Vibro-acoustic optimisation process based on hybrid SEA modelling of a trimmed body vehicle

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Introduction

Hybrid SEA modelling based on the well known power injection method is an essential technique which is required for the build up of trimmed body complete vehicle SEA models which are able to predict air- and structure borne noise sources with sufficient accuracy. We outline our MATLAB based modelling and integration techniques which are used in order to build up and validate hybrid AutoSEA models. Furthermore we present the application of the vibro-acoustic potential analysis which is used within modelling and analysis processes. Based on a SUV SEA model a drive chain noise analysis is presented.

Hybrid modelling and analysis process

A hybrid SEA model [1], denotes a SEA model which consists out of analytical parts where coupling loss factors are estimated based on material and trim geometry parameters and a model part which is based on measured SEA parameters (power injection method [2]) like internal and coupling loss factors (ILF/CLFs), modal densities and equivalent masses/volumes. With hybrid SEA modelling it is possible to improve the performance of the model with respect to transmission, power inputs and response engineering units. In general hybrid SEA modelling can help to improve the simulation accuracy and when prototypes are available also help to speed up modelling time compared to the time which is needed for the acquisition of trim parts and data and the time necessary for acoustic component measurements.

The creation and validation of hybrid SEA models constitutes an error prone process which needs to be implemented in a proper tool environment if one wants to archive reproducibility and cost efficiency.

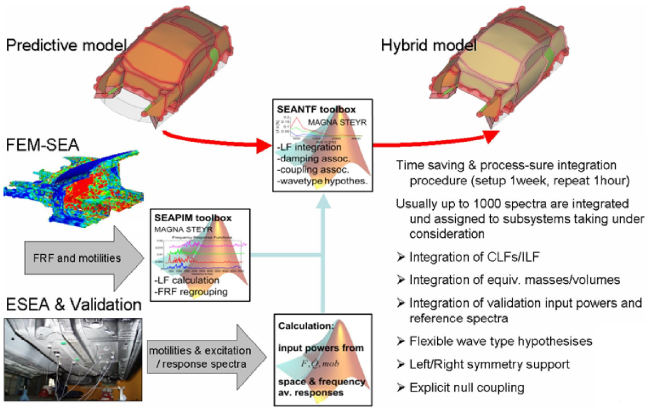

Figure 1: hybrid SEA models are build up within 3 phases until validation is passed.

Usually a hybrid SEA modelling process consists out of a model creation phase, a validation phase and if necessary an alignment phase. At MAGNA STEYR this process is basically driven by MATLAB in house tools, see figure 1. MATLAB is used in order to build up a FRF data base from universal files, is used to calculate SEA parameters (SEAPIM) and an assessment vector for validation and is used in order to transform a predictive model into a hybrid model. For this purpose the complete SEA model (AutoSEA neutral file) is loaded into MATLAB (SEANTF) modified and supplemented with spectra and exported again as neutral file.

Using AutoSEAs batch solver capabilities and SEANTF the complete validation is processed and depicted. In case of discrepancies a model alignment phase is entered. A first task is the identification of model parameters with insufficient performance. Therefore the power flow analysis and the later on introduced vibro-acoustic potential analysis which directly identifies ILFs/CLFs is applied. As the validation takes place with a very limited assessment vector compared to the whole variety of existent paths it is of great importance to let single ILFs/CLFs etc. unchanged in order to avoid path changes which are out of scope. Therefore we only apply the following measures in order to archive good validation results.

- modify null coupling list to correct coupling topology
- refine material parameters for the analytical part of the model
- check and repair FRFs in the PIM data base and recalculate and reintegrate SEA parameters

Vibro-acoustic potential analysis

The application of optimisation methods typically results in an optimal design of preselected component related optimisation parameters. But very often it is of even more importance to identify and judge dominant vibro-acoustics paths within an SEA model. For this purpose the vibro-acoustic potential analysis (VAPA) was developed. For details see [3, 4]. The methods relays on the explicit relation between subsystem energy $E = \frac{ax+b}{x+c}$ and an arbitrary SEA loss factor x. a, b, c are parameters estimated from numerical data. The complete method consists out of three subsequent steps.

Sensitivity analysis and parameter selection: Solely based on a SEA model and input powers all dominant ILF and CLF parameters are identified.

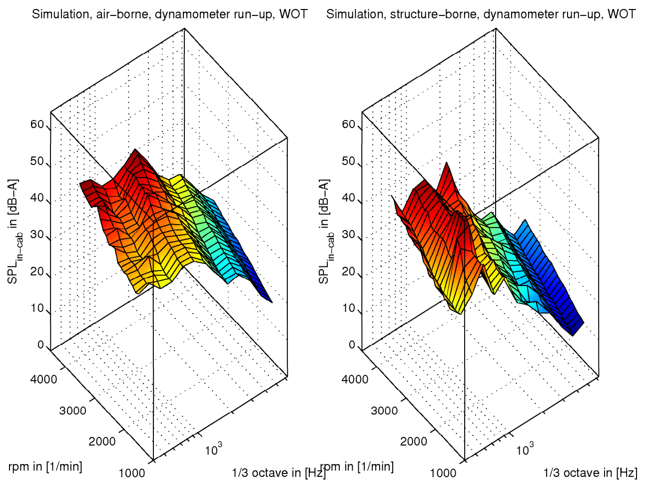

Figure 2: SEA run-up simulation. The analysis shows that structure born excitations are dominant for 800Hz.

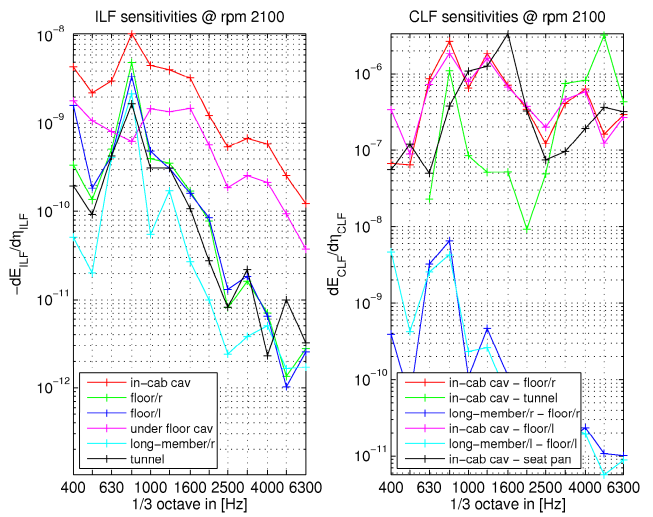

Figure 3: shows the sensitivities and the ranking of dominant model parameters in the legend. The structural path longitudinal/right – floor/right – in-cabin cavity is identified.

Vibro-acoustic potentials: Also regarding large parameter changes the maximum influence onto the transmission of all identified parameters is analysed.
Loss factor target calculation: With a given SPL or velocity limit curve the target values for SEA parameters which would fulfil the targets are calculated.

Therefore complete vehicle target curves for a given load case can be translated into component targets. Possible application fields of the VAPA are:

- identify integration/model errors during validation
- identify vibro-acoustic weak spot in a vehicle design
- generate target curves for trim component specifications based on complete vehicle targets

Analysis example

Within this analysis an annoying drive chain phenomena between 630Hz-800Hz was investigated. The aim was to classify the noise type (air- or structure borne) and to evaluate the effectiveness of secondary vibro-acoustic measures.

The analysis is based on a hybrid SUV SEA model which consists out of 113 subsystems. The damping and equivalent masses/volumes for 55 subsystems and 424 CLF spectra have been integrated. In parallel a source estimation measurement on a roller dynamo-meter was performed. As a result the input powers at the subsystems: engine bay, under floor cavity, longitudinal members, front sub-frame, gear box bridge, where estimated. At 600Hz-800Hz high excitation levels are reached for both acoustic (engine bay) and structural subsystems (longitudinals). Therefore a SEA run-up simulations is applied see figure 2, which results in a comparison between structure born and air borne noise responses of the drivers cabin. This analysis reveals that the drive chain noise phenomena is mainly caused by a structure borne excitation.

Further insight into vibro-acoustic paths is given after application of the VAPA. The results of step 1 are depicted in figure 3.

One can see high sensitivities at 800Hz. The ranking of dominant parameters is given in the figure legends. Therefore it is indicated that the damping of the left and right under floor panels are of most importance. In terms of coupling the CLF with most influence are the structural couplings between in-cabin and under floor panels and between longitudinals and under floor panels. Notice that the level of sensitivity does not unnecessarily correlates with the ranking of the parameter.

Conclusion: drive chain noise is transfered via structural noise into the drivers cabin. The most dominant path is *right longitudinal member- floor right - in-cabin cavity*. Therefore measures which decrease the longitudinal excitation, e.g. barrier masses at engine mount brackets or decoupling and damping measures at the right under floor panel are suggested out of this investigation.

Literatur

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