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# Gearbox Whining Noise Modeling: Experimental Validation of a Computational Scheme

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## Abstract:

*LTDS and VIBRATEC founded the Labcom LADAGE (gear dynamics joint laboratory) to develop numerical methods and simulation tools for predicting gear dynamics, in order to follow the evolution of industrial demand towards more and more complex systems. One of the goals is to take account of multiphysics couplings between internal and external excitations. Geared systems are the seat of vibrations induced by the meshing principle itself. For this reason, a gearbox is an important source of noise and vibration in automotive. The gearbox internal sources of excitation are various. For instance the whining noise arises from loaded shafts especially when the gears are not optimized in that sense, e.g. the gear reverse noise on a low-class car. The internal excitation that arises from the meshing is a parametric excitation and is transmitted to the gearbox housing via the shafts and bearings.*

*The aim of this work is to present an efficient computational scheme which allows the calculation of the whining noise of complex geared systems. In this paper, the method is applied to a two-stages automotive gearbox.*

*The global procedure is presented on Figure 1. First the parametric excitations, i.e. the transmission error and mesh stiffness, are characterized through the macro and micro-geometrical characteristics of the meshing gears. These values are one of the input data of the complete computational procedure. Then, the numerical scheme requires a finite element model of the complete gearbox in order to obtain its modal basis. To achieve that, the mean value of the mesh stiffness is taken, leading to mean modal characteristics. Indeed, the contact between the gears is modelled with a stiffness matrix linking the degrees of freedom of each pair of meshing gears. Then a powerful resolution algorithm in frequency domain is used to solve the dynamic equations with an iterative procedure. This original spectral iterative method can take into account more than one parametric excitation. In that case, there is a coupling between the excitations due to the stiffness fluctuations.*

*The final outputs are the housing vibrations as functions of the frequency and of the motor rotation speed. The amplitude of the housing vibrations and the frequency position of the peaks characterize the whining noise severity. The process can be repeated for several applied torques and can be used to optimize the teeth geometry and the other gearbox components (for instance the geometry of the housing to minimize its vibration, stiffness of gear bearings...).*

*Measurements have been performed on the physical system, showing that the computational scheme lead to satisfying results. Indeed the differences observed between the simulations and the measurements are totally acceptable for quantitative assessments. A noise contribution ranking can be done, order by order or excitation by excitation and the dynamic response order of magnitude is correct.*

The computation scheme has been validated step by step by comparison with extensive and complex measurements on a modified but representative automotive gearbox.

Four quantities have been measured: the static transmission error fluctuation, the dynamic transmission error (intermediate quantity that corresponds to the fluctuation of the transmission error due to the gearbox dynamic behavior), housing vibrations and whining noise. Accelerometers, microphones and optical encoders are used in this way. In this paper, the results are mainly focused on the housing vibration.

The measurements were performed at RENAULT's workshop in Lardy in France, on the BACY acyclism test bench. An electrical motor drives the gearbox, while a braking torque simulates the reaction of the wheel. The rotation speed and the torque are also measured. In order to compare properly the vibration measurements with the computations, an order tracking has also been done.

The numerical procedure is globally validated and can be used to optimize the current studied gearbox. The computations will allow identifying the key parameters to minimize the whining noise for given functioning configurations. As the computation time is low enough to run an important number of dynamic calculations, parametric studies are easily achievable. The measurements made cannot take into account the variability of the results, but the simulation can. Extracted from teeth metrology, a dispersion study has been made to determine the envelope of the dynamic response.

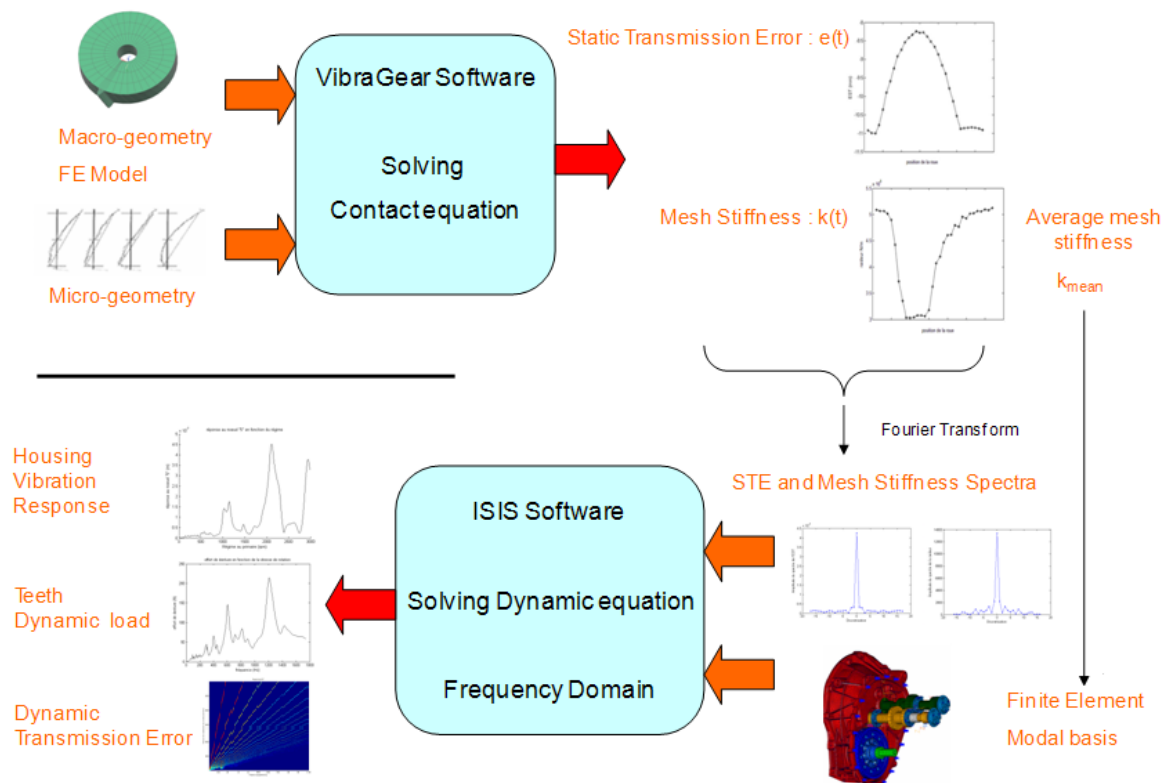


Figure 1: Overview of the computational scheme

**Keywords: Whining noise, gearbox, simulation**

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