Gears Quality Diagnostics

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Abstract

Gears quality diagnostic will be done with special measurement stand. This stand has been designed and realized. A few sensors have been installed. This paper describes it.

Keywords

gears, gearbox, quality, vibrations

1. Introduction of stand

Niemann's back-to-back circuit is less energy demanding than open-loop. Testing circuit consists of measuring and additional gearboxes, driving electromotor, loading equipment, and sensors of torque, rotational speed, vibration and temperature. The torque in circuit is established during stand operation. The test-rig is adjust for possibility of geometry change for testing of pitting and tooth bending.

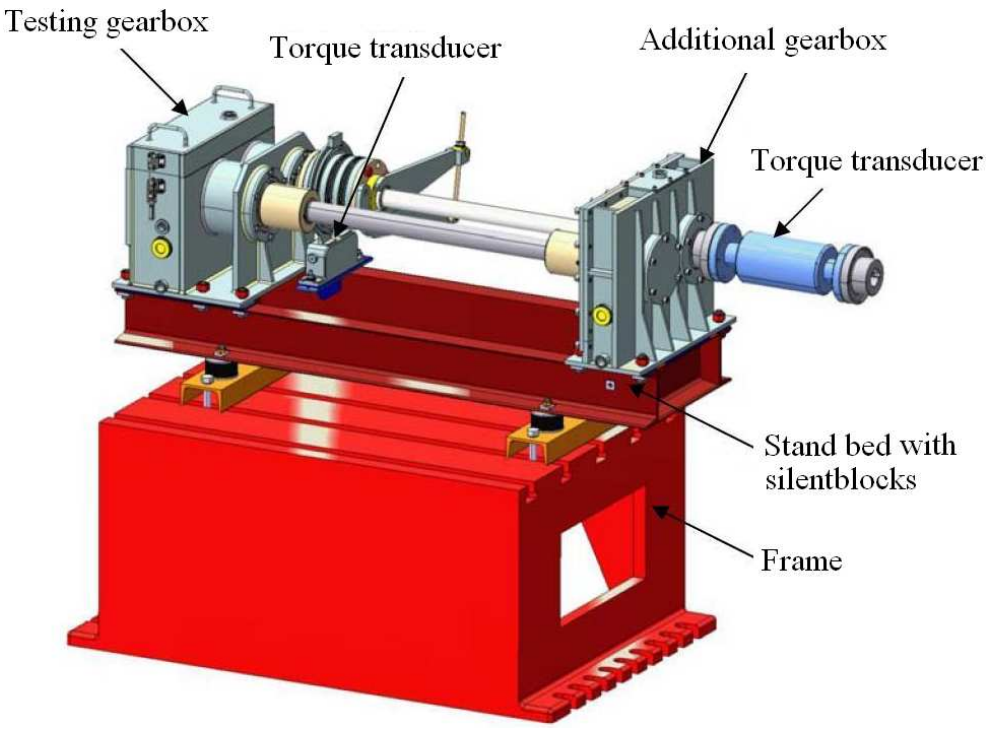

Fig. 1 *– Testing stand*

Testing conditions of gearwheels and its assembly should be similar as actual operational conditions. By reason of test time shortening it is necessary to select larger torque in closed-loop circuit than in industrial operation.

2. Sensors of torque and other circuit parts

Power losses and virtual power in circuit during running are recorded by two rotational speed sensors and two torque sensors. There is no attendance during the operation, an overload safety is needed. Torque sensors are mechanically secured against overload. Tooth root break

can arise during testing of tooth bending fatigue and the inertia moment can exceed the torque sensor permissible overload during unexpected gear block. Maximal overload is 150 % of nominal torque. The breakable screws which are parallel with coupling axis are used for security against torque sensor damage. The disk with holes for fixing laminar springy element and breakable screw thread is between parts of Radex-N coupling.

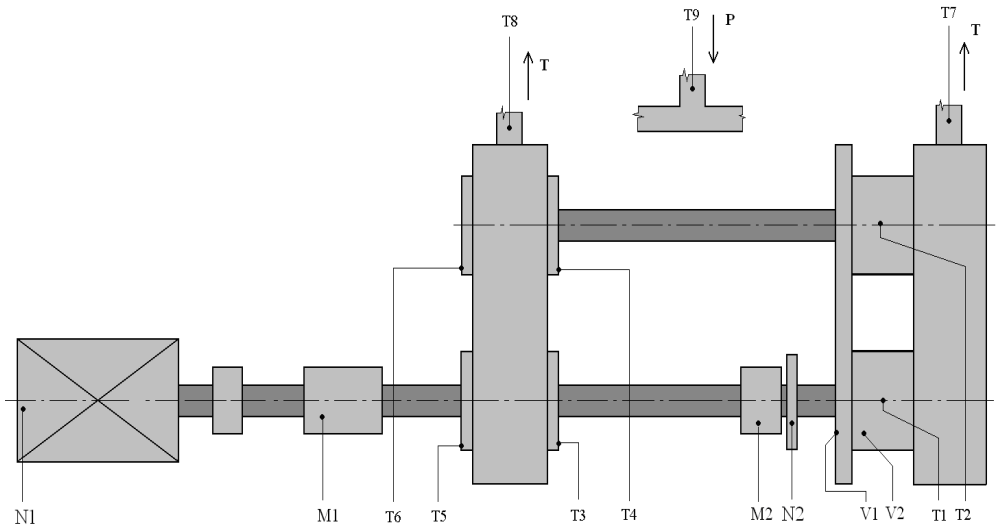

Fig. 2 *– Testing stand*

Testing gearbox is divided in two parts because of easier test gearwheels change. Coupling with involute splines and ETP-Techno coupling is securing simple connection of the gearbox to the circuit. Measuring of torque, rotational speed (N1, N2), temperatures and oil pressure (P1, P2) can be placed in to group of global values.

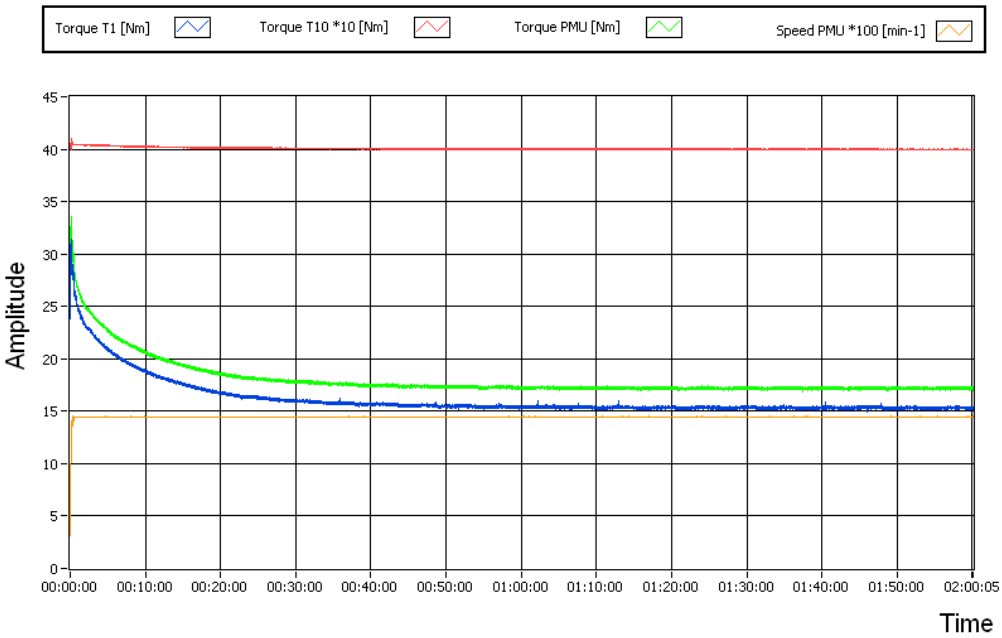

Fig. 3. *Torque and running speed history*

The torque scanning between electromotor and additional gearbox is used for determining the whole circuit efficiency. This value corresponds to losses in gear assembly, bearings, coupling, etc..

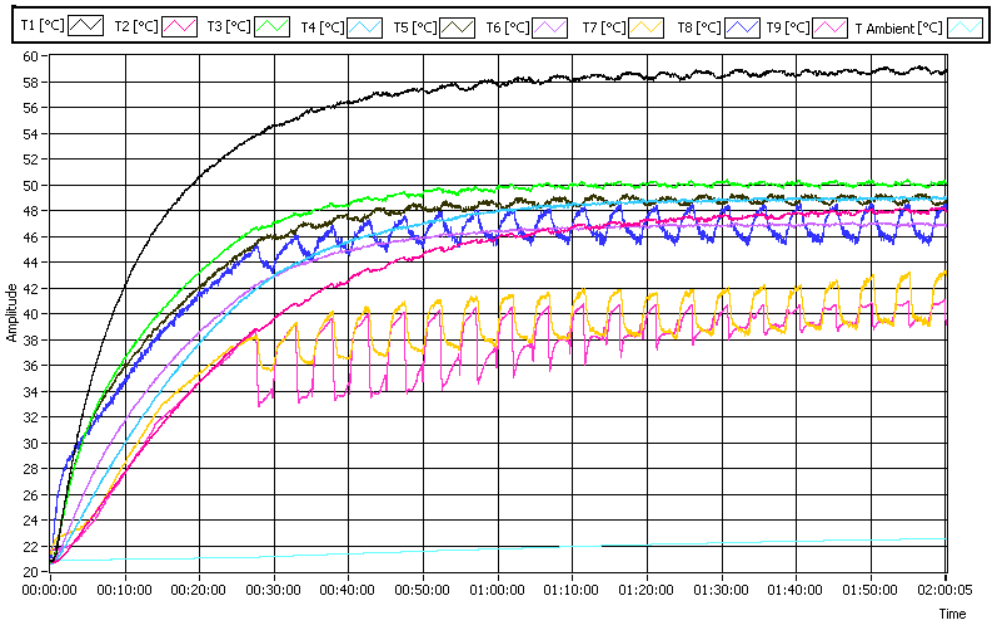

Fig. 4. *Temperature history*

Nine thermocouples are attached on testing stand and they are used for measurement of oil temperature in the input and output (T1, T2, … T9). These values are needed for the calculation of oil heat transfer. Temperature fluctuation is caused by fan switching.

3. Process loading of gearwheels

Process load is defined as history of gearwheels loading during its expected lifetime. In this case it is change of torque and rotational speed in time and description of all of abnormal cases in operation with gearwheels. The history of loading is composed of different limited time periods, where loading process is sufficiently accurately characterized. For example, the process can be sectionalized to these operating phases: run-up, steady regime, braking, run-out, idle regime, overloading etc. The loading regime has to be determined in advance. Process of gearwheel load is opportunely characterized by the torque and rotation speed in the time. To control of these actions the automation is needed.

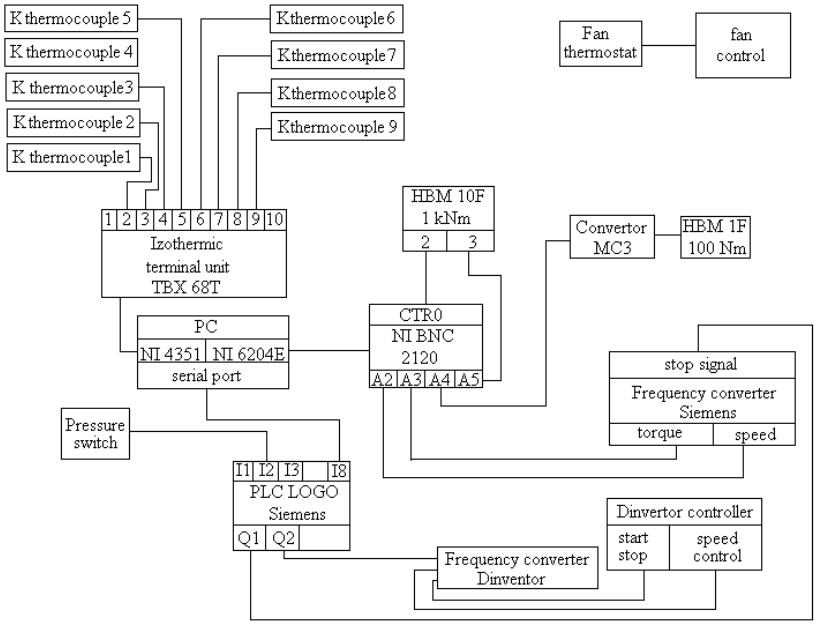

Fig. 5. *Block signal diagram*

For controlling of rotation speed, we used electromotor frequency converter which is controlled by PC. The torque in circuit can be changed during operation by the turning of coupling parts. The automatic solution for control of torque is not applied yet, but the design of this device is ready to produce. At the start of the test it is possible to setup requested automatic periods. Setup is formed on control touch screen by putting requested values in time dependence.

4. Scuffing problem

In the test starts a problem with initial scuffing occurred. As scuffing influences the pitting lifetime, the scuffing elimination is necessary. Scuffing arises at specific conditions influenced by size of tooth line load, tooth geometry, specific sliding, lubrication, temperature and other factors. Test requirements did not allow a lot of changes (oil, temperature, geometry, load, etc.).

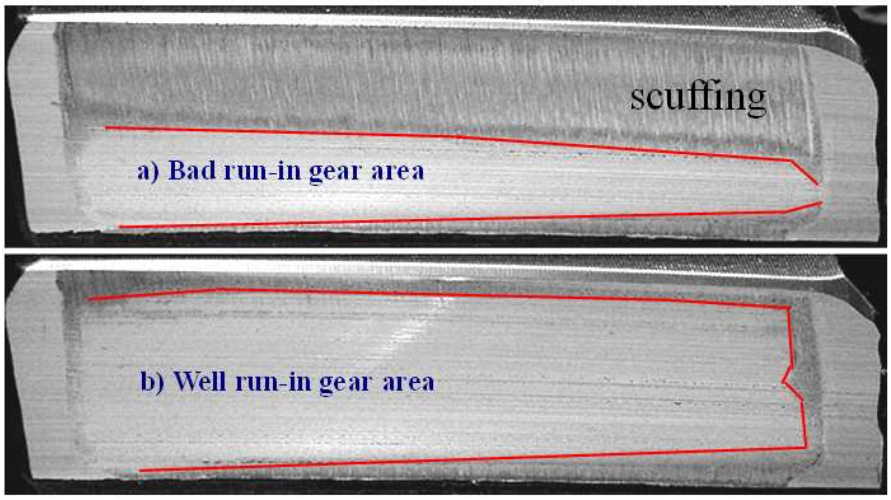

Fig. 6. *Sample of scuffing failure*

Finally, the way to eliminate scuffing was found. The solution is in longer gradual run-in. The load starts on the same level and rises by 50 Nm every half an hour up to testing load. It probably causes the peaks effacement and better meshing condition. Residual edge wear should be removed by applying of modifications.

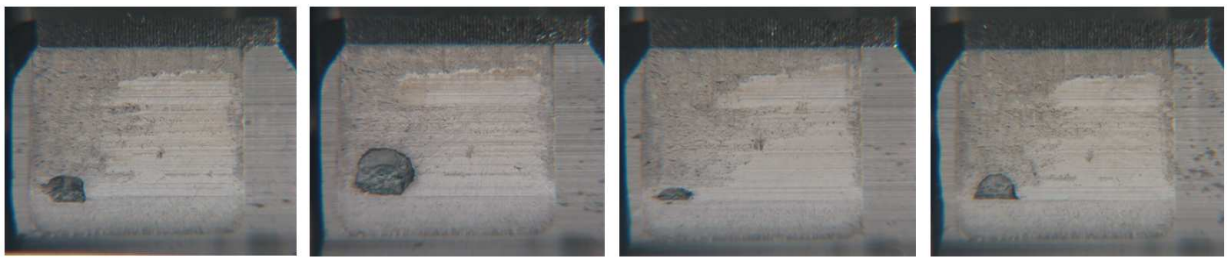

Fig. 7. *Pitting growth*

5. Fem calculation of gearing

The solution of the contact and geometry problem is made in the group gearing models, which are stored in the coordinates of intersections axis of the shaft and the front planes of the gearing on the deformed shaft in the given plane, to define the gear mesh, and are loaded of the loads moment.

6. Vibrations

The next measuring, which is in tuning mode is measuring of gearbox vibrations. Collected data may be used to evaluate some typical gear errors. On the base of it the gears quality may be determined.

A key indicator of gear tooth wear is excitation of the Gear Natural Frequency, along with sidebands around it spaced at the running speed of the bad gear. Gear Mesh Frequency (GMF) may or may not change in amplitude, although high amplitude sidebands surrounding GMF usually occur when wear is noticeable. Sidebands may be a better wear indicator than Gear Mesh Frequencies themselves.

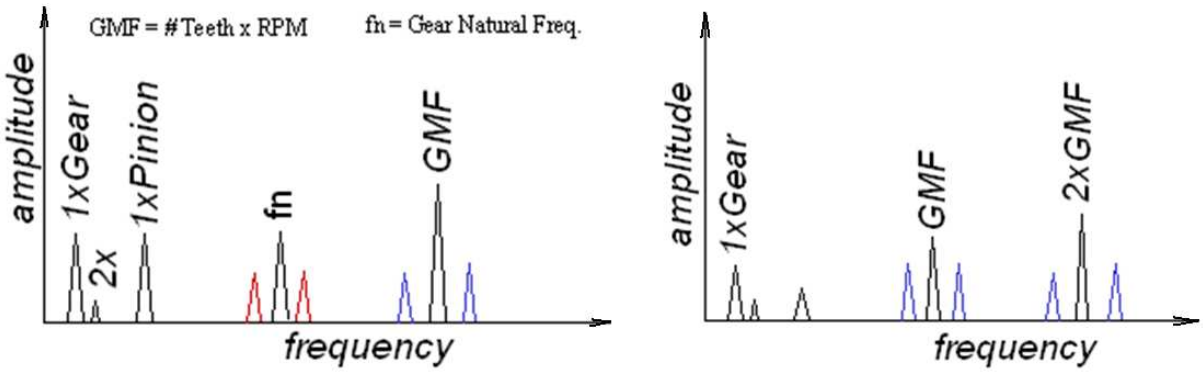

Fig. 8. *Typical spectra of tooth wear and gear missalignment*

Gear Misalignment almost always excites second order or higher GMF harmonics which are sidebanded at running speed. Often will show only small amplitude 1x GMF, but much higher levels at 2x or 3x GMF. Important to set the Fmax high enough to capture at least 2 GMF harmonics if the transducer has the capability.

Gear Mesh frequencies are often very sensitive to load. High GMF amplitudes do not necessarily indicate a problem, particularly if sideband frequencies remain low and no gear natural frequencies are excited. Each analysis should be performed with the system at maximum operating load.

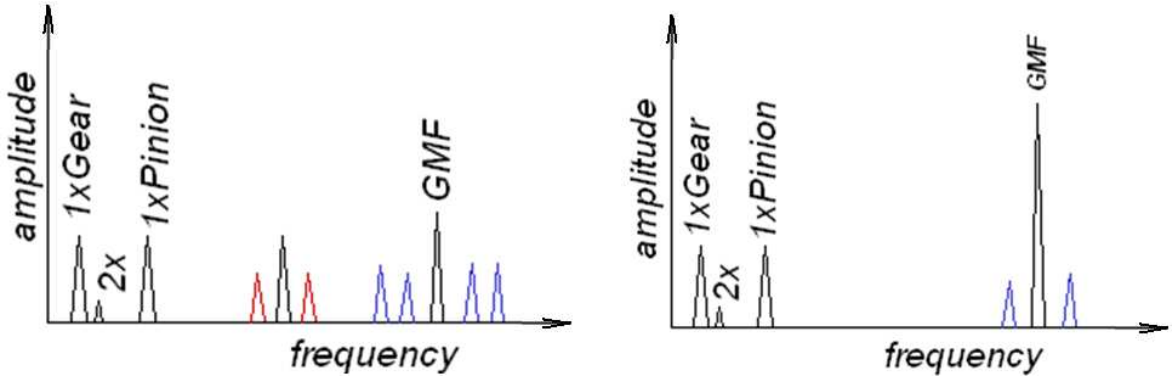

Fig. 9. *Typical spectra of tooth load and gear eccentricity and backlash*

Fairly high amplitude sidebands around GMF often suggest gear eccentricity, backlash or non-parallel shafts which allow the rotation of one gear to "modulate" the running speed of the other. The gear with the problem is indicated by the spacing of the sideband frequencies. Improper backlash normally excites GMF and Gear Natural Frequencies, both of which will be sidebanded at 1x RPM. GMF amplitudes will often decrease with increasing load if backlash is the problem.

7. Conclusion

Measuring stand is ready to work, the first tests are done. Methodology of measurement is tuning now. Samples for testing have been produced and the tests are planned to be done this year.

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