Medium frequency phenomena on heavy vehicles: experimental analysis and numerical applications

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Abstract :

Driveline vibrations of a truck are a cause of strong discomfort for drivers, and have to be investigated in pre-design phases. In order to develop numerical and analytical tools for the prediction of noise and vibration of such a complex structure, a deep knowledge of the physical phenomena involved is imperative. Few experimental studies have been performed on truck vibrations, and they mostly concerned single components of a vehicle. Therefore an Experimental Modal Analysis (EMA) of a complete truck has been performed in order to observe vibratory phenomena and determine influencing parameters involved in the vibration transmission. This study brings new insights into the field of truck vibrations. The results of the test campaign have been used for correlation with a numerical model and for the identification of dynamic behaviour and related frequency ranges. This work constitutes the preliminary part for an on-going project aiming at the development of reduced numerical models for the prediction of sound and vibration in truck cabins.

Keywords : EMA, truck, driveline vibrations, medium frequency

1 Introduction

Experimental Modal Analysis ([1], [2]) is commonly applied in the heavy vehicle industry ([3], [4]). Though, studies usually focus on the dynamics of single parts of a vehicle and, to the authors' knowledge, no EMA of a whole truck exists in the literature; that is why a test campaign was launched, with a twofold objective: to give a preliminary idea of the vibratory phenomena found in a heavy vehicle and to provide an experimental reference for the validation of a numerical model.

The numerical model will be used for assessments on vibroacoustic performance estimators. The need for a numerical model to perform this kind of assessments is of primary importance for truck analysis, due to the large variability of truck configurations, which makes the study of every specimen unachievable.

2 Test campaign

2.1 Setup and configurations

Roughly speaking, a heavy vehicle is made up of a chassis, a cabin, a powertrain, axles, and elements suspended to the chassis. The chassis constitutes the main transfer path for vibration originating from the powertrain. This is the reason why the present analysis focuses on the chassis; all the elements suspended to the chassis are also considered important, because they are supposed to modify the dynamic stiffness of the former. The test campaign is performed on a Medium duty truck, having a Gross Vehicle Weight (GVW) of 12 tonnes.

The truck is tested while lying on its tyres; indeed, it is assumed that free-free boundary conditions are not attainable, so the latter are rather chosen to fit the numerical model conditions.

The structure is excited through an impact hammer, heavy enough to inject an adequate amount of energy into the structure. Measurements are performed on the frequency range [0 Hz - 256 Hz]. Pre-test check of input excitation allows limiting the validity of Frequency Response Function's (FRF) to the range [0 Hz - 160 Hz].

A compromise between testing time and accuracy leads to choose a frequency step of 0.25 Hz for all acquisitions, thus causing a limitation with respect to the estimation of damping at low frequencies.

The structure is impacted at two reference points so as to excite the highest possible number of modes. Additional measurements are also performed with input forces on several suspended elements, so as to inject energy specifically to the latter.

Frequency Response Functions are acquired by roving tri-axial accelerometers over 143 points (most of which lied on the chassis). Mass loading from accelerometers is considered to be negligible.

Modal parameters are identified and validated through the commercial software LMS® Test.Lab by using a poly-reference Least-Squares Complex Frequency-domain (LSCF) estimation method (PolyMax) [5].

2.2 Results

The analysis of the sum of all FRF's brings to light a fundamental information: in the frequency range considered, the structure presents well separated behaviours that are typical of the Low Frequency (LF) and High Frequency (HF) ranges. Besides, a transition range commonly called Medium Frequency (MF) range is observed (Fig. 1).

Both global and local modes are identified, depending on the frequency range considered (Figs. 2a, 2b and 2c). The transition from a global to a local behaviour happens in the MF domain; the interaction between stiffer and more flexible components (the chassis and the suspended elements, respectively) is thought to drive the said transition.

A check on the quality of modal parameter estimation shows that modal data are better identified in the Low and Mid Frequency ranges (up to approximately 50 Hz), where identified modes have mostly real deformation shapes.

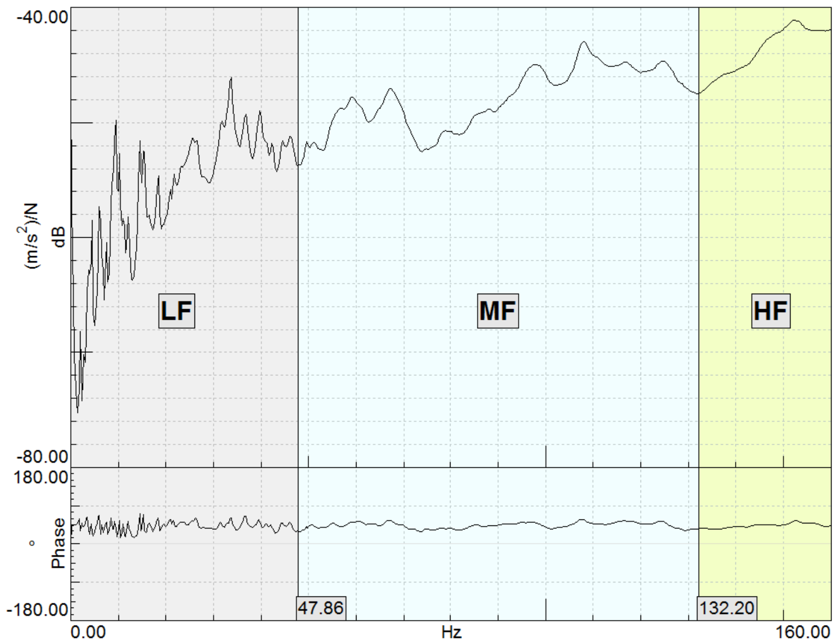
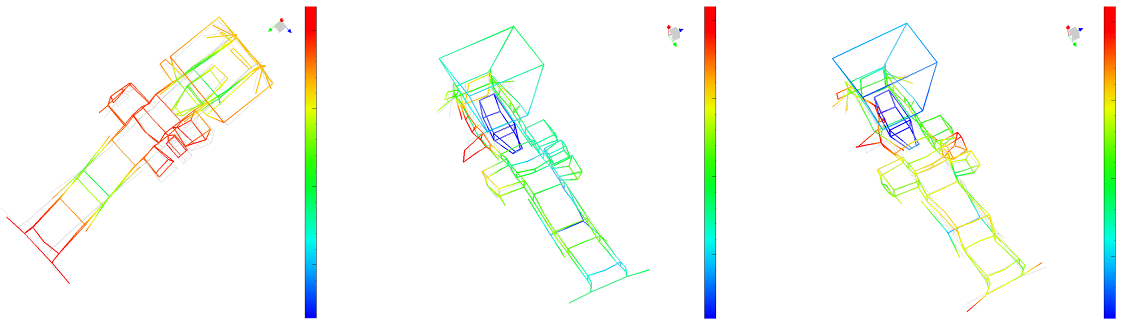


Figure 1: Sum of all the measured FRF's and characteristic frequency ranges identified.



(a) Mode 10: 9.30 Hz, 1^{st} horizontal bending.

(b) Mode 33: 39.64 Hz, local bending of front chassis LHS.

(c) Mode 56: 110.67 Hz, local modes.

Figure 2: Some estimated mode shapes.

3 Numerical model validation

A Finite Element model has been assembled for a complete truck; it includes all the main components of the tested truck. Different levels of detail are used in the model, so that some components are represented by rigid models, while others by geometrically detailed flexible models.

The comparison of measured and calculated frequency responses is promising, since orders of magnitude and trends on frequency response functions are well predicted.

4 Conclusions

An experimental modal campaign on an industrial vehicle is described and the estimation of modal parameters carried on. Physical phenomena linked to the onset of the so called Mid-frequency range

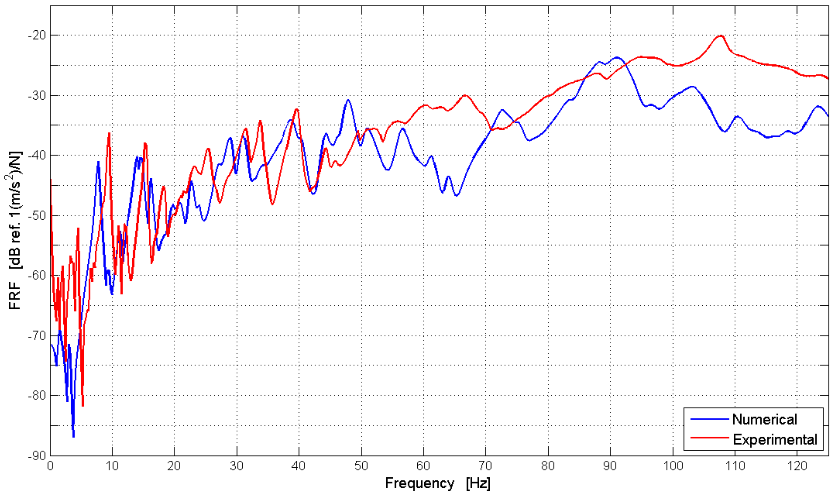


Figure 3: Point FRF's on a selected point of chassis: comparison between experimental and measured results.

are highlighted thanks to the measurements. The results of the experimental campaign can serve as a reference for comparisons with numerical models developed in the truck industry, most of all when concerning frequency ranges and expected physical phenomena.

The estimated modal parameters are used as a basis for modal update of a FE model. First correlations are promising, but an effort must be made to further improve the predictability of the numerical model.

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