Using flexible gears in order to detect the root cause of gear damage

Heidi Götz / Dr. Wolfgang Stamm
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Contents

1. Motivation
2. Vorecon – Variable Speed Drives
3. Multibody model
4. Results of simulations
5. Result of technical implementation
6. Summary
Motivation
Damage symptoms

Emergency stop of the Vorecon during running-in

→ Inspection was showing scuffing on all gears (sun, planets and annulus)
Motivation for multibody simulation

- Drive train has stopped
- Such a damage was never seen before
- No idea regarding the root cause

→ Need of simulation
→ Need of a dynamic multibody model
Vorecon – Variable Speed Drives
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**Description**

- **Variable speed hydrodynamic planetary gear**
- **Oil and Gas Industry / Chemical and Petrochemical Industry / Power Generation**
- **Boiler feed pumps, blowers, pumps, compressors**
- **Power up to 50 MW / speed up to 20,000 rpm**
- **Two planetary gears**
- **Hydrodynamic torque converter**
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Animation of the SIMPACK-model
Multibody model

- Flexible sun wheel shaft
- Flexible annulus gear
- Turbine wheel of torque converter
- PGF including spline coupling at annulus gear
- Flexible coupling sleeve
- Planet carrier of PGR
- Flexible housing
- All blue parts: ball bearings
- Journal bearing

- Ball bearings
Modelling of elastic gears

SIMPACK *elastic gear pair, method A* was used: „Macroscopic elasticity“ from modal reduction, gear meshing stiffness the same as in rigid gear pair

→ New challenges (824 RBE3s; big amounts of data)
Results of simulations
Natural frequencies

Exemplary natural frequency at 270 Hz
Natural frequencies

- Many natural frequencies were found within the operating range
- Good agreement between calculation and measurement
- Resonance phenomena were not identified as root cause
Circumferential forces

Impact

$F_{\text{max}} \approx 60\text{kN}$
Dynamic factor $K_V$

$$K_V = \frac{\text{max. peak}}{\text{average}}$$
### Dynamic factor $K_V$

<table>
<thead>
<tr>
<th>Operating Point</th>
<th>$K_{V \text{ max}}$</th>
<th>Meshing sun/planet</th>
<th>Meshing planet/annulus</th>
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</thead>
<tbody>
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<td>Rigid</td>
<td>Flexible</td>
<td>Rigid</td>
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<td>1.33</td>
<td>1.22</td>
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</table>
Average of circumferential forces
Load distribution factor $K_{\text{gamma}}$

$K_{\text{gamma}} = \frac{\text{max. planet load}}{\text{average planet loads}}$

Average of all planet loads
## Load distribution factor $K_{\gamma}$

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<th>$K_{\gamma}$ [-]</th>
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<td>1.21</td>
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</tbody>
</table>
Summary

• $K_v$ and $K_{\text{gamma}}$ values were higher than expected from design

• With the help of flexible gears the dynamic behavior seems to be closer to reality

• **Impacts were identified as root cause**

→ Now: possible to search for a suitable corrective measure in accordance with the results
Derived corrective measure

Modifying the existing tooth profile modifications of the planet gears:

- Tip modification
- Root modification

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Results of corrective measure

- Impacts were reduced (in both meshing transitions)
- Amplitudes were reduced
- Corrective measure led to an improvement for almost all required operating points
Results of technical implementation
New borescope inspection

No scuffing anymore
Summary

• Using **flexible gears** could show us the root cause for the damage
• Differences were identified to the results with rigid gears
• Were able to determine a suitable corrective measure for a dynamic system
• Technical implementation of the corrective measure led to a **success** regarding scuffing
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