About Machinery Failure Analysis

In past columns we have stressed the need for continuous improvement in machinery operation and maintenance. We said we believe that every maintenance occasion should be looked at as an opportunity for improvement by, for instance, consistently applying root cause failure analysis (RCFA).

Making a case for RCFA. Let us suppose that, when a centrifugal pump fails, it is taken to the repair shop and dismantled. The mechanic, technician, machinist or artisan finds a defective bearing and replaces it. The pump is reassembled, reinstalled and recommissioned. There is a probability that it will fail again soon. Why?

The answer is no one bothered to find the true cause of the bearing distress. With world-wide statistics showing that about 90% of all antifriction bearings fail prematurely, it can be demonstrated that many hydrocarbon processing facilities in the U.S. continue to set themselves up for numerous repeat failures unless the true root causes of failures are uncovered and removed.

A properly structured RCFA program will have an immediate, measurable pay back. A good program is deceptively simple. It recognizes that *all* failures, without exception, belong to one or more of *only seven* categories[1]:

- Faulty design
- Material defects
- Fabrication or processing errors
- Assembly or installation defects
- Off-design or unintended service conditions
- Maintenance deficiencies (neglect, procedures)
- Improper operation.

Root cause analysis further recognizes that without exception, the basic agents of machinery component and part failures are *always* force, time, temperature, and a reactive environment, contained in the acronym FRETT, or a combination thereof.

Our involvement with pump maintenance and repair activities led to a typical example of a failure cause estimate for centrifugal pumps in process plants as shown in the table below. The failure analysis and troubleshooting process attempts to first find the root causes of failures in the categories with the highest probability ranking. The approach emphasizes the need to:

Start at the beginning by:

- Reviewing the pump cross- section drawing
- "Understanding" how the individual parts function or malfunction
- Being aware of the process loop and process operations. Take a systems approach. Never lose sight of the facts that:

[1] See references

1. The machine is only part of the overall loop
2. The part that failed is very often not the root cause of the problem and unless we find the root cause, repeat failures are likely to occur.
3. Preserve failure information
   a. Do not move or touch anything until a record of position has been established.
   b. Collect *all* the pieces.
   c. Interview witnesses
   d. Note and record general themes that appear when talking to people involved in the failure event
   e. Access electronic data and operational records from operator field logs, DCS[2] or SCADA[3] systems
4. Missing parts may contain clues which must be examined and which may have had an influence on failure cause or failure progression.

- Use a calculation approach while not, of course, neglecting intuition or prior experience.

Operators can do much to reduce the risk of equipment failures. What comes to mind are well thought-out specifications, drawing and document reviews, operating instructions and compliance with installation procedures, operator and mechanical work force training, as well as a good combination of preventive and predictive maintenance programs including condition monitoring as just a few of the proven ways.

The machinery troubleshooter should remember the seven principal cause categories and rank them in logical order applying to the case at hand – see Table 1. Using a process of elimination, the most probable causes, or perhaps the ones that are most easily and rapidly screened, are investigated first. Concurrently, the four basic agents of machinery component and part failure must be kept in mind. The final and most important review will then almost naturally focus on the one area which contains the root cause of a failure event.

Using this approach may involve and retrain the "experienced" machinist, who has become expert at replacing the same failed part many times, to becoming a problem solver.

[2] Distributed Control System
[3] Supervisory Control and Data Acquisition

Table 1. Failure cause distribution estimate for centrifugal pumps in HC process plants.

	Incidence	Probability ranking
Maintenance deficiencies (neglect, procedures)	30%	1
Assembly or installation defects	25%	2
Off-design or unintended service conditions	15%	3
Improper operation	12%	4
Fabrication or processing errors	8%	5
Faulty design	6%	6
Material defects	4%	7

References

[1] Geitner, F.K. & Bloch, H.P., Series *Practical Machinery Management for Process Plants*, Volume 2, *Machinery Failure Analysis and Troubleshooting*, Fourth Edition, 2012 Butterworth-Heinemann, an imprint of Elsevier, Oxford, UK, www.books.elsevier.com, and preceding editions, 743 Pages.

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