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Failure Analysis of Steam Turbine Blades

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ABSTRACT

Edge harm can once in a while happen from the unforgiving working circumstances of steam turbines, which incorporate tall temperatures and weights with fluctuating loads. In most examinations into edge disappointments, a metallurgical think about is the final organize, and it is deficiently to conclusively distinguish the components included. Hence, in the current investigate work, a mechanical examination is conducted in conjunction with a metallurgical investigation for a competent examination of edge disappointment. To assess the harm, non-destructive testing (NDT) was conducted. This consider points to assess this 48 MW control plant's 22 MW high-pressure steam turbine edge subjectively. I am an build here, and it took me 1,52, 241 hours of work to recognize the basic harm areas. The reason for this is that turbines, which work at a exceptionally quick transformation rate, are pivotal pieces of apparatus. Like the all-too-familiar subcritical and USC (ultra-super-critical) turbines. There was a last course of action turbine edge dissatisfaction in two 660 MW units. These machines have two tandem-compound low-pressure turbines with 44-inch last-stage edges and one high-pressure turbine. The edges that fizzled were in an LP turbine associated to the generator (LP2) and a moo weight (LP) turbine associated to the tall weight turbine (LP1). The trailing edge, concave side of the tower most remote filet span was where the failed edges' roots broke. Tall cycle exhaustion (HCF), as decided by the inquire about facility's appraisal of the part, is the baffled component.

The examination of last-stage edges disappointment was completed. The examination comprised a standard repeat test, metallographic investigation of the part edges, and examination, break mechanics and break causing examination, unit's operation limits and history of events examination, and edge extend request. An diagram of this disillusionment examination is given in this consider. It driven to the distinguishing proof of the edge's torsional vibrations at a recurrence of around 120 Hz and a few working times amid which moo stack moo vacuum was the essential commitment to the watched disappointment.

Introduction

The energy produced by the boiler is converted into shaft rotation by a turbine that drives the generator rotor. When the exciter excites the rotor winding, current can flow through the stator winding of the three-phase generator. The stator is connected to the grid through a transformer and other equipment. The size of the generator and the electrical line connected to the rotor by the stator provide torsional resistance to the rotation of the turbine drive shaft. The ideal torque under constant conditions is almost constant (constant voltage and consta nt rotation speed). Two types of changes in turbine power (t/g) can cause changes: (a) disturbances in the grid and (b) disturbances in the turbine.

Power outages are caused by sudden changes in the electrical grid. It is similar to lighting an electric arc furnace or turning a large machine. Generally speaking, a small disturbance will cause a loud background noise; but for large equipment (such as electric arc furnaces) the effect can vary from 20 to 100 MW with similar changes in power. These changes may make the level unstable and not as good as the current level. vibration. Rapid changes cause more vibration; The disadvantage of the current system will be 120 Hz power; Any force change occurring simultaneously with torsional resonance will increase the vibration amplitude. For the torsional power function, there is the possibility of so-called steady-state and intermittent states, where the power amplitude changes within a few seconds (motor size start-up, grid frequency) to an instantaneous change (a few milliseconds) (arc, line faults).The analysis shows that IP turbine blades generally have a lower failure rate than LP turbine blades. The place where the stress is high is usu ally where turbine blade root failure begins. Due to model geometry or uniformity. The explosion of the sixth pha se medium voltage rotor blade of the 330 megawatt thermal power plant during operation caused an unplanned shutdown. The unit was operated for 15,914 hours before shutting down. Subcritical, single-shaft, single-stage, medium-reheat, high-, medium- and low-pressure three-cylinder, two-line steaming, pulsed, direct air-cooled, two-adjustable extraction condensing steam turbine manufactured at Shanghai Steam Turbine Co., Ltd. The medium pressure flow section has seven levels. In 2016, the unit suffered an unplanned shutdown due to excessive front-end movement. The tooth examined is a sixth-level tooth with a crown tip and a fir tree root. The blade material is 2Cr12NiMo1W1V-D-5 and its length is 193 mm.

The work includes visual inspection as well as non-destructive testing. Then, to determine failure, fracture was examined by completing material properties, metallog raphic examination, microhardness scanning and energy spectroscopy examination. A stress simulation analysis o f tooth roots was also performed.

Literature Review

As we all know the control plants are the heart of the plant since by title ready to effortlessly get it control plant which tells us that the plant which has control or creates power(electricity) can be known as control plant, and in this incorporates steam turbine for power generation this concludes us assortments of plant which can be expressed as:

1. Thermal control plant
2.Hydro control plant
3.Wind power plant
4.Nuclear control plant

But here we'll ponder in depth almost warm control plant, here we have a few categories of warm control plants classified as:

-Basic warm control plant
-Super basic control plant
-Ultra super basic control plant

Presently I'm working on basic warm control plant unit since these basic title not as it were appears basic it too has a few covered up classification of control plants like evaporator working weight, working steam temperature and boiler stack on which the steam is created utilizing coal or bagasse, Evaporator may be a closed sort vessel in which water is show interior it from the encompassing in which from the interior there's a furnace. Then steam is assist taken to turbine.

Turbine:

A rotating mechanical device called a turbine (derived from the Latin turbo, a vortex, which is connected to the Greek word for "turbulence") may extract energy from a liquid stream and convert it into useful work. When paired with a generator or used alone, as in the case of fly motors, the work generated by a turbine can be used to create electrical control. A turbine is a turbomachine that has at least one moving part, known as a rotor gathering. This part could be a coupled shaft or drum. The edges move as a result of the moving liquid acting on them, giving the rotor its rotational liveliness. Waterwheels and windmills are examples of early turbines. Turbines that use gas, steam, or water have a casing around the edges that holds and regulates the working fluid. Both Swedish designer Gustaf de Laval (1845–1913) and British builder Sir Charles Parsons (1854–1931) share credit for the invention of the steam turbine's motivation turbine and reaction turbine, respectively. Modern steam turbines typically use both motivation and response in the same unit, moving the motivation and response from the edge root to the periphery.

Sorts of STEAM TURBINES:

-Drive and Response

- steam turbine on-demand

One device that could be used to extract mechanical work from the energy stored in steam is the steam turbine. The "impulse" and "reaction" turbines are the two main types. The names make reference to the kind of constraint that rotates the turbine wheel by acting on its edges. A ring of spouts and a ring of blades comprise the motivation line of action. The spout extends the high-pressure, high-energy steam to a higher-velocity, lower-weight steam fly. This stream of steam is directed into the impulse blades and exits in a variety of directions. A harsh force is created by the direction and speed changes, and this force essentially acts when the turbine edges are rotating. Only a very small conclusion is applied to the turbine shaft.

Reaction steam turbine:

The reaction path consists of a push of similar edges mounted on the rotor, or moving edges, and a ring of settling edges attached to the casing. The edges are created and mounted to provide a narrowing section that increases the steam speed similarly to a spout. Additionally, a change in direction causes the steam to change in speed, and this kind of blading also creates an impulsive constraint. Impulse reaction is a better term to describe this risky line of action. A Response steam turbine fly is used by a response turbine:

- steam that emerges from a rotor spout.

Research Methodology

This study carried out the analysis and damage of the turbine edge of a group of 13 hundred people of a 22 MW st eam turbine operating at 515 °C. Tests 1 and 2 were written with good results. First, follow tests 3 to 16, it shows the destruction of the coast. The chemical composition of the sample fabrics and fabrics used is shown in Table 1. Use optical magnification to observe the metal sample and contract. Microhardness measurements were determin ed using a microhardness tester calibrated according to ASTM E384-
11 standard. At the same time, composite electronic equipment was used to examine the damage of turbine edge f ractures using X-ray spectroscopy (SEM-
EDS, Hitachi Flex SEM 100, Japan), and the fabric was analyzed in the village of the turbine.

Operational Information

Calculation of "running time" from the perspective of turbine performance parameter information that represents a combination of control, weight, flow in base steam, and vibration from the previous month when the turbine wa s out of management. According to the measuring device, the vibration is still in normal operation and the vibrati on value is 98.62 m.

Plainly visible review

According to the results of macroscopic analysis using sensitive cameras, the fractures occurring on the edge of th e high pressure turbine are different from each other. Fracture morphology is a method for identifying defects start ing with 1) fracture initiation in the fillet area, 2) fracture development, and 3) fracture end. These three levels of depression show that the accumulation of weakness can lead to the universe. Most often this occurs in experiment s 8 and 12 in Figure 4, where various threshold effects can be seen.

Chemical Composition

Optical flow spectroscopy (OES) is used to study the chemical composition of the surface. After inspection, the e dge fabric is steam turbine edge steel. Table 1 lists the chemical composition of the samples compared with the C hina Steam Turbine Edge Fabric Standard (GB/T8732-
2004). It can be seen from the data in Table 1 that the composition of the Chinese standard steam turbine edge is d ifferent from the chemical composition of the sample.

Chemical Make-Up (weight%)

	C	Si	Mn	P	S	Cr	Mo	Cu	Ni	V	W	Fe
Specimen	0.14	0.134	0.542	0.031	0.025	11.060	0.632	0.052	0.217	0.03	–	Bal.
GB/T8732-2004 [7]	0.20-0.25	=< 0.50	0.50-1.10	= <0.030	= <0.025	11.0-12.5	0.90-1.25	= <0.25	0.50-1.00	0.20-0.30	0.90-1.25	Bal.

Microstructural Evaluation

Information obtained from microstructure detection is prepared in a way that facilitates the collection of informati on and evidence. The microstructure, test areas, and test foci of a series of tests were evaluated. Its microstructure consists of tempered martensite and periodization begins to develop as minutes pass. The microstructure of marte nsitic stainless steel consists of martensite that is tempered and quenched at the cutting edge. Although the individ ual can be accelerated by operating at high temperature, as mentioned above, the carbide index in the microstructu re called 1A.3 is generally smaller than the carbide index of edge index 15.

Fractal analysis

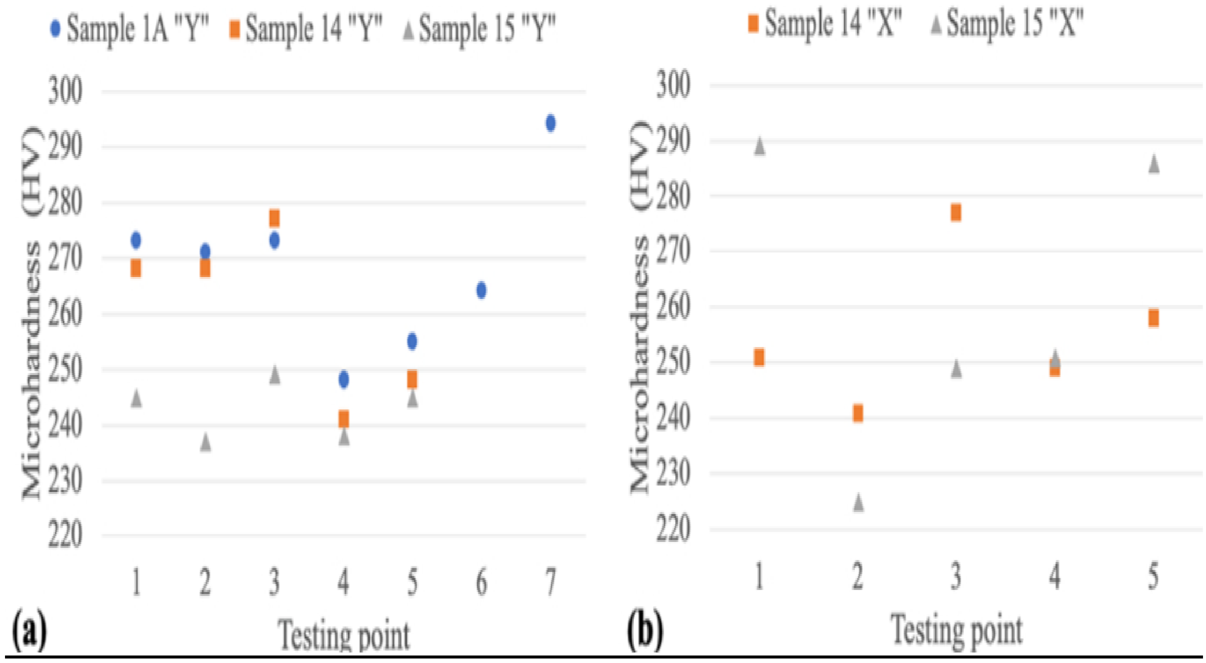
SEM and EDS analysis were used to observe turbine edge fracture of clean and dirty samples. Demonstration anal ysis of the root edge of the bone test showed that the storage materials of the turbine frame contained silicon, calci um, chromium, oxygen and sodium. Apparently the turbine edge testing was not done before backfilling. It is assu med that the edges do not break at the same time, if confirmed by general information. Various analyzes of the cle aning test showed that the deposits and oxide layer could be removed. Additionally, optical emission spectroscopy (OES) testing confirmed that the Cr content of the sample was close to the original data at the edges.

Hardness or microstructure workshop report (2023-2024)

Portraying the headings and test destinations for the hardness tests conducted on tests 1A (alludes to table 2), 14, and 15, after which the microhardness test comes about are arranged.

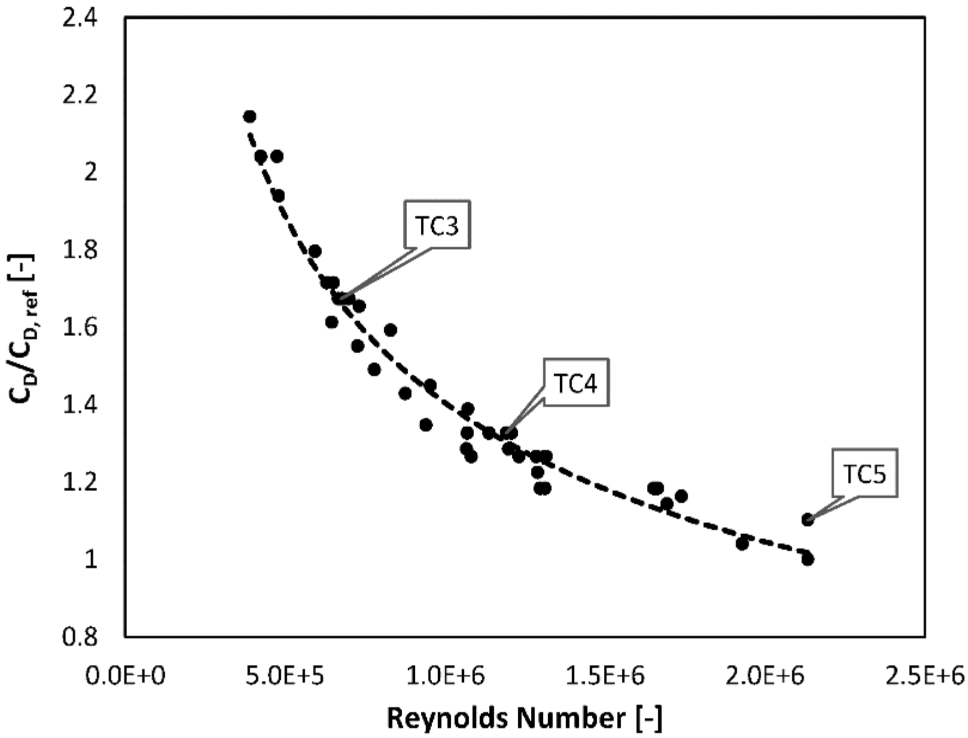
	Direction	Testing point							Average
		1	2	3	4	5	6	7	268
Sample 1A	Y	273	271	273	248	255	264	294	268
Sample 14	X	252	241	277	249	258			255
	Y	268	268	277	241	248			260
Sample 15	X	289	225	249	251	286			260
	Y	245	237	249	238	245			243

Table data indicates an average hardness range of 243 to 268 HV, which is within the Chinese National Standards (225-260 HV) range for steam turbine steel blades. The distribution of hardness values for samples 1A, 14 and 15 is shown in Figure according to the test sites and the X-Y axis direction. The posterior root blade location has the lowest hardness value. This is in line with the root blade fault pattern, where the weakest part of the blade experiences the fracture propagation fault.



Data Analysis

The purpose of this project is to examine the failure of the high pressure generator; The number of starts and stops the generator undergoes during its service life is important. This indicates that rotor blades may experience fatigu e failure due to repeated operating cycles. It is important that steam turbine blades are designed so that their natur al frequencies are free from harmonic excitation of the excitation force. From the creation of Campbell drawings t o the analysis of teeth and analysis using design data. Additionally, the deviation of the teeth is analyzed to evalua te the behavior and associated stress. Also known as diaphragm and nozzle box.



Steam flow through orifice in turbine

WHY WHY ANALYSIS?

-Why this problem occurred

-Getting to the root cause quickly

-Counter measure for the apparent

-Preventing the issue from recurring

-And in the last Who, What, When, Where, and Why?

Why the analysis? when, where and why?

The following processes (alone or in combination) are the most common causes of turbomachinery failur e: fatigue high or low pressure. Erosion Deterioration of materials or fluids. Microscopy and scanning ele ctron microscopy (SEM) analysis of fractures can identify structural failures. Each failure mechanism has specific characteristics that can be used for identification depending on the equipment. The processes and features available in the event of a turbine failure are described below.

Fatigue

Fatigue (sequential, localized, permanent deformation) occurs when the material is subjected to repeated or altere d changes with a maximum value less than its tensile strength. Therefore, fatigue damage is defined as damage th at occurs under repeated loading. This includes changes in thermal stresses during startstop cycles, changing bending loads on the shaft, vibration stresses on the teeth, etc. may contain. High cycle fatig ue (HCF) and low cycle fatigue (LCF) are two categories of fatigue. A low fatigue cycle is generally defined as o ccurring in less than 104 cycles, while a weak fatigue cycle is defined as occurring in more than 104 cycles. Whil e most of the fatigue life of HCF is spent on crack initiation, crack growth in LCF takes most of the life, with crac k initiation varying between 3% and 10% of the fatigue strength. This is the main difference between HCF and L CF. LCF usually occurs at higher altitudes, while HCF is usually associated with lower altitudes.

Excessive fatigue is the primary cause of most turbine engine failures. These failures generally occur at loads that do not have much effect when used statically. Fatigue is divided into three stages:

I) Initiation of cracking

II) Propagation of cracking

III) Final overloading of cracking

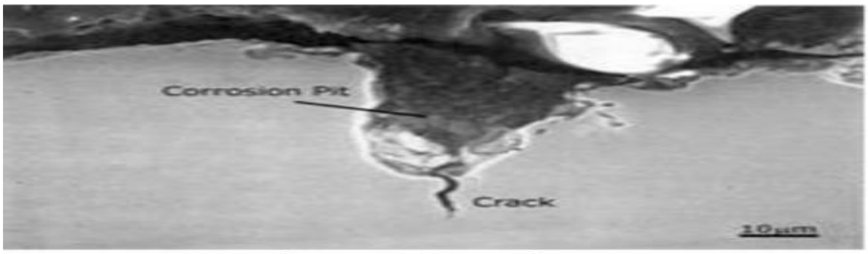
A special insidious method that does not crack. The result is fatigue. 80% to 90% of fatigue failures in life are ded icated to crack initiation.

High cycle fatigue failure of steam turbine airfoil.

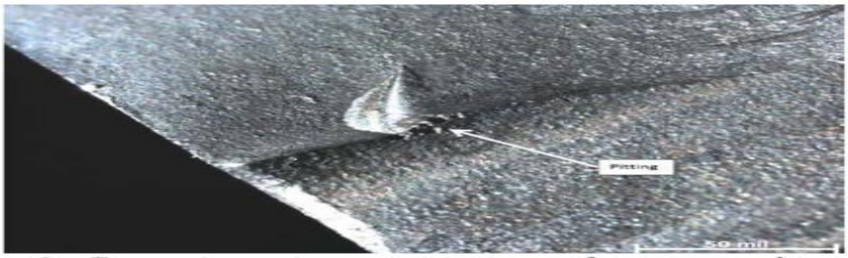
Stress and Fatigue from Corrosion Cracking Corrosion

Corrosion fatigue is the result of repeated or alternating stress combined with a corrosive environment. broke. Cor rosion usually manifests itself as pitting and is local. These stressors, when combined with rotational stressors, act as stressors that can lead to fatigue failure.

As seen in the picture, the weak well is increasing.



e 5. Fatigue crack propagating from corrosion pit



Steam turbine blades are susceptible to corrosion fatigue, although it can occur in both compressors and steam tur bines. The image shows a turbine blade failure that begins with pitting corrosion. process [1]. So, we need to keep track of SCC formation:

1) Tensile stress
2) Bad environment
3) Bad materials

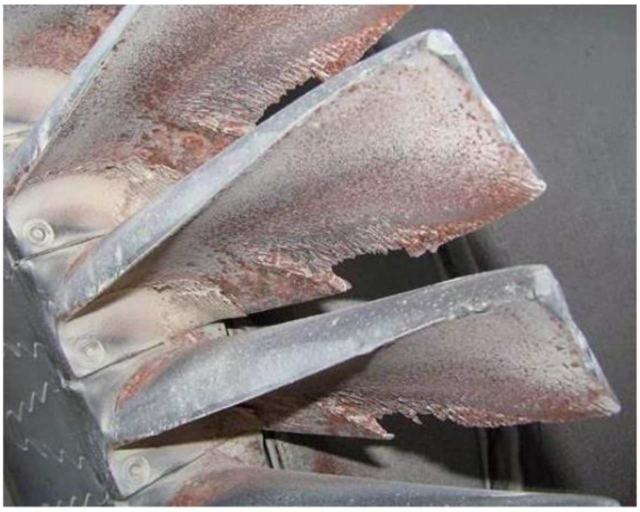
Liquid or Solid Particle Erosion

The loss of material due to contact of the liquid or material with the surface is called erosion. When liquids or soli ds accelerate into air or gas, they can hit and eject material. The final surface will have pits and small cracks. Poth oles and microcracks create stress, and when stress is present fatigue can begin to set in.

Corrosion is a particular problem for steam turbine blades. Steam turbines have more closed paths than centrifuga l compressors and operate at higher temperatures.

Measuring pipelines under transient conditions may cause corrosion of components of turbine pipelines. In later st ages, as turbine humidity increases, turbine blades become susceptible to droplet erosion.

In general, damage is manifested by the removal of material from the edges of the teeth. Damage can be caused b y hot oil and air compressor fan blades.



Creep

The change in stress over time under stress is called creep. Creep is a problem in turbomachinery parts exposed to high temperatures. There is evidence of creep damage in the high-temperature region where the turbine rotor blade is installed.

Damage caused by creep appears as a gap that eventually becomes directional and extends into cracks. This indicates conflicting clearance in the nose cone support at the hot oil expander inlet housing weld.

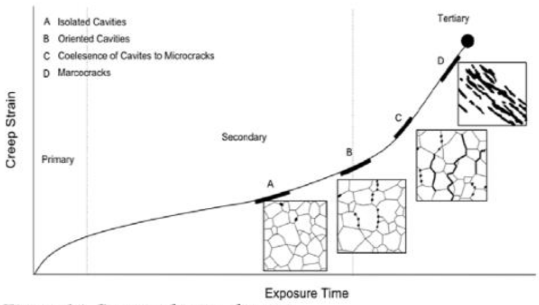
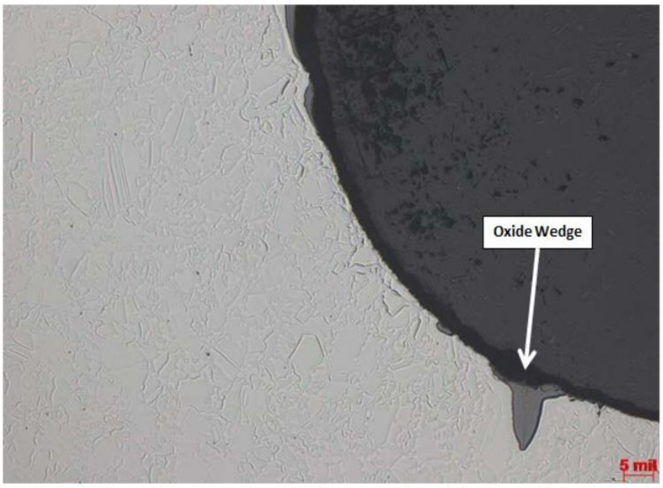


Figure 14. Stages of creep damage

Figure 15. Oriented creep cavities in nose cone strut weld

Elevated Temperature Rust

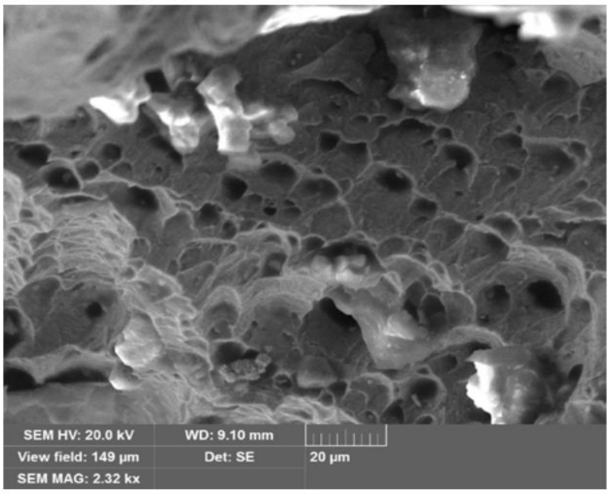
Hot oil using liquid catalytic cracking (FCC) can operate in corrosive and corrosive environments. Regenerated c atalyst delivered by hot flue gases from FCCs is known as a source of corrosion, but its effect on high temperature corrosion was negative. the nature and quality of the process and the resulting flue gas composition. An important factor in the propagation of tooth fracture is the formation of oxide wedges.
An oxide wedge often forms in the upper rooton the high side of the tooth. One type of oxidation/sulphidation da mage associated with the development of a corrosion layer and refragmentation of the tip of the oxide wedge is ca lled oxide wedge formation. The oxide wedge eventually reaches a certain size, at which point fatigue cracking ca n begin. Dowson Rishel and Stinner's paper describes the effect of temperature on the corrosion/cracking mechani cs of Waspaloy in different catalyst environments.



Cross-section of the blade reveals oxide wedges at the base**.**

Mechanical Injury

Replaced parts will eventually come into contact with foreign objects in gas/vapour form. Overload failure occurs when the result is greater than the power of the equipment.
However, in most cases, damage resulting from these impacts weakens the product and leads to fatigue failure rat her than immediate failure.



Conclusion

Finding the failure mode is just the first step in the failure analysis process. A thorough analysis of the data is necessary, with assistance from design engineers, materials engineers, process engineers, and other specialists, to identify the primary cause of the failure. Finding the failure mode alone is insufficient. The aim of any failure analysis is to determine why a component failed via a particular mechanism. The failed components themselves may contain the evidence needed to identify a clear root cause. In these situations, all that's required to conclude a failure analysis is a metallurgical analysis. However, as previously stated, additional analysis involving fracture mechanics, modal and frequency testing, finite element analysis, etc., is required to provide. The following are the findings from the examination of turbine blade fracture failure analysis: Shaft vibration fluctuations always increased in tandem with variations in turbine steam flow and pressure, based on turbine operating data. Friction with the turbine blade during maintenance resulted in damage to the stage 9 diaphragm gland sealing ring and deformation of the fixed blade diaphragm/stator HP turbine blade stage 9. Stress corrosion in the fillet area of some blades suggests that corrosion may have contributed to the fracture, although fatigue is the primary cause of the fracture, according to macro observation. The surface of the fracture is loaded with oxides and deposits, according to the SEM-EDS results, suggesting that root blade fractures happen gradually rather than randomly. The results of the fracture failure analysis of the turbine blades are as follows: Based on turbine operating data, shaft vibration fluctuations consistently increased in tandem with changes in turbine steam flow and pressure. The fixed blade diaphragm/stator HP turbine blade stage 9 was deformed and the stage 9 diaphragm gland sealing ring was damaged as a result of friction with the turbine blade during maintenance. Stress corrosion in the fillet area of some blades indicates that corrosion may have contributed to the fracture, although macro observation indicates that fatigue is the primary cause of the fracture. The SEM-EDS results show that the fracture's surface is loaded with oxides and deposits, indicating that root blade fractures occur gradually as opposed to arbitrarily.

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