

Chapter 2

Literature Review

This chapter provides information on past research on track and vehicle interactions. An extensive literature search was conducted with the most relevant results presented in this chapter. Although the interaction of the track and rail vehicles has been addressed in a number of articles, none of the previous studies had the abundant data that were available for this research. As such, most of the previous studies were limited to numerical modeling of the interactions, determining "quality factors" for the track, and determining the theoretical ride quality that a vehicle should have for a specific track.

2.1 Track and Vehicle Interaction Modeling

The interaction between rail vehicles and the track has been studied for several decades. A vast assortment of models have been proposed and are used for many different circumstances [1 - 6]. The articles referenced draw specific attention to the interaction between the track parameters and the vehicle response that are of interest to this study. In some cases, a theoretical transfer function has been determined and used to relate the track and vehicle parameters [1 - 2]. Mauer [1] has mathematically developed a new method for the deconvolution of the track data by digitally filtering the time domain measurements and creating a general vehicle response. The study conducted by Esveld [2] consisted largely of determining the transfer function between the wheels and the acceleration of the carbody using a mass-spring damper model. The models addressed in these studies

are mainly linear, and some are supported with a relatively small amount of data. The study conducted by the Office for Research and Experiments of the International Union of Railways (ORE) describes the need for a statistical analysis of the track data and recommends improvements in the track measurements [3]. Some of the difficulties resulting from the modeling techniques were addressed in the previous articles [1 - 3]. In particular, the location of the actual contact points versus the location of the measured parameters, the nonlinearities of the interactions, the climate (environment), and the effects of dynamic loading are major factors that are not often addressed by the modeling techniques. These parameters are difficult to accurately model, resulting in models that may not be sufficiently accurate. The nonlinear aspects of rail dynamics have been studied a great deal by many researches. As this is a significant divergence from the topic of this study, a limited sample of articles has been provided for reference [4 - 6]. The models addressing the nonlinear aspects of the track and wheel interaction are relatively new and still require further development. The studies conducted by Scheffel et al. [4 - 5] deal with the nonlinear creep forces between the wheel and rail, and the effect of truck suspension parameters on the hunting stability of rail vehicles. The study conducted by Yang and Ahmadian [6] models the effects of nonlinear suspension damping on the vehicle's response. A study by Law [7] addressed the nonlinear response of a wheelset to random lateral rail irregularities. The complexity of the models necessary to adequately define all of the nonlinear track and vehicle interactions is a limiting factor in predicting the track and vehicle dynamic interaction using these models. In many cases, the accuracy of a highly complex model can be reduced by an inaccurate estimate of a specific characteristic or a relative minor change in the system [8].

2.2 Track 'Quality' Estimator

Ultimately, the perceived quality of a section of track is determined based on the performance of the vehicles traveling on it. As such, many studies have been conducted to determine vehicle responses to a section of track [9 - 13]. In many of the studies, certain characteristics of the track have been analytically related to a perceived ride quality through models. Each track characteristic was assigned a relative effect on the ride quality such that a measured section of the track could be estimated to generate a certain ride quality on a given vehicle. The study by Hamin and Gross [9] estimated a track quality index for various track parameters and used the result to objectively determine if the track parameters were individually in need of maintenance. Ullman and O'Sullivan [10] proposed a study to relate the nature of track parameters to the quality of ride using a track measurement vehicle and accelerometers to measure the 'ride quality' parameters. Crane, Sullivan, and Kaelin [11] define the limitations of track measuring techniques as the sole means of track evaluation, and define a framework for formulating a measure of track quality. The study by Blair et al. [13] suggests modern measurement techniques that could be employed to find significant defects in the track parameters, and a testing procedure for evaluating the effects of the defects present. Although these studies lacked the quantities of data present for the research presented in this thesis, many used the limited amount of data that was available to support some of their predictive models and track quality indices.

2.3 Track and Vehicle Interaction Experiments

The expense of instrumentation and the time necessary to acquire experimental data is often limiting factors to the amount of measured data

available for most dynamic studies. As a result, models are frequently necessary for many of the analytical studies that occur in the rail industry. The interaction of the track and wheel, however, has been such an important issue in the rail industry that many studies have addressed different aspects of these interactions and have had the resources available to perform experimental tests [14 - 21]. Several of these studies relate the major deviation of the vehicle's response to specific deviations in the track. Kalaycioglu et al. [14 - 16] employed over-the-road testing to determine the number of occurrences where the load on a rail vehicle exceeded a certain limit, and the location where these exceeding loads occurred. This data was used to correlate which types of track irregularities cause excessive loads. Some of these tests were conducted by outfitting the rail vehicle with equipment to mark the track when a specific level of excitation was experienced. Other studies [17 - 19] related a specific vehicle reaction to a specific track condition. The study by Robson and Kamash [17] relates the vehicle response to the surface profile. The study by Sattaripour [18] similarly relates the vehicle performance to the roughness of the track. The study by Illingworth [19] relates the lateral excitation of a wheelset to track irregularities. These studies did not relate any coupling that may exist between the various track parameters and vehicle reactions. A study by Dickhart [20] relates the response of two different rail vehicle designs to the same track conditions. As many of these same issues are faced by the automotive industry, a study by Krebs and Cantieni [21] has been included. In this study, the dynamic wheel loads are compared for two different subgrade stiffnesses. Overall, the amount of attention that has been given to the wheel and rail interaction has been significant.

2.4 Conclusions

The exact nature of the interaction between the rail and wheel is of great importance to the rail industry and has therefore been the object of many studies. Previous studies have addressed many aspects of the interaction and have attempted to define quality values for the track based on the estimated vehicle reactions. Most of the previous studies have been limited in scope and have lacked the enormous volume of data that was available for the study presented in this document. The progress of computer technology has made this analysis possible, significantly reducing the time and resource investment that may have been necessary until recently. The HTL program at the Transportation Technology Center, Inc. (TTCI) has been vital to the completion of this project. This program was responsible for the collection and availability of the data that is used in this study, allowing for a nearly complete statistical characterization of the track and wheel interaction, perhaps for the first time.