Powertrain mounts dynamc characterization for low frequency structure borne noise prediction

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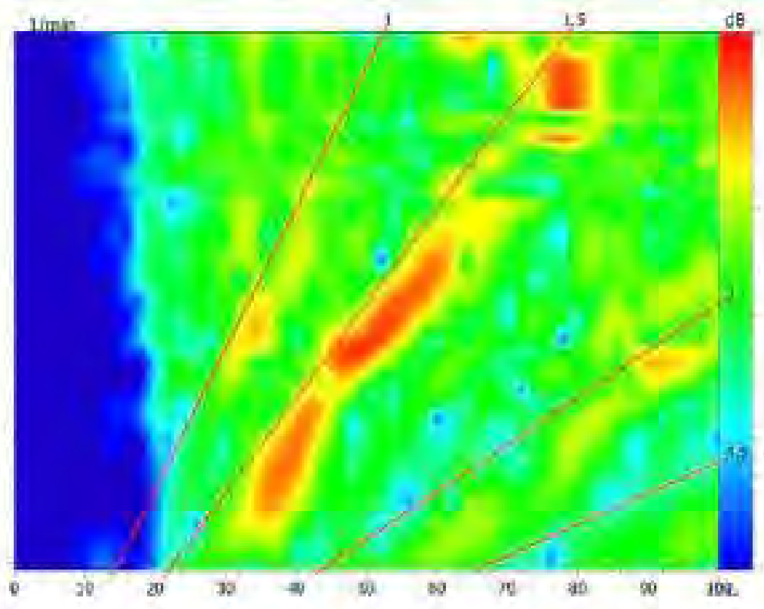
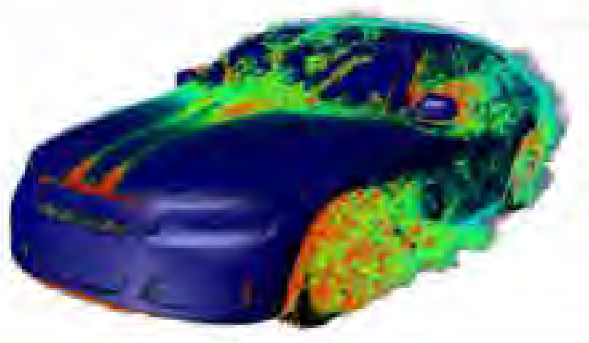
Introduction

The acoustic performance, in the development of luxury class vehicles, is very important. In the latter development stages, it becomes essential to predict the influence and effects of sub-components' modification in the global car. Due to the complexity of creating models for the entire vehicle, the dynamic substructures, and in particular the component-based dynamic substructures, are used for this purpose. The booming noise, linked to the engine firing order, is a phenomenon that occurs rather often in vehicles with internal combustion engine, but also in the family of hybrid vehicles that still have such type of engines. As shown in the figure, for frequencies between 20-80 Hz the noise in the cabin is largely dominated by the boom resulting from the engine combustion. In the advanced stages of development, the modification of the mounts characteristics represents one of the most feasible way to reduce booming noise issues. Other modifications would have a much larger and difficult to control impact.



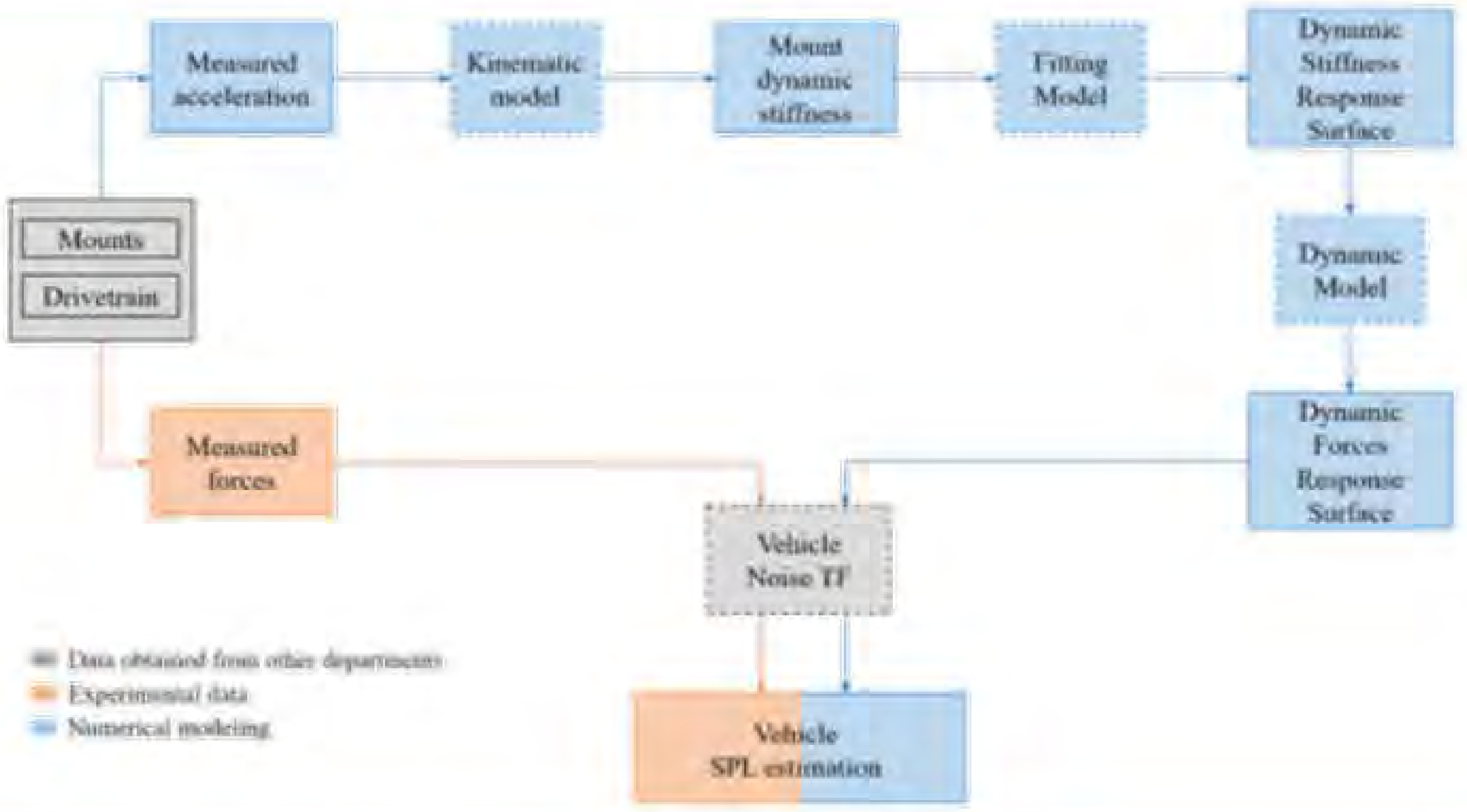


$$SPL_k = \boxed{\sum_{i=1}^{n} NTF_{ik} \cdot F_i} + \boxed{\sum_{j=1}^{p} NTF_{jk} \cdot F_jk}$$

airborne structure-borne

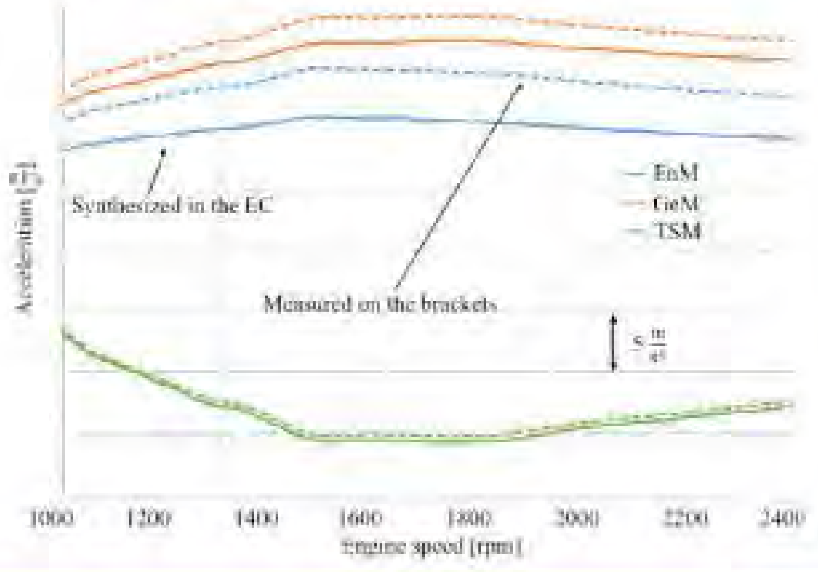
AIM - the procedure detailed here, aims at increasing the prediction capabilities for the low frequency booming issue. This, by reducing the number of required experimental tests while creating a generalized platform usable for the powertrain mounts optimization.

Procedure Flow



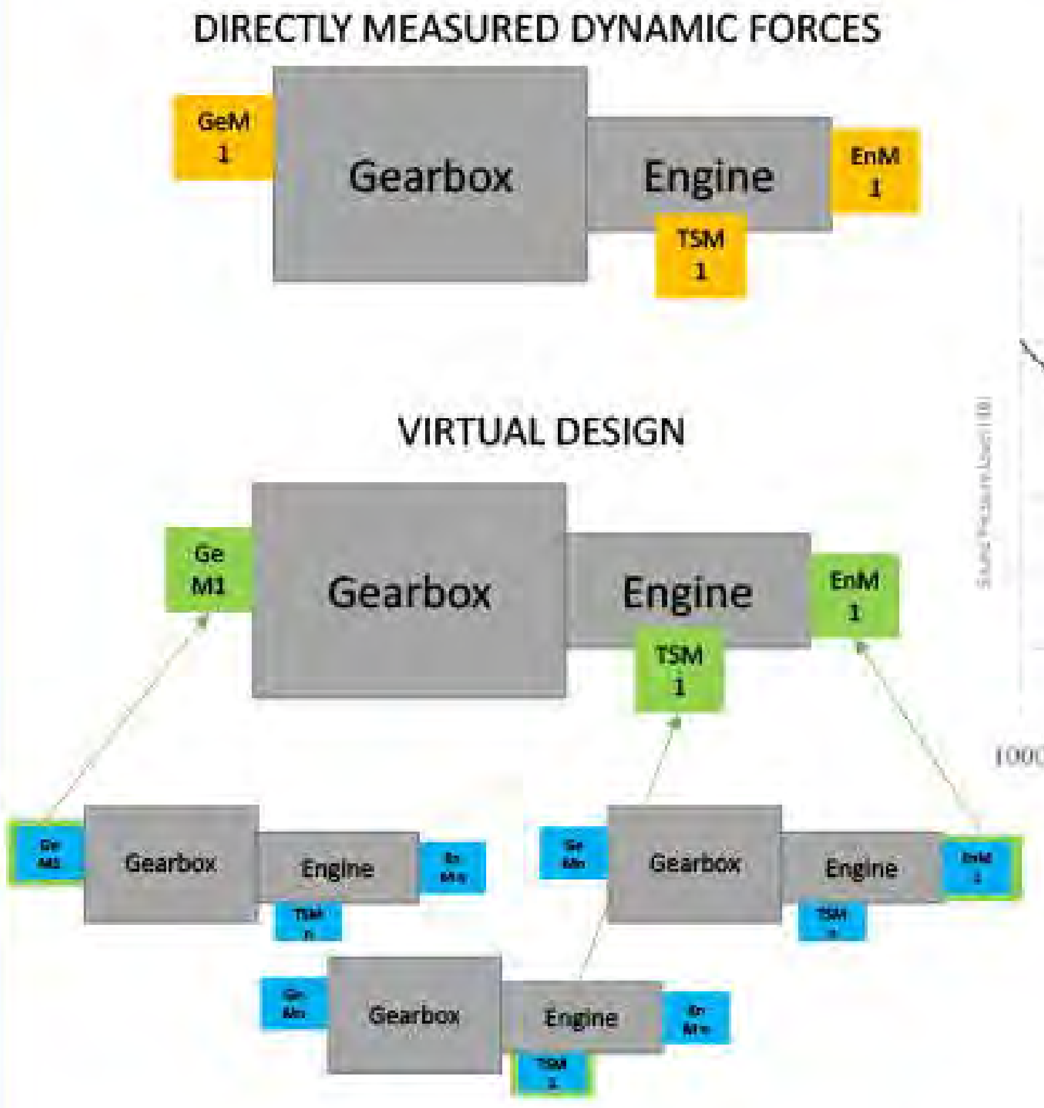
Kinematic Model and Virtual Point

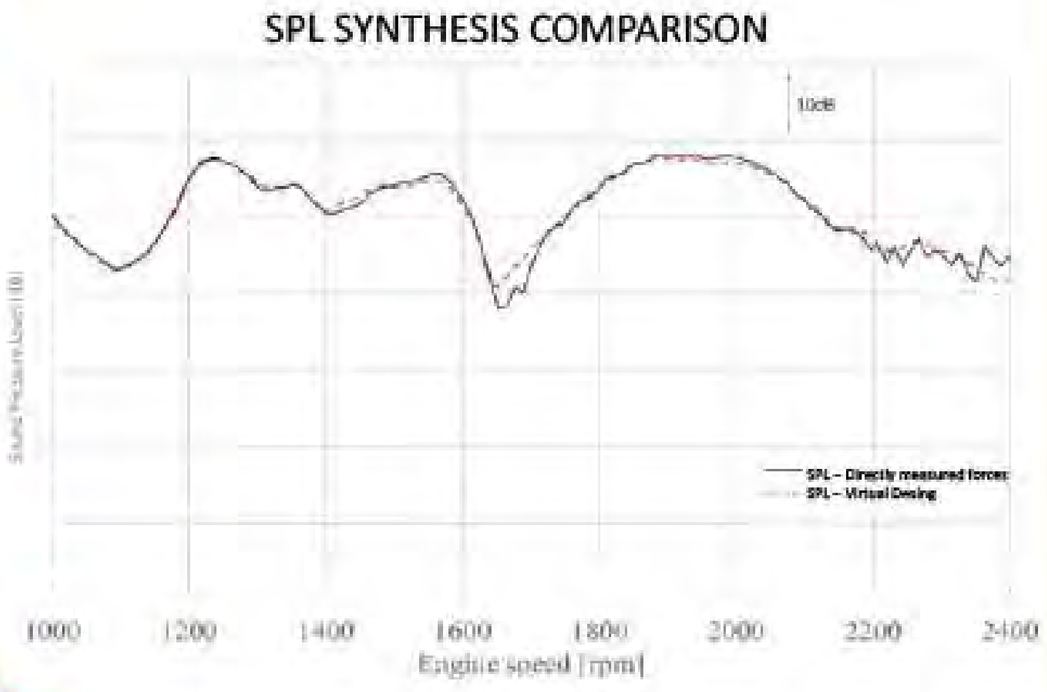
In the frequency range of interest, the engine can be considered as a rigid body. This, allows to obtain a kinematic model, based on the measured acceleration, and to compute the engine movements. The same model allows also to synthesize the accelerations in virtual point for each mount (represented by the red points in the figure). These correspond to the points of transmission of the dynamic forces from the powertrain to the vehicle body



Sound Pressure Level (SPL) prediction and time savings

The comparison between the SPL prediction using the dynamic forces directly acquired from the test bench and transferred in the virtual point (black solid line), and the one obtained by recomposing the desing utilizing dynamic forces extracted from the stiffness response surfaces (red dotted line) is very satisfying.

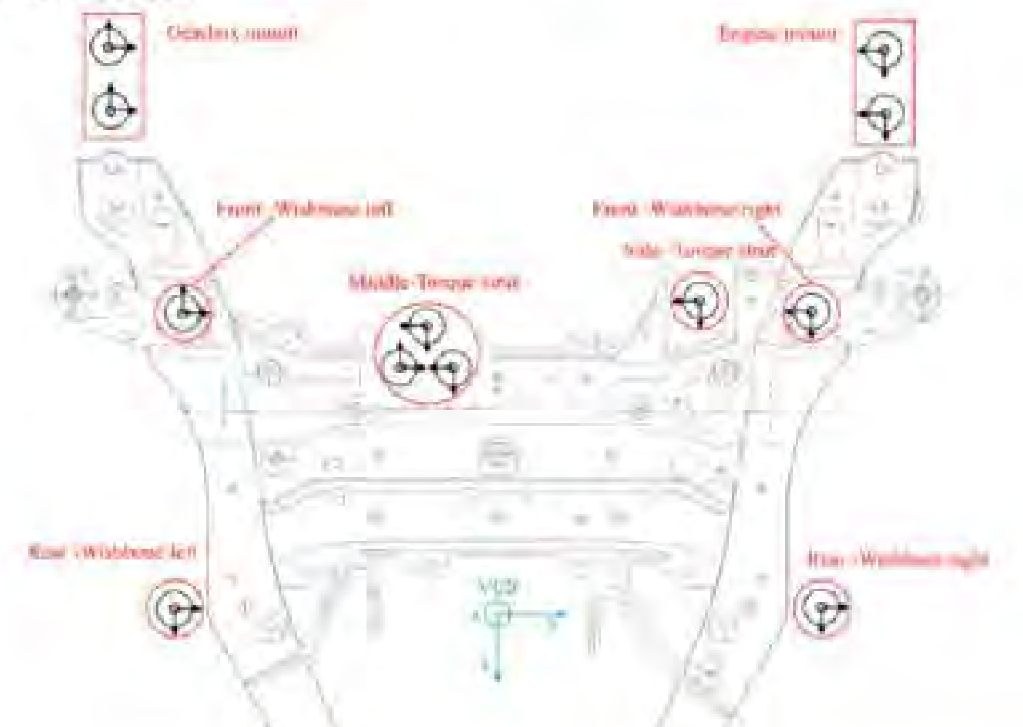


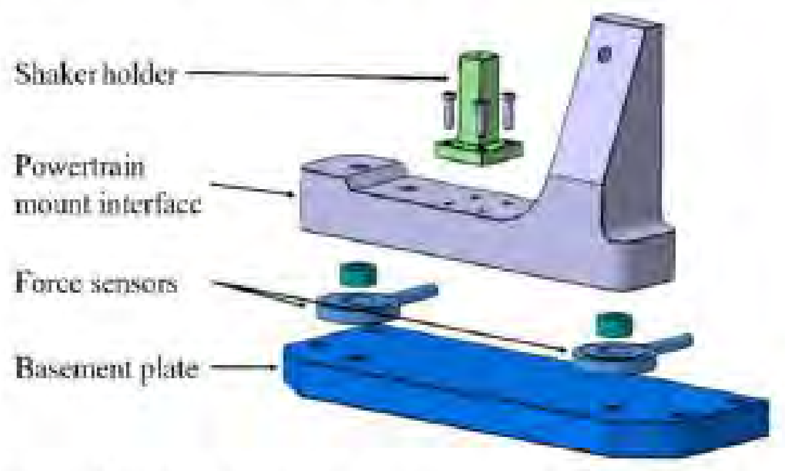


Each powertrain mount can be tested and characterized in a different configuration, even utilizing a different powertrain for each test. Each mount can be than reused for the evaluation of different virtual designs.

Dynamic Force

To to synthesize the sound pressure in the vehicle, using the transfer path analysis theory, it is necessary to have both the mechanical acoustic transfer functions and the dynamic forces. In this approach, these are measured rather than obtained using inversion methods.



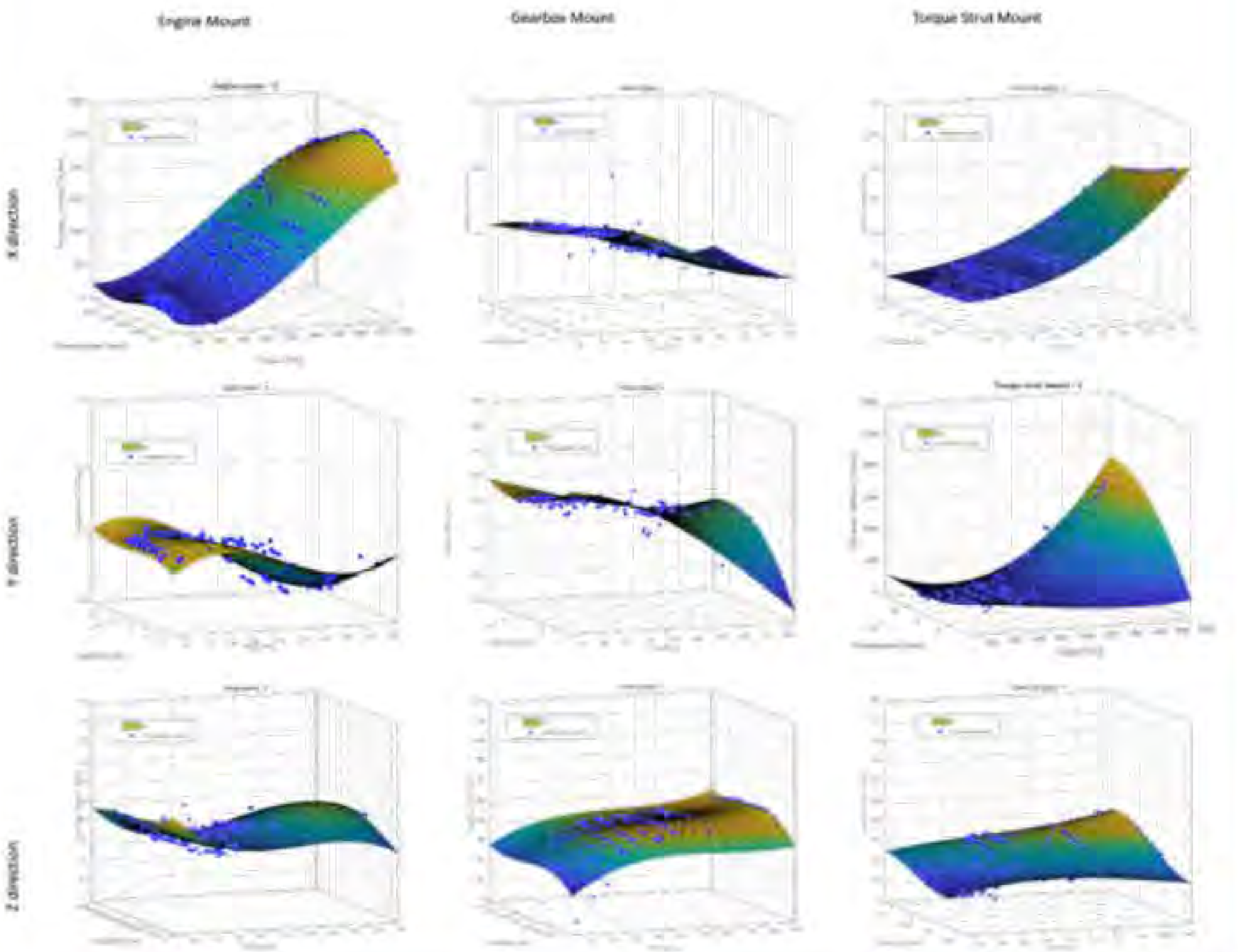


The force sensors are mounted as in the figure above. Using a dedicated force transfer procedure, it is possible to determine the forces acting in the virtual point (see Kinematics)

Dynamic Stiffness Response Surfaces

From the dynamic forces, transferred in the virtual points, and the virtual synthesized virtual displacements, in the same coordinates, it is possible to determine the mounts' dynamic stiffnesses. The experimental-numerical results are fitted with a polynomial surface, as function of displacement, frequency and torque (static preload). The results have been simplified, neglecting the frequency dependency.

$$C_{dyn} = f(\tau, d, F)$$



Conclusions and Further Developments

The proposed approach allows to measure the dynamic forces, transferred from the engine to the chassis, and also to synthesize the dynamic stiffness of the mounts under operating conditions. Having defined the response surfaces it is possible to improve the simulation capabilities while reducing the number of experimental tests. Each component can be measured, once in any design and then, reused for the synthesis of other virtual designs. The same methodology can also be used to predict other low frequency phenomena (start, MSA). The developed analysis framework represents the starting point for optimization of the dynamic stiffness of mounts. The actual development aims at extending the methodology also for higher frequency phenomena.