**Lecture 32 Maintenance and Troubleshooting of Centrifugal Pumps**

32.1 Introduction

Proper maintenance of a centrifugal pump is very important in order to ensure its trouble-free operation and long service life. The major causes of deteriorating pump performance can be summarized as follows (Roscoe Moss Company, 1990):

1. Improper pump installation. For example, leakage from the column pipe and power losses due to crooked shafts and improper tightening.
2. Changes in system conditions that force the pump to operate inefficiently.
3. Insufficient line-shaft lubrication that causes power loss and premature wear of line-shaft bearings.
4. Motor overloading and/or overheating that decreases efficiency and breakdown insulation.
5. Improper pump adjustment causing increased wear and power losses.
6. Cavitation either from entrapped air or from insufficient NPSH.
7. Abrasion from sand and/or silt produced from the well.
8. Wear from rubbing mechanical parts. This can be normal wear expected over time or abnormal wear caused by deformed or bent parts.
9. Corrosion and incrustation of pump components.
10. Mechanical plugging of the impellers or the pump suction.

Therefore, a good maintenance program should be implemented. A well-planned maintenance program maintains high pump efficiency, helps reduce power costs, improves dependability of the equipment, reduces operating costs and provides extended service life of the pump (Jensen, 1980). The maintenance operations of a centrifugal pump can be classified into two groups (Michael and Khepar, 1999): (a) preventive/routine maintenance, and (b) overhaul or repair operations. They are discussed in subsequent sections.

32.2 Preventive Maintenance of Centrifugal Pumps

32.2.1 Daily Maintenance

The operating conditions of pumps vary widely and so do the maintenance requirements. The performance of the pump should be observed daily. Any abnormality in operation should be taken care of promptly. This refers mainly to any change in the sound of running, undesired leakage in the stuffing box, abnormal change in voltage and current, and temperature. The alignment of the pump unit should be checked occasionally. The bearings that require lubrication should be given a regular attention.

32.2.2 Half-yearly Maintenance

At least once in six months, the shaft packing should be checked by observing leakage from it. Generally, a leak of 15-30 drops of liquid per minute from the stuffing box is desirable. If the leakage from the stuffing box is excessive or the packing is worn, the entire packing in the box will have to be replaced. Replacing just a ring or two will not result in an effective sealing. While overhauling the stuffing box, all the old packing rings are removed and the interior of the stuffing box cleaned thoroughly. The shaft and shaft sleeve surface are properly cleaned before inserting the packing rings. There should not be any burrs or scores on the working surface. If the shaft sleeve is badly worn or scored, it is replaced. Similarly, the straightness of the shaft is ensured.

The radial clearance between the shaft and the stuffing-box bore is measured for determining the size of a new gland packing to be provided. The packing should not be inserted in a spiral form; rather it is installed in individual rings. The rings are carefully cut to the exact size by wrapping the packing around the shaft. The packing rings are fitted carefully, opening them radially until the ends are as wide apart as half the shaft diameters, then the ends are turned apart in an axial direction, until the rings slide over the shaft. Then, each ring is pushed into the stuffing box, inserting the joint first. It should be ensured that the joints of succeeding packing rings are staggered. This is followed by assembling the gland ring and tightening the nuts by hand or a spanner. When the pump is in operation, the nuts are again adjusted to achieve the desired leakage from the stuffing box.

The pumps installed on cavity wells require half-yearly checking. Sometimes, pieces of stones or gravel get into the pump casing owing to overpumping which results in the decrease of discharge. In such situations, the pump is opened and cleaned.

32.3 Preventive Maintenance Techniques

A brief description of the salient techniques for preventive maintenance of pumps is provided below.

(1) Standby units: In most major industries failure of an essential item of equipment can result in a total emergency shut-down of the complete plant. It is for this reason that on the more vulnerable possible points of failure, such as rotating machinery, it has become normal practice to employ a working machine with a 100% standby machine standing alongside to take over the function in the event of failure occurring (Myles and Associates, 2003). If such an occurrence takes place, immediate action must be taken to restore the damaged unit to service with minimum downtime to ensure continuity of service in the event of a repeat occurrence.

(2) Regular routine checks: Despite the above precautions, regular checks on all the more vital items of equipment, including almost without exception any installed pump units should be made to identify in good time, possible developing problems which will have to be faced at the first opportunity.

(3) ‘OEM’ parts and service: To minimise failures in service, the repairs which are carried out on pumps and motors should be in strict accordance with the manufacturer’s original standards in all respects, and should incorporate only ‘Original Equipment Manufacturers (OEM)’ replacement components. The ideal would, of course, be to return the unit for periodic servicing to the maker’s workshop.

(4) Cost of plant shutdown: It must be realized that the cost of possible plant shutdown can totally outweigh possible obvious saving in price by purchase of substandard parts, not of original design standards from pirate suppliers.

(5) Cost of power: If the original maker’s efficiency levels are not maintained by the use of ‘OEM’ components, the costs of power consumption are also a most significant item in the total production costs, and again this emphasizes the need for use at all times of ‘OEM’ parts. Taking the equivalent capital cost of power from a calculation undertaken by a major South African Water Board for application in a contract, awarded in 1986, the equivalent capital cost of 1 kW consumption was calculated at Rs. 2300.00 (Myles and Associates, 2003).

(6) Danger to life and limb: The most important of all reasons for maintaining original standards by use of original manufactures’ components and facilities is the possibilities of pump failure creating a hazardous situation, where the operating staff may, as a result, be subjected to unnecessary dangers.

(7) Quality assurance: The design, manufacturing, inspection and quality assurance standards and limitations set by the original manufacturer are a vital ingredient mix in ensuring that the above standards of performance, reliability in service, continued high efficiency and safety in operations are maintained. This is the foundation of preventive maintenance (Myles and Associates, 2003).

32.4 Overhauling of Centrifugal Pumps

Centrifugal pumps have two basic types of parts: rotating and stationary. Rotating parts include the impeller, shaft, wearing rings, shaft sleeves, and bearings. Stationary parts include the casing with the suction and discharge flanges, bearing housing and packing. Most overhaul work on centrifugal pumps is concerned with the rotating parts.

It is desirable that the pump is completely overhauled annually or once in two years. However, in many situations, the operating conditions do not permit annual shutdown periods for overhaul. In such cases, overhauling is done when it is absolutely essential, on the basis of pump performance and symptoms indicating major problems. The following situations call for a shutdown of the pumping plant for troubleshooting, repair and possible overhaul (Michael and Khepar, 1999):

1. Fall-off in pump performance,
2. Excessive noise during pump operation,
3. Excessive vibration of pump, and
4. Symptoms of corrosion or erosion trouble.

32.4.1 Dismantling of Centrifugal Pumps

The pump has to be dismantled for overhauling. As discussed in earlier lessons, there are different types of horizontal centrifugal pumps such as monoblock or close-coupled pumps, belt-driven pumps and directly-coupled pumps. The dismantling and reassembling procedure of a belt-driven pump is discussed in this section. However, the basic principles are the same, irrespective of the types of centrifugal pumps.

The pump is first disconnected from the piping system (if the pump is directly coupled, it is uncoupled by removing the coupling bolts and rubber bushes). The steps involved in dismantling a belt-driven centrifugal pump are as follows (Michael and Khepar, 1999):

1. Remove the inlet and outlet flanges.
2. Remove the bearing cap by removing the bolts holding it.
3. Remove the grease cup and bearing lock nut.
4. Remove the pedestal and take out the ball bearing, using a bearing puller.
5. Remove the belt shifter.
6. Remove the nuts and bolts joining the casings and remove the casing slowly, taking care not to damage the impeller and casing rings.
7. Remove the impeller nut.
8. Dismantle the rotating unit and remove the impeller slowly by gently hammering back the shaft using a wooden block.
9. Remove the impeller from the rotating unit.
10. Remove the pulleys using a pulley puller.
11. Finally, dismantle the stuffing box.

 The detailed description about the above steps can be found in Michael and Khepar (1999).

32.4.2 Reassembling of Centrifugal Pumps

After overhauling, the pump is reassembled. The procedure of reassembling is more or less the reverse of dismantling. The following are the major steps involved in reassembling a centrifugal pump with pulley (Michael and Khepar, 1999):

1. Mount the pulleys on the shaft.
2. Mount the casing and stuffing box bushes on the shaft.
3. Gently mount the impeller on the shaft.
4. Insert the impeller key carefully.
5. Adjust the impeller at its correct position and tighten the impeller unit.
6. Insert the gasket and grease it properly.
7. Mount the casing by tightening its nuts and bolts.
8. Insert the belt shifter at its correct position.
9. Insert the shaft sleeve and tighten it properly.
10. Mount the pedestal and align it properly by inserting the desired packing.
11. Mount the ball bearing using hand press and tighten the bearing locking nut. Do not hammer the ball bearing!
12. Finally, mount the bearing cap.

32.5 Centrifugal Pump Troubles and Remedies

Troubles in centrifugal pumps can be grouped into two classes: mechanical troubles and hydraulic troubles. Mechanical troubles include breakage of the pump coupling or shaft. These troubles are easily traceable and can be attended to promptly. However, hydraulic troubles such as failure to deliver water, reduction in discharge and overloading of the prime mover are more difficult to rectify. The major troubles encountered in a centrifugal pump and their remedial measures are discussed below, which can serve as guidelines for the pump users.

Table 32.1. Summary of troubles encountered in centrifugal pumps and their remedies (Source: Myles and Associates, 2003)

|  |  |  |
| --- | --- | --- |
| SYMPTOM | PROBABLE FAULT | REMEDY |
| 1.  Pump does not deliver water | * Impeller rotating in wrong direction. | Reverse direction of rotation. |
| * Pump not properly primed  ¾ air or vapor lock in the suction line. | Stop pump and reprime. |
| * Inlet of suction pipe insufficiently submerged. | Ensure adequate supply of liquid. |
| * Air leaks in suction line or gland arrangement. | Make good any leaks or repack gland. |
| * Pump not up to rated speed. | Increase speed. |
| 2.   Pump does not deliver rated quantity | * Air or vapor lock in the suction line. | Stop pump and reprime. |
| * Inlet of suction pipe insufficiently submerged. | Ensure adequate supply of liquid. |
| * Pump not up to rated speed. | Increase speed. |
| * Air leaks in suction line or gland arrangement. | Make good any leaks or repack gland. |
| * Foot valve or suction strainer choked. | Clean foot valve or strainer. |
| * Restriction in delivery pipework or pipework incorrect. | Clear obstruction or rectify error in pipework. |
| * Head underestimated. | Check head losses in delivery pipes, bends and valves, reduce losses as required. |
| * Unobserved leak in delivery. | Examine pipework and repair leak. |
| * Blockage in impeller or casing. | Remove half casing and clear obstruction. |
| * Excessive wear at neck rings or wearing plates. | Dismantle pump and restore clearances to original dimensions. |
| * Impeller damaged. | Dismantle pump and renew impeller. |
| * Pump gaskets leaking. | Renew defective gaskets. |
| 3.   Pump does not generate its rated delivery pressure | * Impeller rotating in wrong direction. | Reverse direction of rotation. |
| * Pump not up to rated speed. | Increase speed. |
| * Impeller neck rings worn excessively. | Dismantle pump and restore clearances to original dimensions. |
| * Impeller damaged or choked. | Dismantle pump and renew impeller or clear blockage. |
| * Pump gaskets leaking. | Renew defective gaskets. |

|  |  |  |  |
| --- | --- | --- | --- |
| **4.**Pump loses liquid after starting | | * Suction line not fully primed  ¾ air or vapor lock in the suction line. | Stop pump and reprime. |
| * Inlet of suction pipe insufficiently submerged. | Ensure adequate supply of liquid at suction pipe inlet. |
| * Air leaks in suction line or gland arrangement. | Make good any leaks or renew gland packing. |
| * Liquid seal to gland arrangement logging ring (if fitted) choked. | Clean out liquid seal supply. |
| * Logging ring not properly located. | Unpack gland and relocate logging ring under supply orifice. |
| **5.**Pump overloads driving unit | | * Pump gaskets leaking. | Renew defective gaskets. |
| * Serious leak in delivery line, pump delivering more than its rated quantity. | Repair leakage. |
| * Speed too high. | Reduce speed. |
| * Impeller neck rings worn excessively. | Dismantle pump and restore clearance to original dimensions. |
| * Gland packing too tight. | Stop pump, close delivery valve to relieve internal pressure on packing, slacken back the gland nuts and retighten to finger tightness. |
| * Impeller damaged. | Dismantle pump and renew impeller. |
| * Mechanical tightness at pump internal components. | Dismantle pump, check internal clearance and adjust as necessary. |
| * Pipework exerting strain on pump. | Disconnect pipework and realign to pump. |
|  | 6.  Excessive  vibration | * Air or vapor lock in suction. | Stop pump and reprime. |
| * Inlet of suction pipe insufficiently submerged. | Ensure adequate supply of liquid at suction pipe inlet. |
| * Pump and driving unit incorrectly aligned. | Disconnect coupling and realign pump and driving unit. |
| * Worn or loose bearings. | Dismantle and renew bearings. |
| * Impeller chocked or damaged. | Dismantle pump and clear or renew impeller. |
| * Rotating element shaft bent. | Dismantle pump and straighten or renew shaft. |
| * Foundation not rigid. | Remove pump, strengthen the foundation and reinstall pump. |
| * Coupling damaged. | Renew coupling. |
| * Pipework exerting strain on pump. | Disconnect pipework and realign to pump. |
| **7.**Bearing    overhauling | | * Pump and driving unit out of alignment. | Disconnect coupling and realign pump and driving unit. |
| * Oil level too low or too high. | Replenish with correct grade of oil or drain down to correct level. |
| * Wrong grade of oil. | Drain out bearing, flush through bearings; refill with correct grade of oil. |
| * Dirt in bearings. | Dismantle, clean out and flush through bearings; refill with correct grade of oil. |
| * Moisture in oil. | Drain out bearing, flush through and refill with correct grade of oil. Determine cause of contamination and rectify. |
| * Bearings too tight. | Ensure that bearings are correctly bedded to their journals with the correct amount of oil clearance. Renew bearings if necessary. |
| * Too much grease in bearing. | Clean out old grease and repack with correct grade and amount of grease. |
| * Pipework exerting strain on pump. | Disconnect pipework and realign to pump. |
| **8.**Bearing     wear | | * Pump and driving unit out of alignment. | Disconnect coupling and realign pump and driving unit. Renew bearings if necessary. |
| * Rotating element shaft bent. | Dismantle pump, straighten or renew shaft. Renew bearings if necessary. |
| * Dirt in bearing. | Ensure that only clean oil is used to lubricate bearings. Renew bearings if necessary. Refill with clean oil. |
| * Lack of lubrication. | Ensure that oil is maintained at its correct level or that oil system is functioning correctly. Renew bearings if necessary. |
| * Bearing badly installed. | Ensure that bearings are correctly bedded to their journals with the correct amount of oil clearance. Renew bearings if necessary. |
| * Pipework exerting strain on pump. | Ensure that pipework is correctly aligned to pump. Renew bearings if necessary. |
| * Excessive Vibration. | Refer to symptom 6. |
| **9.**Irregular delivery | | * Air or vapor lock in the suction line. | Stop pump and reprime. |
| * Fault in driving unit. | Examine driving unit and make good any defect. |
| * Air leaks in suction line or gland arrangement. | Make good any leaks or repack gland. |
| * Inlet of suction pipe insufficiently immersed in liquid. | Ensure adequate supply of liquid at suction pipe inlet. |
| **10.** Excessive noise level | | * Air or vapor lock in suction line. | Stop pump and reprime. |
| * Inlet of suction pipe insufficiently submerged. | Ensure adequate supply of liquid at suction pipe inlet. |
| * Air leaks in suction line or gland arrangement. | Make good any leaks or repack gland. |
| * Pump and driving unit out of alignment. | Disconnect coupling and realign pump and driving unit. |
| * Worn or loose bearings. | Dismantle and renew bearings. |
| * Rotating element shaft bent. | Dismantle pump, straighten or renew shaft. |
| * Foundation not rigid. | Remove pump and driving unit, strengthen foundation. |

References

* Jensen, M.E. (Editor) (1980). Design and Operation of Farm Irrigation Systems. ASAE Monograph No. 3, ASAE, St. Joseph, Mi.
* Michael, A.M. and Khepar, S.D. (1999). Water Well and Pump Engineering. Tata McGraw-Hill Publishing Co. Ltd., New Delhi, India.
* Myles, K. and Associates, cc. (2003). Pumps: Principles and Practice. Jaico Publishing House, Mumbai, India.
* Roscoe Moss Company (1990). Handbook of Ground Water Development. John Wiley & Sons, New York.

Suggested Readings

* Michael, A.M. and Khepar, S.D. (1999). Water Well and Pump Engineering. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
* Murty, V.V.N. and Jha, M.K. (2011). Land and Water Management Engineering. Sixth Edition, Kalyani Publishers, Ludhiana.
* Jensen, M.E. (Editor) (1980). Design and Operation of Farm Irrigation Systems. ASAE Monograph No. 3, ASAE, St. Joseph, Mi.
* Lal, J. (1969). Hydraulic Machines. Metropolitan Book Co. (Pvt.) Ltd., Delhi.
* Stepanoff, A.J. (1994). Centrifugal and Axial Pumps: Theory, Design and Application. John Wiley & Sons, New York.