Modelling collisions of rail vehicles with deformable objects (T305)

**Background**
Over a number of years considerable effort has been put into rail vehicle design to improve crashworthiness. Extensive use has been made of computer modelling to predict structural performance and in particular that of the front-end. Historically the most common collisions have involved two trains, which is reasonably represented in computer modelling by collision of a single train into a rigid wall. More recently, advances in train protection have led to a reduction in this type of collision.

Within the last five years there have been a number of accidents involving collisions between trains and road vehicles, typically at level crossings, which have led to derailment of the train and consequential fatalities. The above form of modelling assumes similar deformation of both colliding vehicles. It is thus inappropriate for modelling collisions with road vehicles because the road vehicle deforms in a very different manner to the train. Since the manner of the road vehicle’s deformation plays a key role in determining whether or not the train derails, it is vital to model the deformation of the road vehicle.

**Aims**
This project conducted preliminary investigations into the benefit of modelling object deformation. This allowed not only impacts with centrally placed objects to be modelled but also impacts with off-centre objects only partly in front of the train. The work utilised Finite Element Analysis (FEA), which is traditionally used for crashworthiness modelling.

**Method**
The project was carried out as a PhD thesis and commenced with a review of previous collision modelling. This culminated in the selection of a number of collision scenarios that were more representative of real life situations than those traditionally used in FEA studies. These included deformable object shapes and sizes representative of road vehicles. Two closing speeds were used and examples of vehicles placed centrally at the point of impact and off-centre were included. For comparison purposes collisions with a rigid movable object were also analysed.

The accident scenarios were simulated in a detailed FEA with deformation, vehicle movement, energy dissipation and incident time histories all recorded. In addition to tabular and graphical outputs, the results were also provided in animated visual format providing very clear presentation of the findings.

**Findings**
The analysis suggests that modelling the deformation of the impacted object is crucial to determining the risk of derailment.

The results have identified some highly significant differences between modelling collisions using deformable objects and rigid objects. This is particularly the case where the impact is off-centre.

The work has shown that collisions with deformable objects introduce moments that rotate the vehicle both laterally (yaw) and
vertically (pitch) which will increase the risk of derailment. This is exacerbated when the collision is off-centre.

Furthermore, hazards relating to object size and mass have been identified. In the case of smaller lighter objects, the smaller amount of energy absorbed by the rail vehicle and the propensity of the smaller object to disintegrate increase derailment risk. The increased risk results from the increase in incident duration and the potential for entrapment of material in bogies and under wheel sets during the time in which the rail vehicle comes to a stop. In the case of larger heavier objects, the energy absorbed by the rail vehicle is greater, leading to greater deformation of the driver’s cab, a higher risk of derailment during the initial impact and a shorter incident duration. Both cases, although different in nature, pose a significant risk of derailment and risk of injury to driver and/or passengers.

It was also shown that deformation of the cab is likely to be less in the case of collisions with deformable objects. However, the tendency of the deformable object to wrap around the cab may lead to deformation in areas (for example, cab sides), which are not exposed in rigid body collision simulations.

Impact with a rigid object

Next Steps

The work has revealed some interesting aspects related to trains colliding with deformable objects, but there are factors that were not included in the analysis. For instance, the object model does not break up, separation of internal components that could affect survivability is not considered, the wheel/rail contact ignores the wheel flange and the role of obstacle deflectors is not considered. There are also some unexplained phenomena, such as momentary acceleration of the vehicle after impact, that also need to be understood. The modelling would need thorough validation before the results are utilised (perhaps through simulating recent accidents). Nevertheless, the Rail Safety and Standards Board see value in a peer review of the work.

The work will be considered within project T118 ‘Whole train dynamic behaviour in collisions and improving Crashworthiness’ and will also inform further development of Euronorms for rail vehicle crashworthiness.

Using FEA to model deformation in collisions could be further enhanced by combining with vehicle dynamics modelling to expose additional factors that could lead to derailment. This approach has been taken in project T189 ‘Optimal design and deployment of obstacle deflectors & lifeguards’.

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