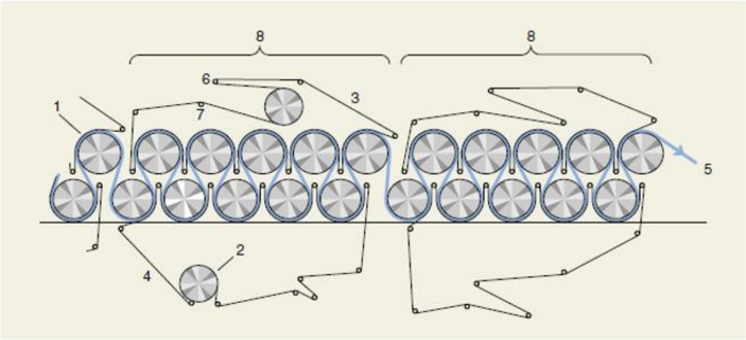
Case Study | Route-based Vibration Analysis

Machine Overview

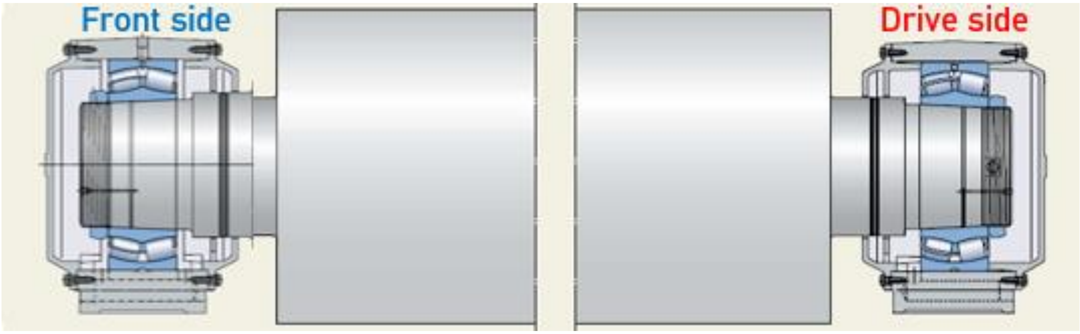
- Cardboard
  - Max Speed 780 MPM
- Running Speed: 165 RPM
- Measurement periodicity: **3 weekly (offline) measurements**
- **Problem**: Bearing damages on drying cylinders



Traditional drying section
1. Drying cylinder
2. Felt drying cylinder
3. Top felt
4. Bottom felt
5. Paper web
6. Felt stretch roll
7. Felt guide roll
8. Drive group

23044 CCK/W33 type spherical roller bearings on both sides

FTF	: 0,448
BSF	: 4,688
BPFO	: 11,198
BPFI	: 13,802



Non-located outer ring for thermal expansion

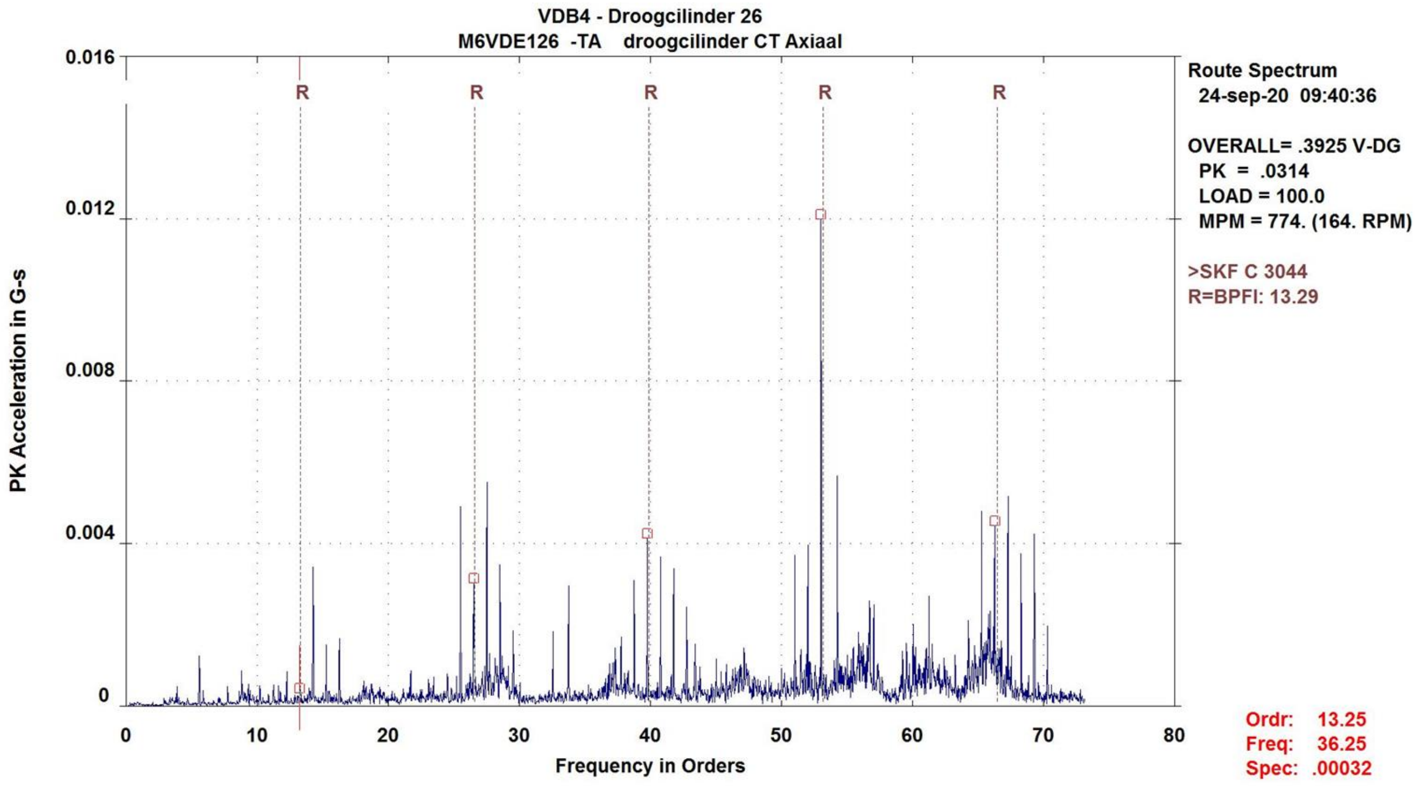
Located outer ring in the housing

Cylinder 26 - Measurement of the **Drive Side Bearing**

- During the routine vibration measurements at PM6, an **increase of the vibration levels** is noted on the drive side of the drying cylinder 26.

- **Asynchronous frequencies** at 13,2 x order became visible with sidebands on 1x order in the spectra.

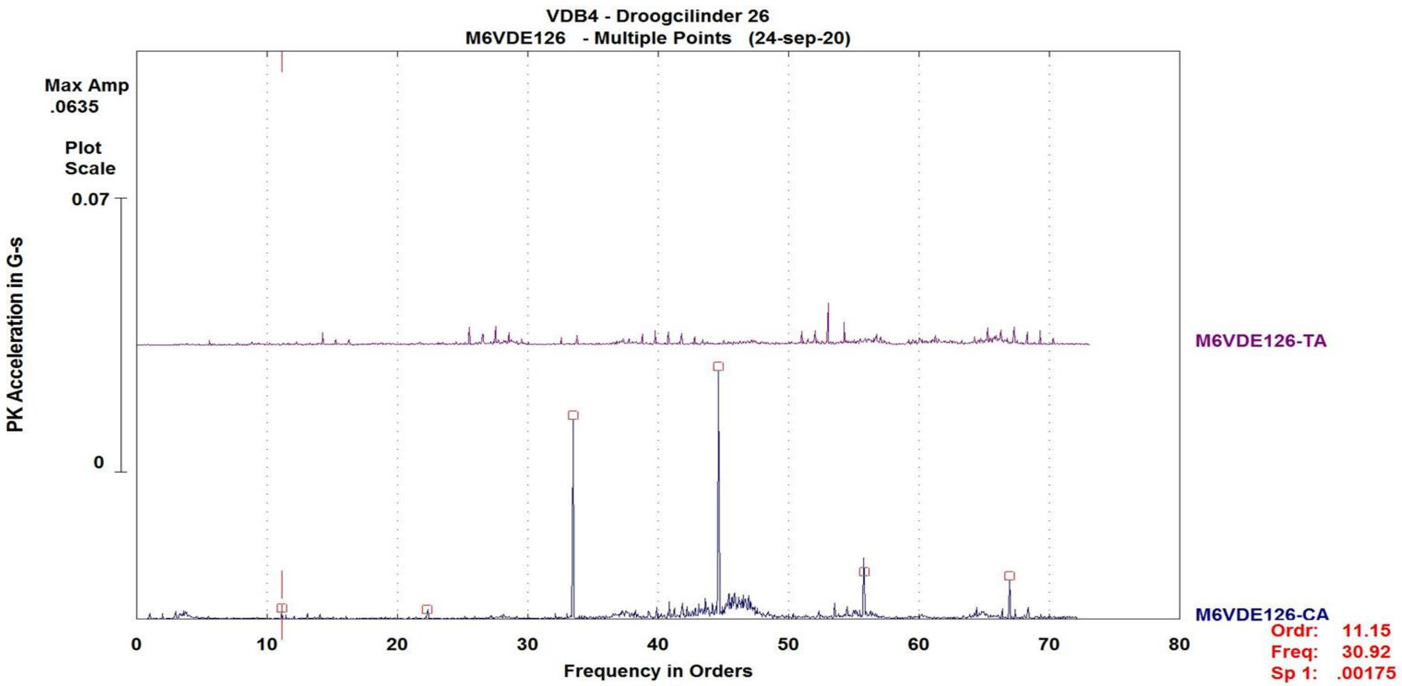
- However, 13,2x order doesn't match with any fault frequencies of 23,044 CCK type bearing (with 25 rolling elements).

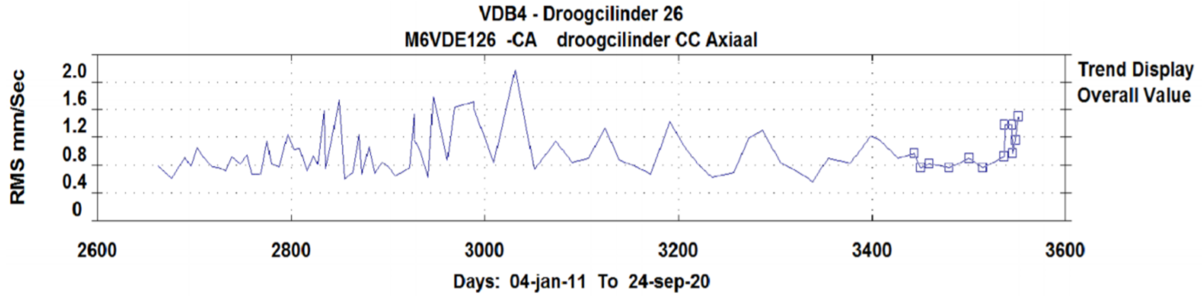


Comparison of **Both Sides**

- When the measurements of both bearings are compared with each other, the amplitude level of the front side bearing was quite high.

- Keep in mind that the front side had a quite stable trend (i.e. no indication of a serious deterioration).





Cylinder 26 – Diagnosis for the **Drive Side** Bearing

- To find the origin of asynchronous frequency at 13,2x order, the bearing fault frequencies are calculated manually by decreasing the number of rolling elements.
- BPFI of a 23044 CCK bearing with 24 rolling elements is calculated as 13,25x order.
- So, early bearing damage was apparently present on the drive side of the drying cylinder-26 (given the lower amplitude levels compared to the bearing damage on the front side bearing).

To verify the vibration readings, both bearings are checked using an electronic stethoscope.
The results:
- Drive side: A clear audible noise of a damaged bearing.
- Front side: No audible noise of a damaged bearing?

Bearing component	*Characteristic frequencies, Hz*
Cage	$f_c = \frac{f_R}{2}\left(1 - \frac{d}{D}\cos\,\alpha\right) + \frac{f_{Rout}}{2}\left(1 + \frac{d}{D}\cos\,\alpha\right)$
Inner race	$f_i = \frac{Z}{2}\left[(f_R - f_{Rout})\left(1 + \frac{d}{D}\cos\,\alpha\right)\right]$
Outer race	$f_o = \frac{Z}{2}\left[(f_R - f_{Rout})\left(1 - \frac{d}{D}\cos\,\alpha\right)\right]$
Rolling	$f_b = \frac{1}{2}\frac{D}{d}(f_R - f_{Rout})\left[\left(1 - \frac{d}{D}\cos\,\alpha\right)^2\right]$

f_R = shaft rotation frequency, f_{Rout} = outer race rotation frequencies, D = mean diameter (to the ball center), d = ball diameter; Z = number of rolling elements, α = contact angle.

```
Number of Balls/Rollers   :    24
Ball/Roller Diameter      :  1.1811
Pitch Diameter of Races   :  11.196
Contact Angle (Degrees)   :    9.1
Inner Race Rotating       :    Yes
```

HARMONICS	SHAFT SPEED	TRAIN (FTF)	SPIN (BSF)	OUTER (BPFO)	INNER (BPFI)
1	1.00	.448	4.69	10.75	13.25
2	2.00	.896	9.38	21.50	26.50
3	3.00	1.344	14.07	32.25	39.75
4	4.00	1.792	18.75	43.00	53.00

```
Number of Balls/Rollers   :    25
Ball/Roller Diameter      :  1.1811
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Contact Angle (Degrees)   :    9.1
Inner Race Rotating       :    Yes
```
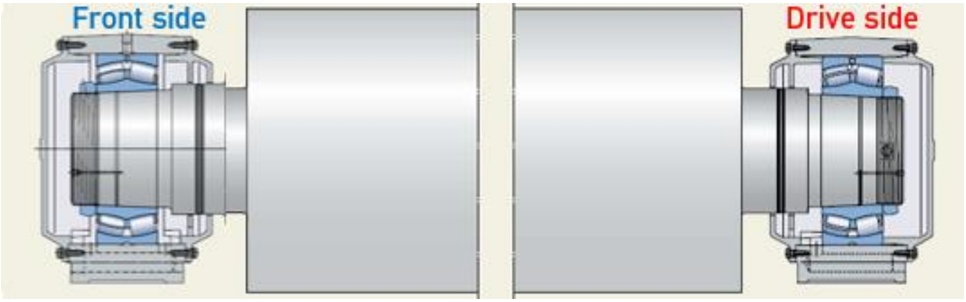

HARMONICS	SHAFT SPEED	TRAIN (FTF)	SPIN (BSF)	OUTER (BPFO)	INNER (BPFI)
1	1.00	.448	4.69	11.20	13.80
2	2.00	.896	9.38	22.40	27.60
3	3.00	1.344	14.07	33.59	41.41
4	4.00	1.792	18.75	44.79	55.21



VIB: BPFO (moderate)
NOISE: no damage

VIB: BPFI (mild)
NOISE: damage

Cylinder 26 – **Corrective Action** for the **Drive Side** Bearing

1

- The evolution of both bearing damages is monitored further. After a while, the amplitude levels of the drive side bearing increased.
- A bearing replacement is planned during the next planned shutdown to avoid an imminent failure.

2

Signs of abrasive wear and spalling are clearly seen on the right rolling contact surface; as a result of bearing misalignment and/or excessive axial thrust.

1

2

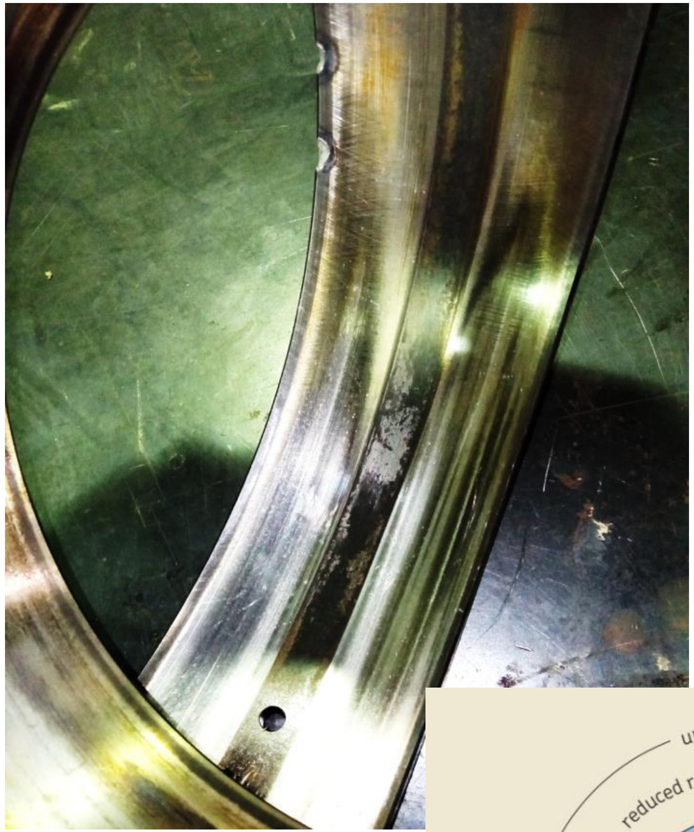
Cylinder 26 – **Corrective Action** for the **Front Side** Bearing

Later, the front side bearing is also replaced during the subsequent planned shutdown. **Signs of polishing wear** are clearly visible on the **rolling elements** and on the **outer raceway**.

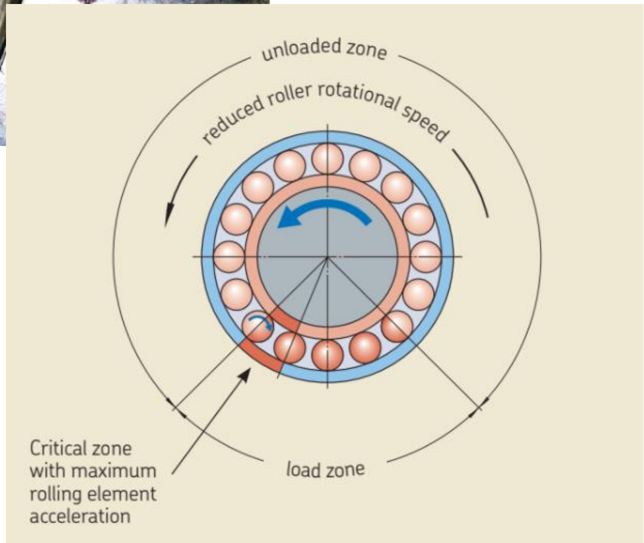
The most usual explanation for mirror-like raceway surfaces in a rolling bearing is that the bearing has been **poorly lubricated**, which normally means a thin oil film. A thin oil film allows metal-to-metal contact that leads to wear and plastic deformation of asperities.

The **viscosity** of the oil is too low and there are a lot of very small abrasive contaminant particles in the oil. Then the bearing becomes subjected to continuous polishing wear. These microparticles are always present in a lubricant, but not every bearing with a thin oil film becomes polished. **Why does this happen?** It is presumed that there are additional factors influencing the start of the polishing wear process, e.g. a certain **combination of low speed, heavy load, and thin oil film.**

The best way to avoid this kind of abrasive polishing wear is to increase the oil film thickness and use oils with good **EP or AW properties.**



Shiny surfaces on the entrance of the load zone



Cylinder 26 – **Corrective Action** for the **Drive Side** Bearing

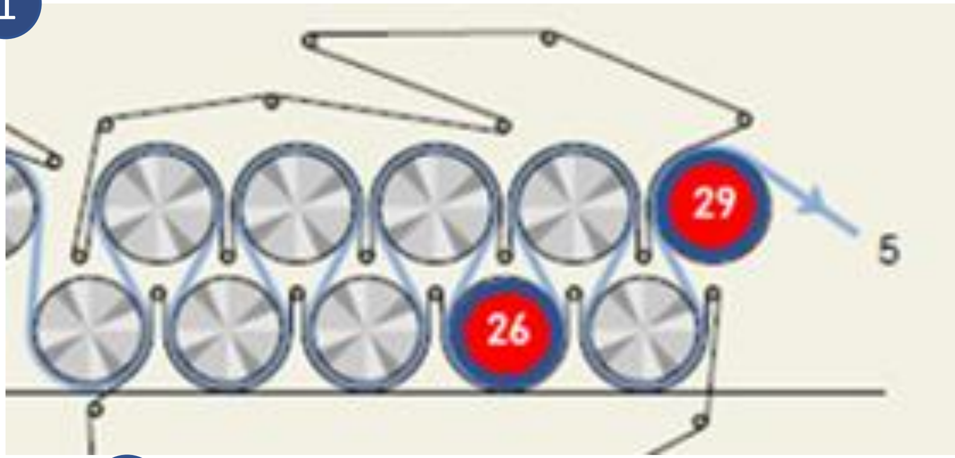
1

It is common to see this phenomenon on lightly loaded bearings when operated at high speeds.

2

Higher belt tension increases the loads on the bearings of upper cylinders, but can also decrease the loads on the bearings of lower cylinders.

1

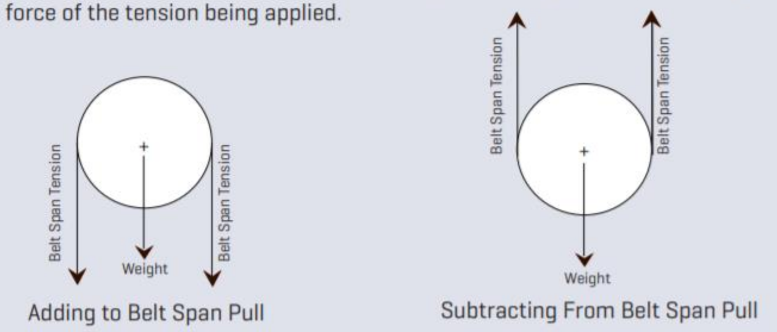


2

Shaft and Bearing Load

Shaft Load

Shaft load is a commonly used industry term that describes the load on a shaft exerted by the tension, or pull, of a belt or chain, combined with the weight of the sheave or sprocket that's attached to the shaft. Depending on the orientation of the drive, the sheave/sprocket weight could be adding or subtracting from the force of the tension being applied.



Bearing Load

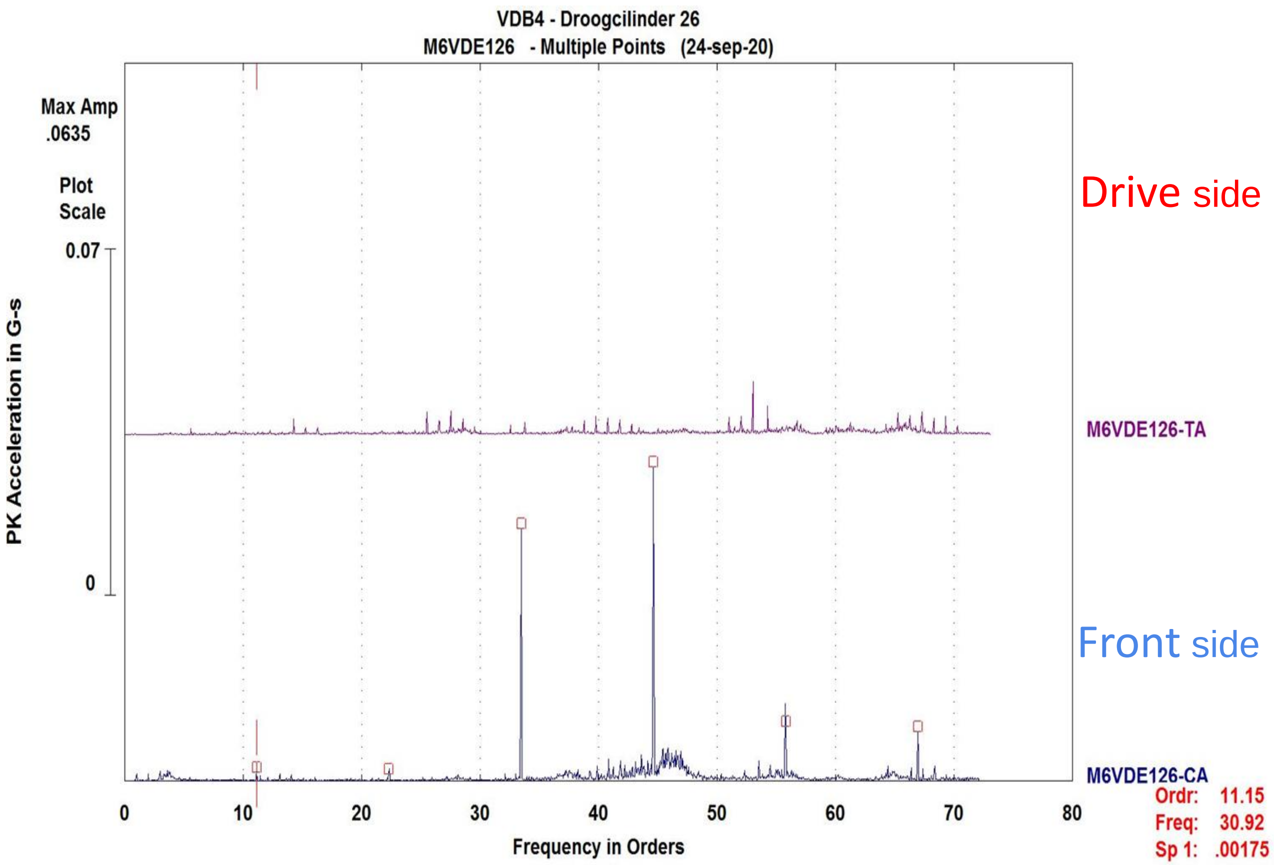
Bearing load is another commonly used term. Weight and tension applied to the shaft exerts a force on the supporting bearings. The amount of this force depends on where the bearings are located on the shaft in relation to the center of the sheave or sprocket, where the pulling force is being applied.

Cylinder 26 – **Measurements** compared to **Damage Pictures**

1. Severity determination of bearing damage cannot be done solely based on amplitude levels.

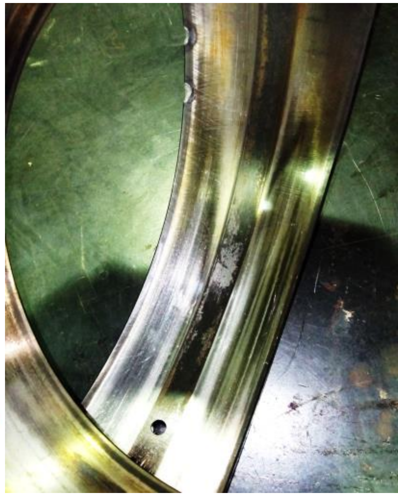
2. Look for evolving patterns in spectra & time signals, elevating nose floors, changing trends,...

3. Noise measurements are sometimes very useful to identify the bearing problems: use a stethoscope.



Drive side

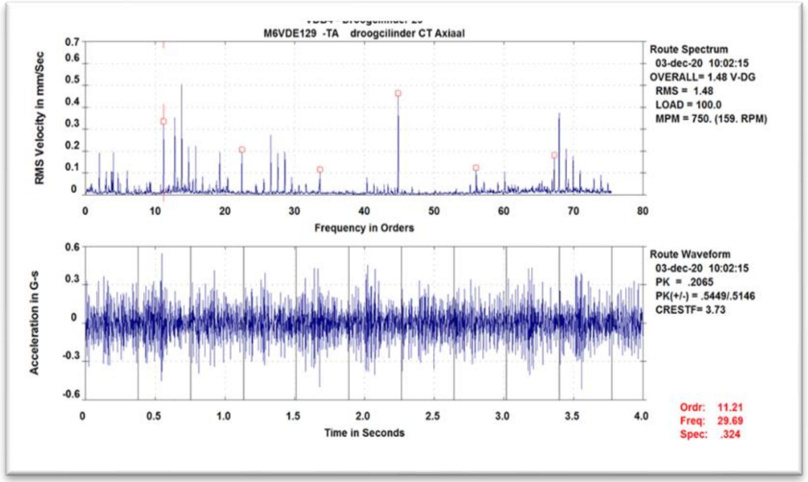
Front side

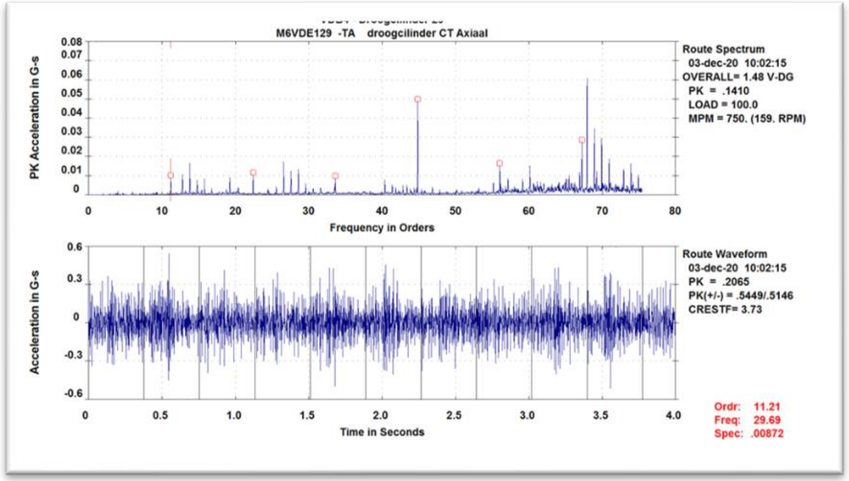


Cylinder 29 - **Exact Location** of the **Bearing Damage**. Front Side vs. Drive Side

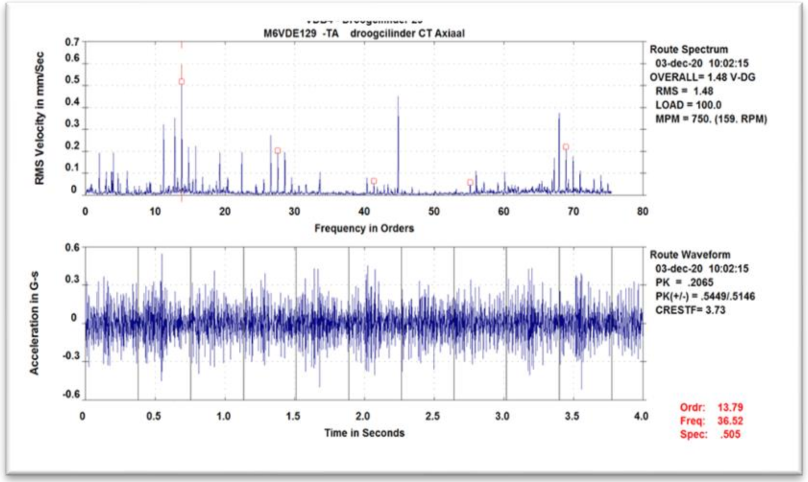
VELOCITY

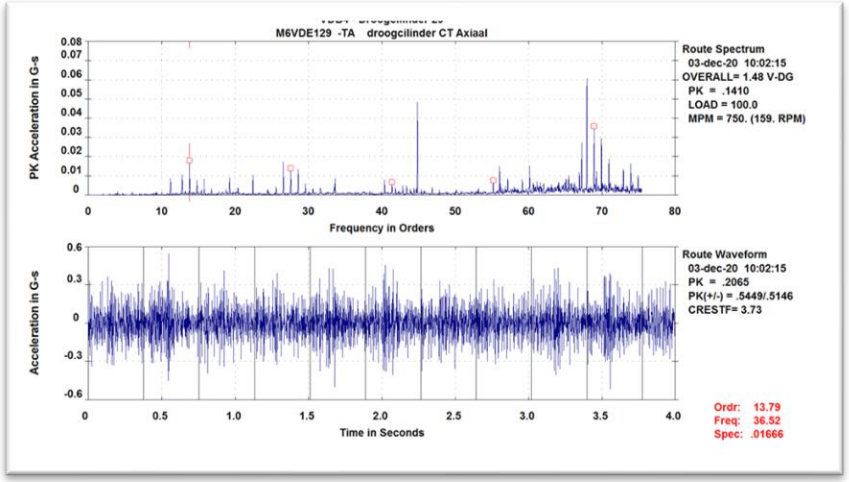
ACCELERATION





BPFO at 11,2x order



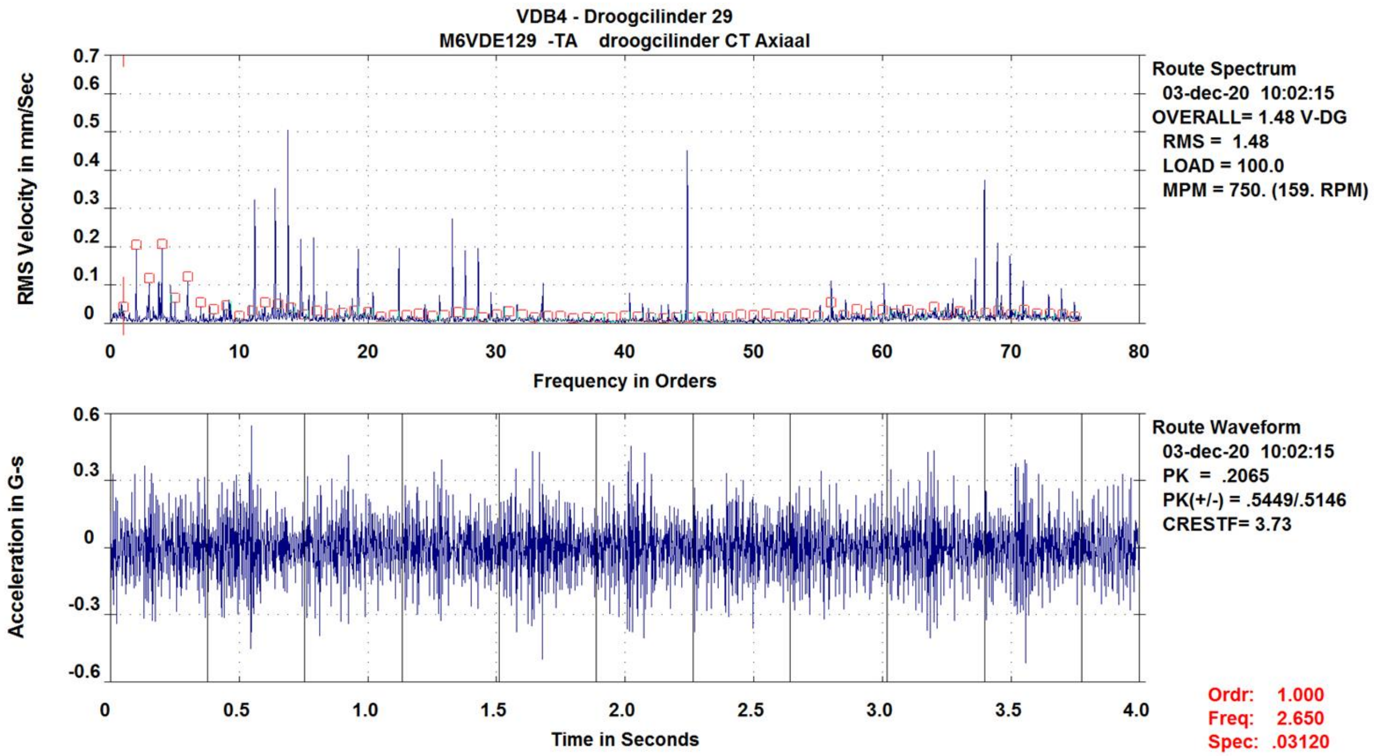


BPFI at 13,8x order

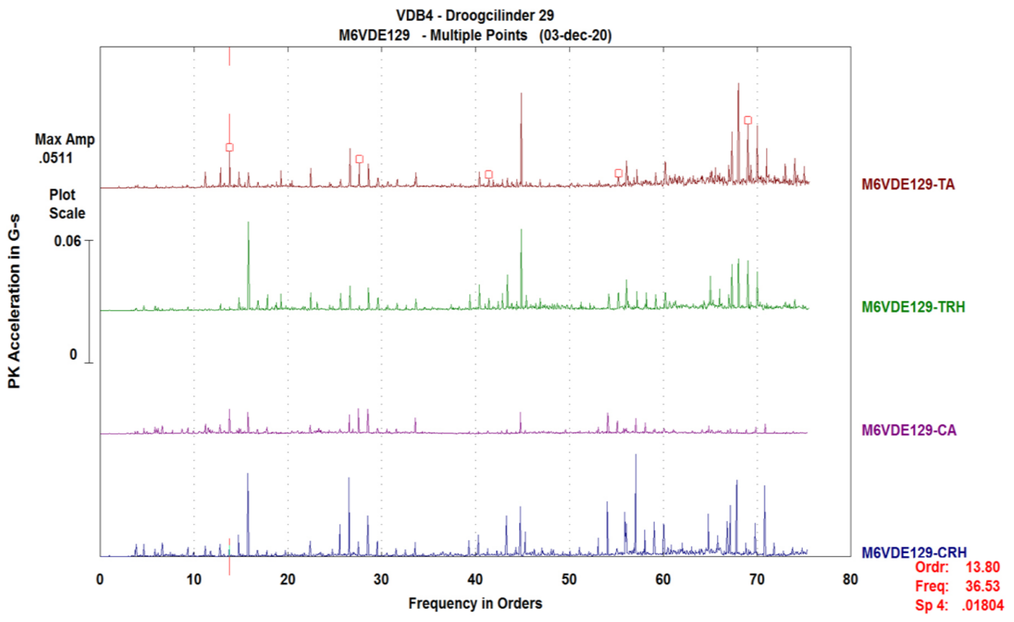
Cylinder 29 - **Exact Location** of the **Bearing Damage**. Front Side vs. Drive Side, **cont.**

1x order and harmonics:

Likely some looseness or an indication of severe bearing damage (because bearing fault frequencies are also present)?



Cylinder 29 – **Exact Location** of the **Bearing Damage**

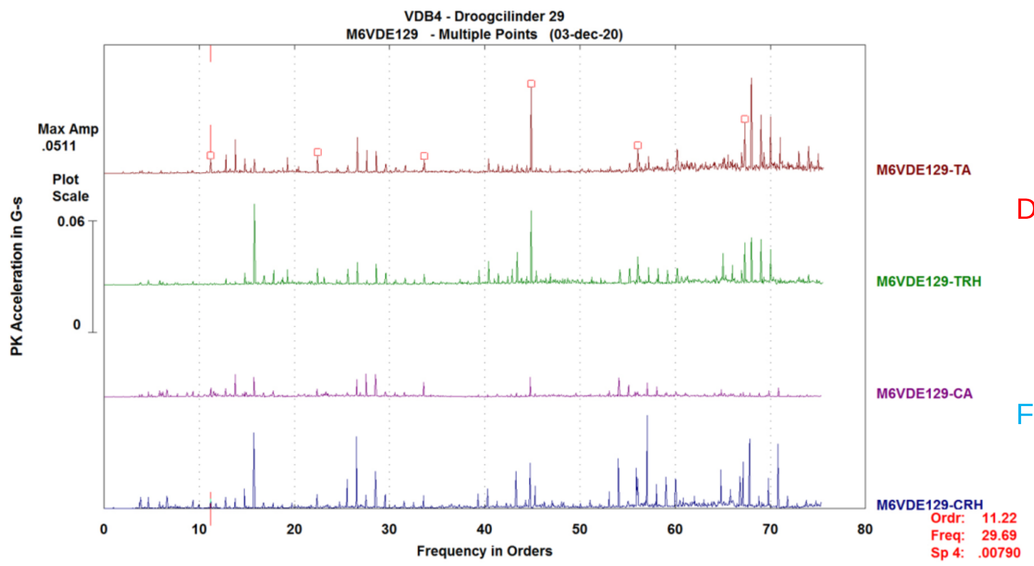


Drive side

Front side

Given more sidebands at 1x, BPFI (13,8x) on the **front side**?

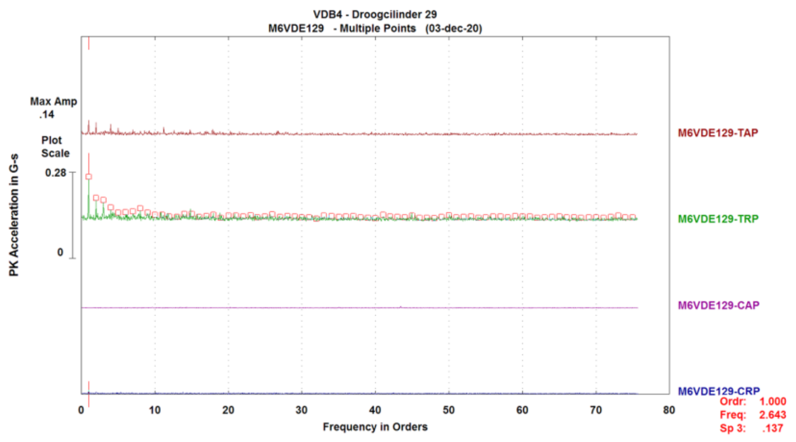
Or given higher amplitude levels, BPFO (11,2x) on the **drive side**?



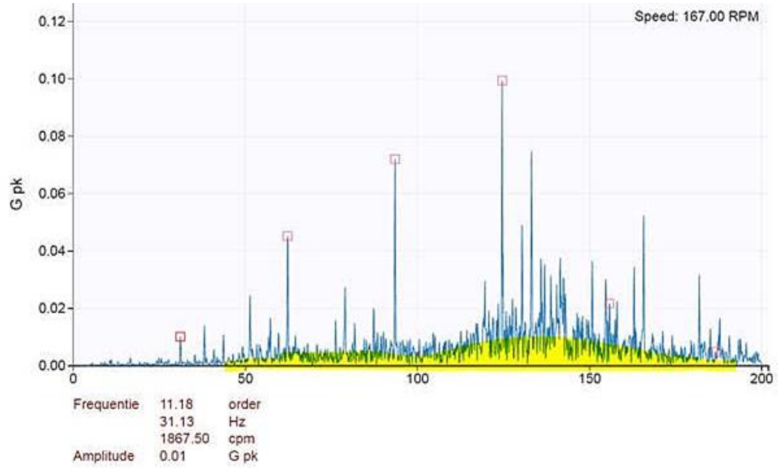
Drive side

Front side

Cylinder 29- **Envelope Measurement** & **Noise Floor** of Spectra

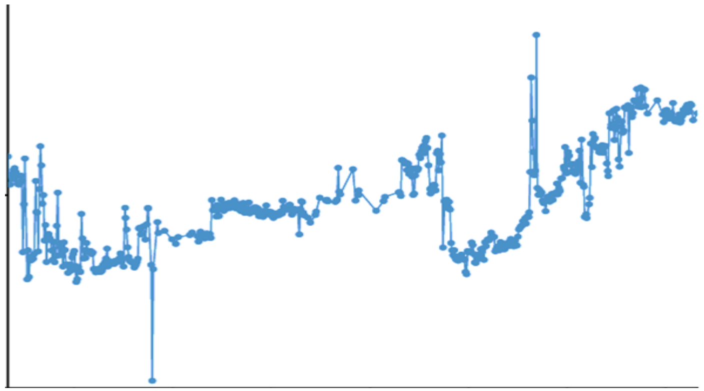


High-frequency impacts at 1x order can be a sign of inner ring cracking. Which means:
"Envelope measurements such as PeakVue, SPM HD, or Spike are used to detect stress waves due to impacting (metal-metal contact), friction, and fatigue cracking. Stress waves propagate in all directions and the velocity at which the waves propagate away from the damage location is proportional to the square root of frequency. So the amplitude will decrease and the duration of the event will increase as the measurement point is further removed from the initiation site."



To closely follow up the vibration level and the spectral noise, a **hybrid monitoring method** is applied at this aged paper mill by using Wi-care 100 wireless sensors.

The gradual increase of the noise floor in the vibration spectrum is noted after a period of time which is a sign of deterioration on the rolling surfaces.



Note: The overall vibration level and the amplitude levels of the bearing fault frequencies showed no radical changes.

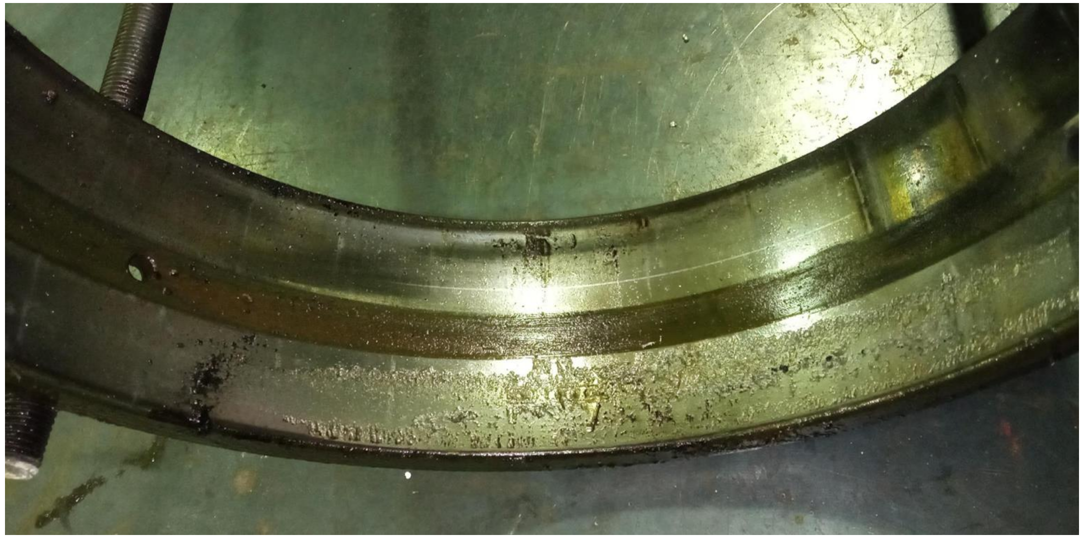
Cylinder 29- **Corrective Action** for the **Drive side Bearing**

The drive side bearing is replaced during the planned shutdown.
Fortunately, the inner ring was not cracked.

The rolling surface on one side was severely damaged due to excessive bearing misalignment probably due to a deformed housing or machine frame.

- Abrasive wear on one side due to high load and the bearing's internal misalignment: the front side locating bearing has probably not enough space for axial displacement.

- Fretting corrosion on the shaft and on the inner diameter. Keep in mind that 1x order with harmonics was visible in the spectra due to a probable loose fit on the shaft.



Cylinder 29- Measurement of the Drive side Bearing **after Corrective Action**

Vibration measurements can tell you a story about the condition of your bearings.