Abstract:

*Machines only Stop Working after their Parts Fail.* The level of care given to an equipment item depends directly on the size of business risk if it fails. Reduce the chance of its failure and you increase its reliability. It becomes vital to know the full range of risks each part within an equipment item will suffer. The right asset management strategy starts by knowing which parts are at risk and it is completed when the necessary actions to prevent all failures are in use. Asset Management that does not identify all the risks to equipment parts when selecting equipment maintenance and operating strategies will get you doing the wrong work.

Keywords: maintenance strategy selection, failure prevention, asset management strategy

How do you get high equipment reliability, low maintenance costs and world class production uptime? We know those outcomes are the result of applying the right practices across the asset life cycle and that you need to design your business systems to intentionally deliver them. If you want world class operational performance you cannot have it by accident or luck. To have highly reliable production plant, machines and equipment it is necessary to ensure that they do not fail, and are not failed, from their operating circumstances.

Figure 1 shows a typical electric motor drive end bearing and housing assembly. From the drawing we can construct the flow chart of how it works. The diagram for the drive end bearing and housing is shown in Figure 1. The flow chart makes it clear that the motor is made of a chain of parts strung together. All machines are designed and built in the same way—parts put together in long series. This is an arrangement at high risk of ruin and it explains why high reliability is so difficult to get—break a part, any part along the chain, and the whole machine fails.

**All Our Machines are Components in Series**

1. For the motor to be highly reliable every bearing must be highly reliable.
2. For the bearing to be highly reliable each of its parts must be even more reliable.
3. For every part to be reliable its design and operating health must be risk-free.

**Reliability:** the chance of completing the mission

Figure 1 – Every Machine is a Long Chain of Parts
Reliability engineering analysis tells us that the failure rate of machines is the sum of the failure rate of the parts. Figure 2 represents a 3-part machine and shows how the machine failure rate is the addition of its individual parts’ failure rate.

A Machine is a System of Parts and Components

![Diagram of a 3-part machine showing the failure rate of the machine as the sum of the failure rates of its individual parts.]

**Figure 2** – A Machine’s Failure Fate is the Sum of Its Parts Failure Rates

Figure 3 shows the three parts failure history and the effect it has on the machine downtime. First a part fails and then the machine stops. The secret to world class reliability success is in the last sentence—prevent a machine’s parts from failing and you will create a highly reliable machine. The machine failure rate has the naming convention ROCOF—Rate of Occurrence of Failure.

**A Machine Fails because its Parts First Fail**

![Diagram showing the ROCOF curve and the effect of parts failure on the machine.]

Machine Failure Rate is the Sum of Its Parts Instantaneous Failure Rate

**Figure 3** – A Machine Fails because its Parts First Fail
When the working parts are not failed the machine continues to operate. When the working parts fail the machine is stopped. The message to take-away is simple and clear—if you want to create a reliable machine then stop its working parts from failing. A working part is a component, including lubricant, which must be present for the equipment to function properly and faithfully meet its duty. Most reasons machine parts fail are indicated for the ‘bathtub’ curve of Figure 4. Every time the ‘chain’ of parts is broken (any part, anyhow, anytime) a machine dies. Mostly parts fail because poor business processes do not prevent materials-of-construction over-stress and/or stop human error. Plant and equipment failures are no accident; your machines are sent to their deaths.

Why the Loss of Reliability in Machines

![Figure 4 – Parts are failed for only a Few Reasons, though each has Many Causes](image)

Select Operating and Maintenance Strategy that Prevent the Risk of Parts Failure

A highly reliable machine needs strategies and practices across its life-cycle that reduces the chance of its parts failing in operation. When you keep working parts in top condition you make machines reliable. This makes the aim of your operating and maintenance strategy twofold:

1. First create the right conditions inside your machinery and equipment for their working parts to naturally have long, reliable and productive lives by removing all risks of over-stress.
2. Secondly, proactively keep the conditions of working parts to within their ideal operating envelope by putting in-place the right reliability practices and preventing human error.

Where these two requirements cannot be achieved failure and maintenance result.

Intentionally create the exact situations that make the working parts in your machines live for a very long time. You will see a huge growth in production plant availability when you introduce the causes of reliability. Figure 5 shows the very few activities to focus on to stop equipment failures. You make machines highly reliable by using your business management systems, maintenance strategies and operating practices to deliver sure, failure-free operation. Teach your people exactly how to cause reliability, document it precisely and refresh that education regularly.

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1 Bennett, Rod. 'Machines don’t die;… they’re murdered!', SIRFRt Condition Monitoring National Forum, 8th – 11th August 2006, Practices Leader Condition Monitoring, Silcar, Australia
Figure 5 – We Know Exactly How to Control and Prevent Equipment Failure

The effect will be like that shown in Figure 6 where machine failure rates fall as fewer and fewer parts are put at risk of failure.

Equipment Reliability is Malleable by Choice of Policy and Quality of Practice

Figure 6 – Prevent Parts from Failing and You Create Equipment Reliability

Identifying Parts at Risk

To identify the parts at risk of failure in your equipment you only need the parts drawings and Bill...
of Materials (BOM) like those shown in Figures 7 and 8.

**Parts at Risk of ‘Induced’ Age and Stress**

![Exploded Parts Drawing](image)

Figure 7 – Exploded Parts Drawing

On the BOM parts list you identify the working parts that can fail and the types of failure causes that they can suffer—error, induced stress, and wear-and-tear. Once you know the risks and where they will come from you use your business management systems to prevent them from happening.

**Using Bills of Materials for Operating Risk Reduction and Maintenance Selection**

![Bill of Materials Identifying Failure Types for Working Parts](image)

Figure 8 – Bill of Materials Identifying Failure Types for Working Parts
Focus on Prevention Instead of Cure

The end we want is to achieve a very particular outcome for our plant, machines and equipment—long, failure-free operating lives. Using predictive strategies like reliability modelling, condition monitoring and preventive maintenance are necessary but poor ways to care for machines and equipment because they permit their failure. They are not failure prevention strategies. They are maintenance and repair strategies that need failures to exist for them to be used and their use invites countless outages to replace failing parts and to fix frequent breakdowns. You will achieve far greater reliability more quickly by focusing your effort, time and money on preventing the risks that cause equipment failure than by looking for failures starting and then correcting the problems. Figure 9 shows the defect prevention strategy to adopt for long-lived, highly reliable equipment—remove the causes of failure by providing the ideal conditions for outstanding parts reliability.

“Chop Out The Roots of Failure”

Figure 9 – Prevent Machine Failures by Preventing the Risk of Failures for Working Parts

Conclusion

Machines intentionally need be treated in the right ways that produce failure-free operation. It requires designing life-cycle business processes that remove the risks of failure to the ‘chain-of-parts’ in your machines by making sure every working component in your plant, machinery and equipment are actively given the necessary conditions for low-stress, error-free operation. Identify the design, operational and maintenance activities that produce high parts reliability and then build business process to deliver them successfully to your operating plant and equipment. Work on removing the risks to the ‘chain-of-parts’ in your machines so they cannot break.

My best regards to you,

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