Multistage gearbox failure

Root cause analysis and recommendations for gearbox monitoring with HD technology

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Contents

1 Introduction

This case study describes a failure in a gearbox driving a disc filter in a pulp mill. The installation was part of a gearbox monitoring project handled by the SPM Strategic Sales & Applications group. The measurements started when the gearbox was in healthy condition and continued throughout the period during which bearing and gear condition deteriorated, and continued after the gearbox had been repaired.

2 Summary

The root cause of this gearbox damage was that water had accidentally entered the gearbox during cleaning of the shaft.

The water adversely affected bearing lubrication, hence damaging the bearings. Consequently, the gears did not work properly and were also damaged.

It has been an instructive project where we have successfully detected gear damage in the gearbox. Among other things, the measurements from this and other gearboxes have resulted in recommendations regarding the most suitable measurement techniques for different gearbox problems.

3 Application description

The disc filter is a low-speed application driven by a four-stage gearbox and an electrical motor, see Figures 1, 2, and 3 (below).

The disc filter is an important part of the pulp process. If the disc filter stops, the production of pulp will stop immediately. The paper machine will also stop shortly after that due to lack of pulp.

Fig. 1 *Disc filter.*

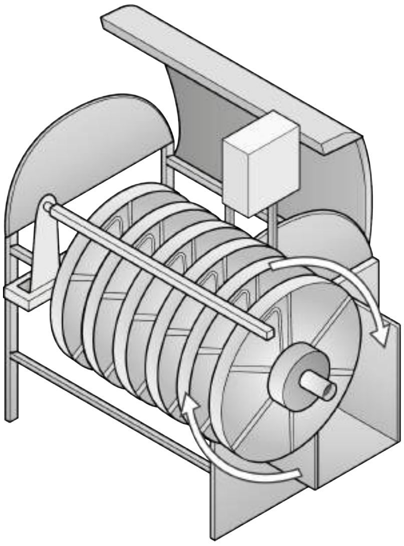


Fig. 2 *The gearbox and motor driving the disc filter.*

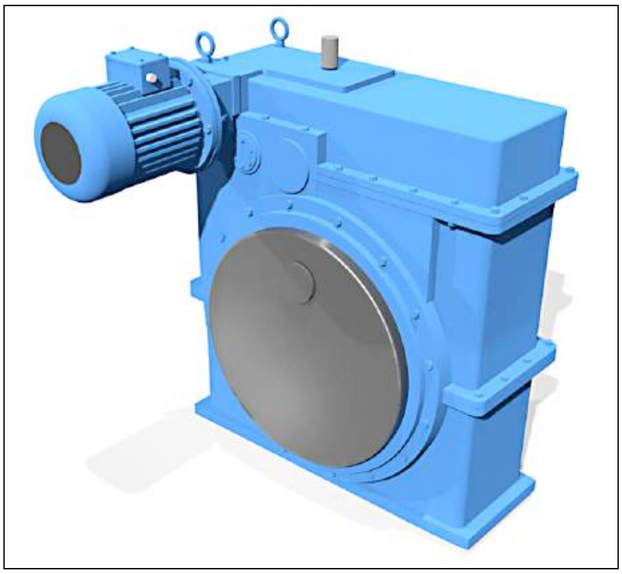
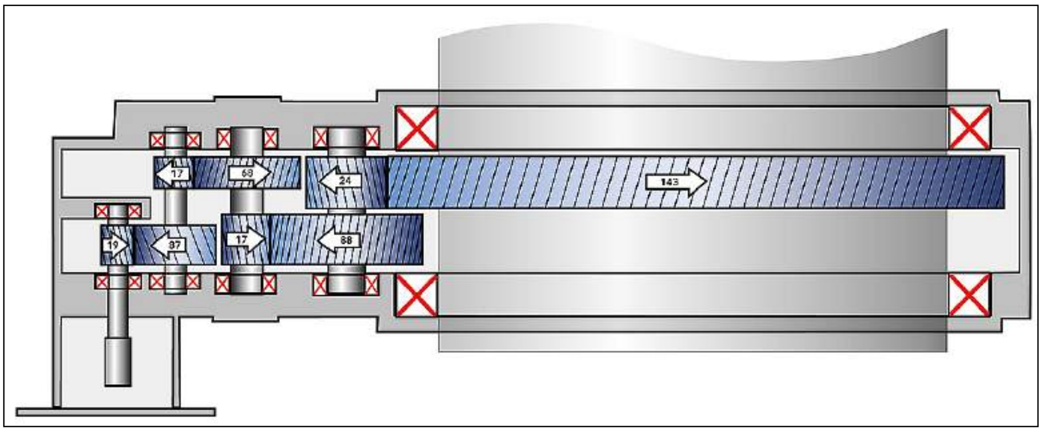


Fig. 3 *Section from the gearbox.*



4 Background

The Strategic Sales & Applications group runs a project involving gearbox monitoring, where the goal is to understand how gearboxes behave and how to best measure the mechanical and lubrication condition of a gearbox.

Several different test installations have been made in Sweden, one of which is on the gearbox in this case study. The reason for this installation was that the customer had experienced problems with this gearbox earlier.

5 System setup

5.1 Measuring equipment

The online system used was Intellinova Compact INS08V with eight DuoTech transducers and one RPM transducer.

5.2 Measuring techniques

The following measurement techniques were used on all sensors:

- SPM HD TSA
  - SPMHD and Time Synchronous Averaging (TSA)
- HD ENV3
  - HD ENV filter 500 – 10,000 Hz
- HD ENV3 TSA
  - HD ENV filter 500 – 10,000 Hz and Time Synchronous Averaging
- HD ENV4 TSA
  - HD ENV filter 5 000 – 40,000 Hz and Time Synchronous Averaging
- VEL TSA
  - Velocity and Time Synchronous Averaging

The reason for using mainly TSA measurements is that we were focusing on the gears, while the explanation for the relatively many measurement assignments is that we wanted to show how the different assignments respond if a gear problem were to occur.

To be able to do TSA measurements on intermediate shafts, we need to use the Pseudo Tach function. A normal TSA requires a trigger pulse from the very same shaft where the gears are mounted. By using Pseudo Tach, an artificial and VERY accurate trigger pulse is used to trigger measurements. If, say 200 averages, is used and the artificial signal is not accurate enough, the fault will increase for every revolution and the result will be meaningless. By using HD Technology also for the Pseudo Tach, accuracy is ensured.

5.3 Condmaster setup

The following measurement setup was used.

Fig. 4 *SPM HD TSA*

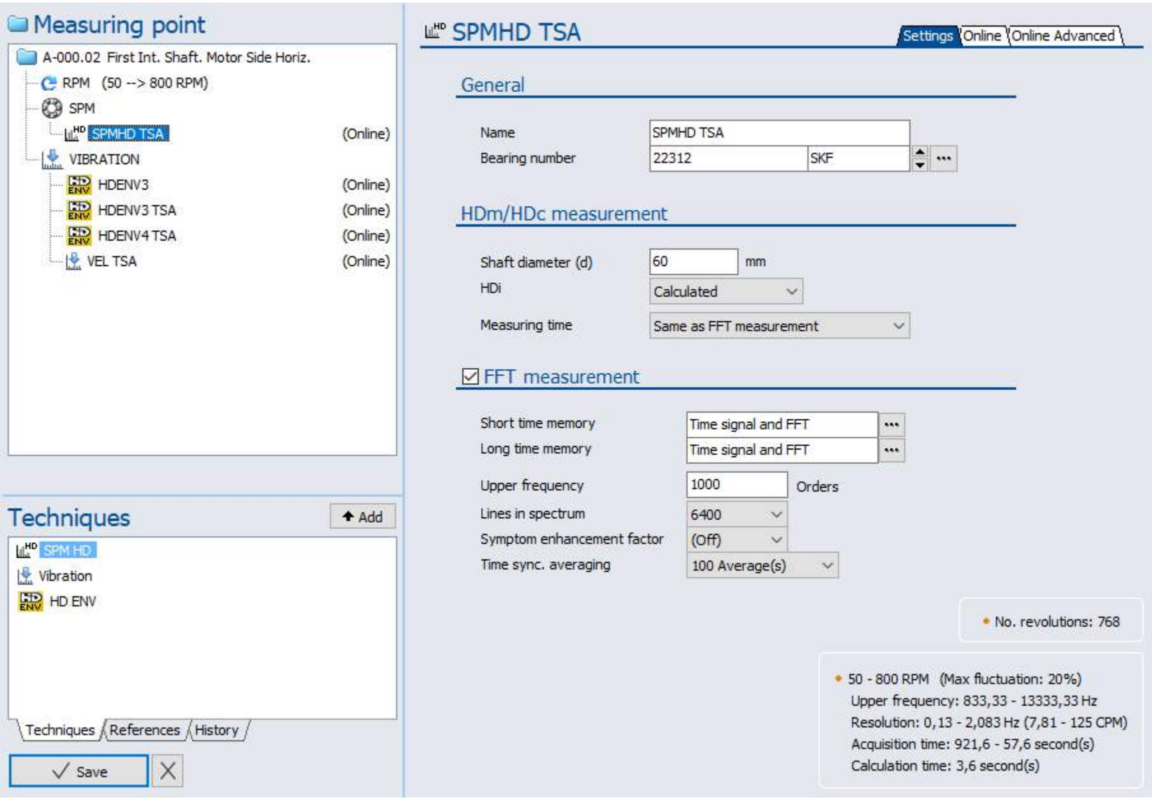


Fig. 5 *HD ENV, Filter 3*

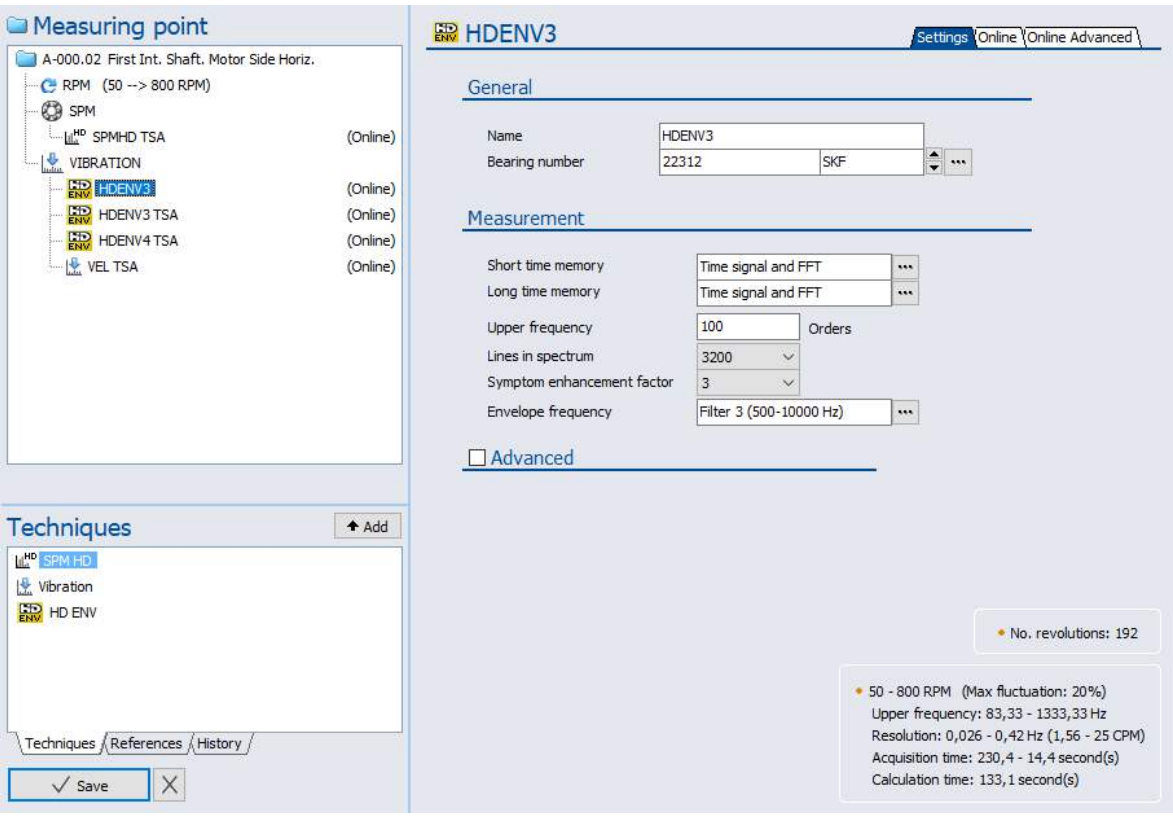


Fig. 6 *HD ENV, Filter 3 with TSA*

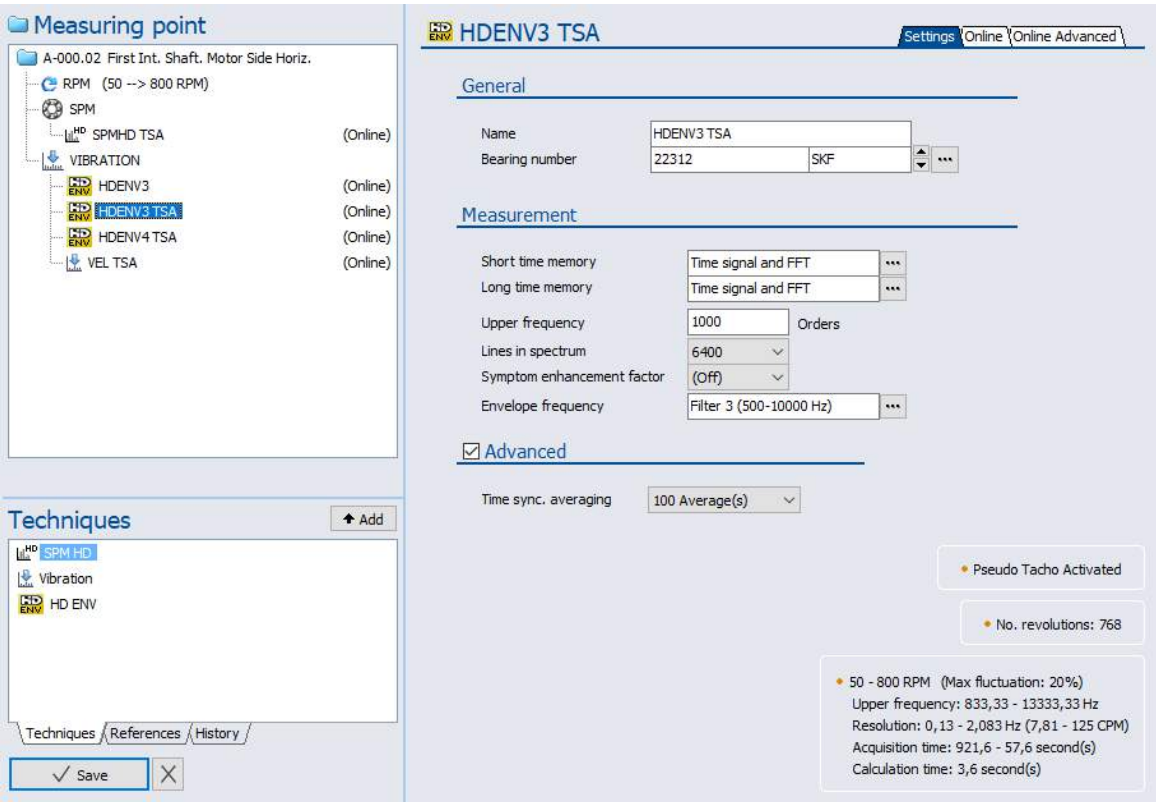


Fig. 7 *HD ENV, Filter 4 with TSA*

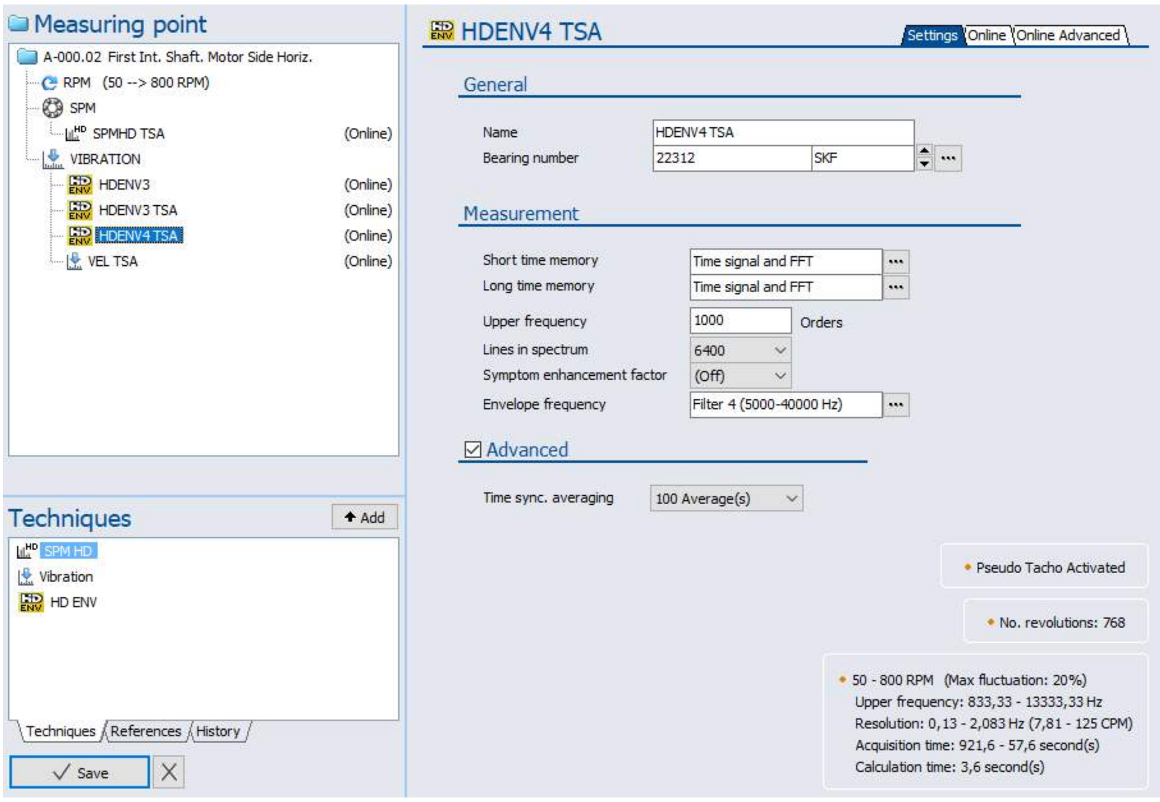
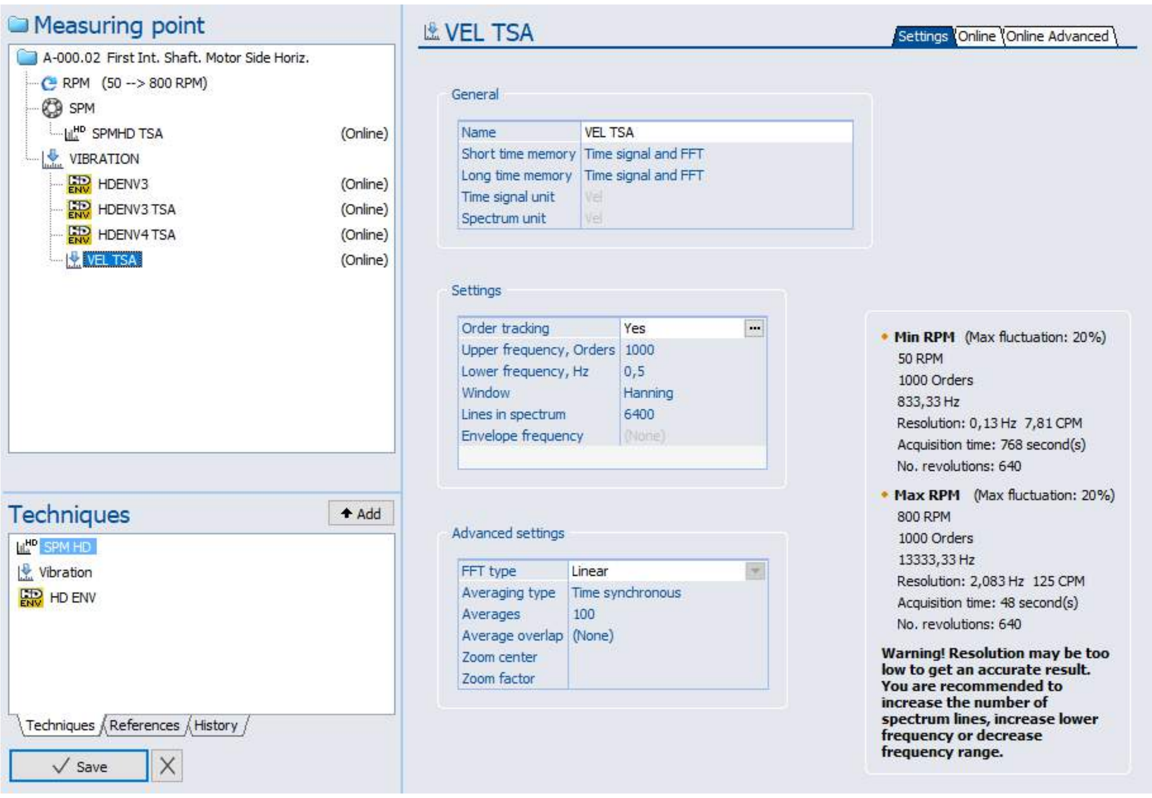


Fig. 8 *VEL TSA*



The reason for the high upper frequency – 1000 orders – of the TSA measurements is to visualize the gear in a circular plot with a high-resolution time signal.

6 Case descriptions

The root cause of this gearbox damage was that water accidentally entered the gearbox.

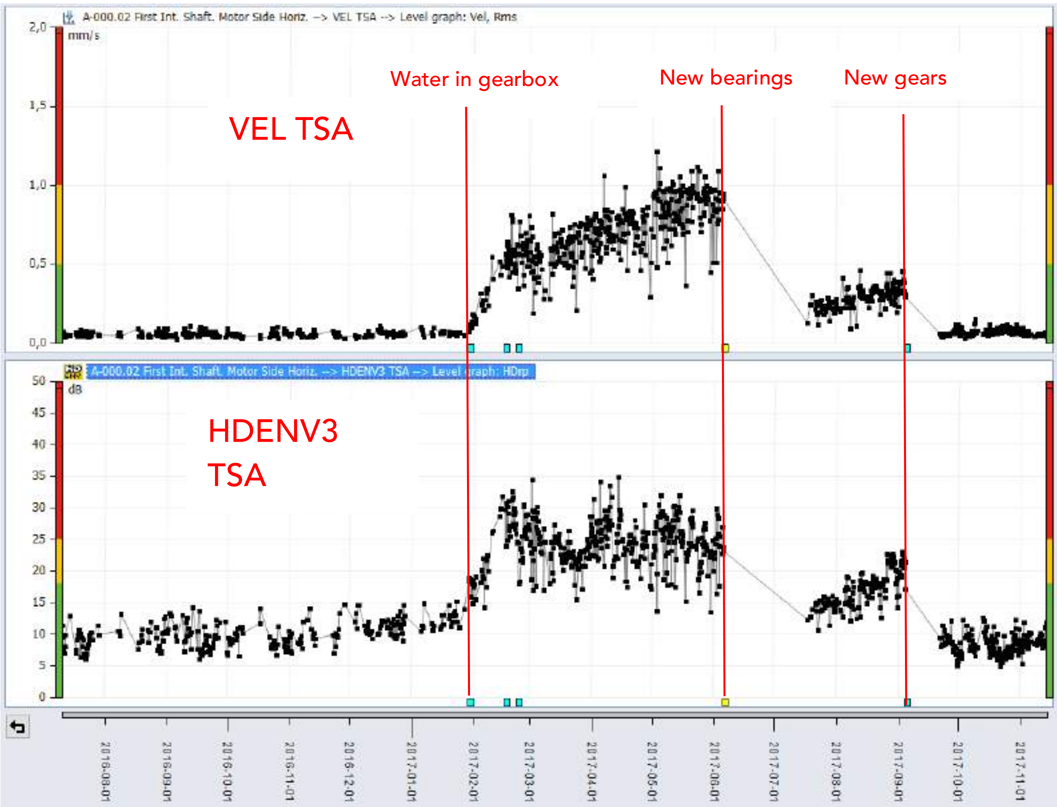
When the water came into the gearbox, the vibration levels increased very quickly and remained on a high level. During a planned machine stop, the gearbox was opened and inspected. There were clear damages on all gears, but due to a lack of spares, only the bearings could be replaced. After the bearing change, the vibration levels decreased but were still higher than normal.

In conjunction with another planned stop four months later, new gears were also mounted, after which the vibration readings dropped to a normal level.

6.1 Case #1: Intermediate shaft

The amplitude of the measurements from the intermediate shaft showed a clear increase, mainly in the VEL TSA (Time Synchronous Averaging) measurements. Because TSA measurements only measure gear condition, this is a clear indication that there was a gear problem.

Fig. 9 *Trend graphs of VEL TSA and HD ENV, Filter 3 TSA measurements.*



The reason for the gear damage was poor lubrication. Unfortunately, the only measuring assignment for bearing measurements that was activated was HD ENV, Filter 3, and in those measurements, we could not see any bearing frequencies.

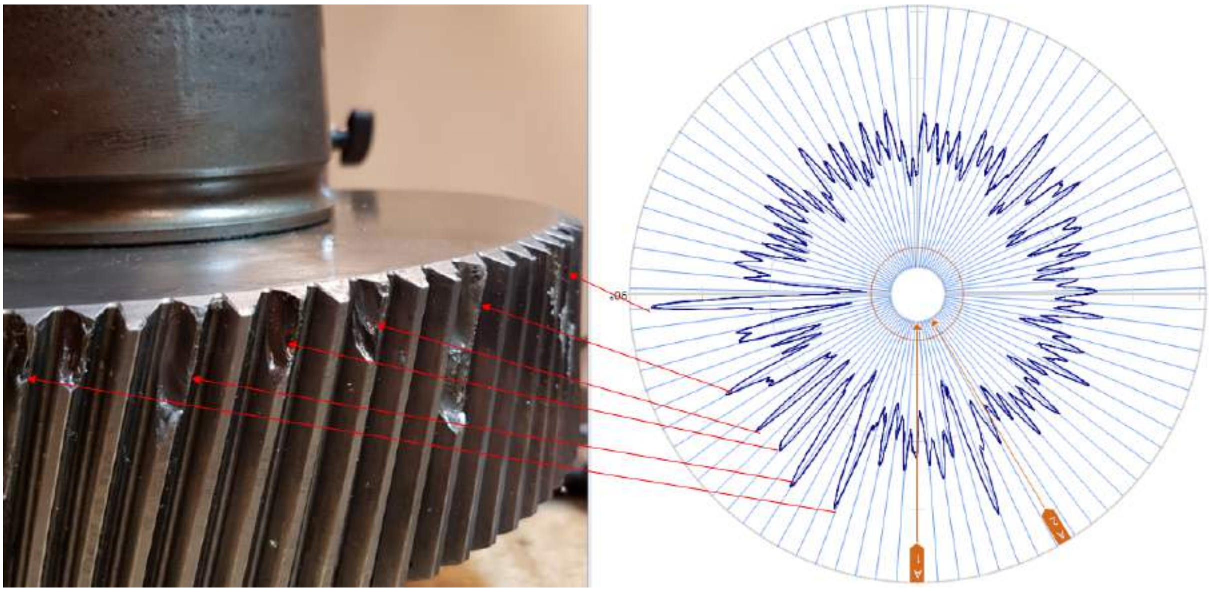
The bearing damage is quite interesting. There are no spalls in the bearing surface, but the surface is very worn, see Images 1 and 2:

Img. 1 *Damaged bearing from the 1st intermediate shaft.*

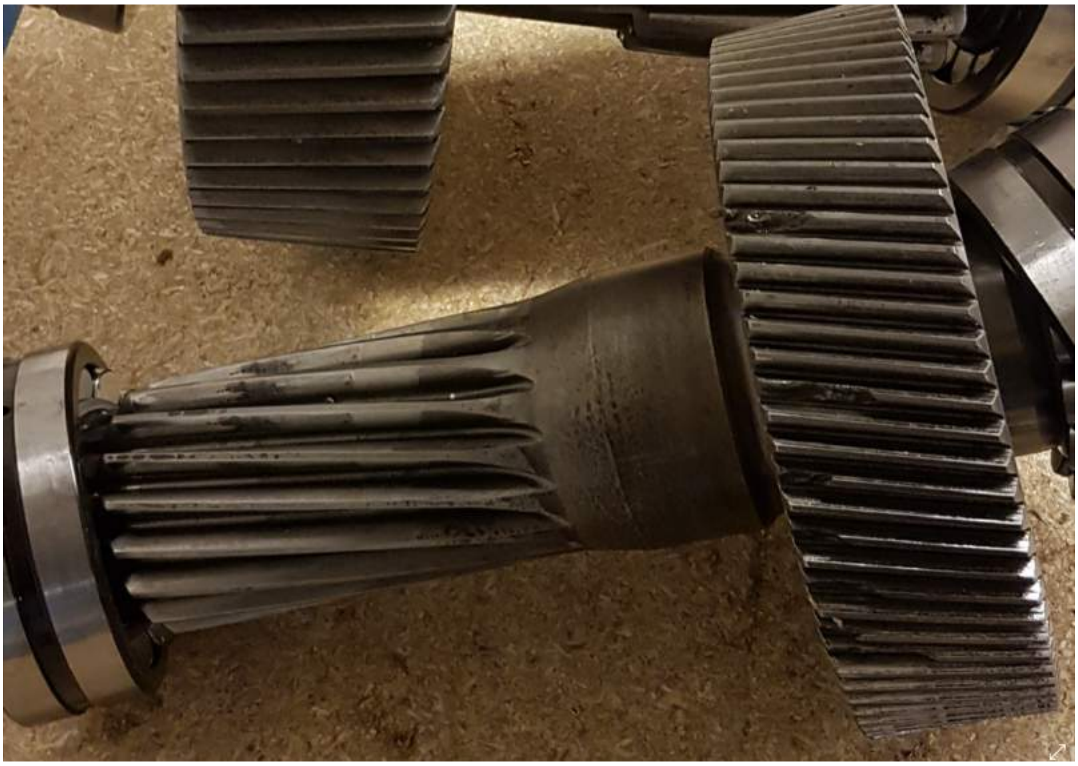
Img. 2 *Damaged bearing from the 1st intermediate shaft.*

As the bearings became worn out, the gears did not mesh as designed and were therefore damaged, see Images 3 and 4 below. In Image 3, it is possible to see the gear damages of the 1st intermediate shaft shown in the circular plot.

Img 3. *Damaged 1st intermediate shaft and circular plot.*



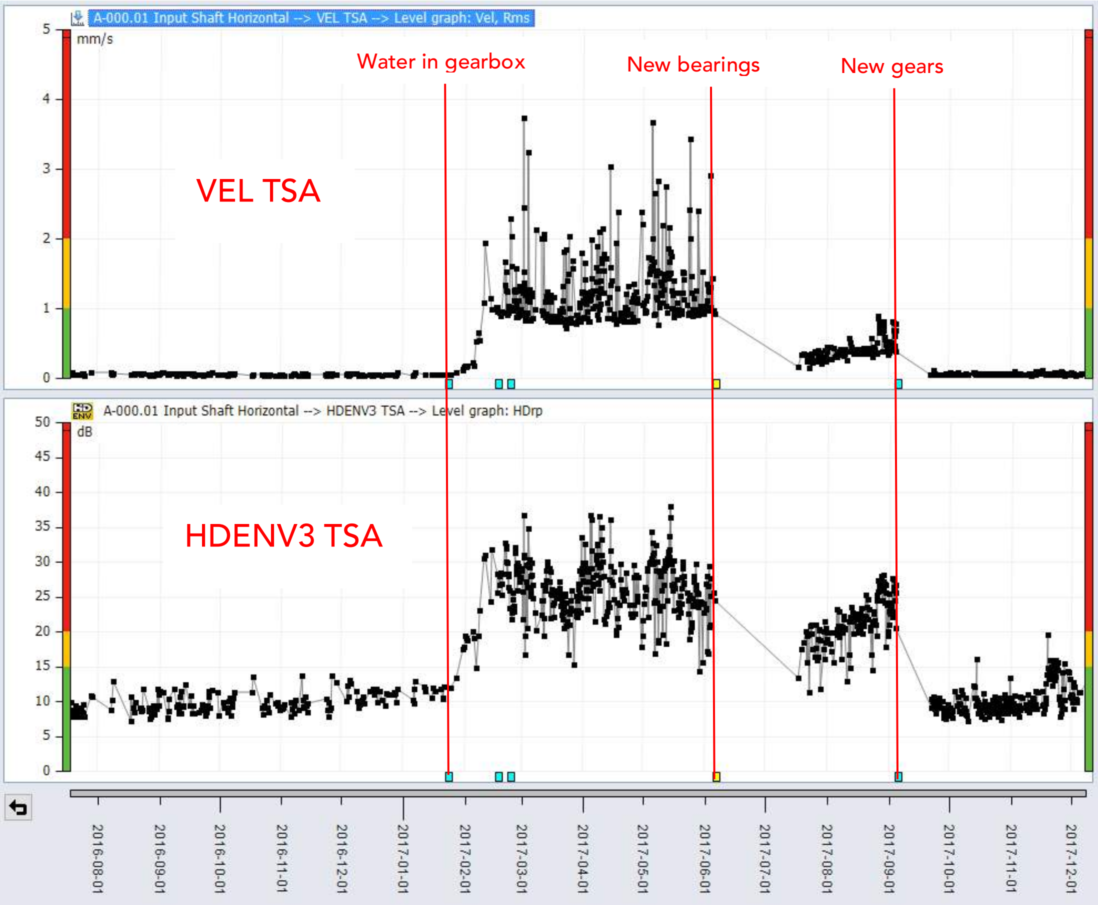
Img 4. *Damaged 1st intermediate shaft.*



6.2 Case #2: Input shaft

The measurements from the input shaft showed quite the same thing as those acquired from the intermediate shaft. The damaged gears are shown in Images 5 and 6.

***Fig. 10** Measurements from the input shaft.*

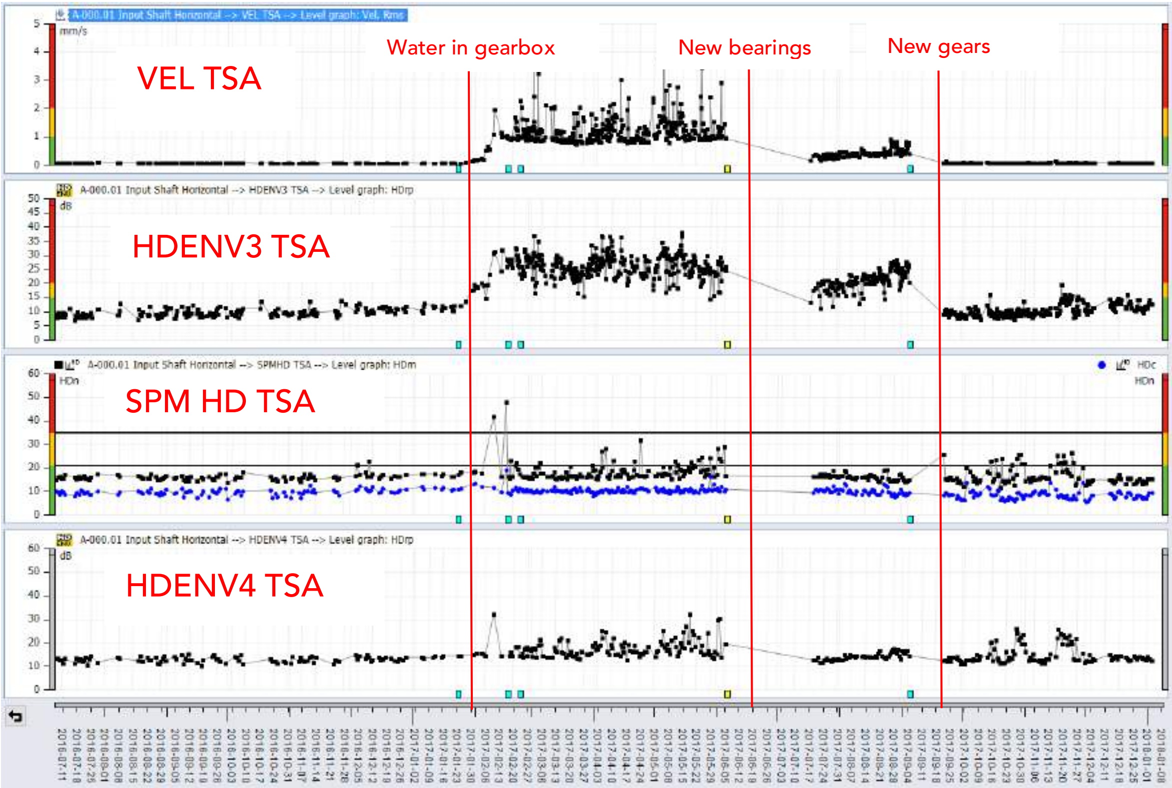


Img. 5 Damaged input shaft gear.

Img. 6 Damaged input shaft gear.

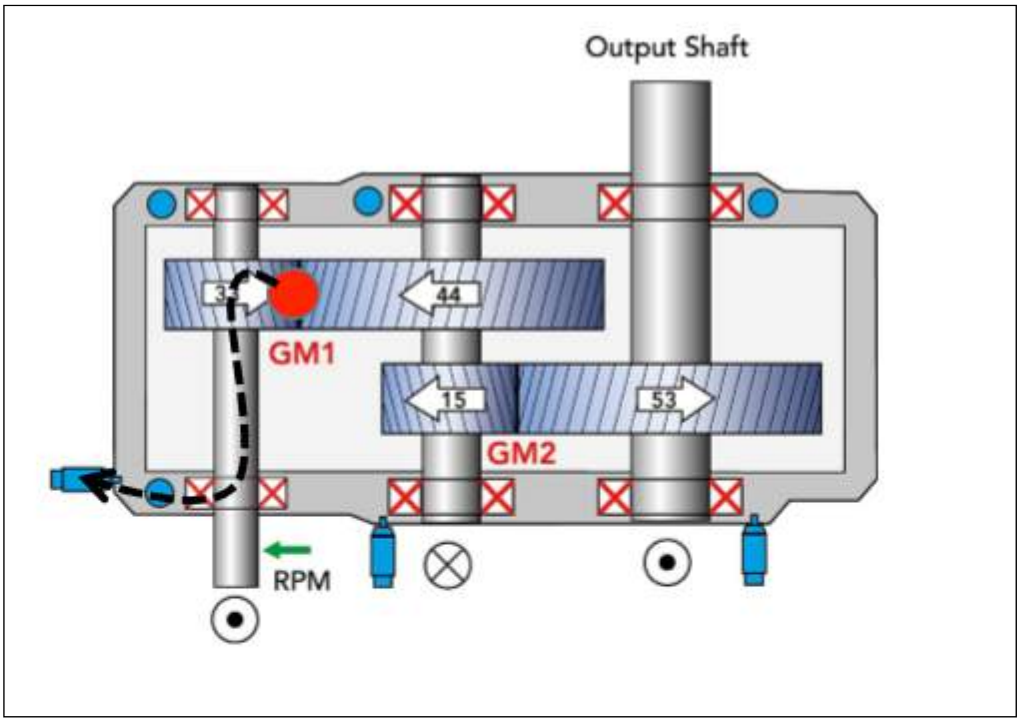
Comparing the different TSA assignments is interesting. In Figure 11 below, all TSA assignments from the input shaft are shown, and it is clear that only VEL TSA and HD ENV, Filter 3 with TSA measurement assignments react to this gear damage.

Fig. 11 *Only VEL TSA and HD ENV, Filter 3 TSA indicate the gear damage.*



The reason for this behavior can be seen in Figure 12. The high-frequency signals – originating from the gear damage and measured with SPM HD and HD ENV, Filter 4 – are damped at each of the material interfaces in the bearings.

Fig. 12 *Only VEL TSA and HD ENV, Filter 3 with TSA indicate the gear damage.*



7 Conclusion

The results in this case study show that HD ENV is ideal for detecting gear problems such as gear mesh, while SPM HD works very well for monitoring bearing and lubrication condition.

For successful gearbox monitoring, we recommend using one sensor per shaft, with the following measurement assignments set up on all sensors:

Bearing condition assignments

- *VEL*
- *HD ENV, Filter 3*
- *HD ENV, Filter 4, or SPM HD*

Gear condition assignments

- *VEL TSA*
- *HD ENV, Filter 3 with TSA*

Pseudo Tach will automatically be activated when using an RPM factor. To ensure the factor is accurate enough, enter the number of teeth on the gearwheels in the RPM factor settings.