APPLICATION OF RIGID MULTI BODY SYSTEM MODELLING TO VEHICLE OBSTACLE NEGOTIATION CAPABILITIES

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Abstract: This paper presents the need for vehicle dynamics modelling stemming out of the vehicles lifecycle and its intended use. It introduces the prerequisites and means for addressing the challenge of appropriate design determination. Further it describes a general approach to vehicle dynamics modelling with use of rigid multi body modelling. Methods therefore and steps needed to be taken for a composition of a detailed rigid multi body system model of a vehicle are also presented. It additionally presents the extensive experimental work performed for verification of the dynamic model, coupled with results of rigid multi body system based vehicle model simulation. Various measurement principles used are outlined. Some shortcomings of the rigid multi body system models are presented and further fields of application of rigid multi body system models are proposed.

KEYWORDS: VEHICLE DYNAMICS, RIGID MULTI BODY SYSTEMS; NUMERICAL SIMULATION, SPECIAL PURPOSE HIGH MOBILITY VEHICLE

1. Introduction

One of many crucial issues of military vehicle capabilities is their ability to negotiate various natural as well as man made obstacles. Determination of military vehicle obstacle negotiation capabilities is therefore an indispensable part of military vehicle product lifecycle. Vehicle object negotiation capabilities determination can be carried out through testing of the final produced vehicle, carried through on purpose built test tracks. This option however is less than optimal, as it can only be carried through once the vehicle has already been produced, and any changes needed to be made to the vehicle prove to be extremely costly at this time.

In addition to this, appropriate test tracks are not easy to come across and the cost of test equipment and inevitable man-hours are not to be neglected. In view of the aforementioned facts, it seems pertinent to approach the determination of object negotiating capabilities of vehicles as soon in the development phase of the vehicle as possible.

2. Prerequisites and means for resolving the problem

The task of early vehicle capabilities determination is made possible by a variety of computer aided tools which aid Rigid Multi Body System (RMBS) dynamics modelling.

In order to build a sensible RMBS model of the vehicle in the form of a system of rigid bodies, a good estimation of mass and inertial properties of each influential vehicle component (each body in a multi body system) is needed. There are many approaches to mass and inertial properties determination ranging from measurement to detailed geometrical modelling. With the use of the latest in CAD software, it turns out to be the simplest and most user friendly approach, to determine the inertial properties with the use of geometrical model of a vehicle component, which if modelled parametrically is of great use even in the eventual case of a redesign of a component. The relative motion of bodies in a system is constrained with the use of set of kinematic constraints [1-3] with careful consideration placed on their proper selection and application.

Next to kinematic constraints, elements of force need to be introduced to the model as well. These are implemented to model vehicle components such as springs and dampers.

For determination of vehicle obstacle negotiation capabilities, it is most important to input proper parameters of its suspension component models. For a limited range of vehicle motions a linear description of spring and damper characteristics might suffice, but since we are dealing with high mobility vehicles, designed to cover wide range of terrain and modes of operation, we must not limit ourselves to linear representations of suspension components with highly nonlinear characteristics, fig. 2.

First a vehicle geometrical model is required. It is derived from the initial design of the vehicle and is subject to change if analyses show it to be necessary. This geometrical model defines the arrangement of individual bodies in a multi body system as well as their geometric properties.

fig. 1: 3D geometric model of a vehicle component.

fig. 2: Highly nonlinear characteristics of suspension components.

Force over displacement and force over velocity values of springs and dampers are best measured, or modelled by purpose built software applications capable of analysing hydraulic...
components. An example of measured data for two hydraulic dampers is given in Fig. 2.

In view of nature of high mobility vehicle intent of use, it is also crucial to include into our consideration the bump stops, elements intended to limit motion of vehicle components near the limits of their operation. Bump stops prevent metal to metal contact of vehicle components and alleviate eventual extreme stresses. Since the engagement of these elements is not at all infrequent it is appropriate to model them in an exact, nonlinear manner, with their characteristics determined experimentally or through designated software analyses tools usually incorporating finite element methods.

Yet another force element that needs to be applied to rigid multi body system model of a vehicle is the tire force element. Although the importance of tire to road surface force generation modelling cannot be overestimated, modelling of tire forces is out of scope of this article. Tire force modelling is documented in various references [4-7]. Suffice it to say that force element is usually included as a module to a RMBS software application and is readily usable if we have the appropriate tire parameters at our avail. These are usually determined by the tire manufacturer or specialized tire modelling laboratories. Tire parameters are in general somewhat illusive, as only some simpler and consequently limited tire models lend themselves to relatively simple experimental parameter determination.

We have now determined all the basic building blocks that are needed in preparation of a rigid multi body vehicle model. Graphical representation of this RMBS based vehicle model, together with the occupant model is shown in fig. 3.

The model can be used to determine vehicle response to various inputs. Since majority of imputes to the vehicle result from unevenness of the terrain the vehicle traverses, modelling of terrain surface geometry is one of our additional concerns.

We can model terrain surface geometries of shapes similar to those appearing in natural environment or even man made obstacles [8], therewith relieving the need for physical testing on test courses hard to get to or sometimes even testing at operating conditions dangerous for personnel and equipment. fig. 4 represents a geometrically surveyed strip of land of approximate dimensions 80 by 200 meters, while test obstacles in fig. 5-7 represent man made obstacles.

Many examples of test courses have been modelled and simulations ran to determine the vehicle response, only few are shown here. fig. 5 – 6 show a time frame in a simulation of vehicle negotiating a trench, high road wave obstacle and a steep slope.

3. Results and discussion
Once the vehicle has been manufactured, physical testing needs to be done as well, but probability for the need of major design changes to arise is minimal. Such physical testing is used in this example also to verify the RMBS based vehicle dynamics model.

We have conducted numerous measurements of kinematic quantities (displacements, velocities and accelerations) of various vehicle components, by implementing accelerometers, inertial measuring system and a system of calibrated high speed digital cameras.

fig. 8 shows a step in an analysis of picture plane marker paths for two calibrated cameras. Data from image analyses together with additional camera calibration data (intrinsic and extrinsic camera parameters) in turn enable determination of spatial marker motions appropriate for comparison to vehicle dynamic simulation results.

The obstacle being negotiated in the picture is of a typical half cylinder shape of standardised height. The vehicle passes the obstacle with required velocity.

fig. 9 shows a comparison of measured and simulated results. It exhibits a good correspondence between them.

A good correspondence is observable also from fig. 11, in which measured and simulated accelerations of vehicle centre of gravity are compared. The comparison is being shown in this example for a test run down a high wave obstacle course such as presented in fig. 6.

In addition to the accelerometer placed at the vehicle centre of gravity, we arranged a number of accelerometers according to fig. 10. Accelerometers were placed on various locations on the suspended part of the vehicle as well as mounted on the unsuspended parts.

fig. 8: Simulation validation – analysis of footage taken by a set of calibrated high speed cameras.

fig. 10: Simulation validation – positioning of accelerometers.

fig. 9: Simulation validation - comparison of measured and simulated accelerations of vehicle centre of mass.

4. Conclusion

The rigid multi body approach to vehicle dynamics modelling turns out to be an appropriate approach for the purpose of obstacle negotiation capabilities, as the results of physical model verify the model with great accuracy.

There are some applications, for which a RMBS model of a vehicle is not suitable, however. Namely, a dynamic response of a vehicle, to a highly impulsive force loading, for example from a mortar recoil action, has proven itself to be influenced by the deformation of the vehicle structure to the extent that RMBS model response is no longer representative of the physical event.

Due to the success of RMBS approach to vehicle dynamics modelling as demonstrated through model verification above, and the current work conducted in the field of biomechanics [9], we are confident that vehicle occupant dynamics will be superimposed on to vehicle dynamics with great success and enable vehicle operating conditions analysis also from the standpoint of occupant safety. The use of the vehicle on a rough terrain may cause severe loads to the occupant’s body, consequentialy leading to injuries. Currently the work in this direction is already in progress, fig. 3.

5. References


