Turbine damage is still an everyday reality in the lifetime of a wind park. Owners are frustrated by repeated gearbox failures or blade repairs. In order to minimise failure rates and downtime it is becoming increasingly common to use independent assessors to check the status of the whole turbine or of certain critical parts like the gearbox or main bearings.

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Damage on Wind Turbines

What is the Best Way to Assess This?

Independent engineers from the 8.2 partnership are often hired to check for damage on wind turbines and have to date assessed about 8,000 turbines. The 14 specialists in different fields evaluate failures as well as the future operation and maintenance costs based on the findings of the assessment. This article concentrates on the problems of the drive train as this component has a high value and a still unacceptably high failure rate.

Possible Assessment Methods

For quick checks (as opposed to long-term methods such as Condition Monitoring System, CMS) of the condition of the drive train the following methods are possible:

- A visual check through inspection apertures (however, these are often blocked by hoses or other equipment).
- Listening into the drive train with an electronic stethoscope during operation of the turbine.
- Video endoscopy of the main gearbox (sometimes also the main bearing and generator windings). 8.2 uses a flexible probe with 2m length and a diameter of 3.9mm.
- Vibration analysis offline (8-channel measurement, additional rotational speed measurement). 8.2 uses the 'Peakstore' and 'OmegaExpert2' data acquisition devices and its own evaluation software.

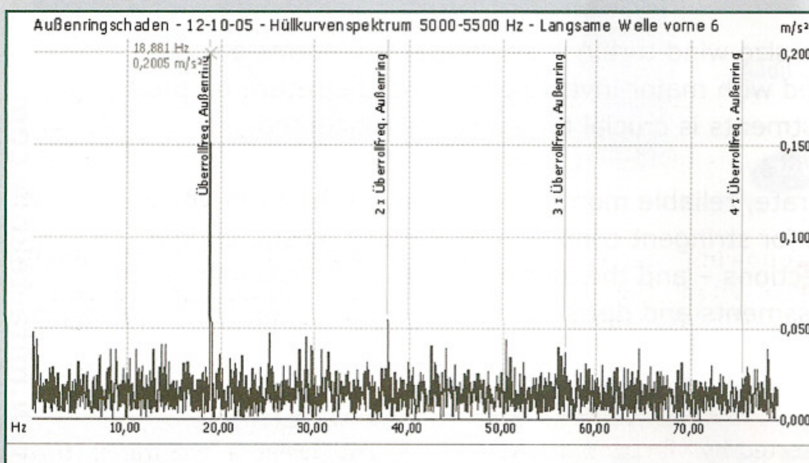
However, by using all methods the assessment costs are becoming unacceptably high. 8.2 has analysed the pros and cons of the different methods in order to assess whether one method could be abandoned without reducing the assessment certainty.

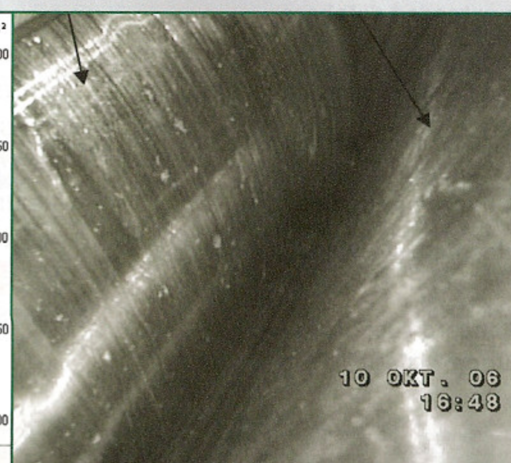
Selected Assessment Results

Which results can be expected by which assessment method? In the following case studies we give some examples of real damage and the assessment results.

Case study 1: Bearing damage on the low speed shaft

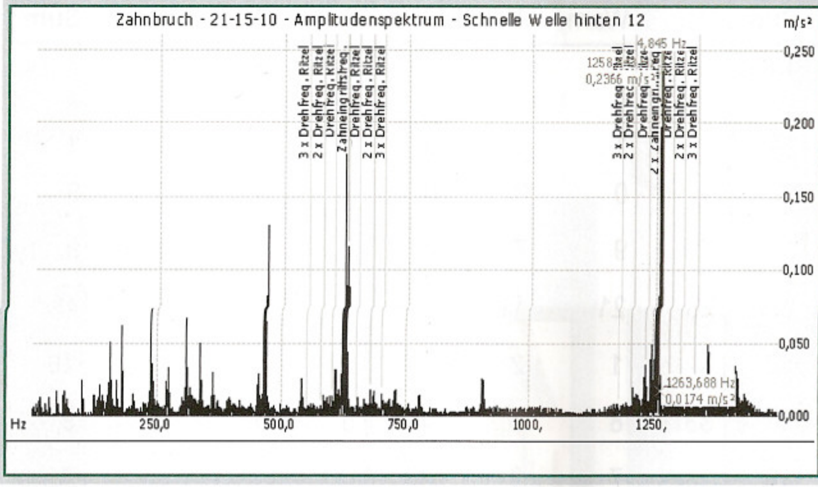
Visual inspection and stethoscope:	No indication of any damage
Video endoscopy:	Damage category 'Alarm'
Vibration analysis:	Outer ring damage category 'Alarm'





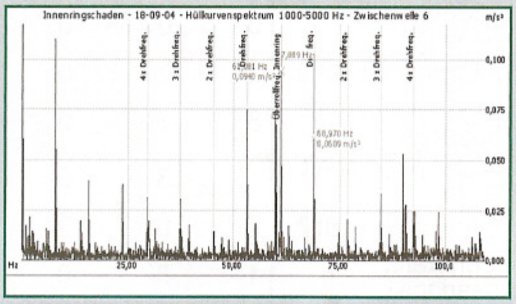
Case study 2: Broken teeth on the pinion of the high speed shaft

Visual inspection and stethoscope:	Damage category 'Warning'
Video endoscopy:	Damage category 'Warning'
Vibration analysis:	No noticeable problems



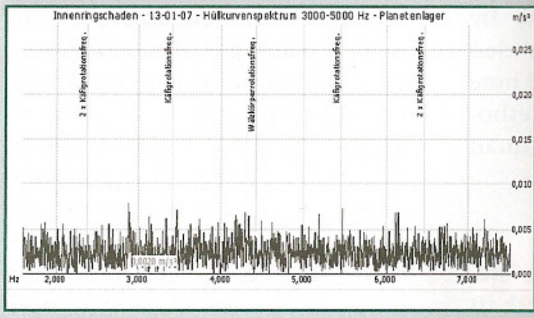
Case study 3: Damage on a bearing of the intermediate shaft

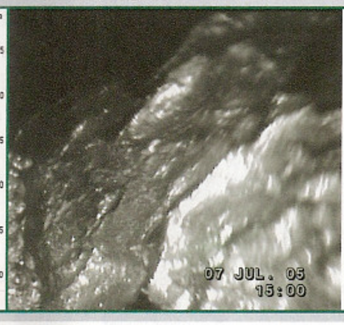
Visual inspection and stethoscope:	No noticeable problems
Video endoscopy:	No noticeable problems (bearing not accessible)
Vibration analysis:	Damage category 'Warning'

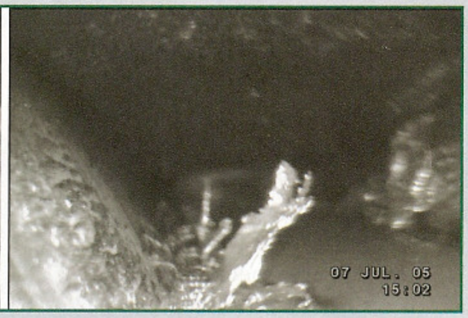


Case study 4: Damage on a planetary bearing

Stethoscope:	No noticeable problems
Video endoscopy:	Damage category 'Alarm'
Vibration analysis:	No noticeable problems







Statistical Assessment of the Methods

The strengths and weaknesses of the different methods indicated by the case studies are backed by an evaluation of 385 assessments (as of 31 July 2006). The evaluation only considers turbines with one main gearbox and an installed power of more than 1,000kW. The problems and damage detected have been categorised in five categories (OK/To be observed/Warning/Alarm/Damage). Only the three middle categories are summarised in Table 1.

The following statements can be made about the differences between the assessment methods:

- Possible damage on the main shaft and main bearing is only detected by vibration analysis. Video endoscopy cannot be used for these parts and listening with the stethoscope does not produce any result.
- Possible damage on the planet bearings is only detected by video endoscopy (47% of the assessed gearboxes had noticeable problems). The vibration analysis detects damages on planet bearings with a much lower certainty.
- The faster a bearing is turning, the better vibration analy-

Assessment method	Visual inspection + stethoscope				Video endoscopy				Vibration analysis			
Cases	76				95				214			
Categories	Obs.	Warn.	Alarm	**Sum**	Obs.	Warn.	Alarm	**Sum**	Obs.	Warn.	Alarm	**Sum**
Rotor shaft	0	1	0	**1**					5	3	0	**7**
Main bearing	1	0	0	**1**					3	0	0	**4**
Gearbox generally	9	5	0	**14**	1	1	3	**5**	1	0	0	**1**
Planetary gear generally	1	0	0	**1**	0	0	0	**0**	6	3	0	**9**
Planetary gear bearings	0	0	0	**0**	31	9	7	**47**	6	2	1	**9**
Planetary gear tooth	0	0	0	**0**	28	21	11	**60**	32	14	1	**48**
Spur gear stages generally	16	3	0	**18**	4	1	2	**7**	21	4	0	**26**
Low speed shaft bearings	1	0	0	**1**	33	8	5	**46**	5	1	1	**8**
Low speed shaft teeth	25	3	0	**28**	23	7	3	**34**	6	1	0	**7**
Interm. shaft bearings	0	0	0	**0**	22	7	4	**34**	20	7	2	**29**
Interm. shaft teeth	21	3	0	**24**	27	8	4	**40**	16	1	0	**17**
High speed shaft bearings	8	7	0	**14**	38	9	13	**60**	30	12	8	**51**
High speed shaft teeth	29	3	0	**32**	22	3	4	**29**	23	5	1	**29**
Generator shaft	0	0	0	**0**					35	10	2	**46**
Generator bearings	14	5	0	**20**					28	23	20	**71**

Table 1. The occurrences of noticeable problems and damage to different parts of the drive train detected by different assessment methods (rounded to the nearest percentage)

sis detects damage. Therefore, for high speed shaft bearings the detection rate is similar for video endoscopy or vibration analysis.

- When only visual inspection and a stethoscope are used, considerably less damages are detected. In particular, a categorisation of the damage is not possible because of a lack of objective criteria.
- Possible damage on the generator is currently only detected with a high reliability by vibration analysis. Video endoscopy cannot be used here and listening with the stethoscope does not result in quan titative and reliable results.

Summary

If a good diagnosis of the status of the whole mains shaft is required, video endoscopy and vibration analysis should be used as assessment methods. The main advantages of video endoscopy are found in assessments of the planetary gear and the slow speed bearings of the gearbox; vibration analysis has its advantages with the assessment of the whole drive train (main bearing–gearbox–generator). Both assessments in combination

	Visual inspection/ stethoscope	Video endoscopy	Vibration analysis
Visualisation	+	+	-
Audio test possible	+	-	+
Quantification possible	-	o	+
Significance	-	+	o
100% assessment possible	o	-	+
Accessibility of parts	-	o	+
Costs	+	-	-
Organisational effort	+	+	o

+ = good, o = medium, - = bad

Table 2. summarises some of the pros and cons of the three methods considered

deliver visual and quantifiable results for the main gearbox and increase the possibility of defining the damage progress more exactly. However, visual inspection and stethoscopes should be used in addition to the two above-mentioned methods, as the subjective impression of the assessor can deliver very important information on the damage status of the respective part without much more additional effort.

Biography of the authors

Jürgen Holzmüller has a BSc in Mechanical Engineering from the University of Karlsruhe. From 1989 until 1998 he worked for Enercon GmbH, Design and Construction. In 1998 he established the 8.2 Engineering Office Holzmüller in Aurich and he works as an independent assessor and consultant for wind turbines.

Dietmar Obst holds a BSc in Mechanical Engineering from the University of Applied Science, Hamburg. From 1993 until 2002 he worked for HEIN GAS Hamburg Gasworks. He joined the 8.2 partnership in 2003. He specialises in technical assessment of wind turbines and photovoltaic plants, and vibration analysis.

Jochen Ziehmann has a BSc in Electrical Engineering from the University of Applied Science, Hamburg. From 1990 until 2004 he worked for various companies in the computer hardware and software industry, and on development of modems, ISDN and Bluetooth technology. Since 2004 he has been part of the 8.2 Engineering Partnership Obst & Ziehmann and has specialised in vibration analysis. He has developed software for this purpose, called VibraLyze.

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