ID Fan - Basic Data

◆ ID Fans are major critical Boiler Auxiliary, vital to Power generation.
◆ Design & cost optimisation has resulted in no standby ID Fan.
◆ Non-availability of one ID Fan leads to partial generation loss to the extent of minimum 40% of unit capacity.

ID Fans of TSTPS:

◆ Double suction radial fan (BHEL make NDZV 47S type) simply supported between two journal bearings.
◆ Driven by a 4MW, 590RPM Induction motor (Alsthom make) with grease lubricated antifriction bearings in St-I, and 3.7MW, 540RPM slip-ring motor (BHEL make) with journal bearings (St-II).
◆ Regulation: IGV + Hydraulic coupling (Voith make) in St-I & VFD in St-II.
◆ Equipment Rating: 570 m³/s @ 450-480 mmwc at 150°C.
ID Fan - Typical Problems

- **Operational Characteristics**
  - Operates in a variable speed range with torque variations
  - Handles hot flue gas laden with ash particles

- **Typical Problems**
  - Barring the usual problem of drive system & machine-train like that of motor & VFD, bearings, coupling & alignment, ID Fans are prone to have the typical problems of:
    - **Unbalance** due to erosion or ash deposition/accumulation.
    - In the presence of any stress raiser or flaw from manufacturing stage itself, **shaft cracks** can develop due to excessive stress under hot & hostile environment, high radial load & torque variations.
ID Fan - Vibration Monitoring

- **ID Fan Vibration Monitoring**
  - To detect any incipient fault at an early stage, online vibration monitoring system has been provided.
  - In online vibration monitoring system, 1-2 seismic probes have been provided on each bearing to measure bearing casing vibration.
  - Vibration parameter provided for monitoring is usually velocity. Manufacturer’s recommendation/operation manual also speaks of alarm limits in terms of velocity.

- **Vibration Parameter for ID Fan Monitoring**
  - ID fans usually operate in the speed range of 450-500RPM and hence the frequencies generated by typical problems of unbalance, misalignment & shaft-crack are in the lower frequency zone.
  - At low frequency, the change in vibration as registered through vibration displacement is much more than that reflected in terms of velocity.
ID Fan - Vibration Monitoring…

Vibration Parameter for ID Fan Monitoring…

- From displacement-to-velocity conversion formula:
  \[
  \text{Velocity} = \pi \times \text{frequency (f)} \times \text{displacement (d)}
  \]

  For ID fans, running at say 450RPM, a significant vibration change of 75\(\mu_{\text{pk-pk}}\) displacement due to unbalance, corresponds to a change in velocity of:

  \[
  \text{Just} = 3.14159 \times (75 \times 10^{-3}/2) \times (450/60) = 0.88 \text{ mm/s}_{\text{pk}}
  \]

  which is not easily noticeable and eye catching.

- As a result of monitoring vibration velocity, we often miss out on timely detection & proper diagnosis of such problems before it becomes an emergency.

- To increase the effectiveness of vibration monitoring system to detect such problems well in advance so as to plan corrective action at an appropriate time for reducing the impact of outage, it is important to select displacement as vibration parameter for monitoring ID Fans.

- As any incipient rotor fault is inherently reflected in shaft vibration which gets modified and damped out when transmitted to the large journal bearing pedestal, shaft vibration is preferable over bearing casing vibration too.
Diagnostics of ID Fan Unbalance & Shaft-crack problems

**UNBALANCE:**

- Unbalance condition in ID Fans may occur due to any mass loss, eccentric/bent shaft, asymmetrical erosion due to flue gas, or any deposition/accumulation of ash inside rotating system.

- All unbalance conditions generate non-directional 1X vibration, but with different phase characteristics depending on type of unbalance. 1X phase due to unbalance from typical problem of ash deposition/accumulation changes from measurement to measurement, while in case of others, it remains almost steady.

**CASE BACKGROUND:**

During periodical vibration measurement, of otherwise normally operating ID Fan, it was observed that the vibration had increased over baseline values.
ID Fan - Vibration Diagnostics...

**APPROACH**

- Observation of all operating parameters and online & periodic vibration values & trend.
- Increase in monitoring frequency & collection of additional spectrum & phase data, etc.
- Signature analysis and correlating the vibration values & pattern with other operating parameters like IGV position, load, speed, bearing temperature, etc.
ID Fan - Vibration Diagnostics...

FINDINGS & ANALYSIS

- No abnormality was evident from online vibration velocity & other operating parameters although periodical vibration displacement was found comparatively higher with increasing trend.

- *At low frequency, vibration displacement is a better parameter than velocity to detect vibration change.*

- Vibration spectrum indicated predominant 1X vibration whose amplitude was varying with speed.

- Phase was observed to be slowly changing too from measurement to measurement, but there was no indication of directional vibration.

- Unbalance not fixed to a position in the rotating system → had it been due to any fixed mass unbalance or bent shaft, 1X amplitude & phase would have remained almost constant from measurement to measurement.
PROGNOSIS

- Inspection & cleaning of the fan during low demand off-peak hours in the night.

- On short duration stoppage & inspection, some ash deposition on impeller vanes was found & cleaned. No other loose mass was found on the rotor.

- On restarting of the fan, the vibration was found to have increased further with significant change in phase. It was again recommended to open the fan cone as it was not opened earlier and thoroughly check & clean it.

- On opening of the fan cone, it was observed that there were almost 3-4 bags of ash inside it.
  - Ingress of ash into fan cone could have occurred through any breach of sealing at the cone & rotor-hub/rib portion due to higher erosive ash content.
  - Accumulated ash inside fan cone was creating unbalance in the system, and as it was not fixed to the fan surface at one place, the phase was changing slowly too.
  - The ash, which was spread over earlier, might have accumulated at new place after 1st stoppage leading to increase in vibration amplitude and change in phase on restarting.
REMEDIAL ACTION

- Fan cone portion was thoroughly cleaned off ash.
- To minimise the risk of ash ingress into cone portion due to any breach of sealing by excessive erosion or slippage, sealing element of higher size, than that provided in original equipment, was used with application of adhesive.
ID Fan - Vibration Diagnostics...

- Diagnostics of ID Fan Unbalance & Shaft-crack problems...
  - **SHAFT-CRACK:**
    - ID Fans are subjected to thermal stress, stresses due to high radial load, torque variations, forces of unbalance, misalignment, aerodynamic load, etc.
    - In the presence of any stress raiser or flaw, the summation of these stresses may exceed the fatigue limit of the material resulting in crack initiation due to cycle fatigue & propagation during further stressing.
    - Shaft-crack cases need to be timely detected, properly diagnosed & differentiated from other problems to successfully remove the equipment from service for repair/replacement prior to catastrophic total shaft failure.
The symptoms of shaft-crack originate from the two related after-effects of a crack:

(i). *Reduction in stiffness of the rotor* → Leads to rotor bending/bow and increase in 1X vibration amplitude in response to operating forces. Due to change in response, 1X phase fluctuates over rotations and gradually changes over a period of time as crack propagates.

(ii) *Asymmetry in rotor stiffness properties* → Results in increase in 2X vibration amplitude. 2X phase differs from 1X phase and remains steady over rotations, but gradually varies with time too.
ID Fan - Vibration Diagnostics…

CASE BACKGROUND:
During normal operation, sudden increase in vibration was detected on one ID fan deck during walk-down checks. The online vibration trend was showing some increase but not of alarm level, and the previous periodic vibration reading (around 30µ pk-pk) was normal too.

APPROACH
- Offline vibration measurement & trending with past data, collection of additional vibration data like spectrum, phase, etc.
- Observation of all operating parameters and online vibration trend and correlating it with other process parameters.
- Detailed vibration signature analysis & diagnosis.

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<th>Table-1</th>
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<td>H</td>
<td>V</td>
<td>A</td>
</tr>
<tr>
<td>MNDE</td>
<td>74/1.8</td>
<td>99/2.2</td>
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<td>MDE</td>
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<td>FNDE</td>
<td>79/1.8</td>
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<td>50/1.6</td>
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FINDINGS & ANALYSIS
- Overall vibration values (Table-1) indicated increase over previous normal maximum values.
- No abnormality was observed with process parameters and no correlations could be established between vibration increase & change in operating parameters.
Vibration spectrum indicated predominant 1X & presence of significant 2X components in radial directions unlike the case of simple unbalance.

The axial vibration mainly contained significant 1X, 2X, 4X components among the harmonics.

The radial 1X vibration at fan DE & NDE were in phase, but the axial vibrations were 180 degrees out of phase.

Unbalance vibration amplification through stiffness reduction due to looseness or shaft-crack with strong possibility of the later as 2X phase significantly differed from 1X phase.
PROGNOSIS

- Recommended for immediate removal of the equipment from service & inspection of the equipment.
  - Initial inspection of the rotor did not reveal any ash accumulation or shaft crack. Minor looseness problem was observed, but it was ruled out as the real cause to effect such a sharp vibration increase.

- Recommended for further thorough checks for presence of any shaft-crack.
  - On thorough inspection of the shaft, crack was detected near the hub/rib → this was not detected earlier as it remained hidden inside cone.
ID Fan - Vibration Diagnostics...

**REMEDIAL ACTION**

- UT was carried out with the help of an expert for thorough inspection.
- The cracked rotor was replaced with a new spare one & realigned.
  - On box up & starting, the equipment could be satisfactorily operated with maximum vibration in the range of 20-25µ with predominant 1X vibration only.
  - Had this fan been allowed to run with the same rotor after balancing to reduce vibration, it would have led to catastrophic failure of the equipment.
Conclusion

ID FAN availability and reliability can be improved by:

1. **Timely detection & proper diagnosis** of vibration problems, especially shaft crack cases to avoid total catastrophic failures.

2. **Increasing vibration monitoring & detection effectiveness** by setting vibration displacement as the monitored parameter in place of velocity.

3. **Provision for online vibration measurement** in more than one orthogonal directions including axial can be more helpful. It would be better to provide online shaft vibration monitoring system with key-phasor facility to provide more insight for early fault detection & accurate diagnostics.

4. **Ensuring effective sealing** to avoid ash ingress and accumulation inside the fan cone causing unbalance.

5. **Periodical inspection & cleaning of ID fan internals** during opportune shutdown periods if past history warrants such actions.
THANK YOU