# MARKED WEAR ON THE PLAIN BEARING OF A FRANCIS TURBINE - A POTENTIAL ALIGNMENT ISSUE?

*An interesting assignment presented itself to the Service Team of PRÜFTECHNIK Alignment Systems in a high-head hydropower plant on the river Isar. Marked bearing damage had been identified in a Francis turbine and its associated generator and PRÜFTECHNIK was appointed with the task of identifying the root cause.*

The hydroelectric power station was commissioned in 1924 and uses a height difference of 26 m in the central Isar Canal to generate electricity by means of four vertically arranged 9-MW Francis turbines. In this power station, the generator sits above the turbine and is connected via a plain-bearing mounted vertical shaft (Figure 1).
The water that accumulates in the Isar Canal above the power plant flows from the south. In the rest of this report, upstream will be used to indicate this flow and downstream the flow of water discharged from the power plant to the north. The terms east and west will be used to indicate those directions respectively.


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Figure 2: Wear on the downstream side of the turbine

### UNEVEN WEAR ON THE PLAIN BEARINGS

During the course of a scheduled overhaul, atypical uneven wear was discovered on the plain bearing of the Francis turbine and the lower plain bearing of the generator. The wear on the generator bearing occurred on the upstream side and that on the turbine (Figure 2) on the downstream side. The operator's overhaul team therefore conducted a plumb line test on the plain bearing from the upper side of the generator. This indicated an apparent 2-mm downstream misalignment of the bearings. The power plant operator contacted PRÜFTECHNIK Alignment Systems to perform a laser measurement to confirm the results of the plumb line test. The Service Team of PRÜFTECHNIK carried out the measurement in two stages.

### HIGH ACCURACY WITH A LASER-OPTICAL MEASUREMENT SYSTEM

The first stage involved checking the alignment of the bearings to one another. This was done using CENTRALIGN® Ultra laser-optical measurement system. This device measures the alignment of bores and bearings relative to one another to a high degree of accuracy.
First, the system's laser was mounted on the upper generator bearing using a magnetic holder (Figure 3). The counter piece to the laser is the sensor. Mounted on a pointed bracket, it was clamped in place using a special quick-assembly holder in the plain bearing being measured in a way that allowed it to be rotated (Figure 4).
The measurement was made by sampling several measurement points on two measu-

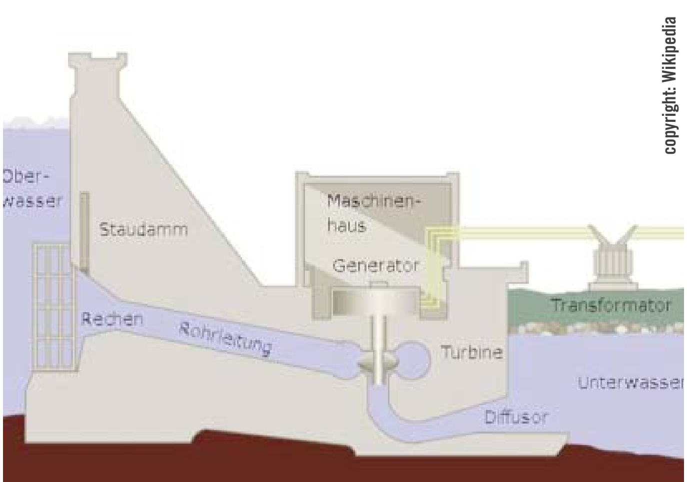

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Figure 1: Arrangement of the generator and turbine


photo credits: Prüftechnik
Figure 3: Assembly of the laser

ring planes on each plain bearing. The laser merely acted as a reference line for the sensor. The sensor then transmitted the measurement data wireless to the control unit of CENTRALIGN® Ultra. The inclination of the individual plain bearings themselves was calculated in addition to their alignment to one another.

The measurement system of ROTALIGN® Ultra is capable of achieving measurements accurate to 1 – 2/100 mm per meter of the measured section. The generator's upper axial support bearings have a strong impact on the position of the vertical shaft. Any angle error in this bearing will affect the radial movement of the plain bearing. It is therefore essential that this support bearing is levelled.

In the second stage of the measurement process, the Service Team of PRÜFTECHNIK checked the level using a high-precision INCLINEO® angle measurement system (Figure 5). INCLINEO® is capable of measuring both absolute (i.e. "under water") and relative surfaces - and it can do this with the rotating measuring cell in either a horizontal or a vertical position. The upper axial support bearing flange was used to determine whether it was level and flat. Although the flange itself was relatively level, it did exhibit an inclination of 2/10 mm on the upstream side of a flange diameter of 1.6 m.

## UNEVEN WEAR RESULTING FROM BEARING MISALIGNMENT

Together with the bearing alignment measurements, the pattern of the shaft movement was also a good indicator of uneven wear on the plain bearings. While the bearings were correctly aligned east-west, they appeared to be misaligned along the upstream-downstream axis with the lower generator bearing being 0.3 mm too far downstream. This explained the shaft contact and thus the increased wear on the upstream side of the plain bearing. A similar pattern could be seen on the turbine bearing. In this case, the bearing was 0.15 mm too far upstream. This matched the wear pattern on the lower turbine bearing which was concentrated on the lower downstream part of the bearing. The results therefore confirmed the power plant operator's initial suspicions that the uneven wear occurring on the plain bearings was caused by some form of misalignment. The reports thus formed a good point of reference for subsequent actions.

The lower generator bearing was corrected by 0.3 mm on the upstream side and the upper axial support bearing was levelled slightly by 2/10 mm.

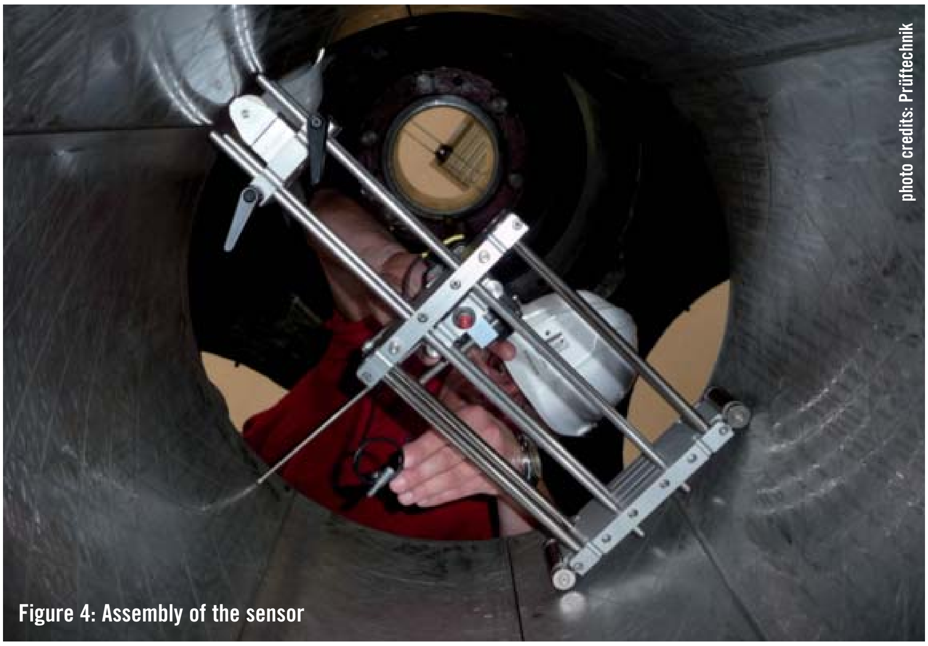

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Figure 4: Assembly of the sensor

A follow-up to the bearing alignment measurements allowed the Service Team of PRÜFTECHNIK to use the new system ROTALIGN® Ultra Hydropower to measure the bearings of a two-part vertical shaft (the drive shaft between the turbine and the generator).

In the meantime, the two 4-metre long segments of the existing shafting had been reassembled. The initial impact tests went well, with neither the turbine nor the generator exhibiting any significant vibrations. The realignment of the bearings had obviously done the trick. However, it was now interesting to note how the two shaft segments were positioned relative to one another.

This would make it possible to check the correction of the plain bearing channel. If there had been any misalignment, the shafting would have bowed. The team also wanted to identify the position of the shaft relative to the perpendicular.

Conventional methods such as using a plumb line are unsuitable in this case. Under optimum conditions, this test device can achieve a level of accuracy of approx. 0.5 mm/m, which is insufficient. This is where ROTALIGN® Ultra Hydropower measurement system from PRÜFTECHNIK comes into its own. The system comprises the powerful ROTALIGN® Ultra platform and the high-precision INCLINEO® inclination measurement device. INCLINEO® is a highly accurate electronic inclinometer which records relative inclination values to less than 0.01 mm/m, which it then transmits to ROTALIGN® Ultra wireless to be analysed and displayed.

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Figure 5: Checking the horizontal alignment of the support bearing with INCLINEO®

Figure 6

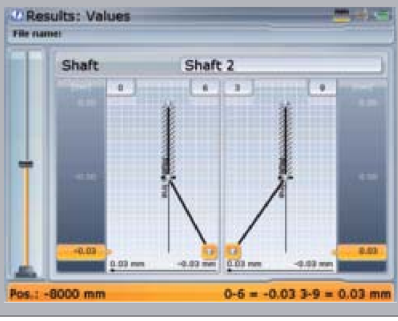


Figure 7a

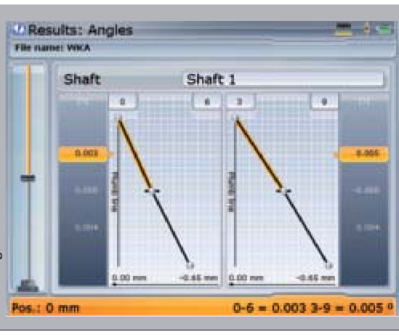


Figure 7b

Figure 6: measurement results being transferred via Bluetooth™ to the ROTALIGN® Ultra computer

Figure 7a: measurement result; aberration of 0.03 mm on 4 m segment length

Figure 7b: measurement result; aberration of 0.65 mm on 8 m of total length of wave

graphics: Prüftechnik

The measurement process: as with the other PRÜFTECHNIK devices, ROTALIGN® Ultra Hydropower takes measurements in three stages. Once the sensors have been set up, the dimensions of the shaft sections to be measured are entered in the control unit.
The next step involves taking the measurement. The inclination measurement is based on the type of transmission. Two measurements are taken on each of the opposite facing points on a shaft and there are two ways of doing this:

- If the shaft rotates, INCLINEO® is fixed to the shaft and rotates with it (circular measurement)
- If the shaft does not rotate, INCLINEO® is placed on two exactly opposite positions on the shaft in succession (static measurement).

Measurements are thus taken on each shaft segment for at least each of the four directions (east, west, downstream and upstream). In this instance, the shaft in the hydropower station rotated and INCLINEO® was attached to the shaft segments using a strong magnetic base. Two circular measurements were taken for each shaft segment in order to check the reproducibility of the measurements. The final step deals with the measurement results. (Figure 6)
ROTALIGN® Ultra Hydropower showed that the position of the shaft segments exhibited a difference of only 3/100 over a segment length of 4 metres (Figure 7a); a very low value. This proves that the bearings are now very well positioned. Examining the perpendicular gives an offset of 0.65 mm along the entire 8-metre length of the shaft downstream (Figure 7b) and to the west. If required, the perpendicular alignment of the shafting could be improved by adjusting it on the upper thrust bearing.
However, according to the operator, this value does not affect the operation of the turbine; rather it is the alignment of the two shaft segments which has the most significance. The shafting itself and the bearing alignment are accurate and very well aligned to one another. The bearing damage on the lower generator and turbine bearing is now a thing of the past. With the new ROTALIGN® Ultra Hydropower the user now has a high-precision, high-speed measurement system capable of determining the relative position of vertical shafts and ensuring they are perpendicular without using the line of sight.