

A Hybrid Development Process for NVH Optimization and Sound Engineering Considering the Future Pass-by Homologation Demands

Bernhard J. Graf, Christian Hubmann, Markus Resch, and Mehdi Mehrgou
AVL LIST GmbH

ABSTRACT

Beside hard facts as performance, emissions and fuel consumption especially the brand specific attributes such as styling and sound are very emotional, unique selling prepositions. To develop these emotional characters, within the given boundary conditions of the future pass-by regulation, it is necessary to define them at the very beginning of the project and to follow a consequent development process. The following paper shows examples of motorcycle NVH development work on noise cleaning and sound engineering using a hybrid development process combining front loading, simulation and testing.

One of the discussed solutions is the investigation of a piston pin offset in combination with a crankshaft offset for the reduction of friction. The optimization of piston slap noise as a result of the piston secondary motion was performed by simulation.

As another example a simulation based development was performed for the exhaust system layout. A prerequisite for the optimization of the exhaust orifice sound was the definition and artificial generation of the target sound. The challenge for the target sound development was to comply with the future pass-by noise legislations and to feature a distinctive, brand specific sound.

A third example in terms of front loading shows the NVH concept design review and evaluation of different cover solutions with a combination of measurement and simulation to avoid disturbing mechanical noise phenomena originating from the engine and gearbox.

The outlined examples demonstrate the flexibility and capability of the hybrid development process.

CITATION: Graf, B., Hubmann, C., Resch, M., and Mehrgou, M., "A Hybrid Development Process for NVH Optimization and Sound Engineering Considering the Future Pass-by Homologation Demands," *SAE Int. J. Veh. Dyn., Stab., and NVH* 1(1):2017, doi:10.4271/2016-32-0043.

INTRODUCTION

Product development nowadays is strongly supported by simulation methods. This is also true for the NVH development of motorcycles, which are known for brand sound signatures and brand specific sound features. Nevertheless, before starting the composition of this dedicated attribute, a careful planning and consideration of given boundary conditions is mandatory. Boundary conditions are e.g. the pass-by homologation requirement, the engine configuration, the competitor segment or packaging constraints. Another aspect is the consideration of the NVH attribute with other attributes like cost, performance, rideability and fuel consumption and the alignment and balancing with those attributes [Figure 1](#).

Based on the marketing oriented product targets and boundary conditions, the product development process can be started by setting targets in different levels



Figure 1. Attributes for product development

THE HYBRID DEVELOPMENT PROCESS

The following paragraphs describe the hybrid NVH development process including attribute definition, benchmarking, target setting and cascading as well as monitoring. [1][4]

Benchmarking - Target Definition (Level 1)

At first the attributes are defined based on benchmarking of competitor motorcycles in selected operating conditions [Figure 2](#).



Figure 2. Competitor benchmark motorcycles

For example a distinctive NVH attribute for a big displacement cruiser bike is a masculine engine start and an exhaust orifice dominated and strong idle sound. [Figure 3](#) shows the measurement setting for this operating conditions.

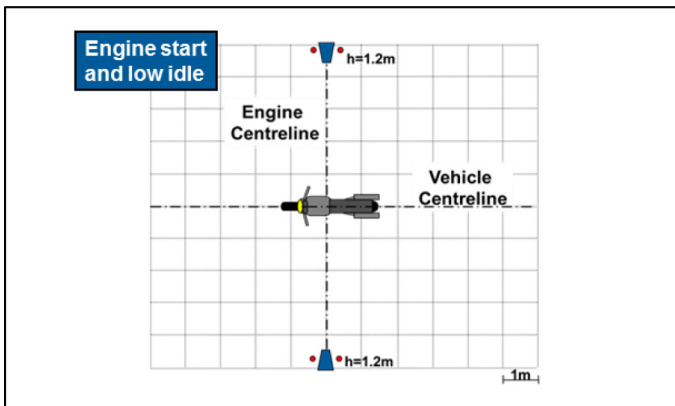


Figure 3. Measurement set-up engine start and idle

Another important NVH attribute for this category of bikes is for example a gentle drive away with low engine rpm and low speed [Figure 4](#).

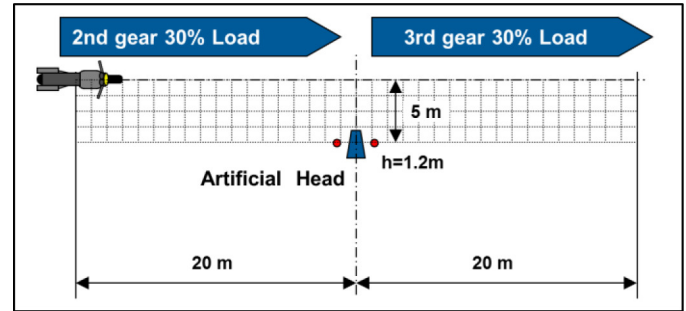


Figure 4. Measurement set-up gentle drive away

To set the target for those attributes a benchmarking is performed recording the selected operating conditions. An overview of the hybrid approach combining experimental NVH development and NVH simulation during the NVH and target sound definition phase is shown in [Figure 5](#).

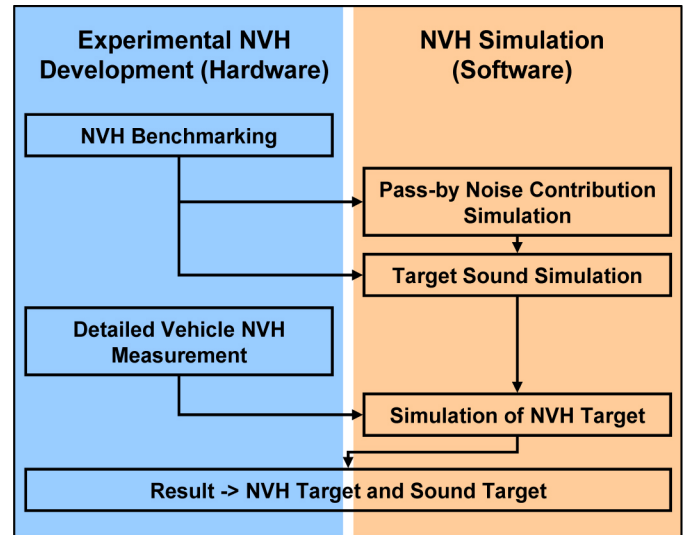


Figure 5. Overview NVH target definition phase

Based on the benchmarking measurements targets for the defined operating conditions are derived. The low idle condition was selected as an example for the target definition process presented in this paper. [Figure 6](#) shows the measurement result and the target curve development on a level 1, vehicle level.

In this example case to achieve the required exhaust orifice dominated sound character in idle it is necessary to limit the mechanical, higher frequent noise content and to emphasize the low frequency sound by increasing the exhaust orifice contribution. By increasing the orifice contribution in idle also other operating conditions have to be considered, especially the pass-by homologation. To consider this different conditions a sound levelling of major noise contributors (intake orifice, powertrain, exhaust orifice) on level 2 (sub-system) target setting has to be set-up and monitored throughout the entire development process.

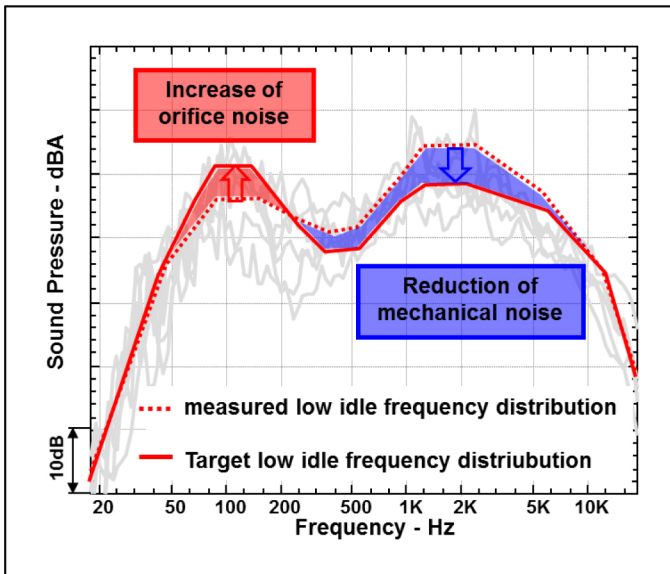


Figure 6. Target definition for idle sound

Target Cascading (Level 2, Level 3)

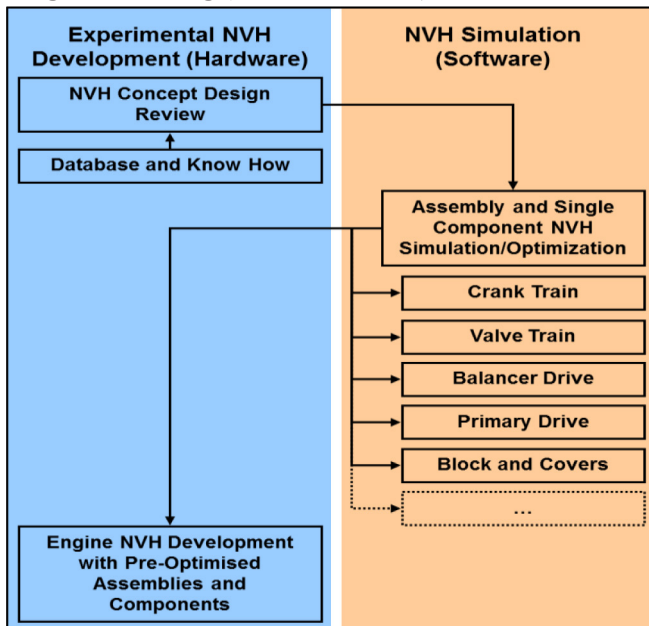


Figure 7. Hybrid development approach

The requirement to lower the mechanical noise contribution leads to the definition of also level 2 (sub-system powertrain) targets and furthermore level 3 targets (component targets). For the assessment the entire engine, the subassemblies as well as major single components were evaluated focusing on the origin of structural vibration and airborne noise, the vibration transfer as well as the noise radiation. Based on the review a number of standard simulation tasks (see Figure 7) to investigate and optimize the NVH behavior of the following subassemblies were made.

- Crank train
- Valve train
- Primary drive
- Gearbox

Furthermore the major components and the engine structure was simulated using modal analysis and FEM in order to optimize the stiffness's, structural damping, resonances as well as the noise transfer path's and noise radiation of engine covers like

- Crankcase
- Alternator cover
- Valve cover
- Clutch cover

EXAMPLE 1: PISTON SLAP NOISE OPTIMIZATION

As a first example in the paper a motorcycle engine development is selected with the following boundary conditions:

- Lowest possible cylinder height for lowest possible vehicle silhouette (seat line)
- Optimum friction for good fuel consumption (small tank volume giving by styling)
- Lowest possible mechanical noise
- Parallel twin cylinder configuration

In order to achieve this requirements the basic concept of the powertrain was defined and to ensure lowest possible engine height different measures were considered. A short conrod with an unfavourable r/l ratio was necessary to achieve the lowest possible engine height. A cylinder offset was designed to manage the increased piston side forces due to the short conrod (see Figure 8). One major concern in this design was the piston secondary motion because of the selected engine concept.

To investigate the aggressive r over l ratio in combination with the cylinder offset a simulation was performed with EXCITE. The target of the dynamic piston simulation was to find the optimum cylinder offset in combination with piston pin offset in order to minimize the piston slap noise. [5] Following cylinder offsets and piston pin offsets were considered in combination with different engine speed and load conditions:

- Cylinder offsets: 0mm, 5mm, 10mm to ATS (Anti Thrust Side)
- Piston pin offsets: 0mm, 0.5mm, 0.75mm, 1.0mm to TS (Thrust side)
- Load conditions: 100% , 25% load, 0% load
- Engine speeds: 1000rpm, 2000rpm, 3000rpm, 4000 rpm, 5000rpm, 6500rpm