Centrifugal Pump Failure Analysis

Investigating why a failure occurs can lead to a permanent solution to the problem

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All too often, the broken part or the entire unit is replaced when a pump fails without an attempt to understand why the situation occurred. Whatever remedial action is taken, it is most likely a temporary fix, and the probability is high the pump will fail again for the same reason. Because of the high cost of maintenance, parts, and downtime, this practice is no longer acceptable.

It is interesting to note that some users literally count on a pump to fail after a specified time period. They now realize that the running time, or Mean Time Between Failure (MTBF), of pumps must be maximized. It is expensive to have a pump failure. (See the accompanying section, "Typical Cost of Recurring Pump Failure.")

For a permanent solution to a failure, it is essential that the root cause of the problem be identified. Once the root cause is known and understood, a course of action is taken to solve the problem. A four-step process is recommended.

- **Categorize failure.** A failure is defined as an event that prevents the pumping system from operating as designed.
- **Establish symptom.** A symptom is any condition that indicates there is a problem with the pumping system.
- **Determine failure mechanism.** The failure mechanism is a physical process leading to failure. Force, time, temperature, and reactive environment are failure mechanisms.
- **Identify root cause.** The root cause is the origin of failure.

The first step in categorizing a centrifugal pump failure is relatively simple, since there are only two categories (hydraulic and mechanical). A case can be made to include system problems as another category; however, system-related problems should be evident in the pump problem.

The accompanying chart, "Symptoms and Causes of Hydraulic and Mechanical Pump Failure," guides the user in identifying the symptom and determining the most probable reason for failure.

Exploring Root Causes

In many cases of failure analysis, once the cause is determined and corrective action taken, there is no need to proceed to step four, since the cause and root cause are the same.

Typical Cost of Recurring Pump Failure

Type: ANSI end-suction process pump

Service: 20% nitric acid

Operation: Runs daily for about 16 hr

Problem: Mechanical seals fail every two to three weeks; failure is anticipated and budgeted

Costs: Labor: 2 mechanics for 5 hours @ $35/hr =	$350
Material (mechanical seal)	$1200
Minimum cost per failure	$1550
Annual cost of 15 failures	$23,250*

*Does not include lost process time or cost of other parts or penalties due to emissions

Symptoms and Causes of Hydraulic and Mechanical Pump Failure

Symptom	Hydraulic Failure				Mechanical Failure					
	1	2	3	4	5	6	7	8	9	10
Cause	Pump does not deliver liquid	Pump does not deliver sufficient capacity	Pump does not deliver sufficient pressure	Pump delivers flow intermittently	Bearings run hot and/or fail on a regular basis	High rate of mechanical seal failure	Packing has short life	Pump vibrates at higher-than-normal levels	Pump is drawing too much power	Wear of internal wetted parts is accelerated
Pump not primed or prime lost	•	•	•	•						
Suction and/or discharge valves closed or clogged	•	•	•					•		
Suction piping incorrect	•	•	•							
Insufficient NPSH available	•	•	•			•		•		•
Excessive air entrapped in liquid	•	•	•	•						
Speed (rpm) too low	•	•	•							
Incorrect rotation		•							•	
Broken impeller or bent vanes		•	•		•			•		
Incorrect impeller or impeller diameter		•	•							
System head too high		•								
Instruments give erroneous readings		•	•							
Air leak in suction line				•						
Excessive shaft misalignment					•	•		•		
Inadequate lubrication					•					
Lubricant contamination					•					
Inadequate lubricant cooling					•					
Axial thrust or radial loads higher than bearing rating					•					
Improper coupling lubrication					•			•		
Suction pressure too high					•	•				
Bearing incorrectly installed					•	•		•		
Impeller out of balance					•	•		•		
Overheating of seal faces						•				
Excessive shaft deflection					•	•		•		
Lack of seal flush at seal faces						•				
Incorrect seal installation						•				
Pump is run dry						•				
Pump run off design point					•	•	•	•	•	
Shaft/shaft sleeve worn						•	•			
Packing gland not properly adjusted							•		•	
Packing not properly installed							•			
Impeller clogged	•							•		
Coupling out of balance					•	•		•		
Baseplate not installed properly					•	•		•		
Pump operating speed too close to system's natural frequency								•		
Bearings failing					•	•		•		
Piping not properly anchored					•	•		•		
Pump and/or driver not secured to base plate					•	•		•		
Specific gravity higher than specified					•	•			•	
Viscosity higher than specified					•	•			•	
Internal clearances too tight								•	•	
Chemicals in liquid other than specified										•
Pump assembled incorrectly			•		•	•	•	•		•
Higher solids concentration than specified										•

Carefully examine all root causes of pump failure — more than one may be at fault

Solving a Pump Failure Problem

The following example shows how, by checking failure mechanisms against the categories of root causes, and by a process of elimination of non-applicable causes, a solution to pump failure was found.

A paper mill was using an ANSI end-suction process pump on white water service. The pump's power end was designed for high loads. The thrust bearing ran hot and failed after three months of operation. An identical bearing replacement also ran for three months before failing. A 40-deg angular contact thrust bearing, mounted back-to-back, was then installed. This bearing failed after five months.

The pump manufacturer's field service representative was called in, and together with the maintenance engineer, systematically began eliminating root causes that did not apply.

The pump's components had an excellent history and, other than shaft size and bearings, all parts were consistent. These facts eliminated material defects as a cause.

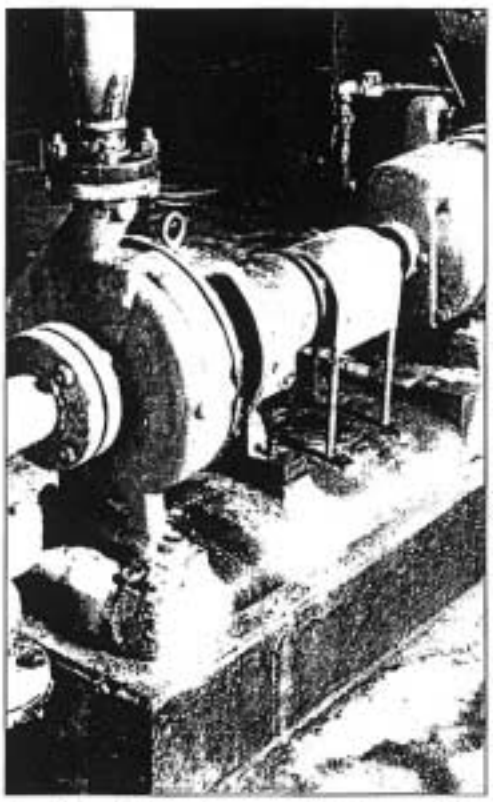
All parts on the failed unit were inspected to ensure they were manufactured to specifications. This step eliminated manufacturing deficiencies.

The maintenance crew was noted to be competent and followed correct maintenance procedures. Maintenance deficiencies were eliminated.

Assembly techniques were according to OEM recommendations. Assembly defects were eliminated.

Even though the pump was being run at 25% of the best efficiency point (BEP), it was designed for this service. This eliminated improper or off-design-point operation.

This left one root cause to explore, the design of the pump. It was determined, from the pump manufacturer's tests, that bearing failures were caused from excessive heat generated by high thrust loads. The manufacturer developed a redesign of the power end that reduced heat generated by 70 deg F and incorporated a flinger/channel lubrication system and a larger oil sump for better oil cooling, circulation, and bearing lubrication. The plant has not experienced a pump failure since the redesigned power end was installed.



***Centrifugal pumps** run or fail in a variety of applications. Failure analysis helps determine the cause of failure and points to a solution.*

In those cases where the "why" was not determined, further analysis is necessary. The additional analysis is highly recommended to take advantage of the pump supplier's expertise in identifying root causes.

There are several major categories of root causes of pump failure:

- Faulty pump design
- Material defects
- Processing and manufacturing deficiencies
- Assembly and/or installation defects
- Operating off the design point or service conditions other than intended
- Improper maintenance
- Improper operation.

Each category should be reviewed as a possible root cause using historical data and failure mechanisms including force, time, temperature, and reactive environment. This should lead to identification of how and why a failure occurred.

For more information . . .

Questions about this article will be answered by the authors at 315-568-2811.

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