Vibrations in transmissions

KISSsoft Webdemo
17. April 2018
1. Motivation
2. Definitions of dynamic calculation
3. Modal Analysis
4. Forced response
5. Validation and literature
6. Excitation frequencies
7. Interfaces to vibration software
Motivation

The world is not static!

Dynamic loads cause damages
• overload due to resonance
• avoid resonance (operating speed not close to resonance frequencies)

Vibrations cause noise
• increasing demands in noise sensitive transmissions, i.e. electric vehicles
• NVH
Resonance

https://youtu.be/ZvsEFeyr1L4

“if the exciting frequency matches with the eigenfrequency, the parts get into resonance”

The designer needs to know the eigenfrequencies (depending on masses and stiffnesses) and the exciting frequencies (depending on operating speed, number of teeth, etc.).
The vibration excitation starts at rotating parts as gears, shafts, bearings. The vibration is transferred through the structure and casing to the human ear.

Definition of dynamic calculation

Eigenfrequency

is a property of a structure, that is also dependent on its boundary conditions.

Forced vibration

is the response (force, amplitude, ..) of the structure based on dynamic forces.

\[
\omega_{eig} = \sqrt{\frac{k}{m}}
\]

\[
\text{response} = \frac{\text{dynamic force}}{-m\omega^2 + j\omega C + k}
\]

stiffness \(k\), damping \(C\), mass \(m\)
Modal analysis

Eigenfrequency calculation needs masses and stiffnesses.

The **stiffness** includes:
- Elasticity (compliance) of the parts (bending, torsion, etc.)
- Stiffness of bearings and supports
- Connections within the transmission, i.e. by the gear meshing stiffness (coupled vibrations)

NOTE: two individual shafts have completely different torsional eigenfrequencies than the same two shafts coupled by the gear meshes!
Forced vibration

The vibration is excited by dynamic forces

\[ response = \frac{\text{dynamic force}}{-m\omega^2 + j\omega C + k} \]

Controlling factors for response:
- at low \( \omega \rightarrow \text{stiffness} \) \((k)\)
- at the critical speed, due to phase shift \( \rightarrow \text{damping} \) \((C)\)
- at high \( \omega \rightarrow \text{mass} \) \((m)\)

Additional data for the forced vibration calculation:
- dynamic force, like unbalance mass, transmission error, etc.
- damping values for bearings and materials,
- evaluation points (like measuring probes)
Implementation of the calculation was done according to:

- E. Krämer, «Maschinendynamik», Springer-Verlag

Validation was done through:

- Specialised software by samples from industrial applications
Exciting frequencies

Calculation of exciting frequencies and higher harmonics in KISSsys

**Gear meshes**
depending on No. of teeth and speed

**Rolling bearings**
considering the inner geometry, the following data are calculated:
- BPFO (Rolling element pass frequency outer race)
- BPFI (Rolling element pass frequency inner race)
- BSF / BPF (Rolling element frequencies)
- FTF (fundamental train frequency)
Interfaces to vibrations software

KISSsys provides specific or general interfaces to specialised vibration software.

General XML export
the complete system, including gears, shafts and bearings data, is exported to an XML file.

Interfaces to specific vibration software
• AVL, FEV Virtual Engine, Recurdyn/FunctionBay, MSC

Planned interfaces
• SIMULIA (former SIMPACK), GT Suite

Detailed interface functionalities on request!
Thank you for your attention!

Visit us: Hall 22, Stand A64
23 – 27 April 2018 • Hannover • Germany

Sharing Knowledge