TYPICAL STEAM TURBINE FAILURES

And how you can prevent them

In our experience, as many as 80% of turbine overhauls uncover something surprising. To help operators understand how turbine faults and failures can be predicted before major affects take place, as well as to prepare for potential findings to ensure the continuity of turbine operations, we have created this paper about the most typical steam turbine failures and how to prevent them.

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1 INTRODUCTION

Turbines keep power plants running. On the whole, turbines perform this important task in a reliable way. In the rare event that a major disturbance does happen, the consequences can be severe.

Turbine performance often starts degrading without notice, until one day a malfunction occurs and causes disturbances in production. For this reason, a consistent approach to equipment life cycle management and maintenance is essential. Turbines are usually equipped with a lot of sensors and indicators to monitor the condition of the turbine, which easily creates the impression that everything is under control. The key, however, is in regular long-term control and monitoring of the data and trends in order to detect potential changes in areas such as vibration levels, bearing temperature levels, and wear and tear, all of which give an indication of the true condition of the turbine.

As a result of our long history and extensive experience as an OEM-independent service provider, we have collected a substantial knowledge base of a wide variety of steam turbines. In this paper we are presenting some of the most common steam turbine failures and what kind of mechanisms are causing them. This can help operators understand how a failure can be predicted before incurring major consequences and to prepare for potential findings to ensure the continuity of turbine operations. Inspections can be targeted to the most critical components and repairs can be planned well in advance. The results can be seen in a clear reduction of maintenance downtime and costs.

2 BACKGROUND

In our experience, as many as 80% of turbine overhauls uncover something unexpected and some 20% require larger repairs than anticipated. This is particularly true for major overhauls, which are basically the only way to inspect the internal parts of the turbine. If the turbine has been running smoothly, the operator easily interprets everything as being in order and expects the turbine to simply be opened, cleaned and closed again. However, our practical experience has shown that in many cases the scope of the overhaul has to be broadened once the turbine has been opened and the findings are clear. This means identifying solutions and executing what can be even extensive repairs on a very short notice when major damages are discovered. In most cases, the time schedule is critical, and the ability to solve the issue quickly is of utmost importance. This underlines the role of careful preparation before a major overhaul. The success of an overhaul should not only be measured by the time taken, it is also essential that the service provider is prepared for any unexpected findings and can react quickly to get the turbine back into operation in the shortest possible time.

3 WHAT ARE THE MOST COMMON TYPES OF STEAM TURBINE FAILURES?

Turbine failures can occur in many parts of the machine. In this paper we concentrate on failures that occur inside the turbine, since those can only be repaired in connection with a major overhaul when the whole turbine is disassembled.

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Turbine failures can be divided into the following categories:

- Wear
- Material failures (steam circumstances)
- Design errors
- Damage caused by external factors:
  - faulty operation
  - poor maintenance

3.1 Wear

Damages related to wearing are difficult to notice from the outside, but careful monitoring of certain parameters can give some indication of wear. For example, monitoring trends in bearing temperatures and vibration levels is essential. However, these values may increase only slightly over the course of time, and thus the changes may go unnoticed in daily monitoring. Therefore, it is recommended to carry out regular and long-term follow-up of these values and to conduct vibration measurements with precision instruments.

Indications of wear-related damages can be discovered by careful monitoring, but they are typically detected during an overhaul. Thus it is important to conduct all maintenance activities as scheduled so that all wear and tear related issues can be identified before any severe damages or failures occur. Furthermore, the wear of certain parts may also reduce turbine efficiency.

In most cases, wear-related damage is repaired by replacing the affected parts. In some cases, larger components can also be repaired.

Optimising spare parts purchases is where the expertise of the service partner is again called for. It is naturally easy to purchase spares of all turbine parts just in case they might be needed, but it requires much more expertise to understand which spare parts will actually be relevant in which overhaul and to thereby optimise the purchases to save costs.

The decisive driver of the overhaul significantly impacts the approach to spare parts purchases.

- In cases where **the decisive driver is the duration of the overhaul**, production and financial losses from an extended overhaul time would be more than the value of the spare parts.

- In cases where **the decisive driver is the cost of the overhaul**, production losses from an extended overhaul duration are perceived as low and more value is seen in optimising the overhaul costs.

If the decisive driver is the duration of the overhaul, a larger range of spares is typically purchased in advance to ensure that the agreed schedule is not exceeded due to unavailability of spares. If the decisive driver is the cost of the overhaul, the purchases can be optimised by acquiring only a limited set of spares in advance and the rest according to actual needs that are discovered once the turbine has been opened.

When parts are being replaced, they are also analysed in terms of their material: is the current material sufficient or would it make sense to use another, better-suited material. Furthermore, the dimensions of each wear part are checked.

In some cases, a part may not be able to withstand the conditions it is exposed to and thus extensive wear occurs. With the proper expertise, these kinds of typical failures by turbine type can be recognised already before the overhaul. By modernising the respective parts rather than just replacing them with identical ones, similar wear damages can be avoided in the future.

Wear on sealing strips

Sealing strips are one example of parts that are sensitive to wear and tear; in many cases, this wear is found during turbine revisions. The wear may have developed during operation or from contacts in start-ups. Sealing strips have different functions: some are essential for turbine operation and some are simply there to ensure high efficiency. Especially for the sealing strips that ensure efficiency, it is impossible to detect wear during operation. Wear is harmless as long as the sealing strip does not completely break off and is not carried away by the steam flow. Wear to sealing strips that are essential for turbine operation may prevent the turbine from operating or can place a heavy load on other components, such as a thrust bearing.

▲ Broken sealing stripes

◄ Wear to sealing stripes

Wear to bearings

In one example, dirty turbine oil caused wear to the radial bearing and had already started destroying the babbit. In this case, the fault was discovered during the overhaul with no prior indication in short-term measurement data. When looking at longer-term measurements, a slight temperature increase could be seen. If this wearing were to have gone undiscovered, it most likely would have caused major damage at some point.

► Wear to radial bearing had already started destroying the babbit.

3.2 Material failures

The most common material failures are related to erosion in the turbine's wet steam area. Erosion damage often goes completely unnoticed and is discovered only during an overhaul. Another way to identify erosion damage is through a borescope inspection. It is cost-effective, but the downside is that the inspection can be performed only for limited areas.

To determine the best solution, erosion damage must always be assessed on a case-by-case basis. It is important to consider where the erosion is located and under what conditions the damage has developed. Typically, the most cost-effective and also the most time-efficient solution in the long run is to repair the damage rather than purchasing a new part.

Erosion is usually found in larger components, and there are diverse repair options that are introduced below.

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Typical repair options for erosion damages:

- Leave the part as it is and monitor the situation, presuming there is enough material left and there is no immediate risk of larger damage or failure.
- Replace the component with a new one. Delivery times for components are typically long, and a new component will not resolve the issue – it will only buy more time, unless the prevailing conditions are changed.
- Repair the component. If there is enough material left for the part to be repaired, this is typically the best solution. It is usually also a faster solution than sourcing a new component. Furthermore, during repair, the component can be enhanced with more erosion-resistant coatings and thereby resolve the original issue. This is also a sustainable solution, as the lifetime of the original component and material can be extended.
- Design and manufacture a completely new component using a more erosion-resistant material. This is the most expensive and time-consuming solution. A new design not only resolves the the original issue, it may also provide an opportunity to otherwise enhance turbine performance.

An example of material failures: erosion in guide vanes

Because it is an environmentally sound solution, the guide vane is repaired and not replaced. The guide vane base material is old but eroded sealing area is repaired with re-engineered new parts.

▲ BEFORE: Heavily eroded sealing area and guide vanes

◄ Erosion in seal surface

▼ AFTER: Repaired sealing area and guide vanes

3.3 Design errors

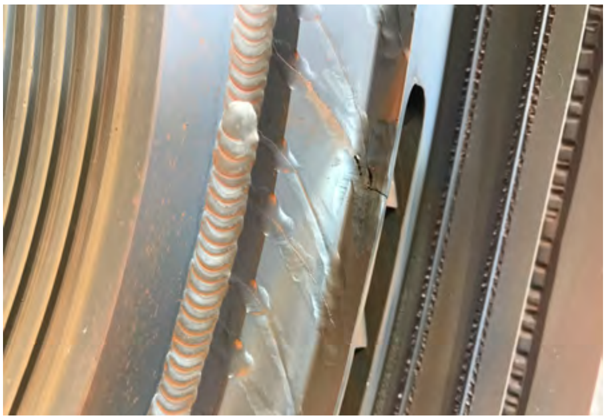
Failures can be categorised as design errors when they tend to occur in a certain type of turbine and re-occur even after parts have been replaced. The only way to completely resolve such failures is via re-engineering and replacing the relevant components with ones that have an improved design or material.

Design errors in components are usually only discovered thorough fact finding during an overhaul – or after they have already caused larger damage.

The main factor leading to design errors is usually the high cost pressures during manufacturing. Manufacturers aiming to produce components as cost-efficiently as possible to keep customer prices reasonable end up selecting less costly manufacturing methods. Sometimes this is reflected in component quality.

One example of a design error is the cracking of sealing welding in the nozzle segment. In most cases, the turbine nozzle is originally manufactured from several pieces, and these pieces are welded together to create a single piece. This is a cost-effective method to manufacturing the nozzle, but the downside is that each weld becomes a potential weak point. During and after start-up, the temperature of the turbine rises and then cools down again when the turbine is run down. Since the thermal elongation in the weld is never equal to the elongation in the base material, the weld begins to crack over time.

The way to rectify such design failure is to produce the complete nozzle as a single piece without any welds. This manufacturing method is often more difficult and costly to execute, but it pays off in the long term by eliminating the root cause of the failure.



▲ Cracking of sealing welding in the nozzle segment

▼ Nozzle segment manufactured in one piece without welding

3.4 Damages caused by an external factor

Turbine failures often occur without any major signs or prior warning. However, things that could have prevented the problem from occurring are often identified during the investigation of the cause of the failure. Therefore, it is of utmost importance that turbine operation and maintenance tasks are always done by professionals and with care.

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There are many different factors that can lead to a turbine failure, including:

- Human factors in operations (monitoring)
- Insufficient maintenance

Damages caused by negligence in operation

Sometimes a failure in turbine operation, or, for example, in turbine automation, can cause excessive acceleration and result in an overspeed situation. As turbine parts are not designed to tolerate high overspeed, even the slightest high-overspeed situation can cause damage.

Most commonly, excessively high centrifugal forces lead to a blade or blade root failure. The damage may become evident already when the failure happens, but it can also go unnoticed and only be discovered during a major overhaul.

One example of blade failure is shown in the image below: a blade has been broken due to the turbine operating outside its designed vibrational environment.

Another example is dirty steam or some other part in the steam that has become loose due to wear and tear. These can cause major damage to rotating blades and, in the worst cases, can jam the entire turbine.

▼ Blade damage caused by foreign particles

▲ A blade has been broken due to the turbine operating outside its designed vibrational environment

▲ Steam strainers full of foreign particles with some already going through into the turbine

Damage due to poor maintenance

Sometimes important steps are neglected in the interest of saving money or time, for example overlooking some minor overhaul or inspection or omitting some part of a major overhaul in maintenance work. However, skipping important repair work during overhauls can lead to serious operational issues and damage; in the end, it always costs more than performing the maintenance work with care and attention to detail.

One example of this is damage caused by the poor condition of a bearing sliding surface. The damage had gone unnoticed due to a skipped inspection during the previous overhaul. A dirty sliding surface can cause the sliding bearing pedestals to get stuck, which prevents the normal thermal expansion of the turbine and may cause serious issues such as vibrations or even blade failures.

▲ Damage caused by dirt in bearing pedestal sliding surface

4 OUR APPROACH

The guiding rule in all turbine maintenance is that repairing damage is the most expensive maintenance method. The extent of turbine failures can vary from minor issues to very serious damages, but when a failure occurs it is imperative that a knowledgeable service partner is readily available to start needed repairs without delay.

Being independent of original equipment manufacturers, Fortum Turbine and Generator Services is able to modernise and maintain equipment from several different suppliers. Thanks to our long and extensive experience, we know the most common types of failures of many common turbine types and the root causes of those failures. This makes it possible to predict the turbine behaviour, react quickly to the findings and provide descriptions of the damage along with recommendations on how to repair the damage in the most cost- and time-efficient way.

Typically, we serve our customers under tight deadlines during standard minor and major overhauls; this requires agility, first-rate project management, and an extensive and specialised partner network. Combining plant owner experience with OEM-like engineering know-how allows us the freedom to offer the customer the most optimal solution. We do not easily recommend replacement of the entire equipment part by part; instead, we work with the customer to find solutions that will repair the faults but keep the costs reasonable.

Fortum's approach to overhauls is to carefully prepare for all possible findings and immediate repairs. A carefully executed fact finding examination makes it possible to determine the actual condition of critical components, which in turn helps in planning the activities with precision. This enables us to give the customer a cost-efficient recommendation for spot-on maintenance services.

Repairs and overhauls are always designed according to the customer's needs and timetable. Downtime can be very expensive for the customer, so it is our priority to react quickly to findings as well as to carefully plan and execute the needed repairs, either onsite or at our own workshop in Naantali, Finland, which is designed for full-scope turbine maintenance services. Our excellent subcontractor network and our own rapid reverse-engineering capabilities help to further optimise delivery times.

MORE INFORMATION

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