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Virtual Articulated Haulers - simulation of vehicle performance and design loads

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Abstract

During the development of construction equipment, usage of virtual complete vehicle models has become an important tool for a rapid development process maintaining low risk. Many properties e.g. stability, handling and ride comfort are today simulated and secured early in the product development process with high accuracy.

During the last years effort have been directed to also extract design loads for fatigue life calculations from the complete vehicle models. This paper gives an status overview regarding articulated haulers, see figure 1. This kind of vehicle have extra ordinary terrain capability which is accomplished by hydraulic articulated steering, stiff individual tractor and load frames connected with a rotational joint and all-wheel drive together with large tires. The vehicles are also equipped with automatic differential locks, automatic powershift transmission and wet brakes with cooling for high gradeability.

Figure 1: Articulated hauler in rough terrain application.

To extract loads from the virtual models implies additional requirements compared to normal handling simulations especially concerning the ability to cover higher frequency content. Models with sufficient resolution have to be used for accurate representation of the road surface, the tires, the suspension system and the frames. To solve the vehicle dynamics but also to build and maintain several different levels of the subsystems models and how they are assembled, ADAMS/Car[1] have been used since several years. At present stage, the road surface of the endurance test tracks is obtained by laser scanning and converted to the OpenCRG[2] format. The tires make use of Ftire[3], a physical tire with high resolution. The hydraulic system (hydraulic suspension and steering) are modeled in Amesim[4] and the simulations are made in co-simulation mode together with ADAMS. The exchange of information between the two solvers are manage by a General State Equation (GSE) and a special interface block in Amesim. Some key components (frames, hitch and body) need to be flexible in order to account for the flexibility of the entire vehicle. For this purpose, the software makes use of Craig-Bampton reduction and an additional orthogonalization step. Figure 2 shows an assembled articulated hauler vehicle model and the Amesim hydraulic model executed in co-simulation mode.

The ultimate target for the virtual models is to deliver accurate component loads - extracted from the full vehicle models, as input to durability calculations. Fatigue life calculations of large welded structure

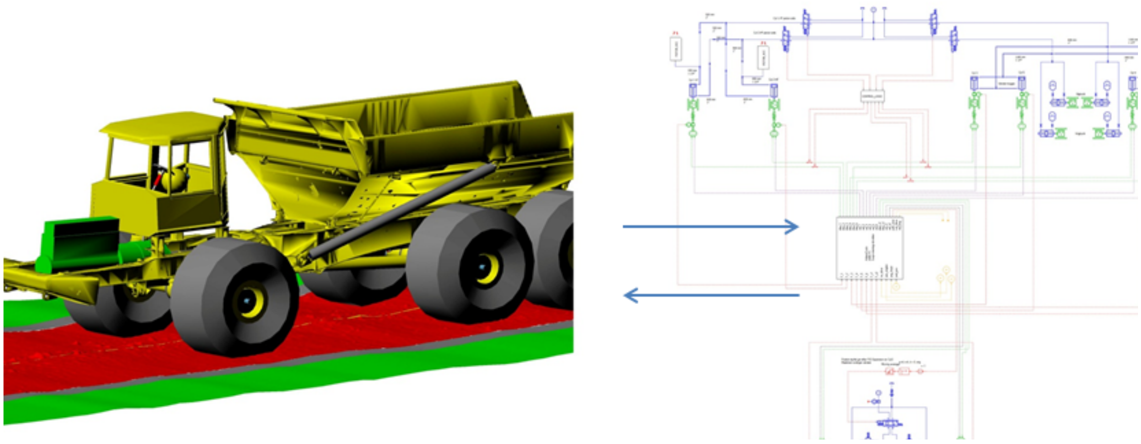

Figure 2: Hauler vehicle model and Amesim hydraulic model.

as e.g. the front and the rear frames, is continuously developed and is mature to use component loads directly in the time domain. This is accomplished through extensive usage of the detailed notch modeling of the weld, load superposition and time based fatigue evaluation using critical plane theory[5] applied to the notch stresses.

Besides a detailed status description this paper presents comparison between fatigue loads from load measurements and virtual simulations. To compare the results in a quantity that is related to fatigue, range-pair information obtained from rainflow counting[6] together with the equivalent load range (a scalar value) defined as

$$R_{ekv} = \left(\frac{k_t}{1000} \sum_{i=1}^{N} n_i {R_i}^m \right)^{(1/m)}, \quad (1)$$

where $\{n_i, R_i\}$ are number of occurrence and the corresponding range from a rainflow computation, k_t is a normalization factor to 1 hour and m is the Wöhler exponent, is used. The agreement between test and simulation is in general good, but for some components the agreement should be improved further by tuning the models.

References

[1] MSC Software Corporation. Adams/car. http://mscsoftware.com/product/adamscar, 2014.

[2] VIRES. Opencrg. http://www.opencrg.org/, 2014.

[3] Cosin scientific software. Ftire product brief. http://www.cosin.eu/, 2014.

[4] Siemens. LMS imagine.lab amesim. http://www.plm.automation.siemens.com, 2014.

[5] L. Susmel, C.M. Sonsino, and R. Tovo. Accuracy of the modified wöhler curve method applied along with the r_{ref} = 1 mm concept in estimating lifetime of welded joints subjected to multiaxial fatigue loading. *Int. J. Fatigue*, 33(8):1075–1091, 2011.

[6] S. D. Downing and D.F. Socie. Simple rainflow couting algorithms. *Int. J. Fatigue*, 4(1):31–40, January 1982.