Modeling and analysis of gear excitations in a full scale gear test rig

Type: Internship for Master students
Duration: 6 months
Starting date: Flexible
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Gearboxes are vital and commonly used component in rotating machinery and power drivetrains. They exhibit an inherent coupling between shaft torques, gear tooth forces and shaft bearing forces, resulting in an interaction of the torsional and transverse system dynamics and vibration [1]. In order to design quieter gearboxes, the tooth contact mechanism under load needs to be understood. Time varying tooth mesh stiffness is the key parameter to excite tooth vibration, and various methodologies to compute this mesh stiffness can be found in literature [2-5].

The analysis of the interaction of gear meshing phenomenon with other interfacing components (such as bearing, shaft and housing) in a gearbox constitutes a crucial point during the NVH process. The dynamic characteristics of gears in operating conditions is usually complex and difficult to model in an exact way. Gear Transmission Error (TE) is widely recognized as the main gear-related source of vibration in power transmissions. It quantifies the deviations from a perfectly kinematic motion transmission which in a real case are introduced by deflections, misalignments and manufacturing errors. The evaluation of gear TE is a prerequisite for ensuring good noise, vibration and durability behavior.

![Image of a gear pair mounted on test rig](image_credit:SISW)

Figure 1: A helical gear pair is mounted and tested on the test rig (image credit: SISW).

The RTD team of Siemens Industry Software (SISW) in Leuven has implemented a state of the art numerical tool that allows to accurately model gear contacts within the Simcenter 3D platform. Simcenter 3D uniquely combines system simulation, 3D CAE and testing capabilities to model, evaluate and predict the performance indicators of different types of systems. In particular, various gear contact methodologies are implemented within the Motion multibody package. Several levels of accuracy and computational complexity are available ranging from simple ISO norms to advanced FE-based gear contact.
A special gear test rig has been designed for the purpose of validating the accuracy of the gear multibody simulation methodologies on the basis of experimental data. One of the main objectives of the test rig activities is the assessment of typical gear-related physical quantities in static and dynamic conditions, under controlled operating conditions (torque, speed, center distance, misalignment, etc.). This test rig provides the possibility of heavily instrumenting a gear pair under controlled operating conditions. A CAD of the test rig is presented in Figure 1.

The objectives of this internship are the following:

- Modeling different types of gears using Simcenter 3D;
- Validation of advanced numerical techniques used for gear contact modeling;
- Application of available processing techniques on the raw data obtained from numerical and experimental analysis;
- Analysis of the dynamic transmission error (DTE) for spur and helical gears in angle and order domain;
- Identification and classification of system harmonics in the spectrum;
- Performing (operational) modal analysis on the acquired acceleration data.

The following figures illustrate some examples of data processing analysis (see Figure 2).

![Figure 2: Some examples of the obtained results, both in static and dynamic conditions.](image)

A summary of the tasks is available below:

**Literature review**
- Understanding the fundamentals of the each gear contact computation method used in SISW tools;
- Review of fundamental signal processing techniques (sampling, windowing, frequency/order analysis, etc.);
- Understanding the spectral content of experimental or simulated data;

**Getting familiar with various software and tools**
- Simcenter 3D Motion: General purpose multibody simulation software;
- Transmission Builder (TB): Preprocessing software to automatically build complex gear transmissions;
- Simcenter Test.Lab: Acquisition and processing of raw experimental data;
- Matlab: Programming language used for implementing processing techniques;

**Performing signal processing**
- Post-process the measured transmission error signals acquired from the gear test-rig;
- Identification and classification of frequency/order harmonics: gear mesh, modulation, etc.;
- Create various types of plots, such as waterfall, spectrogram, etc. in different operating condition (speed and load);

**Validation (Simcenter models vs. experiments)**
- Compare the static or dynamic TE for each loading conditions;
- Iterate the validation process by:
• applying misalignments and center distance variations;
• increasing model complexity;
  - Validate the modulation sidebands of the gear systems;
  - Optional: Evaluation of the strain in gear body; To be compared with measured strain signals;

What do we look for in students?
This internship seeks a motivated student willing to dive into the various technologies present in the proposal. The requirements are listed here below:

**Essentials**
- **English language**: Effective communication and collaboration, both written and oral;
- **Independence**: Drive your own competence development and networking/teaming efforts;
- **Dedication and motivation**: Expand your skills and competences across the scientific and the non-technical dimensions;
- **Key assets towards industry**: Structured research approach, abstraction, develop an application view;
- **Programming**: Knowledge of Matlab is required;

**Desirable**
- **Programming**: Knowledge of Python or any other programming language is a plus;

SISW carefully evaluates each fellowship application before making a decision. After the revision of the CV and motivation letter, an interview with the candidate will be organized (either face-to-face or online). The final decision will be made after the interview. The student will be informed about the decision via email.

**Student benefits**
During this internship, SISW provides the student with:
- an apartment during the stay;
- a computer to be used for research during the stay;
- guidance and coaching for the research/work.

**Academic supervision**
The student has to propose an academic supervisor in the university in which he/she is conducting the research (usually a professor). The academic supervisor should be a member of the partner university. The second supervisor (technical) will be automatically assigned by SISW.

**Holidays**
In addition to the official (Belgian) holidays, the student is entitled to 10 holidays for an internship of 6 months.

**Company profile**
Siemens Industry Software (SISW) is a software and engineering company based in Leuven, Belgium, which is part of the Siemens PLM (Product Lifecycle Management) Software division. Originating as LMS International, one of the oldest and the largest spin-offs of the KU Leuven University, it was acquired in 2013 by Siemens to enable the development of a truly end-to-end closed loop.

The PLM solution portfolio helps industry in their objective to build the right product, and build it the right way. This quest is complicated by a number of factors, including increasing product
complexity, regulatory requirements, and global development with local requirements. To enable industry to turn complexity into a competitive advantage, the driving mission of SISW is to collaborate with companies to deliver open solutions that help them turn more ideas into successful products. As such, we help thousands of companies to make great products by optimizing their lifecycle processes, from planning and development through manufacturing and support.

References: