



ASIA TURBOMACHINERY & PUMP SYMPOSIUM
MARCH 2018 | SUNTEC SINGAPORE

Cooling water pump gearbox diagnostics, failure and remedial actions

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Authors



Haider Ali
Machinery Diagnostics
Engineer - Engro fertilizer

Haider Ali joined Engro Fertilizer in 2013, and carries with him 4 years of diagnostic experience on centrifugal compressors in addition to maintenance/overhaul of BCL compressors and tandem Dry Gas seals.



Asad Akram Awan
Senior Machinery
Diagnostics Engineer
Engro fertilizer

Asad Akram joined Engro Fertilizer in 2009, and carries with him 10 years of advance diagnostic experience on centrifugal compressors, gearbox and steam turbines.



Mojiz Mansoor
Unit Manager Machinery
Diagnostics section
Engro fertilizer

Mojiz joined Engro fertilizers in 2011, and carries with him an experience of 14 years with different multinational fertilizer groups and power plants. Mojiz has extensive machinery commissioning experience.



Nooruddin Burrero
Senior Machinery
Adviser
Engro fertilizer

Mr. Nooruddin joined Engro fertilizers in 1971, and carries with him vast machinery experience. Nooruddin lead the machinery scope of worlds largest single train ammonia urea complex and the upgrade of existing plant machinery. Nooruddin overlooked the entire relocation of an existing Amm-Urea complex from outside the country.



Abstract

Failure of an industrial scale bevel gear assemble in 2.5 years of its commissioning. The gear box drives a pumps rated at 16240m³/h at 47.5 meter of head. The unit developed an abnormal noise with slightly higher impacting (vibration waveform) on the gearbox. However upon inspection, increased back-lash (still in recommended limit) was observed on the unit and the machine was kept in operation.

During a startup in March 2014, high cyclic impacting was observed in vibration waveform which indicated gearbox wear/damage. Upon inspection leading edge teeth of the bevel gearbox was found broken. Further investigation revealed increased back-lash and change in contact area of the gears.

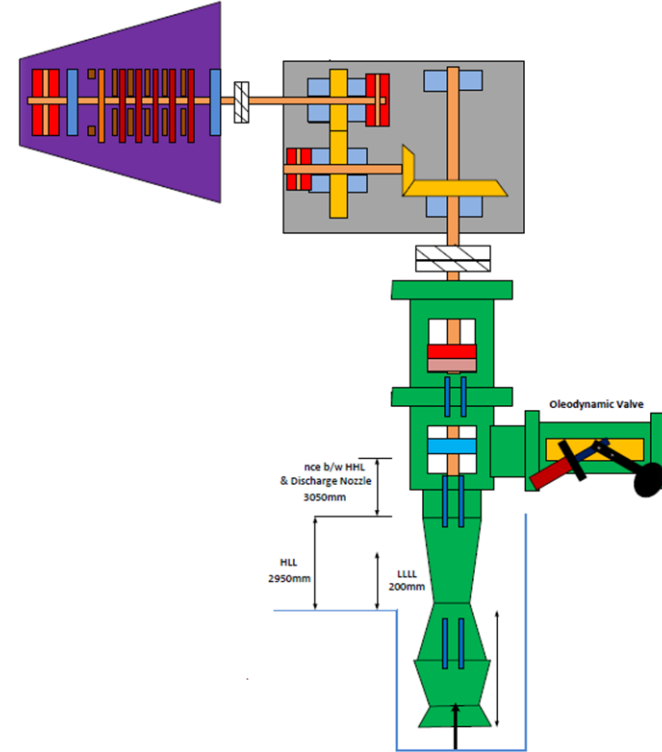
The case study covers the complete RCA of GB failure and the remedial action taken on similar units installed on site.



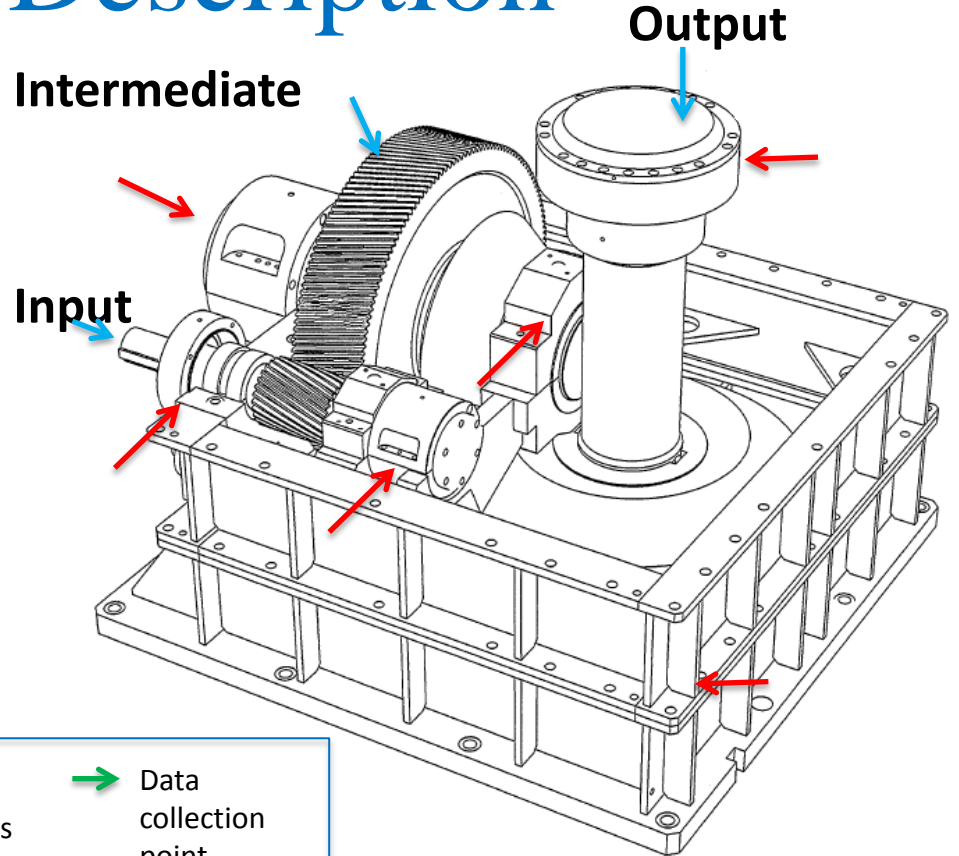
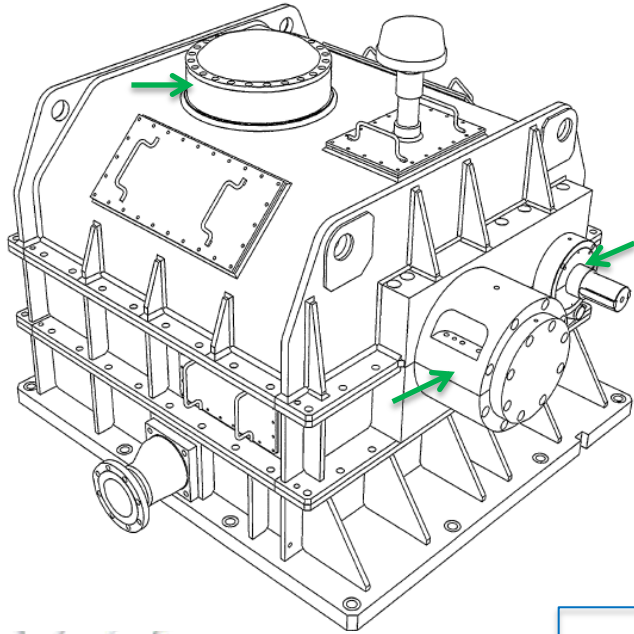
Machine Description



Gearbox

Type	Reducer bevel gear
Input Speed	5143 RPM
Output	595 RPM
Trip speed	1062.1 RP
Gear ratio	8.64
Radial bearing	Sleeve/ roller
Thrust bearing	Tilting pad/Roller



Machine Description



- | | | | |
|--|----------|--|-----------------------|
|  | Shaft |  | Data collection point |
|  | Bearings | | |

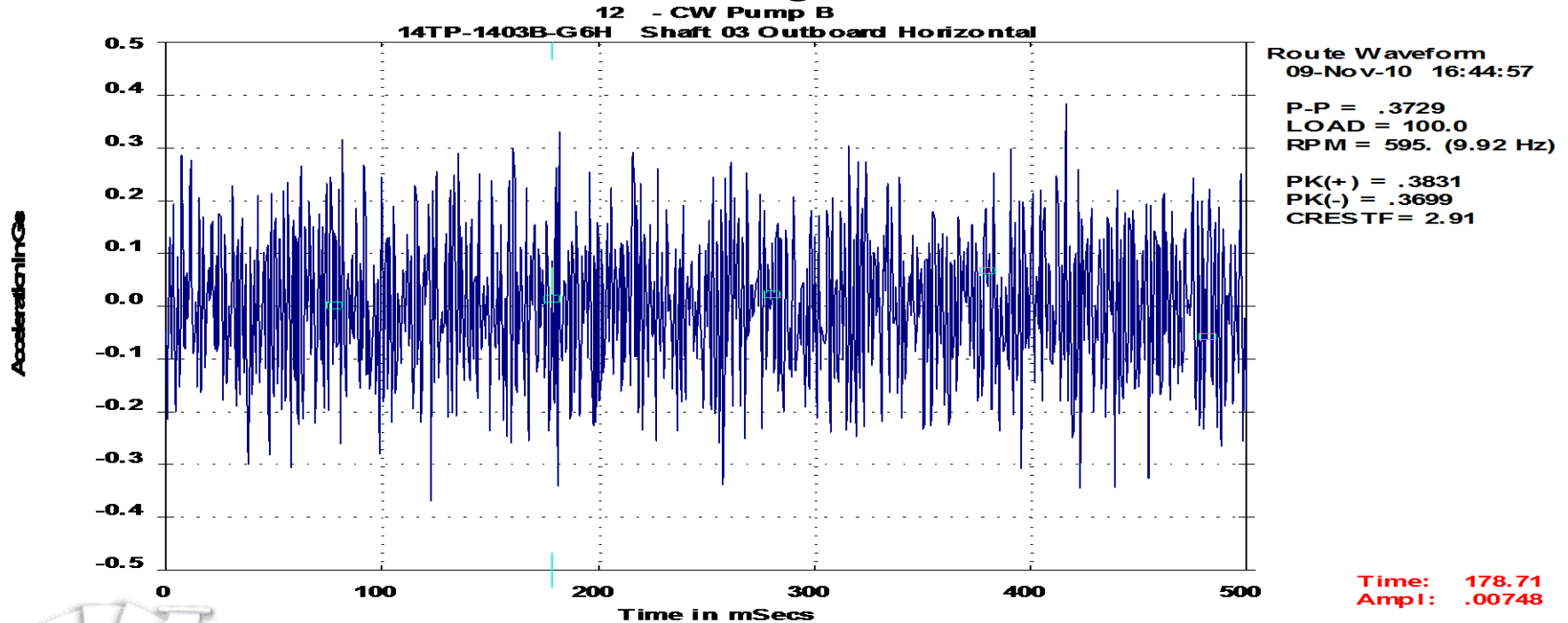
Series of event

Date	Time	Event
2010		Installation of C.W pumps
Oct 2012		Continuous operation from this point on
Jan 2014		-Abnormal noise and vibrations were observed -Unit taken offline and inspections performed -Increased backlash was observed on the bevel gear
12 Mar 2014	11:05 hrs	Total Power Failure occurred; resulting in tripping of motor and steam driven C.W pumps
13 Mar 2014	18:00 hrs	-Increased abnormal sound from Turbine driven GB -Waveform revealed increasing impacting, with spikes at 1x speed
14 Mar 2014	02:05 hrs	Unit shutdown



Vibration data

Commissioning data of 3rd shaft

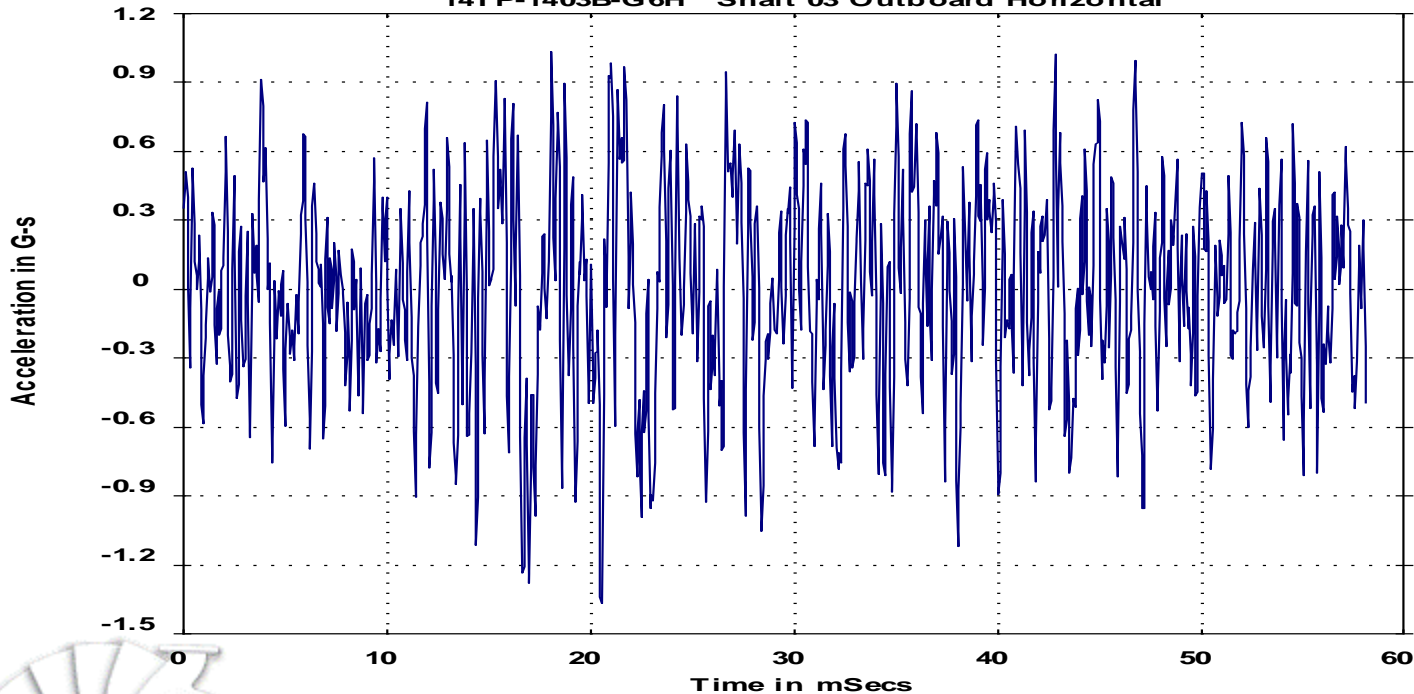


Vibration data

Apr 2014 data of 3rd shaft

12 - CW Pump B

14TP-1403B-G6H Shaft 03 Outboard Horizontal



Route Waveform
23-Apr-14 20:47:46

P-P = 1.21
LOAD = 100.0
RPM = 5100. (85.00 Hz)

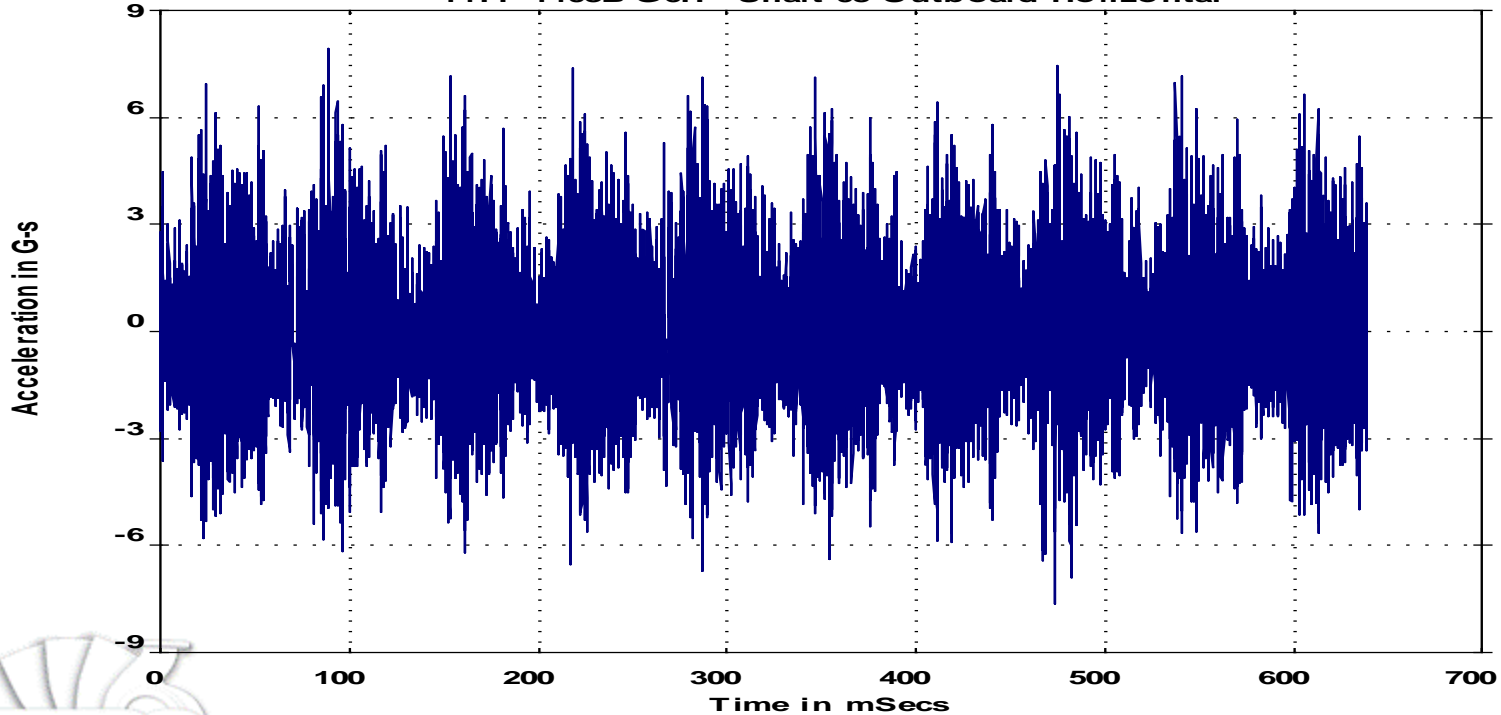
PK(+) = 1.04
PK(-) = 1.37
CRESTF = 3.20



Vibration data

After tripping data of 3rd shaft

12 - CW Pump B
14TP-1403B-G6H Shaft 03 Outboard Horizontal



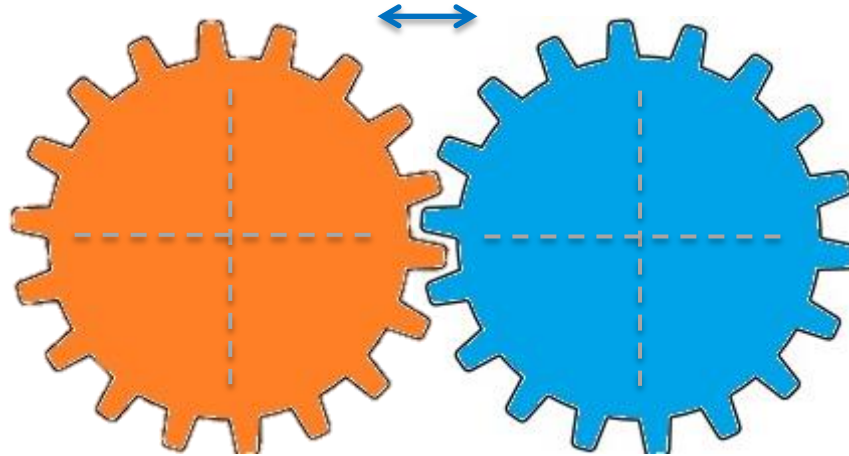
Analyze Wavef
15-Mar-14 02:

P-P = 6.24
LOAD = 100.0
RPM = 595.0

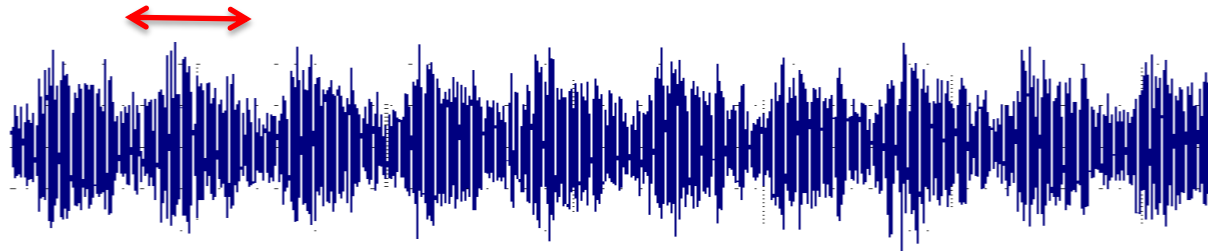
PK(+) = 7.93
PK(-) = 7.63
CRESTF = 3.6



Amplitude modulation

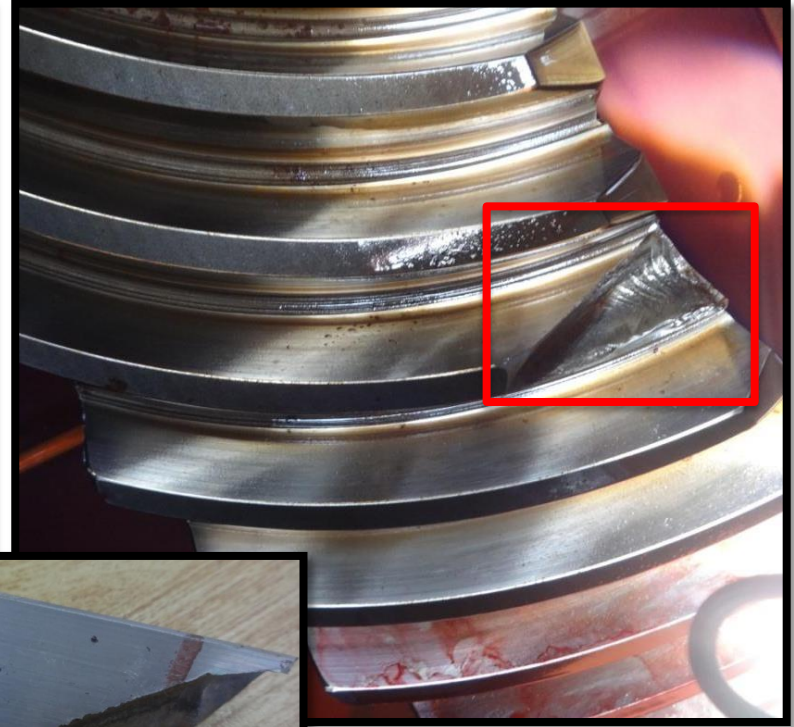
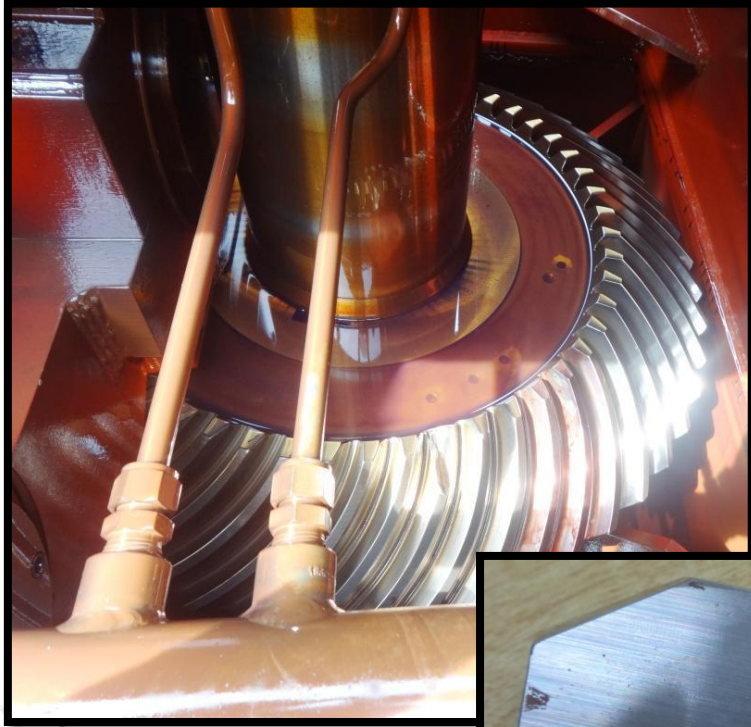


Running RPM of loose teeth



Inspection

Broken teeth in reverse direction



Observations

- While measuring Axial of Intermediate shaft it was observed that the **bevel gear was loose on the shaft** (in clearance). According to vendor documentation this was set to 0.002 inches.
- This explains the **Amplitude modulation** in gearbox shaft, however does not explain why the gear broke in reverse direction.
- Keys used to lock pinion had extruded on one end due to high torque and loose pinion.
- A step had been generated near the ID of the Gear due to the continuous rubbing of the gear against the shaft collar. The depth of the step ranges up to **0.025"**.
- Uneven wear was observed on the teeth of the pinion gear.



Observations



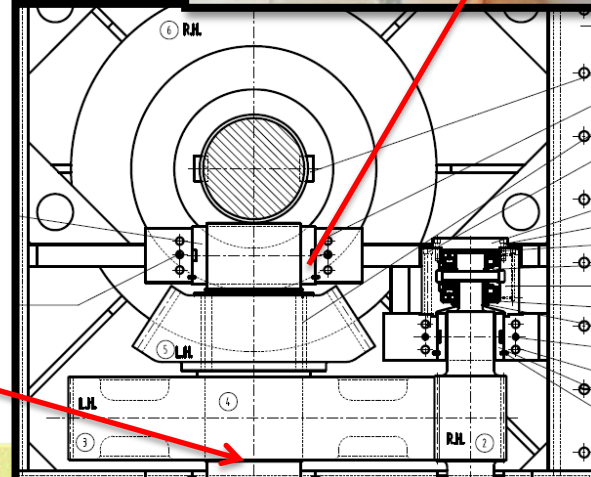
Keys used to lock pinion had extruded on one end due to high torque and loose pinion.



Step had been generated near the ID of the Gear

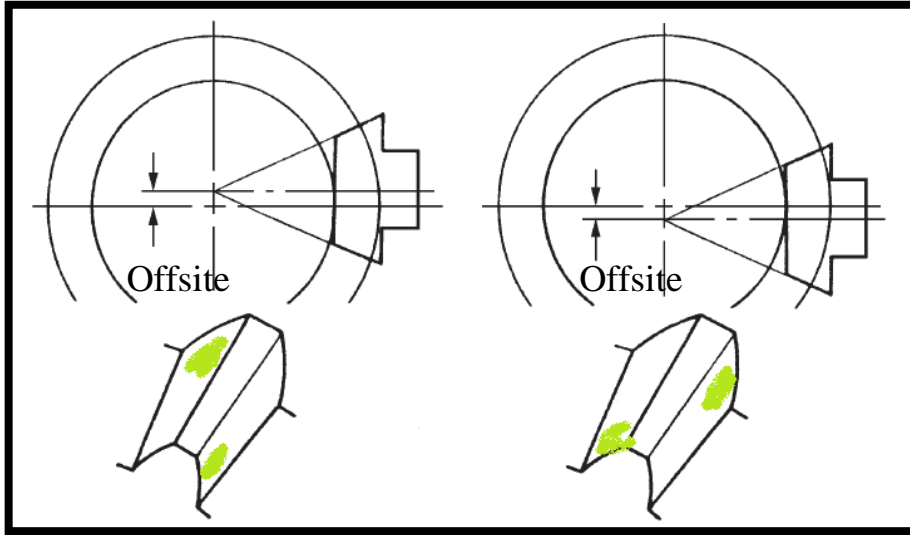


Material removed from step / collar on shaft which is provided as a gear stopper

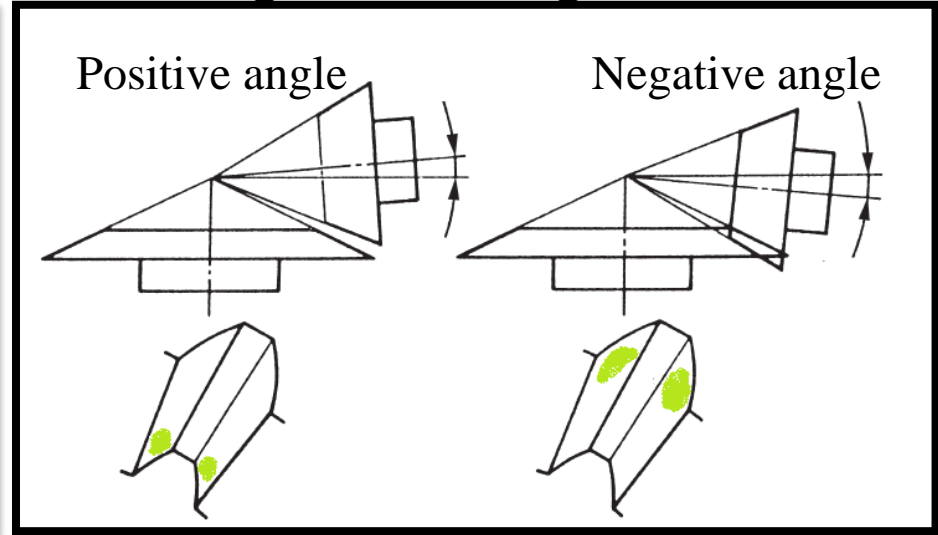


Teeth contact profile

Offset error

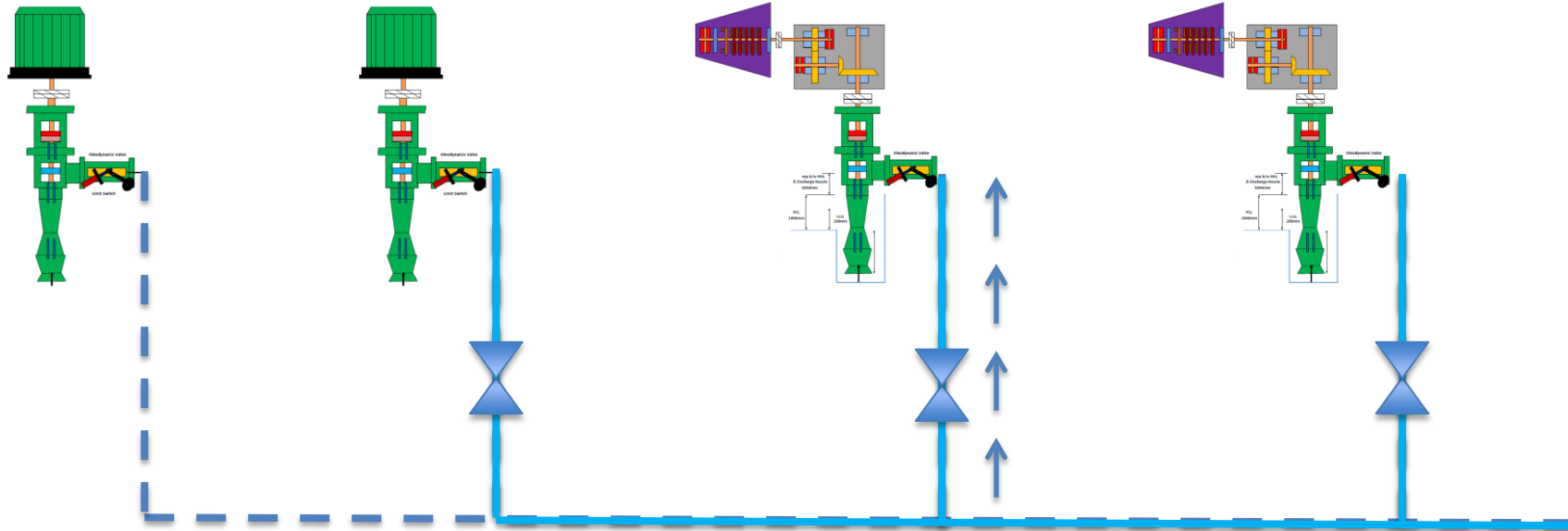


Angular misalignment



Contact area shown in green

How teeth broke in reverse



In case of tripping, the valve takes 40 seconds to shutdown while the pressure from the header breaks the momentum of the unit

Repair Procedure

- Due to non-availability of spare rotor, the same gear set had to be **reused**, while a new gear set was immediately ordered.
- Machining of the Shaft to a depth of 1/16” to remove shaft ovality.
- Machining of the Bevel Pinion I.D to remove the ovality inside.
- Welding buildup of shaft and final machining to adjust the **interference between the Shaft and the Pinion to 0.003” to 0.0035”**.
- Fabrication of New Keys.
- Machining of the Pinion near the ID of the gear to remove the uneven surface.



Repair Procedure(cont.)

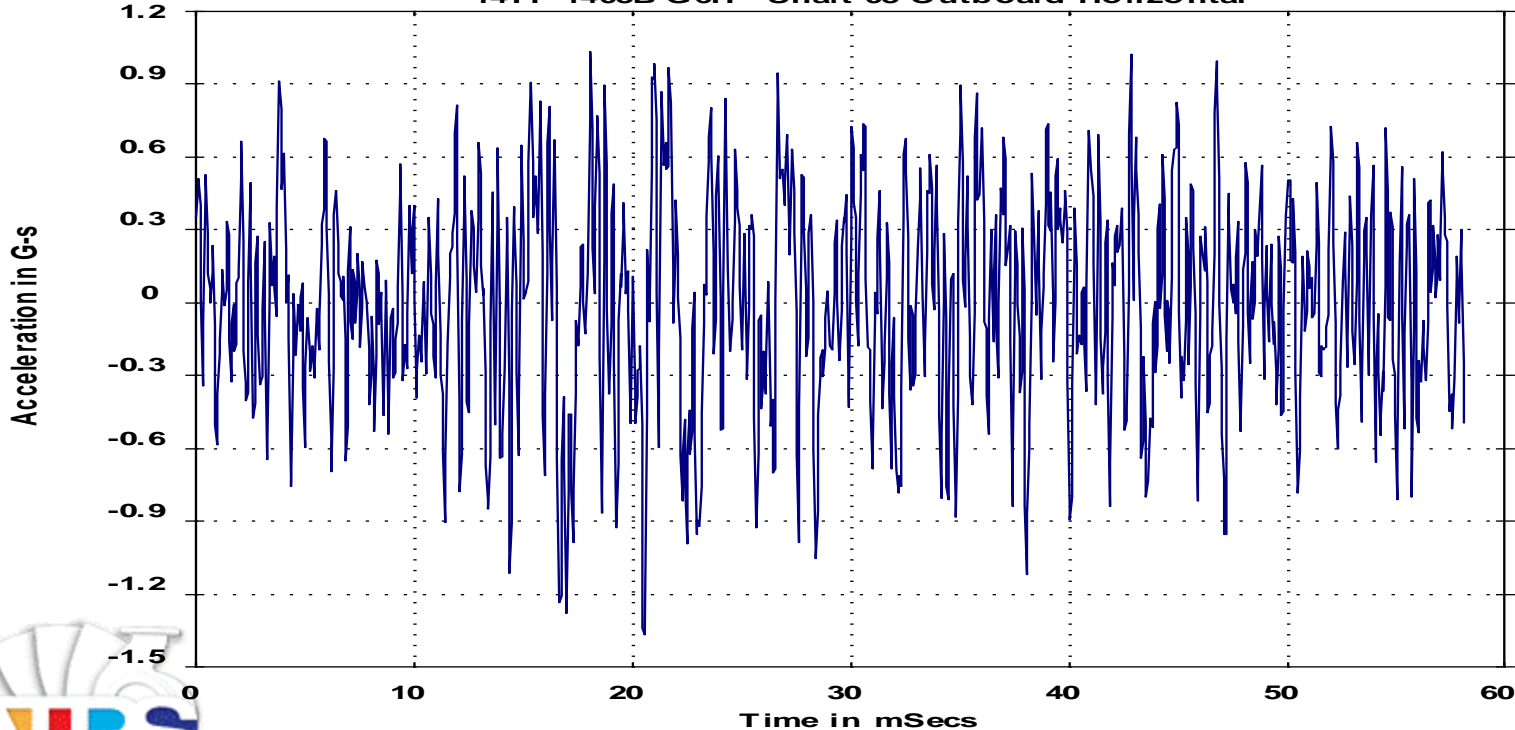
- Polishing of broken tooth area and wear on other gear teeth with fine emery paper.
- Re-adjusting mounting distance as per the original drawing.
- Ensure best possible backlash figure (which was hard to attain due to varying backlash).
- Contact check was performed to bring the gear contact area back to the middle of teeth (~40% from the toe).



Vibration data

After repair data of 3rd shaft

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14TP-1403B-G6H Shaft 03 Outboard Horizontal



Route Waveform
23-Apr-14 20:47:4

P-P = 1.21
LOAD = 100.0
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PK(+) = 1.04
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CRESTF = 3.20



Lesson Learned/Recommendations

- Upon discussion with the vendor it was revealed that the interference (0.002”) for this level of torque transfer was less and was increased to 0.005-0.006” in the new gear set.
- Meanwhile the other pump was also inspected. Same problem was found in that gear box and the interference was increased to 0.003”.
- Waveform (AM) **indicated bend shaft** with heavy impacting at the running speed of main bevel gear. However the issue was different. This could have been discovered/rectified before the secondary damage.



Thank you

