Vibration Observations in Final Drives

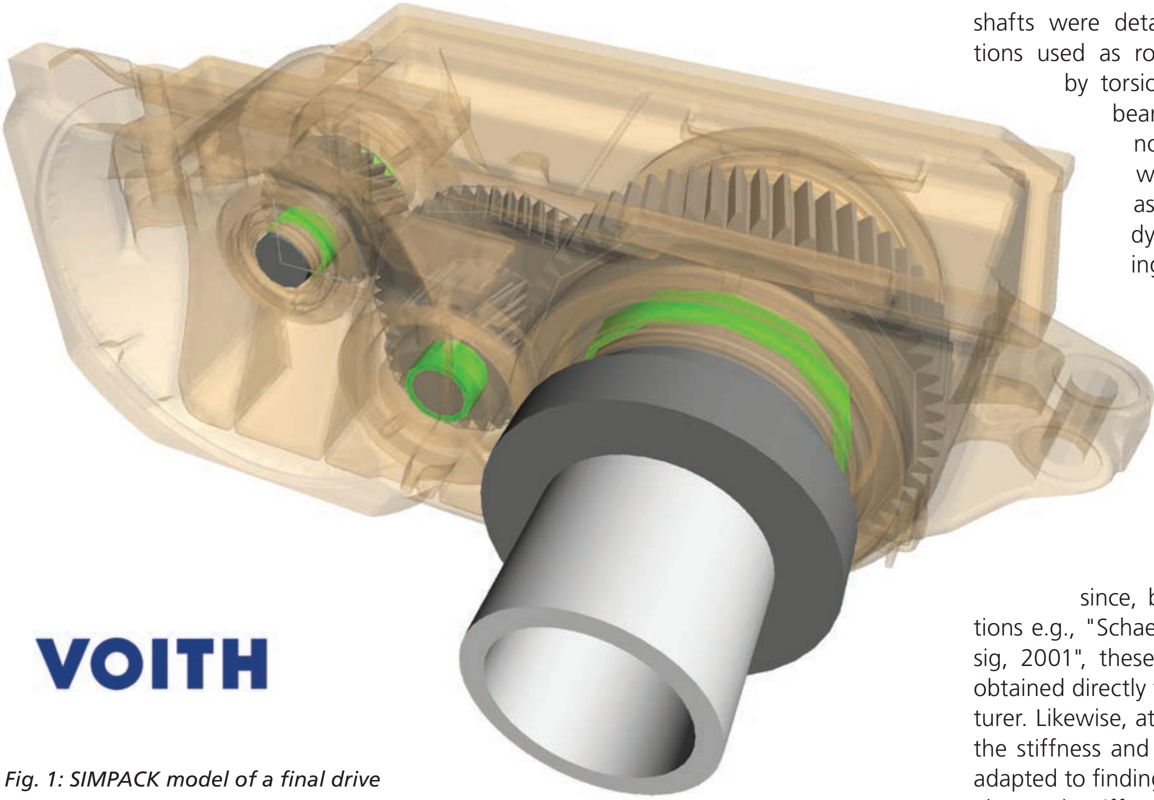

Fig. 1: SIMPACK model of a final drive

The use of CAE tools like SIMPACK in the development process is more important than ever. High product quality with ever shorter development periods is only possible with the early detection of issues like vibration phenomena that can lead to acoustic problems or damage. An example of this is presented as part of a bachelor's thesis at Voith Turbo GmbH & Co. KG in Heidenheim, Germany.

MOTIVATION

Railroad components are designed for long service life. This is typically achieved through robust construction. However, lightweight design is becoming more important in order to reduce energy consumption in operation. This brings with it an increased susceptibility to vibration phenomena, which can lead to the early failure of even well designed components. Accelerating development cycles aggravate the risk of bringing products to market prematurely. The objective of this bachelor's thesis is to determine what steps may be necessary in order to recognize vibration at an early stage of development using simulation to derive possible remedial measures.

METHODOLOGY

Simulative vibration testing requires a sufficiently realistic model. Accordingly, models with varying degrees of detail were created in SIMPACK in order to identify vibration influences. Brief time segments were examined using time domain calculation. The results were compared in the frequency domain in order to identify agreements and discrepancies between model and measurement. This method was applied to a two-stage helical parallel shaft gear unit, as used in electric locomotives (Fig. 1). The housing accelerations at various loadings were measured on a test bed and in a locomotive. On the test bed, the gear unit operates largely free of outside influences while in the locomotive, it is subjected to forces from the movement of the wheelset and bogie. Therefore, in order to provide a common basis for comparisons, a model of the final drive was created while the wheelset shaft, electric motors and other components were not considered.

MODELING

To model the gear unit, the shafts were broken down into torsional oscillators. The shafts were detached; the individual sections used as rotating masses and linked by torsional stiffnesses. The roller bearings were represented by non-linear characteristics, which SIMPACK implements as Input Functions. The dynamic stiffness and damping change, as functions of various parameters as described in "Weck, 2002", were disregarded. The static non-linear force-displacement curves of the roller bearings are sufficient for initial observations in the development process since, by means of formula relations e.g., "Schaeffler KG, 2012" and "Dresig, 2001", these can be approximated or obtained directly from the bearing manufacturer. Likewise, at constant operating points the stiffness and damping behavior can be adapted to findings from "Weck, 2002".

The teeth stiffnesses were modeled by the SIMPACK Gear Pair module. While most are just geometric, the "Teeth Stiffness Ratio" SR must be determined as the quotient of the minimum and maximum teeth stiffness. This was done using the teeth stiffnesses calculated by the DZP program from the Forschungsvereinigung Antriebstechnik (Drive Technology Research Association). For the addition of the drive rpm and load torque, dummy masses were applied to the drive and drive shaft. These masses can move in all directions with the exception of the direction of shaft rotation.

"The teeth stiffnesses were modeled by the SIMPACK Gear Pair module."

For example, a rheonomic joint or revolute joint can be used between the dummy mass and shaft, giving 6 degrees of freedom of motion to the shaft system.

Using FEMBS, the housing as a flexible body was integrated via the interface between Abaqus und SIMPACK. The gear model with housing is shown in Fig. 1.

FINDINGS AND OUTLOOK

In the gear unit described, time domain calculations were done at the same load points as the measurements. As may be seen in Fig. 2, evaluation in the frequency domain shows similar vibration behavior over wide ranges, expressed in similar amplitude

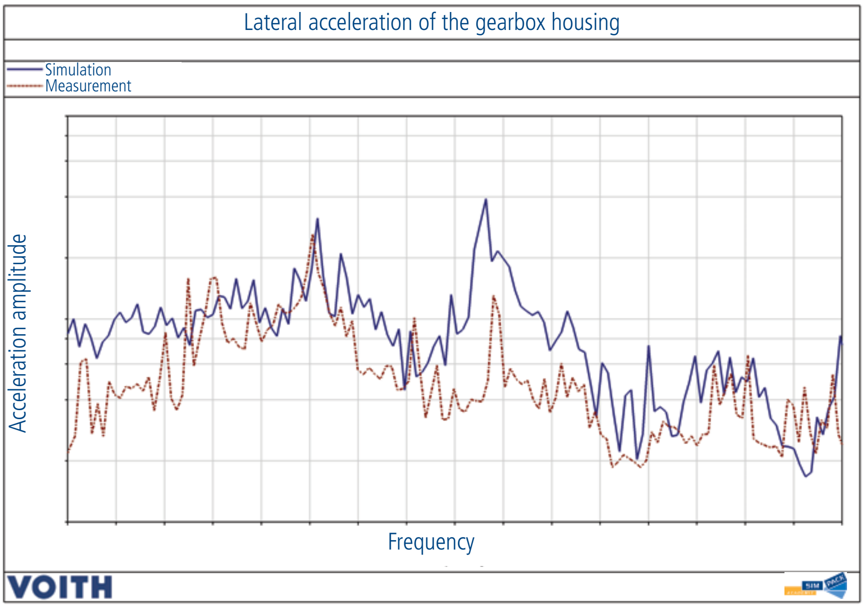

Fig. 2: Comparison of measurement and simulation

level at the housing and by agreement in resonance frequencies. This comparison is necessary in order to draw conclusions as to the plausibility of the model. A resonant frequency examination of the gear system was also performed. However, its validity is limited, as the stiffnesses in the highly non-linear gear model change constantly. Good agreement between the simulation model and actual measurements at the gearbox housing was noted, permitting the conclusion that high model quality is possible with a comparatively simple model without dynamic roller bearing models.

"Good agreement between the simulation model and actual measurements at the gearbox housing was noted."

Based on this, the following steps are recommended for the future:

- Creation of SIMPACK models of parameterizable standard final drive units
- Improvement in roller bearing and gear wheel models
- Full integration in development process

LITERATURE

[1] Dresig, H. (2001): Schwingungen mechanischer Antriebssysteme — Modellbildung, Berechnung, Analyse, Synthese. Berlin, Heidelberg, New York: Springer Verlag.

*[2] Schaeffler KG. (2012): medias® professional — Product Catalog. Accessed August 2, 2012 from http://medias.schaeffler.de/medias/de!hp.tg.cat/tg_hr*ST4_102146955;bjq0lsS62DR7*

[3] Weck, M. (2002): Werkzeugmaschinen — Konstruktion und Berechnung. Berlin, Heidelberg, New York: VDI-Buch, Springer Verlag.

[4] Weidemann, H.-J. (2003): Schwingungsanalyse in der Antriebstechnik. Berlin, Heidelberg, New York: Springer Verlag.

SIMPACK Academy in 2013

Fundamentals of Multi-Body System Dynamics

30–31 October 2013, Hotel Seitner Hof, Pullach/Munich, Germany

Speaker: Prof. Dr. Oskar Wallrapp

Multi-Body Dynamics is one of the most prominent subjects of mechanical, mechatronics and biomechanical engineering. A brief knowledge of kinematics and dynamics is essential for efficient usage of multi-body programs like SIMPACK. This course gives a detailed overview of the kinematics and dynamics of rigid bodies in multi-body systems.
At the end of the academy, participants will be able to understand the motion of rigid bodies attached by arbitrary joints and forces, setup small subsets of equations of MBS motion, and interpret the results of multi-body dynamics simulations.

For more information and registration please visit: www.simpack.com/simpack_academy.html