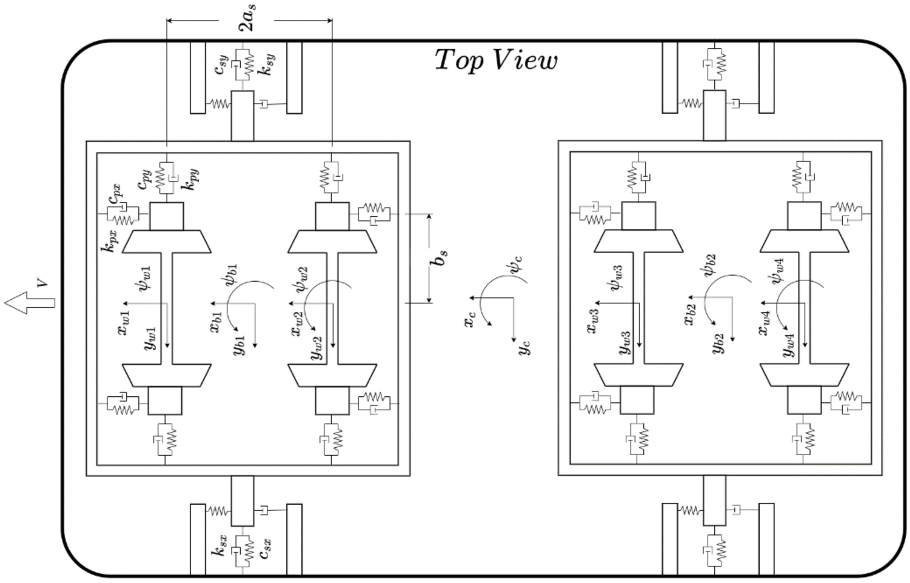

Figure 1. Top View of Carbody System

A railway carbody system consists of several components, each with different parameters. A comprehensive parametric analysis is essential to understand the influence of each component on the running stability. However, it is mundane to perform such study using computer codes. Thus, a Graphical User Interface (GUI), specific to hunting analysis will allow engineers, and researchers to efficiently perform design studies on a railway carbody. Therefore, in this work, we have developed a GUI called Railhunt. Various components, and features of the tool are presented.

2 GUI Architecture

Railhunt allows the users to systematically categorize various stages involved in hunting analysis. They can be broadly described using three parts.

- Pre-Processor: Here, a 17 DOF linear model of a carbody is pre-loaded. In the future the GUI will be extended for connected carbodies with engine, thereby simulating the complete train. Equations of motions were derived offline using the concept of DeNOC method [9]. The user can input vehicle properties such as mass, inertia, etc. Component identifier window allows the user to easily visualize various components of a railway carbody. Pre-processor along with the component identifier window is shown in Figure 2.

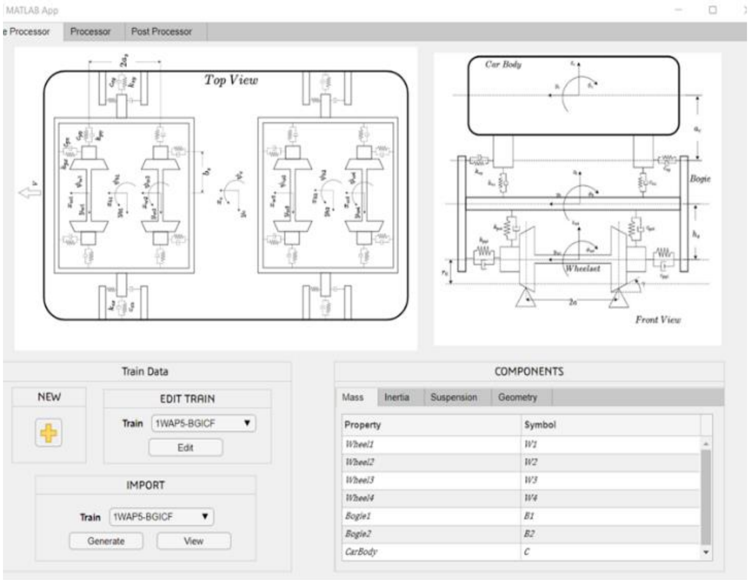

Figure 2. Pre-Processor

• Processor: The processor allows user to select the parameter, whose effect on hunting stability are to be studied. These parameters can be classified into four categories. They are (a) mass, and inertia, (b) suspension, (c) geometry, and (c) wheel-rail contact. Then, the user can define range of values for the parametric analysis. Additionally, the type of solver, as well as few default configurations of parameter variations can also be specified. Critical speeds are estimated using the eigen values [3]. In Figure 3, the processor is illustrated.

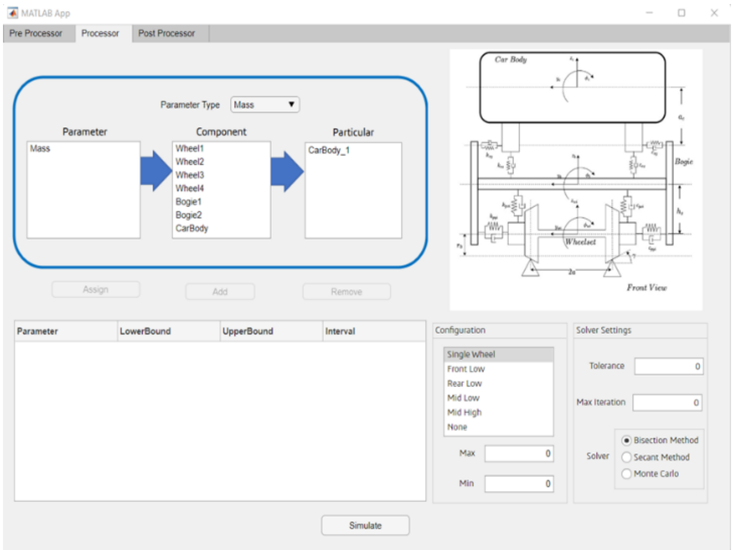

Figure 3. Processor

• Post Processor: Post processor is the final stage, wherein the simulation results are displayed. The obtained results can then be exported for further studies. For instance, effects of change in mass of wheelsets on the critical speed are shown in Figure 4.

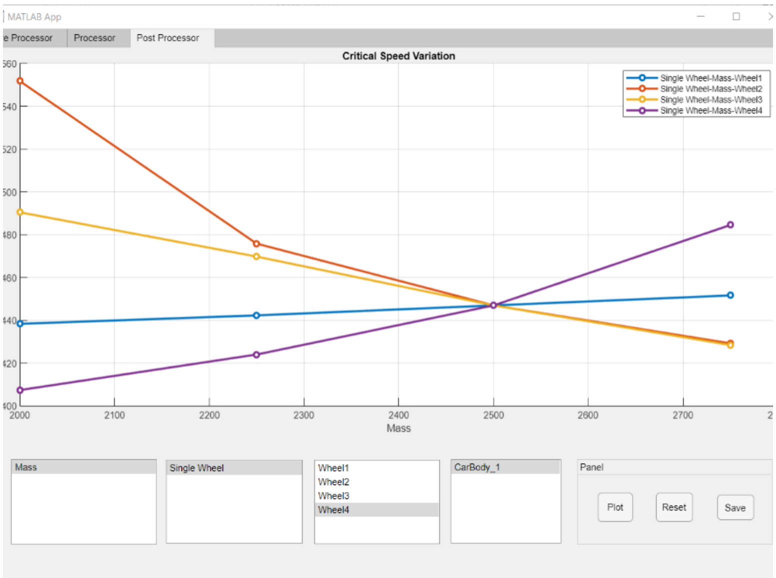

Figure 4. Post-Processor

3 Features

Some features embedded in Railhunt, as well as their benefits are highlighted in this section. They are classified under two main categories.
Interactive attributes

1. Data management: XML files are used to store, retrieve, and re-use carbody parameters.
2. Component selector: Using this feature, the user will be able to view, select, and modify parameters of specific component with minimal effort.
3. Custom parameters: The user can create custom rail vehicles using combination of locomotives and stocks.
4. Guidance: In order to aid the user to systematically perform hunting analysis, certain buttons are enabled only after appropriate inputs are given. For instance, in the post processor, a user is required to select the property along with the component, to plot the results.

Technical elements

1. Configuration selector: Few pre-loaded parameter variation trends are stored to define the parameter variations between different components.
2. Choice of solvers: User can select from a catalogue of solver, as well as specify tolerance value of the estimated critical speed.

3. Multiple results: The ability to juxtapose results from different parameter variations, will allow the user to easily grasp the significance of each parameter.

4 Conclusions and Contributions

In this paper, a simple yet efficient GUI has been presented to simulate hunting stability of a 17 DOF carbody system. Blueprint, features, and benefits of such simulation tool are emphasized. The tool will serve as an environment for engineers, and researchers easily analyse the hunting phenomena, without the need for getting into the dynamic equations. Parametric studies on the railway carbody can be easily automated which in turn helps reduce the design period, as well as identify the maintenance cycles for various components.

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