**Date 18-06-2022**

**TO**
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**SUB: - STUDY OF HIGH VIBRATION PROBLEM OF FGD GEARBOX AT JHAJJAR PLANT**

Respected Sir,

This is in response to our discussions on the aforesaid subject, during the NIMDC Training Programme. Flue-gas desulfurization (FGD) gears play a vital role in the mechanical power transmission system. The efficiency of these gears is determined by various factors, such as wear, improper backlash, loading, eccentricity, and fluctuation of the load. These factors affect the dynamic characteristics of the gearboxes which in turn directly influence the system performance. Gears may fail due to different internal and external excitations. The system has a 996 RPM (16.6 HZ) motor and gear ratios of 25/37; 17/69, 17/69; 21/184, so the speed of the input shaft, intermediate shaft, output shaft, and girth gear are 996 RPM (16.6 Hz), 672.9 CPM (11.21 Hz), 165.8 CPM (2.77 Hz), and 19 CPM (.316 Hz), respectively.

The FGD system trial was taken on June 13, 2022, at 18:30 hrs. Overall, high amplitude vibration of the order of 8.6 mm/sec RMS & 8.9 mm/sec RMS was observed at the gear drive's input and output in the axial direction, which is cause for serious concern. The NTPC data revealed that the predominant vibration frequency, i.e., the gear mesh frequency of the pinion and the girth gear, occurs at 58 Hz with sidebands and 1XGMF & 2XGMF as dominant peaks throughout the spectrums. This frequency is due to backlash and improper gear meshing between a girth gear and pinion. Further, it has been confirmed by time waveform analysis also that meshing between the girth and pinion occurs at 2.77 HZ. Therefore, it was recommended at the site that lapping and blue matching of girth gear and its pinion should be performed at the earliest.

Backlash is a built-in feature of gear drives. It is basically play between the two-meshing gear, or, in other words, it is the difference between the actual tooth thickness and real tooth thickness, usually, when the gear is reversed there is a lag between pinion and gear, this is generally due to backlash. The backlash has some advantages, but excessive backlash causes impact loads during reversing. Proper backlash is provided for the smooth running of the gears with less noise, better lubrication, and prevents the overheating of gears, whereas tightly meshed gears are prone to jamming and eventually lead to system seizure.

**Frequency Domain Analysis**: - The gear defects not only cause vibration at GMF and its harmonics: - these frequencies will often be accompanied by sidebands of the rotating speed of the defective gear. Inadequate backlash excites the gear meshing frequency (GMF) and the natural frequency. When a gear meshing problem exists, the gear mesh frequency is generated. The gear mesh frequency can be modulated by the speed of the problem gear.

The FGD gearbox input speed is 996 rpm and the number of teeth is 25, this gives a gear mesh frequency of 24,900 CPM and the intermediate shaft speed is calculated as being 673 rpm. Therefore, if there is a defect in the input gear, there would be sidebands spaced at 996 CPM above and below the gear mesh of 24,900 CPM. On the other hand, if the defect is on the 37 teeth gear, the sidebands would be spaced at 673 CPM above and below the gear mesh. Lastly, if there is a defect on both the gears, then there would be two families of sidebands around the gear mesh one would be at 996 CPM and the other would be at 673 CPM. Stated simply, the spacing of the sidebands can pinpoint the gear that has the defect. The gear meshing frequency and sidebands are there but the correlation of sidebands could not be established due to the presence of a very high amplitude at 58 Hz frequency predominant across the spectrums.

- **The overall vibration data** recorded on 13.06.2022 are as follows:

| SN | MOTOR DE/ NDE (H/V/A) | GEAR BOX INPUT DE/NDE (H/V/A) | INTERMEDIATE DE H/V/A | GEARBOX OUPUT NDE/DE H/V/A |
|---|---|---|---|---|
| A | OVERALL VIBRATION ANALYSIS 13.06.2022 | | | |
| | 0.69/0.86/0.81 | 4.56/5.34/4.86 | N/A/6.83/7.74 | - |
| | 0.76/1.08/0.91 | 3.98/5.29/4.59 | | 3.68/7.83/8.75 |
| B | | FREQUENCY ANALYSIS | | |
| | The presence of frequency in the signature is at 996 RPM (16.6 Hz) i.e., 1x RPM but has a low amplitude | 1XRPM is present at low amplitude but 58 Hz is predominant in the axial direction which could be due to misalignment or backlash. | 3rd harmonic of 58 Hz i.e 174 Hz is predominant in the vertical direction | 2nd harmonic of 58 Hz (116 Hz) is predominant in the vertical direction & axial direction which could be due to misalignment caused by the backlash. |

- **The frequency spectrum taken** at all the bearings indicates that the predominant frequency is at 58 Hz alongwith and its harmonics:

| GEAR HARMONICS | IX | DOMINENT | AVAILABLE | HIGH | MEDIUM | SLIGHTLY HIGH | MODERATE | LOW | VERY LOW | LOW LOW | ONCE | RARE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HZ | 16.6 | 58 | 75/91. 50/99 | 116 | 122/135 | 174 | 233/249 280/291 | 349/357/ 372/385 | 396/407/ 413/426 | 465/472 | 476/560/ 559/611 | 713/916 |
| MNDE (H) | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | - | - |
| MNDE (V) | - | ✓ | - | ✓ | ✓ | - | ✓ | - | - | - | - | - |
| MNDE (A) | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | - |
| DE (H) | ✓ | - | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - |
| DE (V) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | ✓ | | ✓ | ✓ | - |
| DE (A) | ✓ | ✓ | ✓ | | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - |
| GB I/P DE(H) | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - |
| GB I/P DE(V) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - |
| GB I/P DE(A) | ✓ | ✓ | - | ✓ | - | - | - | - | ✓ | - | ✓ | ✓ |
| GB I/P NDE(H) | - | ✓ | - | ✓ | - | ✓ | - | - | ✓ | - | ✓ | ✓ |
| GB I/P NDE(V) | - | ✓ | - | ✓ | ✓ | - | ✓ | ✓ | ✓ | - | - | - |
| GB I/P NDE(A) | ✓ | ✓ | - | | - | ✓ | ✓ | ✓ | | - | | |
| GB (I/M) (H) | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | - | - | ✓ | ✓ | - |
| GB (I/M) (V) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | - | ✓ | | | - |
| GB (I/M) (A) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | ✓ | - | ✓ | | - |
| GB (O/P)DE(H) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | - | ✓ | ✓ | ✓ | - |
| GE(O/P)DE((V) | ✓ | ✓ | - | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | - |
| GB(O/P) DE(A) | ✓ | ✓ | - | ✓ | - | ✓ | | ✓ | ✓ | - | - | - |
| PINON DE (H) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | ✓ | ✓ | - | - | - |
| PINION DE (V) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | ✓ | ✓ | - | ✓ | - |
| PINION DE (A) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | ✓ | ✓ | - | ✓ | - |
| PINION NDE (H) | | ✓ | - | ✓ | - | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ |
| PINION NDE (V) | | ✓ | - | ✓ | - | ✓ | - | ✓ | ✓ | - | ✓ | - |
| PINION NDE (A) | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | | ✓ | - | ✓ | - |

**Time Waveform Analysis:** -A spall or chipped tooth at or above the pitch line, a cracked tooth, or a tooth completely broken out, can generate a unique signal in the form of a pulse. A defective tooth's pulse has four measurable characteristics: pulse frequency, pulse width, repetition rate, and pulse amplitude (size of the defect). The defect can be heard on some slow-speed machinery as a dull knock or clunk that may occur with each revolution of the defective gear.

A gear with one defective tooth can generate a pulse once per revolution, and the repetition rate is proportional to the gear's speed. If two teeth are broken, the repetition rate may be twice as fast as the gear's speed. The amplitude of the pulse is proportional to the size of the defect, the loading, and the dampening of the system. When more than one pulse exists, the amplitude is used to identify multiple pulses and to describe better and worse conditions.

The time waveform spectrums analysis of the input shaft, intermediate shaft, and output shaft indicates the presence of defective teeth may be due to wear and backlash, resulting in excitation of natural frequencies.

| GEAR BOX | MOTOR | GEAR(I/P) DE | GEAR (I/P) NDE | INTERMEDIATE GEAR | OUTPUT GEAR | PINION NDE | PINION DE |
|---|---|---|---|---|---|---|---|
| | APPROXIMATELY CALCULATED BY SCALE NOT CURSOR** | | | | | | 58.8 |
| SPEED Hz | 16.6 | 16.6 | 16.6 | 11.21 | 2.77 | 2.77 | 2.77 |
| PULSE RATE | NIL | - | - | - | - | - | - |
| PULSE WIDTH | NIL | 17/17/17 ms | 17/17/17 ms | 17/17/17 ms | 17/17/-ms | Not clear | 17/17/-ms |
| PULSE AMP. | NIL | 6g/6g/9g | 6g/5g/3g | 6.5g/5g/8g | 4g/4g/7.5g | 2.5g/1,5g | 3g/8g/2g |
| | | H/V/A | | H/V/A | H/V/A | H/V/A | Vertical high |

*Time in ms milliseconds

**Recommendations: -**

a) Girth gear and pinion lapping and blue matching should be performed as soon as possible to ensure that pinion root clearances and backlash are within tolerance limits. Following that, readings should be taken to determine the frequency pattern change in the system. When the dominant frequency, 58 Hz, is removed, the overall vibration level decreases dramatically across all spectrums.

b) A study of the main gearbox should be carried out to determine the health of the gear trains. Preliminary analysis of available time waveform spectrums of input, intermediate, and output shaft, indicates the presence of tooth wear could be caused by misalignment or backlash. To locate the defective tooth with respect to the marker, a once per revolution marker and the pulse on a dual-channel oscilloscope can be used. This exercise was not carried out because the key phasor was not used or installed.

c) The gear train analysis was hampered by the appearance of the girth gear's predominant frequency at 58 Hz. If this frequency persists, an advanced time waveform analysis instrument should be used to remove the overriding signal.

With Kind Regards,

Sincerely yours,

(C.G. Porwal)
18/06/2022