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A NEW APPROACH TO OVERCOME OF BOILER FEED WATER PUMP SEIZURES

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ABSTRACT

The seizures of boiler feed water pump cause severe damage to critical parts and even may led to replace complete Electric motor. Changing of suction strainer mesh size, verification of pump heat rise calculation at minimum continuous flow, checking of rotor centering, verification of instrumented flow control recycle valve operation and investigation on possible differential magnetic pull of motor may not solve the issue. Even with stringent grade (ISO 1940 Grade -1) of Rotor balancing, increasing the rotor stator gap and lowering vibration trip setting may not render much help. The phenomenon of mismatch in flow / fluctuations are experienced many a times during start up and lead to subsequent seizures of pump due to localized flashing of hot water. These fluctuations are random in event history and quite unpredictable. The consequential damage of motor due to pump seizure is explained in this paper as case study to define the problem statement.

This paper provides the details of methods adopted to successfully eliminate the pump seizure problem in chronological order. The proposed method can be implemented in any installation with similar duty condition.

KEYWORDS: Fishbone Analysis, Ni – Resist, Rub Tolerant, Seizure

INTRODUCTION

Boiler Feed Water (BFW) pumps are mission critical equipment in Power plants, waste heat recovery units and Sulfur recovery units in refineries. Failures during start up and commissioning, jeopardize the schedule of plant start -up and huge liquidated damages imposed. A typical installation of boiler feed water pump shall have following protection devices

Suction strainer, Minimum flow control valve based on forward flow demand to boiler, vibration monitoring system as mandated by specification and API 670 latest edition, motor over current protection device.

The suction strainer is optimally sized to protect commissioning debris and large sized particles which may get logged into close clearance parts of pump. Normally a 40 mesh size strainer is used. If the higher mesh size strainer is used it shall lead to comparatively larger filter housing and chances of collapse of element becomes higher due to sudden rise of differential pressure across the strainer. As a tradeoff between design and optimization, fine particles like sand are allowed to pass through but a point of concerns remains unanswered – how much fine particles should be allowed? If the loading of fine particles is high, it can subsequently sit in close clearance parts and lead to abrasion / galling damage to them. Hence increase of mesh size from 40 to75 does not render much help.

Minimum flow circulation valve is to protect the pump from virtual dry running as it establishes a positive flow and confirms that all close clearance parts are lubricated by pumped liquid.

In most of the BFW pump installation, instead of control valve - Mechanical ARC (Automatic Re-Circulation Valve- refer figure 1) is preferred due to following reasons. It is 100% mechanical valve which will ensure pump running above minimum flow without taking instruments feed backs like pressure or flow from main line. In pump loop, sometimes ARC valve are not recommended by pump supplier based on their long experience on similar service .Installing ARC at later stage is implausible as a lots of changes in system are required. This is the part of the problem statement which is described below – The problem statement provides the case and sequential analysis which should be carried in case of such failures occur in BFW pump.

Problem Statement

Two consecutive seizures of motor driven axial split BFW was attributed to ingress of sand which caused scorings on the Throttle bush, center Bush and stage bush. (Refer Figure 1). These failures were caused by huge sand loading in close clearance areas in spite of properly sized strainers installed in respective pump suction lines. These failures can be put in category of pre commissioning teething trouble in loop.

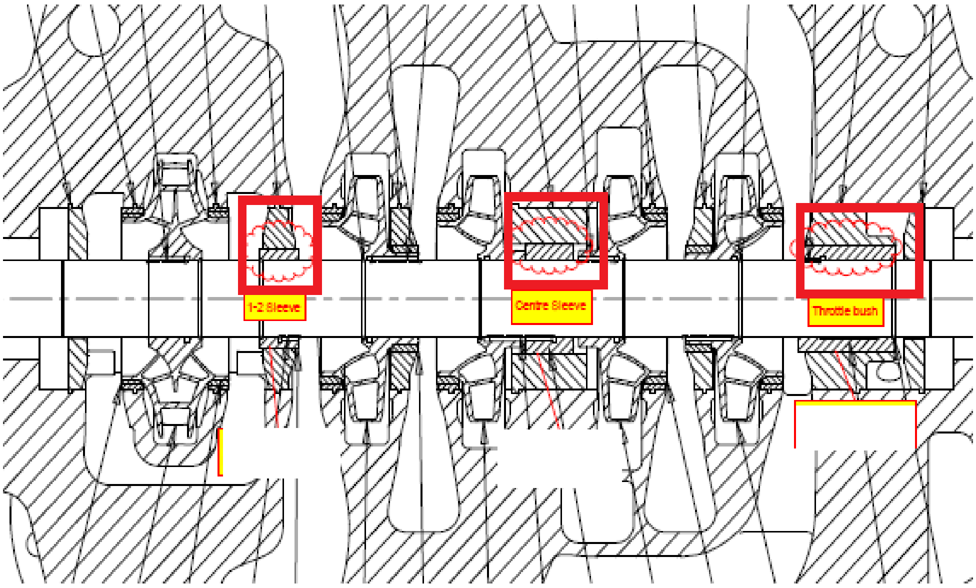

Figure 1: Axially Split Casing -Boiler Feed Water Pump Affected Parts

Both pumps were sent to Pump works for refurbishment and then sent back to site. The Rotor was balanced to very stringent balance grade 1 as per ISO 1940 while API 610 accepts even lower balancing grade.

After running for more than two months the one of the refurbished pump was found seized after a trip due to high vibration at NDE X & Y probes. After detecting the trip was spurious in nature site personnel were not able to re start the pump .While pump was in service the flow (just before trip) was above minimum circulation flow.

The unit was stripped and the rotor removed and observations were

- There are no indications of a bearing problem at the DE and NDE.
- No indication of damage to the impellers
- No signs of a problem on the impellor case and hub wear rings

Extent of damage is shown in below pictures 2, 3, 4 –

Figure 2: Stator Part Damage Due to Seizure

First suggestion was jointly proposed for increasing clearances between close parts as much possible on items in side API 610 limit as long till it does not increase the vibration and observed decrease in volumetric efficiency of pump.

Trends related to this failure suggested a fluctuation in suction flow while pump had ramped up to full speed.

This seizure of pump can be indicated and prevented by Motor over current trip. The seizure did not trip the motor but instead had led to high vibrations of 2 MW motor during its solo run at site reason of which was later attributed as -

The trip system works on thermal sensitivity of system, by that time the protection system worked, it may bend the shaft at once. During start –up of any induction high voltage motor start up current can be 6 times than normal current which in turn induced to winding. The amount of heat generated is proportional to square of current drawn. This means 36 times of heat generated than normal operating case. To prevent the damage of the motor due to such overheating it is imperative to pass through the starting phase as quickly with minimum number of re start. This type of overheating leads to thermal induced bow which in turns may damage the bearings and a permanent bow. Several start-up trials against a jammed pump lead to extensive overheating of the rotor, caused mechanical tension in the shaft and rotor and lamination damage that resulted in a significant unbalance which caused the bearing damage.

This motor faced several months of outage for attempt to repair and subsequent Rotor / stator replacement at motor works

It was then, proposed to run the second pump at 70% of rated flow with lower trip setting of high vibration which was acceptable although the reduced setting could result in increased tripping of the pump. The value of trip setting was based on bench mark of vibration trend of machines at site.

Further investigation in parallel were carried out jointly with Vendor (Based on Fishbone analysis pattern of Root Cause Analysis -

- A heat rise calculation for reduced flow with existing clearance for water at 120 deg. C was carried out. In order to avoid significant loss of NPSHA, the temperature rise at the suction was not to exceed 2 Deg. C. Vendor further confirmed that overall temperature rise across the pump of 4.6 Deg. C will not cause a temperature rise at the suction which is greater than 2 Deg. C. Hence minimum hydraulic flow was considered as safe minimum thermal flow as well.

- Being a volute type design, it was reconfirmed that minimum hydraulic stable flow (140 m3 / hr) had taken into account that sleeve bearing are fully capable to damp hydraulic radial unbalance loads.

It was further checked that pump rotor only exhibits flexible behavior when running dry, Referring to the Campbell Diagrams, no wet critical speed lines are crossed during run-up or rundown. Dry running of BFW pump was considered incredible.

The first stage impeller is of conventional double-suction design.

- Motor Vendor confirmed that axial excursion of 2 pole Electric Motor Magnetic Center during soft starter in line, has no effect which could lead such type of failure in pump. The pump was designed with balance drum not by balance disk, hence axial thrust is well compensated.

The third failure occurred when it was found that Pump failed to reach its operational speed – as it tripped on low flow. When tried for the second time to start –failed to spin & was stopped immediately locally while Pump was decoupled it was found that shaft was very hard to rotate.

The failure of this pump was studied in detail with additional points of consideration-

- **Pump Rotor Encroachment of Clearance Areas Due To Possible Sag at Standstill:** Pump was rotated by hand and found free to rotate. The clearance are in line with pump unit 2 which had been in operation for more than 2 months. This point was later deemed incredible due to dimensional similarity of both pumps.
- **Pump Rotor Bowed Due To Thermal Distortion:** Vibration was below 1/3rd of trip value and spectrum did not show any significant increase in 1x vibration compared to previous reading while machine was in operation). It was concluded that probes setting was done correctly after fixing the top cover of bearing housing. Start- up procedure was followed to avoid any thermally induced rotor bending. The rotor run-out check was carried out of seized pump and found within limits .This issue was deemed incredible.
- **Motor Magnetic Center Caused Axial Pull / Push To Rotor During Start Up:** Pump rotor was placed in casing in its center and DBSE (Distance between Shaft Ends) has been fixed based on Magnetic center of motor in similar procedure to pump B.
- **Foreign Object Caused Damage:** No foreign object found inside casing, the deep groove mark is due to metal – metal rub at second attempt of re start.
- **Lack of Lubrication at Close Clearance Parts Leading To Encroachment of Clearance Parts during First Start up:** It was observed that – 1. Flow dropped before pump went up its operating speed. When Pump was its operating speed for 5secs, flow was already low. Later on the low flow alarm triggered. by that time close clearance area already lost its lubrication regime and pump seizure occurred.

Figure 3: Repeated Attempts to Start Further Aggravated the Issue Taking Out the Metal from Bush

- **Rotor-Dynamic Instability**: This point deemed incredible because of fact that pumps passed the MRT and Performance tests and one of the pumps operated for more than two months before getting seized. The Lateral Critical speed analysis report suggested that Forward and Backward modes of critical speeds of interest are well damped.

Natural frequency		f (Hz)	CPM	Operating speed	GAP %	Damping factor(%)
Mode 1	Reverse	26.68	1601	2980	46.28	96.64
	Front	37.27	2236.3	2980	24.96	*1579.46
Mode 2	Reverse	98.09	5885.4	2980	97.50	32.00
	Front	98.18	5890.9	2980	97.68	21.11
Mode 3	Reverse	209.53	12572	2980	321.88	8.57
	Front	215.28	12917	2980	333.46	7.79

Figure 4: Rotor Dynamic Stability of Pump at Worst Case (2 Times Normal Clearance)

- **In Adequate Clearances**: Based on API 610 LATEST Editions the clearances are within limits. The proposed the option to increase the running clearance of the center & throttle bushing/sleeve was in line with API 610 recommendations.. Vendor conformed that the Close clearances were operating clearances at working temperature.

- **ARC & Process Related Unpredictability:** In most of the BFW pump installation, instead of control valve - Mechanical ARC (Automatic Re-Circulation Valve) is preferred due to following reasons. It is 100% mechanical valve which will ensure pump running above minimum flow without taking instruments feed backs like pressure or flow from main line. In BF service pump running closer to minimum flow water shall have exponential vapor pressure curve against temperature rise when pump operates closer to minimum flow.

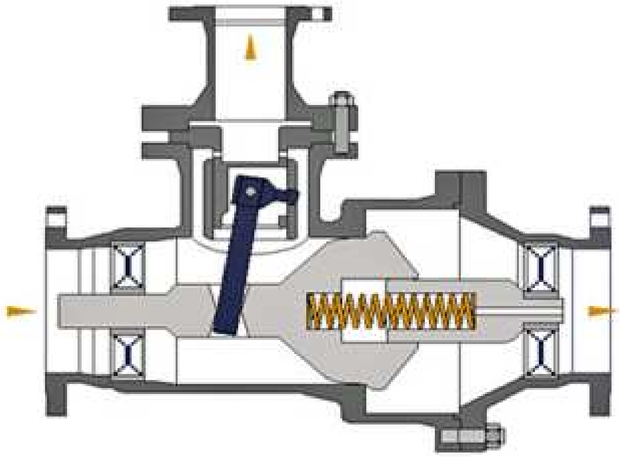

Figure 5: Typical Automatic Re-Circulation (ARC) Valve Commonly Used

ARC Valve as not suggested by Vendor .Installing ARC at such stage was implausible as a lots of changes in system were required.

- **Effect of Main Lube Oil Pump**: It was explored for any possible instability in pump shaft driven main lube oil pump has an effect on NDE vibration and subsequent loss of clearance in throttle bush. Based on vibration readings & confirmation by Vendor this was considered to be an incredible scenario.

The challenge was to solve this issue without major change in loop and system. Due to unpredictable process parameters as concluded by analyzing all probable reasons of failures and time required to procure and install ARC valve to avoid such unprecedented probable flashing a combination of plausible solution was proposed –

1.**Use of rub tolerant (Non Galling) material** for inter stage bushes and sleeves in place of existing 12 % chrome with a higher clearance. The use of Ni resist material in BFW pump service is unconventional as per API 610 material selection as shown in attachment. Following materials were suggested – WP525 (Green Tweed), Vespel or Ni Resist .These materials are normally used in high pressure, high efficiency hydrocarbon pumps to maintain high volumetric efficiency by minimizing leakage losses.

Since these rub tolerant materials are not mandated in API 610, a detailedaudit of material was carried out as below -

- Shaft material – ASTM A 479 XM19 –
- There is no issue if austenitic steel shaft is used till operational temperature range of 250 deg..C. There might be an issue of electrical run-out problem if A479 XM19 is used as described in API 610 para 5.6.11., but no erroneous readings on vibration due to residual magnetism was not reported throughout the timeline of failures
- Impeller Wear ring materials – A 743 CA40
- Casing Wear ring materials – A 276 Gr 420
- Impellers – A487 CA6NM
- Sleeve - A 743 CA40

- Stage Piece 1st Impeller – A 276 Gr 420
- Stage piece Center- A 276 Gr 420 -proposed to change to a rub tolerant / non galling material.
- Throttle Bush - A 276 Gr 420 - proposed to change to a rub tolerant / non galling material.

Being an easily available material in logistic point of view, Ni Resist material was selected.

Properties of Ni-Resist Specification BS3468 1986 F3 – Flaked Graphite

Table 1

Type	Grade	Chemical Composition								
		C%max.	Si%	Mn%	Ni%	Cu%	Cr%	Nb%	P%max	Mg%
	F3	2.5	1.5 – 2.8	0.5 – 1.5	28.0 – 32.0	0.5 max	2.5 – 3.5	-	0.2	-

Table 2

Type	Grade	Tensile Strength (min) N/mm2	0.2% Proof Stress (info only)	Elongation %	Brinell Hardness BHN	Typical Properties/Uses
	F3	190	-	1 – 3	120 – 215	Erosion resistance in wet steam and salt slurry. Good thermal shock resistance up to 800c along with good high temperature corrosion resistance. Uses include Exhaust gas manifolds, turbocharger housings, filters, pumps and valves.

The proposed solution (Increased clearance + Ni resist) is only to lower the issues of hard rubs which leads to seizure not the sand ingress into the system. This is not the solution for high sand loading in pumping fluid. The sand gets embed on soft material and after sometime this part shall act like a sintered grinding stone to cause wear.

Maintain lower value of HH trip on Vibration 63 um in place of original value of 93 um. This means the chances of any rubbing is mitigated by 50%.

The properties of shortlisted non galling material as Ni Resist was further studied in terms of difference of BHN and coefficient of thermal expansion (related to heat generated due to inadvertent flashing of water in close clearance zones). As further modification in rotor bearing system, it was opted for grooved throttle bush and confirmed there shall be no considerable change in stiffness and damping values known as Lomakin stiffness .

Figure 6: Grooved Center Stage Bush

End Result - The above suggestions were implemented on both pumps. A very close monitoring of pump and associated parameters had been carried out relentlessly during start- up of pump B till full stabilization of stream. The pump performed to level of end user satisfaction for six months then switched over to operation of unit A with replaced Motor as a change-over plan.

CONCLUSIONS

The existing safety of BFW pump heavily relies on Flow circulation valves which are instrumented, any small malfunction can lead to damage of pump. The new solution is not widely known for BFW application but can be easily implemented at start of design detailing of pump particularly when an ARCV is not recommended by Pump Vendor.

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