Methodology for Controlling Equipment Noise Behaviour

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Abstract. Increasing the noise reduction requirements for both the users and the environment has led to an increasing need to control the noise and vibration (NV) behaviour of new equipment. This problem arises in practice in the form of various specific and often determining development contingencies: reduction in weight and size of structures, reduction in cost and design time and the external supply of components. For these reasons, optimising the noise and vibrations of equipment requires an overall methodological approach. The elaboration of such a methodology constitutes the object of this contribution. The methodology is first of all based on the principle of dividing up the overall behaviour of the equipment into a reduced number of situations and performances, which in turn are decomposed in terms of dominant contributions. Secondly, the control of the contributions is carried out within the framework of a pre-defined analysis along three main lines: establishing the behaviour criteria of the components, specifying these criteria to the suppliers and controlling and optimising the performance of the critical components. The main interest of this approach lies in the fact that it provides the manufacturers, before the designing stage, with a structured and specific overall schematic diagram of the main actions to be undertaken in relation to noise and vibrations (methodological sections), and enables a specific knowledge base to be drawn up during the development phase. The case study of the noise and vibration optimisation of the VAL208 metro is presented. By identifying and providing a detailed characterisation of all the main elements that need to be taken into consideration for NV optimisation, this case served as a basis for the elaboration of the methodology proposed.

Keywords: acoustics, noise control, equipment, transport, vehicle, methodology, vibroacoustics, noise impact, structure-borne sound, metro, railway, conception, vibration, measurement.

1. Methodology

The next diagram presents the overall methodology (Fig. 1). At the pilot study stage, noise and vibration (NV) objectives must be formerly defined : choice of representative working situations of the equipment, level values, qualification methods. Defining NV objectives can represent a substantial task, if no reference values or methods are available. There is an advantage in performing this task in parallel to the identification of the design contingencies *vs.* NV optimisation (available NV resources, prototyping schedules, external components supplies, etc.). As soon as the design begins, the initial evaluation plan (IEP) is started. The equipment is decomposed into sub-elements with close regards to NV optimisation purposes.

At this stage, the equipment generally exists only through plans and various studies, and obtaining a suitable decomposition implies having a clear overall understanding of the global functioning of the equipment. Based on the obtained decomposition, the identification of the main potential NV contributions must then be performed (Fig. 2). To do so, it is necessary to collect all the experience from the actors of the design: known problems, state-of-art, previous observations and conclusions, etc. The equipment is characterised as objective -> elements -> contribution segments. The segments can be roughly classified against a given objective, from the most potentially critical to less critical contributions. At this stage, the options for the control of the main contributions must be identified and presented : for each contribution, depending on a large and multi-faceted range of aspects and parameters (available NV analysis resources, advantage/disadvantage of prototyping and/or simulating, expected frequency ranges of interest, development responsibilities, etc.), an appropriate approach must be implemented. This procedure, which consists in practice in setting-up the NV Contributions Control Plan (CCP) is the crucial part of the methodology. It requires expertise to evaluate the interests and contingencies specific to each tool in the palette of existing NV methods and the practical problems encountered by the industrialists developing new equipment.

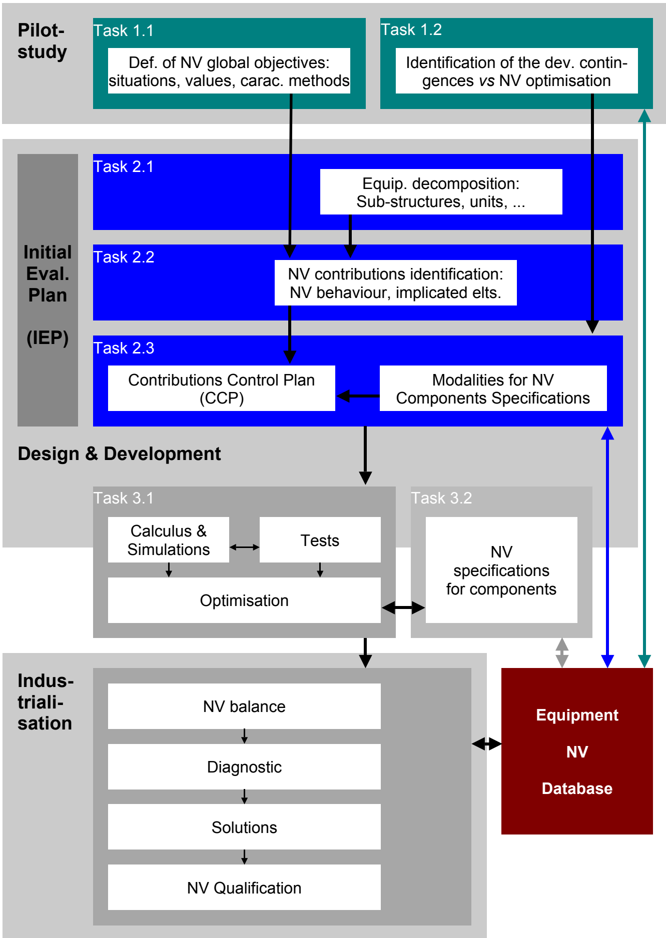


Fig. 1: Methodology

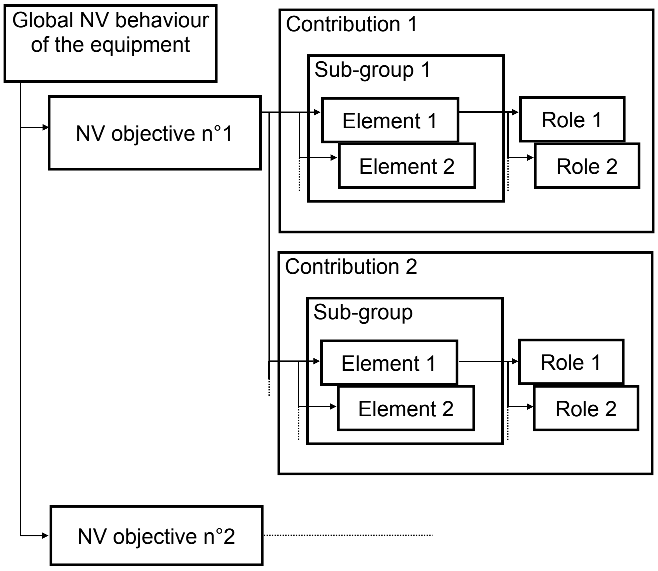


Fig. 2: Identification of NV contributions

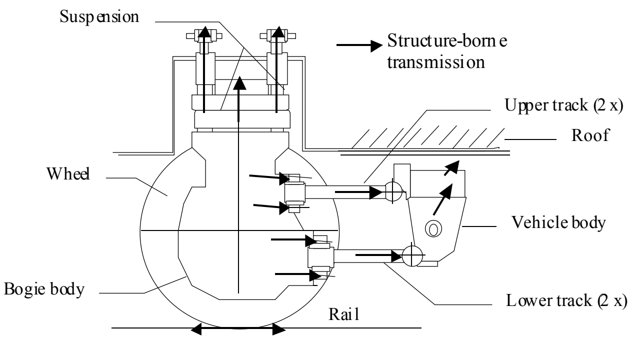
2. Application

The methodology was elaborated on the basis of the NV optimisation carried out on the VAL208 light automatic metro. At the beginning of the development, NV specifications were emitted by the *maitre d'oeuvre* to plan both inside noise levels (comfort for passengers) and outside noise levels (urban disturbances) of the new vehicle. The application of the methodology described hereafter presents the actions performed to control the structure-borne contribution of the gear reductor to inside noise.

2.1 Identification of the components and their role into the contribution

The gear reductor is situated in the wheel. The gear and the wheel are part of the rolling bogie, which is linked to the vehicle body by the suspension and 4 tracks (Fig. 3).

Fig. 3: VAL208 Location of the gear reductor, and elements of the structure borne transmission path



Noise measurements carried out on the previous generation of vehicles (VAL206, 1983), of similar design, show that the gear induces strong time peaks and frequency emerging stripes during the accelerating phase 0 - 20 km/h of a running cycle.

2.2 Contribution Control Plan (CCP)

To control this contribution at the design stage of the new vehicle, the following aspects have to be taken into account - location of the gear reductor, - reduction ratios and forces, - gear reductor technology : tooth profiles, state of surface, damping materials, etc.. - structural characteristics of the crankcases of the gear reductor, - dynamic characteristics of the transmission path between gear reductor and vehicle body, - acoustic response of the body to the structure-borne transmission. Thus, controlling the gear reductor contribution to the inside noise during the accelerating running phase 0-20 km/h means finding an optimal arrangement between the parameters corresponding to the above listed aspects. In practice, such an approach, which requires detailed data on each component, is hardly reliable due to the simple fact that in most cases the data are not available at this stage of the development. So it was decided at the CCP stage to concentrate first the NV optimisation efforts onto the other major contribution of inside noise (airborne transmission), and to specify global NV limit values and bench test requirements to the suppliers of the components involved in the structure-borne transmission path. Then the CCP planned to optimise further the structure-borne contribution by means of - NV characterisation measurements on the prototype of the full vehicle, on bench and running - dynamic simulation of the transmission path.

2.3 Contribution control: optimisation of the dynamic behaviour of the transmission path

The vibration records made on the track links body and heads of the prototype of the vehicle show that the tracks amplify the vibrations in the 315 and 400 Hz band. Comparison of these results to the measurements done previously by the suppliers on the individual components show that the critical behaviour corresponds to the first vibrating modes of both the gear reductor and of the electrical motor. To optimise the transmission path, the dynamic behaviour of the transmission path was then investigated with a model established in the frame of the CCP (Fig. 4). Small displacements with five degrees of freedom were considered : translation and rotation of the half-bogie, translation of the upper track, translation of the lower track, body part in rotation. The behaviour of the model was then simulated, considering various combinations of the mass of the track bodies and elasticity of the SilentBlocks of the heads of the tracks.

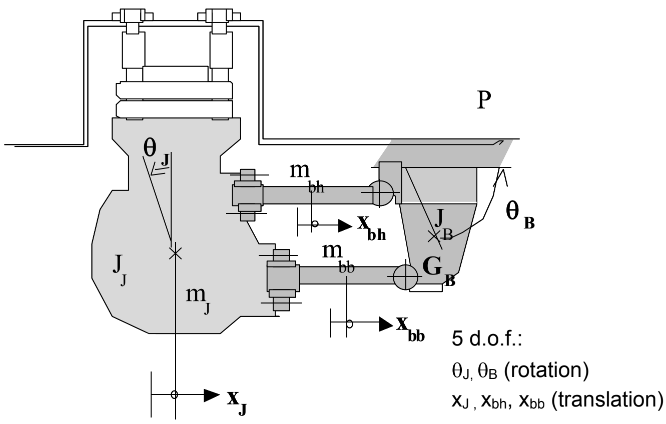


Fig. 4: Dynamic model of the structure-borne path

For each combination, the angular velocity response $d\theta_B/dt$ to an excitation force of constant amplitude applied at the base of the bogie part was calculated. Comparing the responses to the nominal response (standard tracks), the corresponding relative acoustical gains were estimated for each combination (Fig. 5).

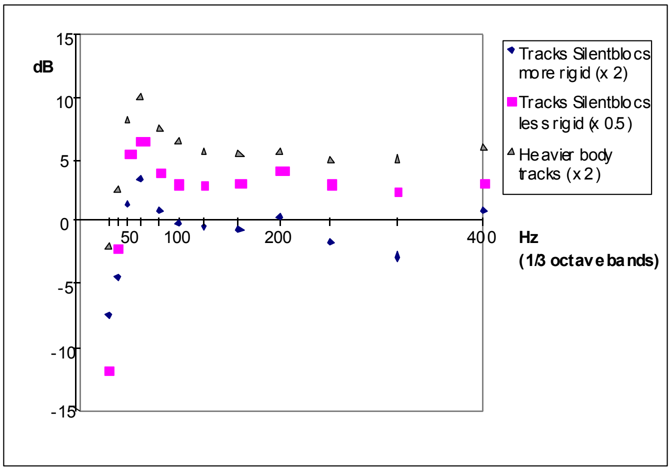


Fig. 5: Expected acoustical gain of modified tracks compared to the nominal tracks configuration

It appears that modifying the track links (Silentblocs less rigid, heavier body) can result in a diminution of about 3 to 6 dB of the noise levels in the critical frequency bands of 200 to 400 Hz observed inside the vehicle.

3. Conclusion

The main interests of the proposed methodology are - to bring a global and pre-defined scheme specific to the NV optimisation process, that can fit into the main classical stages of a new development, - to enable the NV optimisation efforts to be shared between all the actors of the development, on the basis of common improvement criteria, - to tend to the constitution of structured NV know-how and characterisation databases specific to given categories of equipment. The main difficulty encountered in its application lies in determining and formulating suitable individual NV parameters to the various components of each contribution, knowing that - specifying NV behaviour for a given representative situation requires in practice the specification of a large number of parameters, - the parameters can generally present a high variability.

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References

Chritin (V.), 1997, *Méthodologie de maîtrise du bruit des équipements*, PhD Thesis n°1678, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland.

Chritin (V.), 1993, *Optimisation du comportement au bruit d'un véhicule ferroviaire léger (métro)*, Proc. Acoustics'93 IOA/SFA, Southampton, pp355 - 362.