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DESIGN SUPPORTING ANALYSIS FOR POWERTRAIN NOISE AND VIBRATION

B Loibnegger & G Ph Rainer

AVL Gesellschaft fuer Verbrennungskraftmaschinen und Messtechnik, Graz, Austria

1. INTRODUCTION

The development of low noise engines, especially for passenger cars is a strong demand of the automotive industry. On the one hand the legislative limits for the exterior noise of a vehicle can only be achieved, if the noise emission of the combustion engine considerably is reduced. On the other hand the vibration transferred from the engine mountings into the passenger compartment has to be minimized to fulfil comfort criteria. Optimum design solutions can only be obtained if the design engineer is supported by complex calculations in a concurrent egineering process. The close interaction of design and calculation can only be achieved if reliable simulation tools are available providing results of high accuracy to the design engineer. To get confidence in such simulation tools it is necessary to validate the numerical results by measurement results during the software development phase.
The following chapters describe the simulation tool NIDYN developed in a European Joint Research project and the validation via measurements.

2. SIMULATION PROCEDURE

Fig. 1. shows the simulation procedure, based on FEM, for noise and vibration simulation established at AVL [1] including the following steps:

Creation of the FE-Models

FE-models of all engine parts are set up. The fineness of the models depends on the target of the calculation. Parts which are optimized during the calculation are modelled in detail, e.g. cylinder block, and parts which are only included to consider stiffness and mass distribution are modelled with coarse meshes, e.g. auxiliaries [2].

Eigenmode Analysis

This analysis offers the possibility to find out, whether various components of the engine show natural frequences grouped within a narrow frequency band.

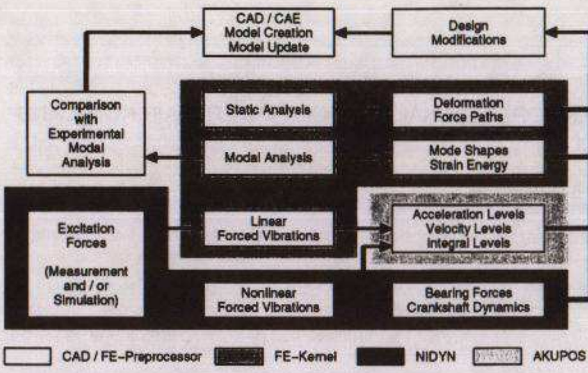

Fig. 1. Procedure for noise and vibration calculation

Based on the modal analysis, the design engineer may carry out structure modifications [3]. Moreover, if an exprimental modal analysis is available, the accuracy of the calculation model can be verified.

Excitation Forces

Forces and moments, which are an external input for the simulation of the forced vibrations, have to be determined by pre-calculations using different software or by measurement. The main exitation forces are: gas forces, piston impact and valve train forces. To calculate the piston movement including kinematic and piston secondary motion AVL uses the software PISLAP. The excitation forces in the timing drive are caused by impacts in the valve train and gear train, on the one hand, and by the rotating inertia forces at the camshafts on the other. AVL uses the software VTDYN to calculate the dynamic loads which act on the cylinder head, at the valve seats and in the bearings of the camshafts.

Nonlinear Forced Vibration Calculation

The tool for the nonlinear forced vibration simulation is the software NIDYN [4,5]. The scheme of the principle interactions is shown in Fig. 2. The "heart" of the simulation procedure is the inclusion of the large motion of the cranktrain, the gyroscopic effects of flywheel, pulley and counterweights and the nonlinear oil film in the bearings to couple vibrating structure parts.

NIDYN treats each engine part (e.g. block, conrod, crankshaft) as a separate structure. The coupling of the different parts in the conrod and main bearings is performed by nonlinear stiffness and damping forces and EHD (ElastoHydroDynamic) forces. The engine block, including cylinder head, adjacent parts and auxiliaries is modelled by Finite Elements which are reduced to about 2000 master degrees of freedom to save computing time. Engine parts which undergo large motions (e.g. conrod and crankshaft) are modelled with beam-mass elements which are tuned by comparison of stiffnesses and natural modes with measurements or volumetric FE models.

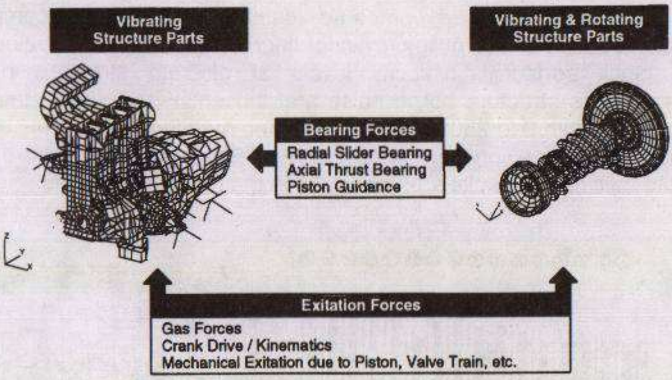

Fig. 2. Schematic interaction for simulation procedure with NIDYN

Additionally several damping effects are included in the model. The damping properties of the main bearings act locally in the calculated EHD oil film forces. The damping effects of the torsional damper and engine mounts are also simulated. The simulation is carried out the in time domain, due to the nonlinearities of the calculation model and the oil film forces, using an implicit integration method (NEWMARK).

Results

As results, distortions, velocities and accelerations in the time domain are calculated. To perform acoustic evaluations these are transformed into the frequency domain via FFT. Usually velocity or acceleration levels on the engine surface are used to judge the quality of the design. Fig. 3 shows the influence of different applied load cases, - the left one with only gas load and the right one with gas load, piston impact and valve train loads - on the integral velocity levels.

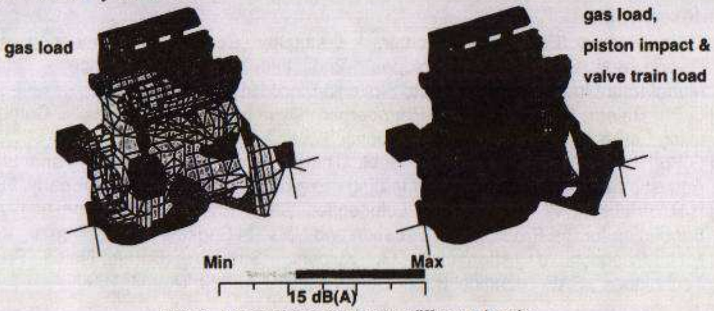

Fig. 3. Integral levels due to different loads

3. VALIDATION

To determine the accuracy of the calculation results, comparisons with measurement results obtained from a 1.8 gasoline engine have been made. From the variety of compared results - journal displacements, torsional vibrations of the pulley, cylinder liner accelerations and velocities at the block surface - velocity levels at discrete structure points representing the structure borne noise are chosen. Fig. 4 shows integral velocity levels from 0 to 2500 Hz of the selected measurement points at the engine block surface, on the exhaust side at 6000 rpm. For most of the points the calculated results are very close to the measured results.

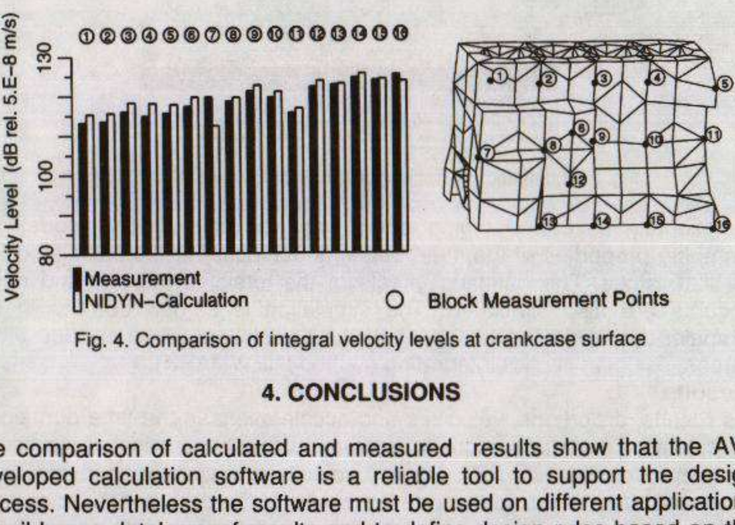

Fig. 4. Comparison of integral velocity levels at crankcase surface

4. CONCLUSIONS

The comparison of calculated and measured results show that the AVL developed calculation software is a reliable tool to support the design process. Nevertheless the software must be used on different applications to build up a database of results and to define design rules based on the calculation.

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