

PUMP CONDITION MONITORING EXPERIENCES BY PERFORMANCE ANALYSIS

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Predicting maintenance requirements of pumps by condition monitoring to detect internal wear is well established. The Head-Flow test is the basic method, and is also relevant to investigation of suspected poor performance.

The head is usually readily measured, but the plant layout may mean that the flow is difficult or expensive to obtain. Where a suitable vessel exists in the system, a simple way is to measure the change in volume with time. This paper describes some experiences with testing of pump performance, including measuring the flow of some slurry pumps that pumped from an underground sump of non-uniform dimensions. The volume change method was successful, using another tank in the system.

Performance monitoring and analysis is often applied to pumps to detect and monitor the extent of internal wear. Of the various methods available, that of Head-Flow is preferred (Beebe, 2004) as it reveals the condition of the pump and also of the system it serves. Other

methods may also be appropriate, such as vibration analysis to monitor bearings, looseness, unbalance and alignment.

Head has long been readily measured with standard test pressure gauges, with a wide range of electronic transducers available. Of particular interest is a new design with an accuracy as low as 0.1% of reading, when used above 20% full scale. Such an instrument has greater intrinsic accuracy than the deadweight testers normally used for calibration! (www.crystal.com)

The availability of non-intrusive flow meters has greatly facilitated field tests where access is available to a length of pipe. If use on lined pipes is proposed, a trial is suggested before buying one. Some plant installations may not have any available pipe, and other methods are needed.

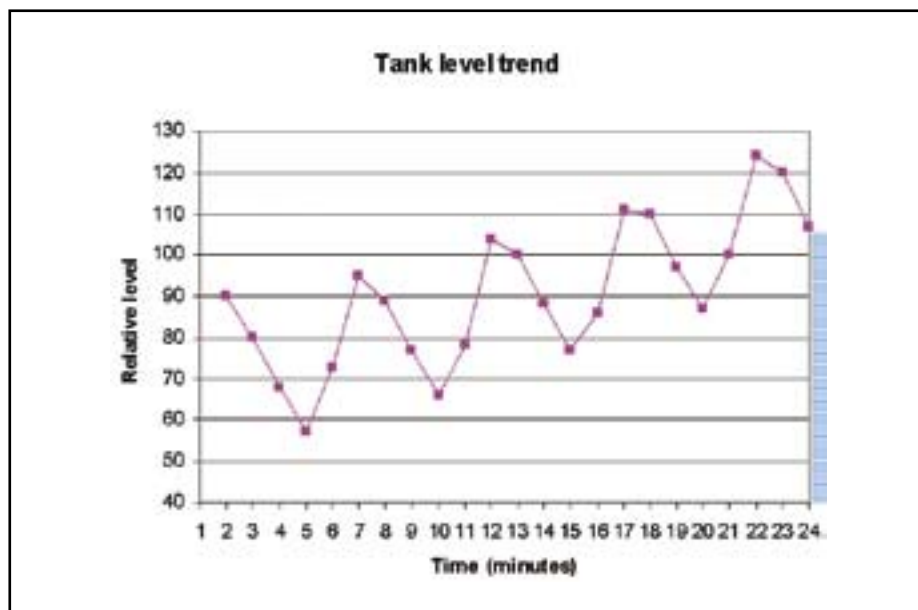


Figure 1: test plot of tank level change with time.



photo: Proftechnik

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A suitable tank of uniform dimensions may be available in the system, and fittings and piping valving arranged so that its change in level can be measured with time and the flow rate calculated. Allowance is required if a tank to be used is on the suction side of the pump, as the suction head will decrease as the tank is emptied. If the discharge head is very high in proportion, it may be that a change in suction head is negligible, as long as adequate NPSH (Net Positive Suction Head) is maintained. This method is applicable for open tanks with that benign liquid, water at atmospheric conditions. Sealed tanks containing less benign liquids, such as hydrocarbons, may have a manometric

level indicator than can be tried.

This paper describes an adaptation of this method where the suction chamber in the system was not of uniform dimensions.

The system

The system is a closed cycle in a coal fired power station. The relevant parts for this case study are simplified as:

- Sluice pumps inject jets of water along the ash sluices from the boiler hearth and the dust collection plant to flush the slurry along into the ash sump.
- The ash sump is below ground level, is of non-uniform cross-section, and the contents are barely visible.
- The ash disposal pumps convey water with low ash slurry content from the ash sump to a disposal pond some kilometres distant through a cement lined pipe. The pipe rises vertically from the pump to run along a coal conveyor structure about 11 metres above the pump. After a horizontal run of about 50 metres, the pipe run takes off at right angles at a lower level, about 5 metres above the pump, to the pond.
- The ash settles out in the disposal pond and the carrying water overflows to a reservoir. From there, return water pumps supply a return water tank of uniform dimensions, located above ground, and therefore also above the ash sump.
- Flow into the ash sump is irregular in quantity, and also needs additional water to prevent ash settling in the sump and ensure adequate net positive suction head.
- A level electrode in the ash sump ensures that the level is maintained by opening an automatic valve in the supply line from the tank.
- Similarly, a drop in tank level sensed by an electrode in a side chamber starts the return water pumps, or if the inflow is insufficient, opens a town water supply valve for an alternative source.
- Return water and ash disposal pumps run unthrottled.
- A small flow of water at high pressure is also supplied to seal the glands of the disposal pumps, and another supply is injected into the sump at high pressure to maintain the ash in suspension. These flows were measured separately for the

plant investigation, but for condition monitoring test on water can be shut off.

This tank-sump-pumps plant arrangement (called “ash plant” here for brevity) was repeated four times, each serving a pair of generating units. As the ash disposal pond was a distance away from one end of the power station, each set of pumps had a different impeller size. The first set had the largest as the conveying distance was further away. Nearer to the pond, the ash plants had a smaller impeller and motor. The last set was larger, as revised site plans had a further pond a greater distance away. To show the relative pump size, the ash disposal pump design performance with a 724mm diameter impeller is 110 L/s @ 72m, with a 210 kW motor fitted. At the time of these tests, all pumps were of constant speed, and operated without discharge throttling.

The investigation

To keep each of the four plants oper-

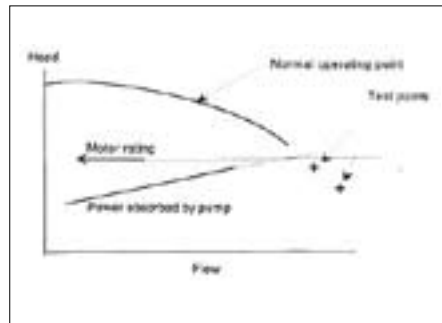


Figure 2: Test results showing that the system resistance had reduced, such that power absorbed by the pump exceeded the motor rating.

ating without town water make up being admitted to the system proved difficult. The eventual spillage via an effluent pond was to the main power station cooling pond, such that chemical content built up to unacceptable levels. Therefore, an investigation was begun to find the required flows from each pump to maintain a closed system operation. Pump performance testing was required to provide information that would lead to adjusting pump impeller sizes. The system was run on water only for the tests. The same test method was to be used for routine condition monitoring.

Given the readily accessible tanks of uniform dimensions from the top down to most of their height, it was decided

to use the rate of tank level change as the flow meter. The concrete tank total capacity is 169kL, with a volume of 27.75kL per metre of depth in its parallel walls section. The level change rate was measured with a stop watch and a weighted tape measure. The flows of the return water pumps were readily found at different tests by running the system on water only. The input flow was found to be 135.7L/s. Pump suction and discharge pressures were measured with test pressure gauges.

The tank outlet automatic valve was manually isolated for these test runs. Although the water level surged vigorously as it gushed in, the level in the side chamber inside the tank was nicely damped and showed no oscillations. Finding the output flow from the disposal pump was a different problem. The initial method was to design and fit an orifice plate in the discharge pipeline. A section containing the orifice plate was made and inserted in a place where access was available

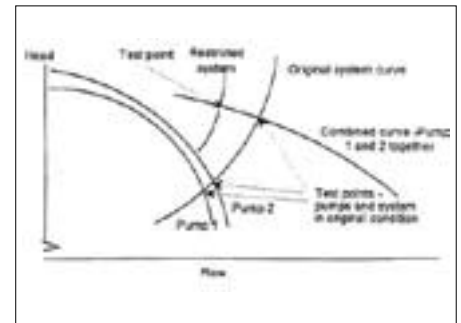


Figure 3: Sketch of test results where the system resistance had increased, leading to low flow to the system.

from walkways adjacent to the pipe. This was in the horizontal run some 11 metres above the pumps.

With the pump running, it came as a surprise to find that the differential pressure measured across the orifice plate read as zero! Investigation showed that the pipe was not running full, and was in fact under symphonic vacuum. The assembly was relocated to a vertical pipe run but special temporary staging was needed for installation and access to the pressure tapping points. Flow readings were now obtained, but the pressure drop across the orifice plate was found to be 4m, and thus restricted flow too much to be representative of the normal system. The assembly was removed and the normal pipe section

reinstated.

Serendipity strikes

Flow tests had just been run on the return water pumps, such that the input flow into the tank was constant and known. An ash disposal pump was started, and the system set to auto operation. The tank automatic outlet valve was controlled by the sump level electrode to open whenever the sump level dropped to the low setting, and in turn, to close when the high level setting was reached.

All flow out of from the tank was replenishing the ash sump, according to the detected sump level change and the autovalve. The level of the tank was measured at regular intervals of one minute, and resulted in plot relating volume contained vs time (figure 1). It was observed when plotting the data afterwards, that because the level in the tank rose, the return water pump has a greater flow rate than the disposal pump. The gradient of the line showed

those new to pumps on any system.

Wrong impeller fitted

With a total of eight pumps of the same external appearance and dimensions, but with more than one interchangeable impeller size available to suit the duty of each location, care is needed so that the correct impeller for that location is fitted. A pump to be sent for overhaul had its impeller severely worn from the abrasive ash slurry. A replacement impeller was obtained from store and fitted. After reinstallation on site, operators reported that the pump could not maintain the required flow. As the pump was newly overhauled, worn clearances were unlikely, so a Head-Flow test was run using the flow measurement method described here. The pump performance was confirmed as below requirements, and corresponded to that expected from a smaller impeller. The diameter was estimated from the Head-Flow curve, and proven correct when the pump was

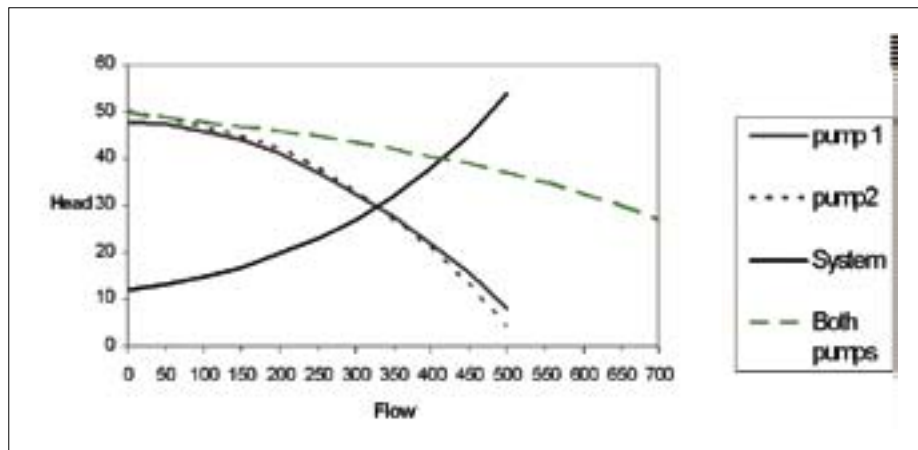


Figure 4: Curves for two pumps showing performance in parallel and a typical system curve.

the difference.

As tested the return water inflow to tank = 136.7 L/s

From the plot above, the gradient of water volume increase in tank was calculated as 10.4L/s

Therefore, the disposal pump flow was less than the incoming flow: 136.7 – 10.4 = 125.3 L/s

Other learning experiences from this system

While not directly associated with this main case study, other experiences on this system are relevant to condition monitoring and should be helpful to

dismantled.

System resistance reduction

A three-stage pump (duty 19 L/s @ 900kPa) supplied high pressure water through a nozzle to agitate ash in the sump, such that the ash was kept in suspension. The pump kept tripping on “high amps”, and it was sent away for overhaul. The pump was returned to service, but the annoying behaviour continued.

In the resulting investigation (which should have been done in the first place), the total head was measured using the supplied tapping points in

the pump flanges, and the flow was found using an expedient method. In this case, a double tip pitot tube was inserted through a gate valve installed on the side of the 100mm diameter discharge pipe.

The resulting test points were consistent with the only available data: the works test curve. They fell on an extension to the curve, as sketched in figure 2. It was evident that the system resistance had become much less, resulting in a pump flow much greater than before, such that the pump reacted by drawing more power. The power draw exceeded the motor rating, and the pump tripped on high current protection.

Despite earlier assurances that the nozzle had been recently checked, inspection revealed that it had come off.

The pump is not always to blame

During the various investigations and tests on the pumps described here, the operators reported that one of the return water pumps was down in performance. The investigating engineer went to the pumphouse, which is unmanned and located outside the power station over 500m from the control room. On arriving, both the pumps were observed to be running, contrary to the operation agreed with the operator. A call to the operator confirmed that his panel showed only one pump to be in service.

On a closer inspection, the pump that was not in service was seen to be rotating in reverse. As most motor noise originated from its cooling fan, it appeared to be in service. A very close look was needed to confirm rotation direction. The suction and discharge isolating valves on these pumps are of the knife-gate type, operated by actuators. The limit switches on the actuators of the offending pump were out of adjustment, such that the valves did not fully close. This allowed water from the service pump to recirculate through its partner, rotating it in reverse. This of course reduced the flow to the system.

System resistance increase

The return water pumps, two nominally identical (100 L/s @ 38m) in parallel, pumped water in the ash system as described above. Normally one pump alone was sufficient to handle the

duty. Condition monitoring tests on both pumps in new condition showed that they differed slightly in head-flow performance.

After some service, it was found that both pumps were needed to run together to maintain the same required flow. Pump performance was suspected, but this time a condition monitoring test was arranged before any pump was removed for overhaul. The flow was measured using the large tank of regular dimensions as described before.

The performance curve for both pumps in parallel was drawn by adding the flow points at selected constant head values, with the result as sketched in figure 3. The test point fell on the curve expected for the pumps in their original condition. However, this point indicated that the system resistance had increased: see the "Restricted system" curve. Inspection revealed that the suction line, some 50m long, had built up with chemical deposition sufficiently to reduce its cross-sectional area diameter by half. The pipe was buried and encased in concrete. Internal blasting

was slow and expensive, so the economic solution was to install a new suction pipe system.

Note in figure 3 that Pump 1 and Pump 2 are shown as having slightly different Head-Flow characteristics. Given tolerances in manufacture, such differences do occur between nominally identical pumps, even when new. From an operational viewpoint, this probably does not matter, but need to be taken into account for condition monitoring and plant investigations. These two latter cases show the importance of head-flow measurements in detecting whether an observed performance shortfall is due to the pump, or its system, or both. All pump users should understand the performance of pumps in parallel. Errors are often made in assuming an individual pump's duty when operating in parallel. In figure 4, with each pump of the same Head-Flow performance, each pump would be contributing half of the total flow, and therefore be operating at 40 units of head, and a flow of 207 units, not at twice the flow of 330 when one pump is operating alone. With two or more

pumps in parallel, the actual system curve can be derived by test, even if the Static Head (at zero flow) is not known. For a system with two pumps in parallel, and a known Static Head from measurements on the plant, or from reliable elevation drawings, then three points are available to plot the system curve (a quadratic from the Static Head value).

Conclusion

A method has been described for finding the flow from a pump when access to its suction chamber is restricted and no other method is available. Given relevant circumstances, the method is suitable for plant investigations, and may also be applicable for condition monitoring. It is hoped that the other lessons learnt will be helpful to people investigating pump performance problems in general, of which many will be discovered from condition monitoring tests and solved. <<



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