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Challenges in Rail Vehicle-Track Modeling and Simulation

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ABSTRACT:

Rail vehicle-track modeling and simulations, in past many years is developed a long way from its origins as a research tool. This paper presents an overview of the current features and applications for components of rail vehicle-track dynamic modeling and few challenges which these applications find while doing the simulations. This paper discusses appropriate modeling choices for different applications and analyse the best practice for the optimum performance of suspension components, wheel-rail contact conditions and modeling inputs such as track geometry.

KEYWORDS:

Vehicle dynamics; Modeling and simulation; Rail vehicle; Suspension components; Track models

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1. Introduction

Railway vehicle running along a track is one of the most complex dynamical systems in engineering. It has many degrees of freedom and the study of rail vehicle dynamics is a difficult task. The interface between the surfaces is established at contact points between the wheels and rail surface, therefore the vehicle/track physical, geometric and mechanical parameters greatly influence the vehicle dynamic behaviour [46]. Most modern passenger-carrying railway vehicles have the configuration shown schematically in Fig. 1. The railway vehicle in general comprises a car body supported by two bogies one at each end. Bolsters are the intermediate members between the car body and each bogie frame and is connected to car body through side bearings. The bogie frame supports the weight of the car body through a secondary suspension located between the car body and the bogie frame. Each bogie usually consists of two wheel axle sets that are connected through the primary suspension to the bogie frame. In addition, the wheels are usually tapered or profiled to provide a self-centering action as the axle traverses the track.

In passenger rail vehicles, the bogie frame is quite rigid. The primary and secondary suspensions are designed to achieve good ride quality, safe curve negotiation and good dynamic behaviour on tangent track. The wheel axle sets are connected to the bogie frame by elastic and energy dissipative suspension elements. These elements may include coil springs, air springs, or elastomeric pads. The primary suspension allows the wheel axle sets to move in relation to the bogie frame and helps to reduce the transmission of vibrations to the car body. Hydraulic dampers are generally used in both primary and secondary suspensions. The bogie frame also has an anti-roll bar to minimise the car body roll, especially in curves.

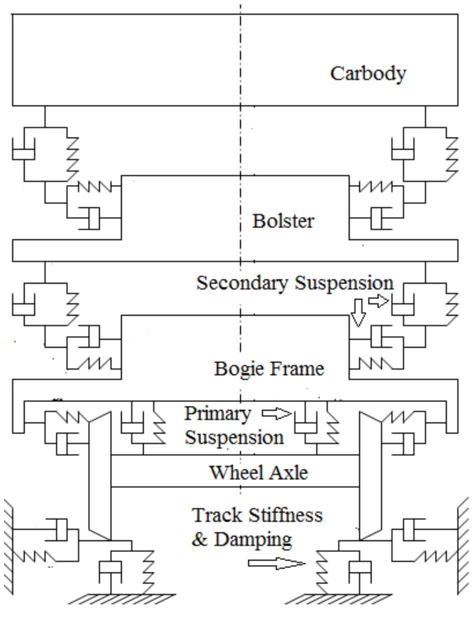

Fig. 1: Simplified view of a passenger rail vehicle [5, 6 and 10]

A freight rail vehicle is different from a passenger rail vehicle in the following ways:

- The bogie frame is relatively less rigid,

- There is less effective primary suspension between wheel-axle sets and bogie frame,
- Dry friction is used in secondary suspension.

The dynamic behaviour of vehicle is a major function of track irregularities or track inputs, which are modelled as deterministic and random. Cusp, bumps, jog, plateau, trough, short ramps, gradients and curves having well-defined characteristics are usually modelled as deterministic inputs. These are generally represented by rectified sine and exponential functions. Random inputs are characterized by a power spectrum and are represented by power spectral density functions. Random inputs represent more realistic features of track irregularities.

Researchers have formulated many mathematical models to study the dynamic behaviour of rail vehicles. These models can be divided into eight groups. Fig. 2 describes the various models developed to study rail vehicle, train and freight dynamics. In order to analyze rail vehicle dynamic performance effectively and to develop an analytical model appropriate for this analysis, it is important to define the performance indices quantitatively. Three major performance indices considered are vehicle lateral stability, vehicle curve negotiation capability and vehicle ride quality. The research efforts in rail vehicle dynamics of British Railways Research Center at Derby are recognized worldwide for its excellence. The Railway Technical Research Institute of the Japanese National Railways has also achieved recognition in this field. Railway research agencies i.e. Office of Research & Experiments (ORE) of the International Union of Railways, Canadian Pacific Railroads, Association of American Railroads (AAR) and Federal Railroad Administration (FRA) of the U.S. Department of Transportation is sponsoring research projects of rail vehicle and track dynamics.

Kalker [38] for his efforts in establishing the wheel/rail contact theories and Wickens [37, 43] for investigating the stability and curving dynamics are regarded as pioneer researcher in the field of rail vehicle dynamics. Researchers with the objective of improving the different performance indices have presented the improved model of suspension components i.e. leaf springs [14, 21], UIC double links [14, 21], friction wedges [15], shear springs [34], air springs [19], spherical centre bowls and friction side bearers. Wheel axle is usually modelled rigid by researchers. However in order to analyse high-frequency effects in the wheel/rail contact, researchers have also considered its flexible modes [18, 24]. Many studies and comparisons were done between various countries worldwide [4].

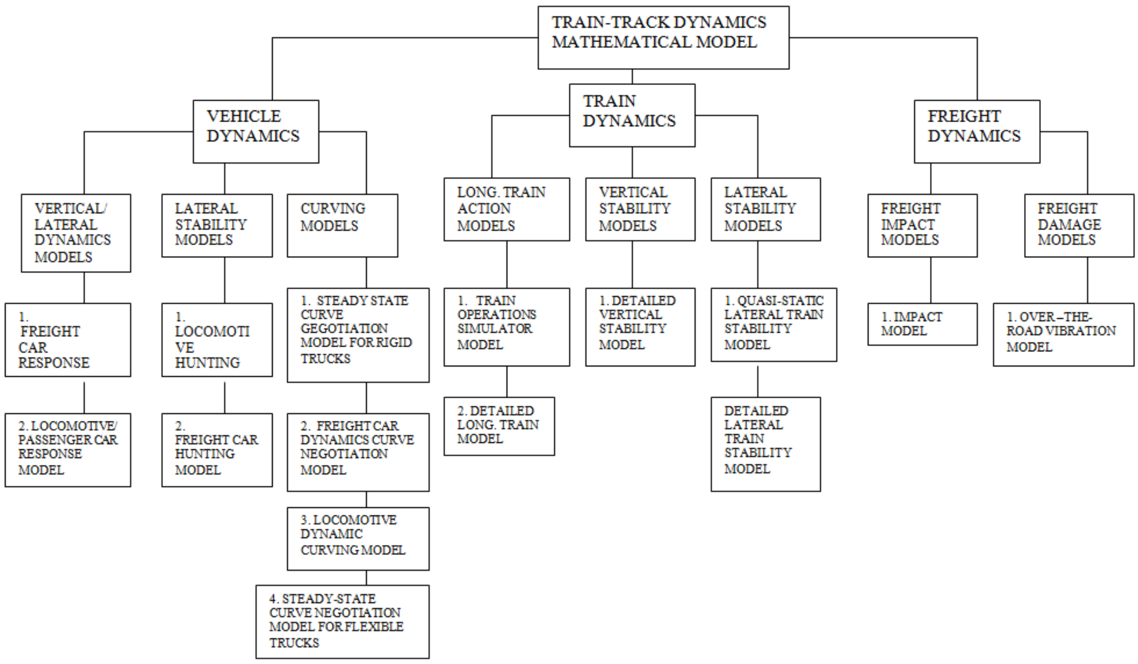

Fig. 2: Classification of railway dynamics mathematical model

2. Challenges in rail vehicle modeling

2.1. Suspension components

A multibody system consists of many interconnected bodies. The main interconnection elements in rail vehicle modeling are called the suspension elements, which connect the masses in a vehicle model. The suspension elements include the bump stop, damper, friction, pin link and shear spring, air spring and bush and constraint elements. These suspension elements may be modelled as linear, piecewise linear, non-linear. The line and rotational elements consist of the bump stop, damper and friction elements. The common characteristics of these elements are that they have a fixed line of action acting along the element's axis, which is determined by the positions of its ends. Rubber springs can be used in place of coil spring due to having intricate properties by frequency dependent stiffness and hysteresis in rubber. Hence to represent their result, some addition in their stiffness is to be done with including series stiffness and viscous damping about 2 to 3 times. This will give more rigidity and structural integrity. A lot of careful physical phenomenon models are projected which can be applicable wherever the physical phenomenon effects are doubtless to be vital. For example internal friction of rubber will increase the stiffness and hysteresis [33]. Bushes, like the radial arm affiliation during primary suspension gives stiffness in various direction in a single point. Once more physical phenomenon effects ought to be taken under consideration.

The damper represents a viscous damping element with either a constant rate or a variable rate specified as a force-velocity characteristic. The damper also includes a stiffness element in series to represent the flexibility of the mountings. Hydraulic dampers (shock absorbers) for damping and absorbing of vibration use the viscous properties of liquids. Usually, they consist of a cylinder in which is inserted a rod with a piston that has drilled holes in it. This makes it possible for fluid to flow from one chamber of the cylinder to another. Flow can also be carried out through channels in the cylinder walls. These dampers have stable damping characteristics for low-frequency vibrations, but they are very sensitive to high frequency because the latter is associated with liquid cavitations processes and hydraulic impact. The performance of these dampers is significantly affected by the ambient temperature and the temperature of their fluid. Often, this type of damper is installed in the secondary suspension.

Rubber dampers or rubber-absorbing elements act based on the damping properties of rubber. To increase the stiffness and strength characteristics of the rubber elements, they are covered and reinforced with metal or composite materials, fabrics and fibres. They can be used in primary and secondary suspensions [17]. As the railway vehicle has many degrees of freedom it becomes a complex situation to account the non-linearity of suspension elements and to account all suspension elements [2, 3 and 5]. It is important to model coil springs accurately that carry large vertical loads while being able to shear laterally. The geometric properties of shear springs are difficult to model by the generation of overturning roll moments as they displace in shear. Air spring elements are designed to represent a detailed model of pneumatic damping in the vertical direction and a non-uniform stiffness distribution in the lateral and longitudinal directions, giving different moments at each end, thus allowing it to represent the characteristics of air springs. It can also have a non-linear stiffness characteristic and it offers a means of representing the frequency-dependent stiffness and hysteresis effects of rubber components. The vertical and lateral behaviours of air spring elements are independent. The vertical behaviour depends on the stiffness and damping, both of which are related to the frequency and load.

Air suspensions are difficult to model. Generally, the vertical and lateral behaviour of air springs may be thought-about severally, except that the lateral stiffness depends on the pressure within the spring and is thus suffering from the vertical load. A typical air spring arrangement and its equivalent model are shown in Fig. 3 and Fig. 4 respectively. Air suspension can have several air springs connected in the loop and several additional air reservoirs. Also, air springs can operate in pairs without the application of an additional reservoir. The advantages of air suspension are the possibility of varying the stiffness and damping characteristics as well as low weight. The disadvantages are the additional energy costs for feeding air to them and cleaning of the air and more expensive maintenance and increased cost in comparison with coil and leaf springs.

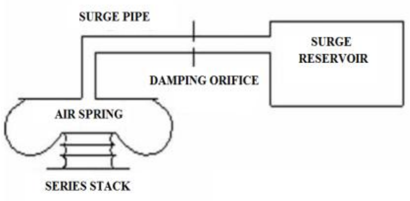

Fig. 3: Typical air spring arrangement

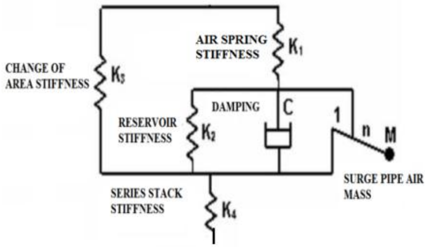

Fig. 4: Equivalent model of air spring arrangement

Hydraulic suspension works on the principle of a mechanical balanced suspension, but, as with air suspension, it can be divided into circuits which allow different options in organizing the damping of vibration. Special oils and liquids for hydraulic transmission and also those commonly used in the hydraulic brake systems have found wide applications in hydraulic suspension systems. The main elements of hydraulic suspension include hydraulic working cylinders, connecting pipes and the master cylinder. The latter has a piston that is connected with an elastic element (coil spring, air spring or torsion bar). This allows adjustment of the required stiffness characteristics of the hydraulic suspension. For the implementation of damping, an additional adjusting system is present which has differential valves. It also has an additional set of valves and pumps for load distribution. The organization of individual hydraulic suspension with double-acting hydraulic cylinders is also possible in the rail vehicles. Hydraulic suspension is commonly used for small rail traction vehicles which transfer passengers. The main disadvantage of such systems is the need for high-precision manufacturing solutions for working cylinders and the application of expensive fluids, which in the case of a leak may heavily pollute the environment. Therefore, it has a high cost of operational service. However, this type of suspension ensures good dynamic ride quality [6]. Hydraulic dampers possess flexibility in series with the viscous damping, because of flexibility of the hydraulic oil, bushes, damper structure and mounting brackets. This effect is necessary to account in vehicle models, especially for anti-yaw dampers.

2.2. Rigid body vs. Flexible body

The car body structural flexibility and related motions and vibration often reduce the ride comfort. This is indicated by the vehicle track simulation shown in Fig. 5. It is found from investigations that for accurate prediction of ride behaviour vertical bending flexibility mode should always be considered in simulations and for stability torsion flexibilities mode must be included. If the structural flexibility is considered in the simulation, the maximum level and domination frequency of the vertical acceleration history are increased. The dominating frequency can be estimated about 10 Hz, a vibration frequency that significantly influences the human ride comfort or rather discomforts. The lowest Eigen frequency of the car body is often used as an overall measure of the structural flexibility. The Eigen frequency usually refers to the case of a free car body, fully equipped but without payload and can be either measured or calculated. Fig. 6 gives the idea about the four lowest Eigen frequencies and corresponding Eigen modes of a car body.

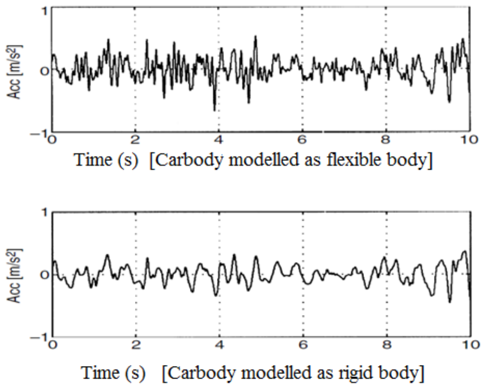

Fig. 5: Simulated vertical acceleration on car body floor, middle position. Influence of structural flexibility [9]

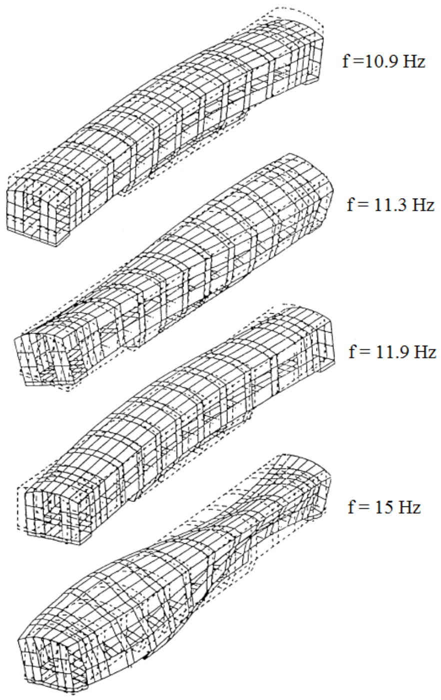

Fig. 6: Four Eigen modes and corresponding Eigen frequencies for a free car body [10]

The lowest frequency 10.9 Hz is close to the dominating excitation frequency. Although not for the same car body, this implies the importance of the lowest Eigen frequency and the corresponding Eigen mode for vertical bending motion. The second Eigen mode is a torsion motion about a longitudinal axis of the car body. The third mode is dominated by a lateral bending motion, whereas the fourth mode is complicated with significant cross-sectional shear. The higher the Eigen frequency, the more complicated the Eigen mode. A stiffer car body in general is a heavier and more expensive car body and have restrictions on the possible window and outer door sizes. The car body might also be short or give a reduced cross section. The effort of making car bodies and rail vehicle lighter to get reduced wheel rail forces and wear as well as lower energy consumption etc. gives a potential risk of a too flexible car body. An additional complication is that the demands on ride comfort, sound and vibration levels have become more and more rigorous during the last 15-20 years. Possible actions to mitigate the comfort effects due to structural flexibility must be based on an understanding of the full dynamic system of the vehicle, track and their interaction. This also indicates that a certain action may in most situations, but sometimes it doesn't help and may even worsen the comfort.

Wheelsets have a significant structural flexibility, in particular in axle bending and torsion. Some types of bogies, e.g. torsion flexible bogies, have a flexibility of the bogie frame that influence the ride stability and therefore could not be neglected. Probably the structural flexibility of car bodies is paid more attention since it often results in poorer ride comfort. Fig. 7 shows Eigen modes and Eigen frequency for a free wheel set.

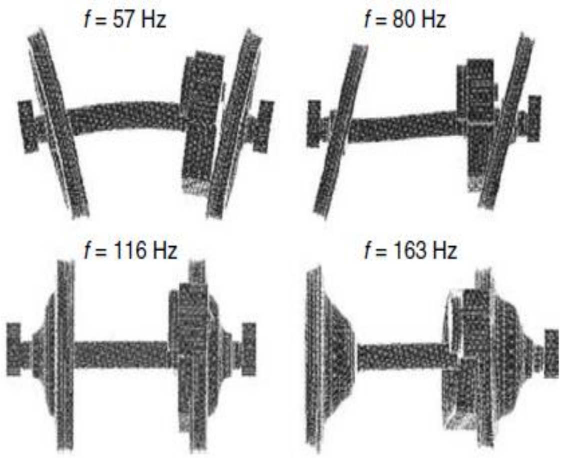

Fig. 7: Four Eigen modes and Eigen frequencies for a free powered wheel set of diameter 1.3 m [47]

Wheelsets, bogie frames and car bodies together represent a clear dominating part of the total vehicle mass. If these components are modelled as rigid bodies it is in addition to motion and forces, only the bodies mass properties that are involved in the pertinent equations of motion. For the rigid body model, the distance between two arbitrary points of the body is by definition constant and independent of the body motion. The body motion can therefore be described by only six motions, three translations and three rotations. If the body performs large rotations the three angles cannot be superposed arbitrarily though a certain order of the angle has to be defined and the body rotation cannot be described by a vector. However, the body angular velocity and acceleration can always be represented by vectors. The six equations of motion of the rigid body achieve their simplest form if we let the three unknown translations and their time derivatives, refer to the body centre of gravity. Then the mass moments of inertia also refer to axes through the Centre of gravity. In this way six scalar equations of motion can be formulated as two equations of motion in vector form; one force equation and one moment equation.

2.3. Inter-Vehicle connections

Longitudinal train dynamics includes the motion of the train as a whole and any relative motions between vehicles allowed due to the looseness and travel allowed by spring and damper connections between vehicles. In the railway industry, the relative motions of vehicles are known as 'slack action'. Coupling 'free slack' is defined as the free movement allowed by the sum of the clearances in the wagon connection. In the case of auto-couplers, these clearances consist of clearances in the auto-coupler knuckles and draft gear assembly pins. In older rolling stock connection systems, such as draw hooks and buffers, free slack is the clearance between the buffers measured in tension. Note that a system with draw hooks and buffers could be preloaded with the screw link to remove free slack. The occurrence of 'slack action' is further classified in various railways by various terms; in the Australian industry vernacular, the events are referred to as 'run-ins' and 'run-outs'. The case of a 'run-in' describes the situation where vehicles are progressively impacting each other as the train compresses. The case of a 'run-out' describes the opposite situation where vehicles are reaching the extended extreme of connection-free slack as the train stretches. In other countries different terms are used, for example, impact accelerations, jerk and so forth. Longitudinal train dynamics therefore has implications for passenger comfort, vehicle stability, rolling stock design and rolling stock metal fatigue [45].

The study and understanding of longitudinal train dynamics was probably firstly motivated by the desire to reduce the longitudinal vehicle dynamics in passenger trains and, in so doing, improve the general comfort of passengers. The practice of 'power braking', which is the seemingly strange technique of keeping the locomotive power applied while a minimum air brake application is made, is still practised widely on passenger trains. Power braking is also used on partly loaded mixed freight trains to keep the train stretched during braking and when operating on undulating track. Interest in train dynamics in freight trains increased as trains became longer, particularly for heavy haul trains as evidenced in technical papers. In the late 1980s, measurement and simulation of in-train forces on such trains was reported by Duncan and Webb [55]. The engineering issues associated with moving to trains of double the existing length was reported at the same time in New South Wales by Jolly and Sismey [54]. More recent research into longitudinal train dynamics was started in the early 1990s. The direction of this research was concerned with the linkage of longitudinal train dynamics to increases in wheel unloading. It stands to reason that, as trains get longer and heavier, in-train forces get larger. When coupler forces become larger, resulting from increased coupler angles on horizontal and vertical curves, at some point, these forces will adversely affect wagon stability. The first known work published addressing this issue was that of El-Sibaie [56], which looked at the relationship between lateral coupler force components and wheel unloading. Further modes of interaction were reported and simulated by McClanachan et al [31] detailing wagon body and bogie pitch.

Concurrent with this emphasis on the relationship between longitudinal dynamics and wagon stability is the emphasis on train energy management. The operation of larger trains meant that the energy consequences for stopping a train became more significant. Train simulators were also applied to the task of training drivers to reduce energy consumption. Measurements and simulations of energy consumed by trains normalised per kilometre-tonne hauled have shown that different driving techniques can cause large variances in the energy consumed [50, 51]. Modeling a single vehicle considering inter-vehicle connections as simple couplings and modern flexible corridor connections many is not realistic or accurate. At places where older corridor connections have high friction and inter-vehicle damping is intentionally provided, multiple vehicles are necessary to be modelled for prediction of actual behaviour. It is essential for articulated vehicles to be modelled as multiple vehicles. In long train, three or five vehicles will provide actual behaviour of intermediate and end vehicles.

2.4. Simulations of multibody dynamics

In the last thirty years, very complex, nonlinear vehicle models, with several degrees of freedom have been developed for the simulations of multibody vehicle dynamics problems. In recent past advanced computers allow to analyse the certain vehicle characteristics, which were not revealed by manual analytical studies. Modern multibody software packages (e.g. GENSYS) are used as an essential feature for improving the design of new vehicles and for preventive maintenance of existing vehicles. Increasingly, simulation is being used as part of the vehicle acceptance process in place of on field track testing [11, 12]. Evans and Berg in their state of the art paper focussed on unique modeling choice for particular application and discussed about the best practice for the idealisation of suspension components, wheel-rail contact conditions and modeling inputs such as track geometry. Fig. 8 explains flowchart of application of different software packages for computer simulation in the rail vehicle design.

Multibody dynamics in combination with genetic algorithm or sequential quadratic programming is also utilized for optimization of performance indices of rail vehicle. Yuping and McPhee have significantly contributed in the past in this field [25, 29] and presented new set of suspension, inertial and geometric parameters for optimized stability and curving performance. Increasingly, simulation is being used as part of the vehicle acceptance process in place of on-track testing. Hardware in the loop (HIL) technique is also presently used for the analysis of multibody simulations of railway vehicle [16]. HIL technique finds applications in rail vehicle problems as these techniques are widely used for fast prototyping of control systems, electronic and mechatronic devices. From an engineering point of view, it is better to define a co-simulation process as a simulation process of the whole system, where two or more subsystems are connected between each other in one simulation environment by specialized communication interface(s) with a pre-defined time step for data exchange. In common practice, the data exchange process can be achieved through integrated memory-shared communication between software products, network data exchange and exporting code from one package to another.

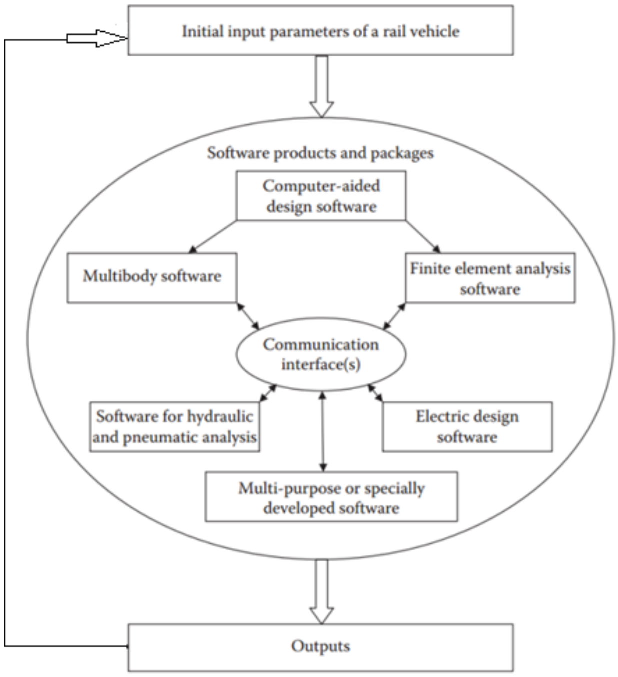

Fig. 8: Flowchart of software packages for rail vehicle design

2.5. Wheel-Rail contact

At the wheel-rail interface, the contact area and the relationship between the displacement and the normal contact force are determined using Hertz static contact theory. In the tangential direction, the relationship between the creepages and the creep forces is determined using Kalker's creep theory. The wheel set containing two cone-profiled wheels runs on the rails that are canted inwards at 1 in 20 (or 1 in 40) as shown in Fig. 9.

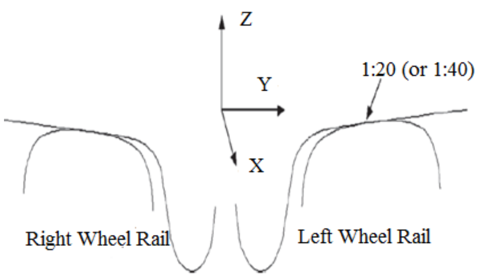

Fig. 9: Wheel-Rail interface

The gap between the flange of the wheel and the gauge face of the railhead generally is sufficient to prevent flange contact. Hence, the coned wheel set would have inherent guidance of pure rolling along straight track if it runs on the railhead with no lateral disturbance. However, the guidance of a wheel set on straight track is modified when the wheel set is fitted to a wagon through the suspensions. Furthermore, the pure rolling motion is affected by the action of creep forces tangential to the contact plane between the wheel and the rail surfaces. As the wheel set rolls longitudinally, it also moves laterally and vertically in addition to rotating about the vertical axis. Therefore, the definition of rolling contact between the wheel and the rail becomes fairly complex.

It is well known that the wheel–rail interface creep significantly affects the dynamics of the vehicle–track system. The interface creep occurs due to the difference in the velocities of the wheel and the rail at the contact point. The term creepage is used to define the velocity differences in the longitudinal and lateral directions as well as spin creepage due to yaw rotation. Hence the term creepage is to be well defined for the modeling. The wheel–rail connection is a very important part of modeling rail vehicles. The contact patch typically forms an elliptical area where the wheel touches the rail and transfers longitudinal, vertical and lateral forces. The curvature of the wheel and rail creates high stresses within the contact patch, causing plastic deformation and thus work hardening of the rail and wheel and this can result in surface and sub-surface fatigue cracks .In normal centre tracking conditions, the wheel tread and rail contact at a single contact patch. When there are high lateral forces, the wheel set can be forced so that the wheel flange also contacts the rail, resulting in a two-point contact. The location of the flange contact is also dependent on the angle of attack of the wheel set.

Two or more points of contact can also occur depending on the wheel–rail profile design and the degrees to which the wheel and rail profiles are worn. Other cases of multiple contact points occur when traversing through points and crossings as the wheel crosses over from one rail to another [22, 23 and 32]. The contact patch location is determined from the relative position of the wheel set in relation to the railhead and the condition of the wheel and rail profiles. In wheel–rail models, the contact force is typically determined from Kalker's rolling contact model [35], the Heuristic non-linear creep force model or Polach's non-linear model [20, 44].When the wheel and rail profiles are very similar, conformal contact can occur and many points of contact result.

2.6. Track models

The conventional rail track structure consists of the rail, the fasteners and the pads, the sleepers (ties), the ballast and sub ballast and the subgrade. A typical cross section of this type of track structure is shown in Fig. 10. The characteristics and the function of each component of the track are described in this section. The widely used rail profile is made up of a base, a web and a head and is designated by its weight per unit length (kg/m).The selection of various rail section is made based on the expected life time and traffic load. Generally, 50, 60 and 68 kg/m rails are used in heavy haul networks. The structural behaviour of the rail is theoretically modelled as an infinitely long elastic beam resting on elastic supports that are either continuous or discrete. In practice, most modern tracks position the rail on a cant so that the base and the top of the rail slope inwards towards the track centre.

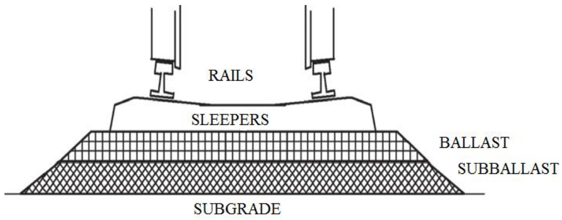

Fig. 10: A typical track structure

The track subsystem models are classified as shown in Fig. 11. The track modeling may be classified into three types, namely, the continuously supported model, the discretely supported model and the finite element (FE) model. The continuously supported model is based on the beams on elastic foundation (BOEF) theory. The discretely supported model (DSM) allows for the discrete spacing of sleepers. In both approaches, the rail is modelled using either the Euler beam theory or the Timoshenko beam theory. The support for the rails is modelled either as a single layer or as multiple layers. Multiple layers allow for the inclusion of various track components such as the rails, the pads, the ballast, the sub ballast and the subgrade. In the lumped-parameter track model, the rails, the sleepers and the ballast are discretised as lumped masses with lumped stiffness's and lumped damping coefficients. These lumped properties are evaluated by equating the kinetic energies of the actual and lumped systems. The FE model is used for more refined stress analysis of track components. Complete FE modeling of the full track system is complicated due to the interface characteristics of the various track components. Tracks are not rigid, but more or less flexible. The pertinent stiffness and damping properties of the track are very important for the dynamic forces and the oscillation phenomena occurring between wheel and rail.

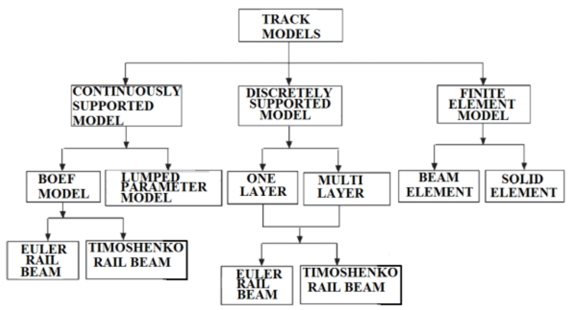

Fig. 11: Model classifications for rail track

The load is also influencing the life of track and vehicle components. Generally speaking stiffer track gives to higher dynamic forces than softer track. Higher damping leads to less isolation. The influence of different track parameter has been investigated by tests and statistical studies. Today, however, a better understanding of the basic phenomena is desired due to the necessity to reduce the maintenance costs. In the analysis of the vehicle dynamics a very simple track models are used in most of the cases. The vertical flexibility of the track depends on both the load and frequency of an oscillating load. It has been seen that the track with wooden sleepers is more flexible than the track with concrete sleepers. The stiffness has a tendency to increase with increased frequency. Even the damping is higher for the track with concrete sleepers. However the lateral stiffness is much lower than the vertical stiffness. Considering the flexibility is very rigid task for a researcher and it is difficult to model as well [30].

In the past research has been conducted towards improving the track design in order to meet increasingly severe operational requirements. Grassie et al [39-42] investigated the response of railway track to high frequency vertical excitation, lateral excitation and longitudinal excitation and high frequency excitations respectively. The dynamic behaviour of the track has also been investigated by Auersch [26] formulating different models. Duffy [36] examined the vibrations that arise when a moving, vibrating load passes over an infinite railroad track**.** An analytical study of riding quality of a railway vehicle entails the computation or simulation of the random motion of the vehicle body in response to the random irregularities of the rail roadbed. The rail roadbed irregularity inputs to such an analysis are in the form of time series data of actual roadbed irregularities and can be brought in power spectral density format through Fast Fourier Transform technique depending on the requirement of the subsequent analysis. Such PSD curves of the track irregularities calculated from actual track measurements are plotted by Goel et al [27]. In this study Goel et al [27] evaluated the auto power spectral density, cross power spectral density and coherence functions of various track irregularities i.e. vertical unevenness, cross level, gauge and alignment etc of the tracks of Indian railways.

3. Future research

As observed in past a huge research is carried out in the development of a wide range of rail vehicle simulation. The academic community is very active in exploring more accurate ways for modeling and simulation of the vehicle. It is not surprising that a lot of research has to be done for carrying out more realistic facets such as developing extreme detailed track dynamics model, Algorithms for wheel/rail contact or finding suitable ways for solving motion equations [48]. The sleeper, the rail and the wheel set are considered for full range of interest in range of frequency. However, The behaviour of rail pad and ballast is very unpredictable in long running time, hence a good life time predict algorithm is required to describe the proper behaviour in dynamics analysis. The extensive use of simulation tool more rigorous analysis is to be done for accepting the vehicle. For more detailed studies, some industries using finite element analysis for more realistic study of the model.

Wheel-rail algorithms are required to give accurate contact patch analysis and take less time for the analysis. Furthermore an online rail profile measurement required to enable the routine in the dynamics simulation. As speed increasing aerodynamic force plays an important role for dynamic simulation of vehicle model, the shape and size of vehicle required more attention. Moreover, a vehicle using an active suspension system is to model accurately for better ride comfort and stability. Also, performances improved in terms of energy efficiency, enhanced bogie design to fulfil more demanding operational requirements, wider dynamic performances with reduced environmental impact and maintenance costs. A prototype decision support system is being developed incorporating system modeling, composition modeling and the tools database.

4. Conclusions

The concept of modeling and simulation of various components of the vehicle is discussed in this paper. The future challenges that required more attention is also discussed .The problem faced by vehicle dynamics is shown for vehicle modeling and simulation. For simulation, lot of input parameters were considered and to get appropriate analysis an exhaustive research is to be done for a vehicle dynamics. MBS algorithms that employ DAE's solver and sparse matrix techniques are necessary for accurate virtual prototyping of railroad vehicle systems. It found that result are very sensitive and if a few inputs were taken incorrect, then exact condition cannot be predicted and the behaviour of the model is not up to the standards. The study of control system for better ride comfort is also discussed. The flexible vehicle modeling is discussed and the appropriate ways of modeling and their mode shape discussed. Flexible body FE/MBS algorithms are integrated to study the track, car body and vehicle component deformations. The new control based method was combined with Stripes methods for the best vehicle performance. The track geometry is defined using ANCF finite elements that allow for accurate calculations of the position coordinates and geometric vectors at the wheel/rail contact points. The inter-vehicle connections of a train have an important influence on the dynamic behaviour of a car body in the frequency range < 20 Hz.

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