

Using AVL EXCITE for Engine Design

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Keywords: cranktrain, dynamics, durability, bearing

Designing a modern advanced powertrain system presents many challenges and requires careful trade off assessment of multiple mutually exclusive design objectives and metrics. The design tends to be done with very short design timing and very cost effectively. These requirements lead to heavy reliance on numerical simulations and CAE modeling. AVL Excite provides CAE capabilities that address the engine design requirements. This paper demonstrates several applications of using AVL Excite for engine system dynamics, crankshaft durability, and bearing assessment.

Influence of shell contour, journal shape, bearing clearance and oil viscosity on conrod big end bearing results.

Authors (please underline main author): Dipl. Ing. Gerald Pichler

Company/ University, Department: SinusPro GmbH

Keywords:

shell contour, journal shape, bearing clearance, oil viscosity, conrod big end bearing, EHD simulation

Abstract:

Due to harsher regulations and more environmental concerns, it is essential to increase the efficiency of the internal combustion engine. On par with efficiency, the engines longevity has to be increased as well, to avoid costly engine maintenance and waste of precious natural resources. We help achieving this goal using advanced simulation tools to optimize the bearing hydrodynamic and mixed friction behavior by modifying the following parameters:

- bearing shell contour
- journal shape
- bearing clearance
- oil viscosity

This lets us help improve:

- longevity
- engine-development-costs
- friction
- bearing material choice

The presentation will give an overview of the influence of each of these parameters used to achieve the technical goals.

Creep deformation in journal bearings under constant load: Influences and Effects

Authors (please underline main author): Christopher Sous, Gero Burghardt

Company/ University, Department: Institute for Machine Elements and Machine Design,
RWTH Aachen University, Tribology

Keywords: Journal Bearing, EHD, Creep, Plastic Deformation, White Metal

Abstract:

(please use Times New Roman, 12 pt., max. 400 words)

In journal bearings the material of the journal shell often differs from the shaft material. Nowadays a wide range of different bearing materials is offered by manufacturer. An often used alloy is white metal. This material shows significantly different creep behaviour than steel.

In design guidelines no absolute pressure values but mean pressures are used for maximum load capacities. Since the creep behaviour is controlled by load and temperature, the much higher maximum pressure in the sliding contact will lead to high deformations in smaller time intervals.

The creep deformation which ensues changes the oil film build-up. This reshaping of the sliding layer surface results in asperity contact and ultimately in failure. Therefore, at first safe operating bearings will fail after some time.

In this report simulations are conducted on a hydrodynamic journal bearing operating under constant load and rotation. The report is focused on white metal as bearing material. To highlight influences on creep deformation variations in the simulations are load, rotational speed, sliding layer thickness and creep law parameters. Furthermore, the effects of creep deformation on operating conditions of journal bearings are outlined.

Simulation of an axial thrust bearing in a Heavy Duty Diesel Engine valvetrain using the AXHD joint in EXCITE Power Unit

Authors: Andrew Spencer, Hubert Herbst

Company/ University, Department: SCANIA, Dynamics and Acoustics

Keywords:

Tribology, AXHD, friction, axial bearing

Abstract:

A model has been developed in EXCITE Power Unit of a bearing assembly supporting a gear in a HDDE valvetrain, composed of a journal bearing and two axial bearings as illustrated in Figure 1. The EHD2 and AXHD joints in EXCITE Power Unit were used to develop an elastohydrodynamic model of the bearing assembly. Furthermore, thermal effects were incorporated into the model by iterating between EXCITE and a heat transfer and thermal expansion finite element model developed in ABAQUS, shown in Figure 2. Frictional heating from the bearings in EXCITE and the cooling effect of the lubricant flow through the bearing was input into ABAQUS and used to calculate the temperature of the bearing surfaces and the change in bearing clearances due to thermal expansion. EXCITE and ABAQUS were iterated between until a converged solution was reached.

The importance of tribology boundary conditions in the model and the effect that they have on bearing performance was also investigated.

The model was able to predict elevated temperatures due to frictional heating and from the understanding gained through these simulations a design change was implemented to improve the bearing performance. The results were compared with temperature measurements taken during engine tests and the data correlated well.

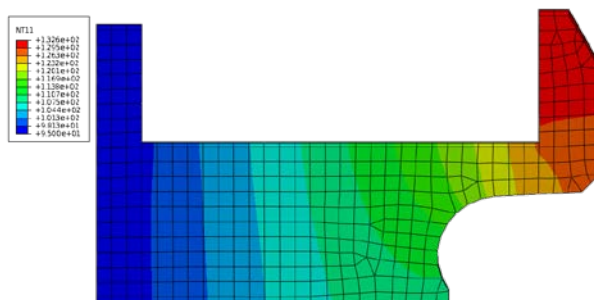


Figure 2 - Thermal model in ABAQUS

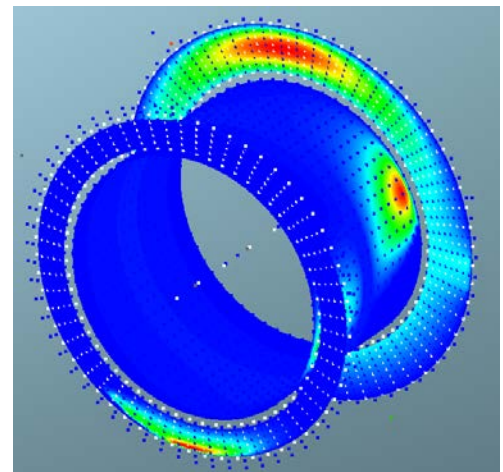


Figure 1 - Bearing assembly model in EXCITE Power Unit

The modelling approach was not only beneficial in time and cost savings by reducing the number of hardware iterations and engine tests required to develop the components, but gave a fundamental understanding of the tribological behaviour of the system that would not have been possible to gain from testing alone.

Cranktrain Bearing Parametric Study - *To Guide Designs*

Authors (please underline main author): Lin Chai

Company/ University, Department: FCA Fiat Chrysler Automobiles

Keywords: Cranktrain, Bearing, Oil Film Thickness, Friction Loss

Abstract:

The objective of this study is to perform bearing analysis and evaluate the effect of each proposed cranktrain design parameters (bearing clearance, width and diameter) by comparing: oil film thickness and cranktrain frictional losses, then to provide guidelines for cranktrain parametric design.

AVL Designer/Excite was employed to have parametric study during concept development phase.

Cranktrain System Assessment of Ecotorq 12.7 Litre Diesel Engine

Authors: O. Deliktas, M.S. Tabak

Company/ University, Department: FORD OTOSAN, Powertrain Engineering, CAD/CAE Department, Powertrain NVH&Dynamics CAE Team, Sancaktepe AR-GE Merkezi, Akpınar Mah. Hasan Basri cd.

Keywords: Torsional vibration, hydrodynamic lubrication, elasto-hydrodynamic lubrication, durability, multibody dynamics

Abstract:

Cranktrain system is the heart of an internal combustion engine. Simulation technology should give direction to design from concept phases to lately physical test stages. Simulation should also give support even after the automobiles appear on the roads. CAE methods are the quickest way to see the effect of a parameter change for fixing a problem in ongoing product development.

In this study, a series of cranktrain simulations which have been performed during the development of Ecotorq 12.7 litre heavy duty diesel engine, are presented. Torsional vibration characteristics of the cranktrain system are analyzed in AVL Excite Designer. It has also been used for hydrodynamic bearing simulation to gain insight regarding the bearing performance. After the component designs have become mature enough, multi-body dynamics model of the heavy duty engine has been built in AVL Excite Power Unit, and the simulations have been carried out with elasto-hydrodynamic joints. A local model has been used for big end bearing calculations and a global model has been built and run for main bearing EHD assessment. This global MBD model has also been used to provide loads for crankshaft and conrod durability analyses.

Introduction of AVL Excite into Cummins Standard Analysis Process

Ilya Piraner and Derek Liu, Cummins Inc.

Keywords: engine design, component analysis, connecting rod bearing, crankshaft

Abstract:

Cummins has a standard for engine development process and a part of this process is ESW – Engineering Standard Work. Each components/subsystem/system has to go through a set of analysis tasks before it gets made and tested. The task specifies failure mode it addresses, basics of the analysis, tool used and the limit associated with this tool. Because of complexity of engine systems, to large extent, these limits have historical nature and reflect successful engine design practice rather than fundamental mechanical properties of the materials used. Therefore introduction of a new tool is a difficult and slow process. However, continuous trend in increasing power density while reducing weight and size of the engines necessitates applying new, more advanced tools to insure reliability of the systems and components. Therefore Cummins started on introduction of AVL/Excite for engine dynamic and tribological analysis, first for research and troubleshooting purposes. Accumulating results for various engine families and applications will lead to developing design goals for new engine. The paper gives few examples of using AVL/Excite for troubleshooting and improving design of the connecting rod bearing and crankshaft for few Cummins engines.

Using OptiStruct with AVL EXCITE

Authors: Harold Thomas

Company/ University, Department: Altair Engineering, Inc.

Keywords: EXCITE, FEA Solver, Flexible Body, .exb File, Dynamic Stress Recovery

Abstract:

The OptiStruct FEA Solver from Altair Engineering provides the complete interface to AVL EXCITE for flexible body generation and dynamic stress recovery. The interface is directly coded in the OptiStruct software and therefore no version dependent DMAP, macros, or scripts are required to use OptiStruct with AVL EXCITE. The results of AVL EXCITE dynamic analysis can be used by OptiStruct to calculate the displacements, velocities, accelerations, stresses, and strains within the flexible body for transient analysis and direct frequency response analysis. For ease of use, OptiStruct uses the same input data format as NASTRAN.

OptiStruct directly generates the flexible body input data file (.exb) for AVL EXCITE. This data includes the:

- Connection and interior grid information
- Condensed mass and stiffness matrices
- Full diagonal mass matrix
- Eigenvalues and eigenvectors of the condensed system
- Full or partial mesh displacement recovery matrices
- Inertia Invariants

The specification data required to generate the .exb file is just the single command: PARAM,EXCEXB,YES. Since the .exb file is generated directly, no large intermediate files and extensive translation time is required.

The generation of the condensed mass and stiffness matrices is very efficient in OptiStruct. The generation time can be much less than that of others solvers because the eigenvalue analysis can be performed with the AMSES multi-level eigensolver.

Complex models may contain different parts that have been meshed independently, such as the flywheel and the crankshaft. OptiStruct has the contact option "FREEZE" that allows for tied contact between solid meshes that do not match. Using the FREEZE contact option, multiple parts can be assembled easily.

The OptiStruct MODEL data can be used to specify subsets of grid displacements and stresses to be calculated by AVL EXCITE. This leads to much smaller input files and computation times. Consider, for example, the case of grid point stress calculations. Since the highest stresses are usually on the surface of the structure, there is little reason to calculate stresses for the internal grids of the structure. Using the OptiStruct MODEL data, the user can

specify stress data recovery just for the set of surface grids. This greatly reduces the size of the input data files and the computation time for AVL EXCITE.

After the AVL EXCITE analysis, the modal participation coefficients can be passed back to OptiStruct for post processing analysis (transient analysis and frequency response analysis). OptiStruct will then calculate motion, stresses, and strains, based on the AVL EXCITE analysis. The stresses can be passed directly in the .h3d or .op2 file format to commercial fatigue analysis codes. This post processing analysis is very fast in OptiStruct because, unlike with other FEA solvers, there is no regeneration of the flexible body super element.

Valve Train Dynamics Study for Two Wheeler Engine

Authors (please underline main author):Rajagopalan Varadarajan Ranganathan, Balasubramanian Tiruvallur Loganathan, Arun Kumar Ramanathan, Lakshminarasimhan Varadaiyengar

Company/ University, Department: TVS Motor Company Limited

Keywords: Valve train, dynamics, deflections, two wheeler engine, spring characteristics

Abstract:

Valve train design is very critical for the high performance engines. High-speed dynamics measurements help to confirm valve train performance and durability.

1D modeling of valve train dynamics is done in AVL Tycoon, measurements of valve displacements with respect to cam angle is verified in motored test rig.

Base engine measurements indicate lower maximum engine speeds before start of jump and bounce. Optimization of valve train parts is carried out to lower the weights, 3 different designs of valve spring is evaluated in model and experiments to finalize spring loads. Effect of spring relaxation, Valve opening & closing ramp is studied in the model and compared with measured results. Further the effect of valve train stiffness on the dynamics of the system is characterized and optimized to achieve minimal deflections.

Flexible multi-body dynamic modeling of an entire PSA I4 cylinder diesel engine

Authors : Haythem KRICHE

Company: Alter Solutions

Keywords:

Excite Power Unit, Excite Timing Drive, Crank Train, Timing Drive, Crankshaft, Camshafts, Dynamics, Co-simulation

Abstract:

The Multi-body dynamic (MBD) modeling is an essential stage to design the moving components of the engine like the Crankshaft, Camshafts, etc... In PSA Company Excite Power Unit (EPU) is the reference software used in the Crank Train MBD modeling. It provides advanced CAE modeling capabilities to accurately model the dynamic crankshaft's behavior in view to improving its fatigue resistance and vibration performance.

The Purpose of the work done by Alter Solutions Company to PSA Company is to improve the current standard EPU Model (only crank train) by adding the Camshafts. The whole model lets us get the dynamic loads in the bearings of camshafts and so to accurately design this key part in the engine. The coupling of Crank Train part and the Camshafts is done by the Timing Drive system modeled in Excite Timing Drive (ETD). The co-simulation between EPU and ETD ensure the connection between the two models.

In this study we try to demonstrate the feasibility of this model and to compare the results obtained by a standard model and a whole model especially for the crankshaft.

Methodology for camshaft bearing failure investigation of an automotive valve train system

Authors (please underline main author): Henrik Jansson*, Saša Bukovnik** , Gudrun Kreuzwirth**

Company/ University, Department: VOLVO Car Cooperation*, AVL List GmbH**

Keywords: valve train, elasto-hydrodynamic, bearing, wear

Abstract:

This paper presents a new methodology for camshaft bearing failure investigation of an automotive valve train system. The method is applied and demonstrated for a new design variant of a VOLVO 4-cylinder 16 valve diesel engine. Nowadays the standard for VT analysis is classical dynamic simulation with simplified bearings as typically camshaft bearing failure in valve train systems are not often observed.

New designs have higher loads and use camshafts with reduced diameter to reduce friction, which increases bearing loads with reduced carrying capacity. The particular design of this investigation has a high pressure injection pump mounted on the back side of the intake camshaft. In this layout the timing belt is driving the intake camshaft and the intake camshaft is driving the exhaust camshaft via gear mounted at the back of the camshaft. The reduced camshaft diameter and the high radial load from the gear and the injection pump represent a potential danger for the intake camshaft rear bearings. High load torque that appears at the camshaft pulley results from superposition of different torques from intake camshaft, exhaust camshaft and the injection pump. The resultant high torque causes high belt forces, which represent a potential danger for the camshaft front bearing close to the belt pulley.

This requires a full system approach including full valve train, timing drive as well as detailed elasto-hydrodynamic bearing models, solving Reynolds equation, to consider all interaction, load mechanisms and their effect on the bearing behavior. The simulation model considers fully flexible FE based camshaft and cylinder head structures. The timing belt is modeled as a discrete model together with the hydraulic tensioner and the idlers.

With obtained results for the oil film and oil flow through the bearings it is possible to make a valid conclusion about the bearing mechanical and thermal loads and about the bearing durability and wear. In addition stress and durability of the camshafts is investigated.