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Root Cause Assessment for a Manufacturing Industry: A Case Study

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Abstract

Root-cause identification for quality related problems are key issues for manufacturing processes. It has been a very challenging engineering problem particularly in a multistage manufacturing, where maximum number of processes and activities are performed. However, it may also be implemented with ease in each and every individual set up and activities in any manufacturing process. Kaizen is aimed towards reduction in different types of losses i.e. Failure Loss/ Breakdown Loss, Minor stoppage, idling loss, Setup and adjustment loss etc. So as to improve quality and productivity.In this report, root-cause identification methodology has been adopted to eliminate the rejection of product manufactured by the enterprise and improving the life of product. Brainstorming and other Root Cause Assesmenttools have been used to find out the reasons of tube failure and vibration in tubular strander. Solutions of these problems have also given in this report. Kaizen activities have reduced the time consumed in daily activities of cleaning, lubricating, inspection etc. A detailed study has illustrated the effectiveness of the proposed methodology.

*Keywords:*RCA(Root Cause Assesment) CED(Cause Effect Diagram)TQM(Total Quality Management) SR(Stress Relieving)PIA(Principle Inertia Axis).

1. Introduction

Root Cause Assesment (RCA) is the process of identifying causal factors using a structured approach with techniques designed to provide a focus for identifying and resolving problems. ***Root Cause*** is the fundamental breakdown or failure of a process which, when resolved, prevents a recurrence of the problem. Tools that assist groups or individuals in identifying the root causes of problems are known as Root Cause Assesmenttools. Every equipment failure happens for a number of reasons. There is a definite progression of actions and consequences that lead to a failure. Root Cause Assesmentis a step-by-step method that leads to the discovery of faults or root cause. An RCA investigation traces the cause and effect trail from the end failure back to the root cause. For a particular product problem, ***Root Cause*** is the factor that,when you fix it, the problem goes away and doesn't come back To meet up the high changing market demands along with high quality at comparable prices, one shall have to identify quickly the root causes of quality related problems by reviewing an event, with the goals of determining what has happened, why it has happened and what can be done to reduce the likelihood of recurrence.

1.1 Basic Term Used In RCA

- Adverse Event
- Barrier
- Brainstorming
- Proximate Cause.
- Facility
- Condition
- Root cause

1.2 Root Cause AssesmentTools and Techniques

a. Cause-and-Effect Diagram (CED)
b. Interrelationship Diagram (ID)
c. Current Reality Tree (CRT)
d. Why Why Analysis
e. Multi Vari Analysis
f. Brainstorming

1.3 Root Cause AssesmentMethods

a. Events and causal factor analysis
b. Change Analysis
c. Barrier analysis
d. Management oversight and risk tree analysis
e. Human performance evaluation
f. Kepner-Tregoe problem solving and decision making

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1.4 Difference between RCA Tools and RCA Methods

To differentiate Root Cause AssesmentTools and Root Cause AssesmentMethods, a standard is needed to which they could be compared. It is generally agreed that the purpose of Root Cause Assesmentis to find effective solutions to our problems such that they do not recur. Accordingly, an effective Root Cause Assesmentprocess should provide a clear understanding of exactly how the proposed solutions meet this goal.

1.5 When to Use RCA

There are usually multiple and varied approaches to solving any given problem, each of which has different resource and time requirements. Root Cause Assesmentis a very structured process of discovery that requires users to go through a series of step-by-step activities, all designed to find out why something happened and what can be done to prevent it from happening again. Because it is a structured and formal process, RCA is relatively time consuming.

The inherent need in most organizations for immediate action following a significant event or major failure can result in a tendency to take "shortcuts," and eliminate steps or modify them to the detriment of the process. This should not be done. Save Root Cause Assesmentfor when it's really needed. And, when it's needed, invest the time and resource to do it right.

1.6 Root Cause AssesmentProcess

The RCA method brings a team of, usually 3 to 6 or as demanded, knowledgeable people together to investigate the failure using evidence left behind from the fault. The brainstorming is to find as many causes of the fault as possible. By using what evidence remained after the fault and through discussions with people involved in the incident, all the non-contributing causes are removed and the contributing causes retained.

A fault tree is constructed starting with the final failure and progressively tracing each cause that led to the previous cause. This continues till the trail can be traced back no further. Each result of a cause must clearly flow from its predecessor (the one before it). If it is clear that a step is missing between causes it is added in and evidence looked for to support its presence. Once the fault tree is completed and checked for logical flow, the team then determines what changes has to be made to prevent the sequence of causes and consequences from again occurring.

Root Cause Assesment is defined in the Canadian Root Cause AssesmentFramework as "an analytic tool that can be used to perform a comprehensive, system-based review of critical incidents. It includes the identification of the root and contributory factors, determination of risk reduction strategies, and development of action plans along with measurement strategies to evaluate the effectiveness of the plans."

Root Cause Assesmentin industries is best conducted by a multidisciplinary team, involving individuals knowledgeable about Productivity, as well as knowledgeable in the Quality area of focus. Information is gathered through interviews with staff members who were directly and indirectly involved. In addition, the team reviews the location where the incident occurred, examines the products, devices, environment and work processes involved, and reviews relevant documentation and literature.

Root Cause Assesmentis a process of discovery that attempts to find out exactly WHAT happened, WHY it happened, and HOW it can be prevented from happening again. Consequently, the goal of RCA is prevention.

To improve product quality and productivity, the analysis team proceeds through a series of probing questions focused on answering "why" and "caused by" questions to delineate the various factors that contributed to the event and which, if left unmitigated, could contribute to another event. The focus is on systems and processes and their interaction with individuals, with the understanding that the individuals involved did not intentionally act to cause harm, and given the same set of circumstances, the outcome would be the same for any individuals involved.

The Root Cause Assesment process encourages high-leverage system changes that, if implemented, will have lasting effects on product quality and productivity with safety. Relevant literature and practice standards are considered in formulating recommendations and actions.

The results of a RCA are typically utilized to guide and direct changes to processes, the environment, and human behavior in order to prevent or reduce the probability that the adverse event will occur in the future.

1.7 Steps for Successful Root Cause Assesment

RCA is a useful tool for trouble shooting breakdowns and efficiently coming to a solution. For successful implementation of RCA following seven steps are necessary and once completed that will naturally result in elimination of root causes and will increase profits.

Seven points of RCA are:

- Identify and Clarify the Issue
- Set up Primary Team (Work as a team, respecting each other's expertise and knowledge, rather than individually)
- Define the physical phenomena of the Cause
- Organize the details of the Cause by using the '3W2H' (with what, when, where, how, how much) tool.
- Consider every possible cause of the Cause.
- Verify all logical causes and eliminate all illogical causes.
- If determined that the cause among the causes was human error, separate that cause from the physical causes.

2. Outline of the Case Study Done

The study was carried out at Cable Manufacturing Industry.The products manufactured by the plant comprise of different components, used in cable industry ranging from Simple Powder Application Machine to Core Laying Machine.

Tubular Strander has been taken for present case study.

The various problems which was encountered in the machine as reported by customers and felt by manufacturer are

- Cracks in Cradle
- Vibration
- Loud noise during machine running

But, no root causes were identified as to why there were such problems. This reason was,one of the key contributory factors for the lower level of productivity.

2.1 Physical causes of problems

- Cracks in cradle is due to material itself
- Cracks may be due to centrifugal force which occurred when pipe rotates at high speed(500 to 750 rpm)
- Cracks may be due to wrong method/way of fabrication
- Cracks may be due to internal residual stresses generated by prior manufacturing processes such as machining
- Vibration and noise is occurred due to improper installation of machine
- Vibration and noise may be due to unbalancing of rotor i.e. pipe or the balancing of rotor is not proper /accurate.
- Vibration and noise may be due to metal to metal contact of matting members (as the rotating pipe is supported on metallic rollers in tubular strander.)
- Vibration and noise may be due to improper maintenance

Fishbone Diagram has been used to associate multiple possible causes with a single effect. The diagram is constructed to identify and organize the possible causes for a particular single effect. After deciding the possible causes of the problem, root cause was identified.

2.2 Identification of root cause

The root cause or most fundamental reason that led to the failure has to be identified. Sometimes the root cause may be related to problems with the prescribed process. By analyzing the Causes-and-effect diagram (CED) gave the following root causes of the above said problems:

1. Crack in tubular strander machine occurred due to internal residual stresses generated by prior fabrication process.
2. Vibration is occurring due to eccentric running of pipe i.e. complete balancing of the rotor is not done and metal to metal contact is responsible for high noise.

2.3 Solutions of the problems

From RCA and literature reviews,following solutions were find out of the above stated root cause.

1. Internal residual stresses generated in pipe due to fabrication process can be removed by stress relieving.
2. Eccentric running of tubular strander machine can be avoided by complete dynamic balancing of pipe by fully automatic balancing machine so that vibration as well as quality of the product can be improved. This will also be helpful in reducing the formation of cracks.
3. Noise can be reduced by using hylem rollers instead of metallic rollers.

2.3.1 Stress Relieving by Heat Treatment

Stress relieving is applied to both ferrous and non-ferrous alloys and is intended to remove **internal residual stresses** generated by prior manufacturing processes such as machining, cold rolling and welding. Without it, subsequent processing may give rise to unacceptable distortion and/or the material can suffer from service problems such as stress corrosion cracking. The treatment is not intended to produce significant changes in material structures or mechanical properties, and is therefore normally restricted to relatively low temperatures.

Carbon steels and alloy steels can be given two forms of stress relief:

- Treatment at typically 150-200°C relieves peak stresses after hardening without significantly reducing hardness (e.g. case-hardened components, bearings, etc.):
- Treatment at typically **600-680°C** (e.g. after welding, machining etc.) provides virtually complete stress relief.

Non-ferrous alloys are stress relieved at a wide variety of temperatures related to alloy type and condition. Alloys that have been age-hardened are restricted to stress relieving temperatures below the ageing temperature. Austenitic stainless steels are stress relieved below 480°C or above 900°C, temperatures in between reducing corrosion resistance in grades that are not stabilized or low-carbon. Treatments above 900°C are often full solution anneals.

Benefits

Stress relieving and normalising all prepare metals and alloys for further processing or for the intended service conditions. They control the ability of materials to be machined with ease, perform without distortion in service, be formed without cracking or splitting, be subsequently hardened or carburised with minimal distortion, or to resist corrosive environments.

All commercial alloys can be stress relieved. Normalising is restricted to certain steels for the reasons indicated above.

Limitations

Stress relieving of carbon or low-alloy steel fabrications is frequently the last heat treatment applied, so it must be ensured that the mechanical properties of the materials treated will not be adversely affected.

Stress relieving between machining operations can be performed on pre-treated material. The stress relieving effectiveness may have to be reduced to prevent loss of mechanical properties.

Many austenitic stainless steels require fast cooling after high-temperature stress relief or solution annealing. A degree of distortion or reintroduction of residual stresses is inevitable in such cases. The size and shape of items that can be stress relieved, annealed or normalised depends on the type of equipment operated by the heat treater. For large items, check the availability of suitably-sized facilities at an early stage.

2.3.2 Stress Relieving by Resonant Vibration Method

It is a resonance based method of vibratory stress relief developed by Stress Relief Engineering Co., USA. Work pieces are subjected to low frequency, high amplitude vibrations for a short period of time based on the weight of the work piece. This allows the residual stresses to be reduced to a much lower level where static equilibrium is restored. The resonance method is used by researchers around the world in stress relief studies using vibration and is currently considered an industry standard.

Working of resonant vibration method

Low frequency vibrations are used as a carrier to deliver high amplitude energy to a metal fabrication, or machined part. The heavy vibrations produce a load that is superimposed on the existing stress patterns that result in a reduction of peak residual stresses. This produces a more dimensionally stable product and reduces the random distortion that often occurs in unstable work pieces. The process can be used on a wide range of ferrous and non-ferrous metals. Typical materials are: carbon steels, stainless steel, aluminium, cast iron, manganese, etc. these are a few of the metals that can be treated in a variety of conditions such as: wrought or cast, forged, formed, welded, ground, polished or machined.

Limitations

There are some limitations as with any metalworking process. The process is not recommended for extrusions or severely cold worked items. On very large, very long or open space frame type structures, the vibration may need to be applied at several locations, which does require more time. Very small items in large quantities are more easily treated thermally in batches. In welding situations where vibration is used during the welding process, this method is most compatible with arc welding.

2.4 Balancing

The unbalancing of rotor will not only cause rotor vibrations, but also transmit rotating forces to bearings and to the foundation structure. The force thus transmitted may cause damage to machine parts and its foundation. If the transmitted force is large enough, it might affect even the neighboring machines and structures. Thus, it is necessary to balance a rotor as much as possible, for its smooth running. From the state of the art of the unbalance estimation, the unbalance can be obtained with fairly good accuracy

A level of unbalance that is acceptable at a low speed is completely unacceptable at a higher speed. This is because the unbalance condition produces centrifugal force, which increases as the speed increases. In fact the force formula shows that the forces caused by unbalance increases by the square of the speed. If the speed is doubled, the force quadruples; if the speed is tripled the force increases by a factor of nine! It is the force that causes vibration of the bearings and surrounding structure. Prolonged exposure to the vibration results in damage and increased downtime of the machine. Vibration can also be transmitted to adjacent machinery, affecting their accuracy or performance. Identifying and correcting the mass distribution and thus minimizing the force and resultant vibration is the technique known as dynamic balancing.

2.4.1 Causes

Unbalance is: “That condition which exists in a rotor when vibratory force or motion is imparted to its bearings as a result of centrifugal forces”. A more popular definition is: “The uneven distribution of mass about a rotor’s rotating centerline.”

The key element is rotating centerline as opposed to geometric centerline of rotor. The rotating centerline being defined as the axis about which the rotor would rotate if not constrained by its bearings (Also called the Principle Inertia Axis or PIA). The geometric centerline is the physical centerline of the rotor. When the two centerlines are coincident, then the rotor will be in a state of balance. When they are apart, the rotor will be unbalanced.

Different types of unbalance can be defined by the relationship between the two centerlines. These include:

Static Unbalance – where the PIA is displaced parallel to the geometric centerline. (Shown in Fig.3.4)

Couple Unbalance – where the PIA intersects the geometric centerline at the center of gravity. (CG)

Dynamic Unbalance – where the PIA and the geometric centerline do not coincide or touch.

The most common of these is dynamic unbalance.

Manufacturing - Causes

Many causes are listed as contributing to an unbalance condition, including material problems such as density, porosity, voids and blowholes, fabrication problems such as misshapen castings, eccentric machining and poor assembly and distortion problems such as rotational stresses, aerodynamics and temperature changes. Even inherent rotor design criteria that cannot be avoided. Many of these occur during manufacture, others during the operational life of the machine.

Assembly – Causes

As previously stated, there are many reasons why unbalance occurs when a rotor is being fabricated. Principle among these is a stack up of tolerances. When a well-balanced shaft and a well-balanced rotor are united, the necessary assembly tolerances can permit radial displacement, which will produce an out of balance condition. The addition of keys and keyways adds to the problem. Although an ISO standard does exist for Shaft and Fitment Key.

Installed Machines - Causes

When a rotor has been in service for some time, various other factors can contribute to the balance condition. These include corrosion, wear, distortion, and deposit build up. Deposits can also break off unevenly, which can lead to severe unbalance. This particularly applies to fans, blowers, compressors and other rotating devices handling process variables. Routine inspection and cleaning can minimize the effect, but eventually the machines will have to be removed from service for balancing. Large unbalances will of course require large weight corrections and unless care is taken, this can have a detrimental effect on the integrity of the rotor. Concentrating a weight adjustment (whether adding or taking away) at a given point can weaken the rotor. For example paper rolls are fabricated from tubing and large additions or removal of weight can affect the strength of the walls of the roll. This may cause it to deflect when spinning at operating speed and thus induce harmful vibrations on the bearings and paper machine frame.

2.4.2 Corrections

When unbalance has been identified and quantified, the correction is straightforward. Weight has to be either added or removed from the rotating element. The ultimate aim being to reduce the uneven mass distribution so that the centrifugal forces and hence the vibrations induced in the supporting structures are at an acceptable level

2.4.3 Effects

There are many documented “good effects” associated with a well balanced, smooth running rotor. Included among these are:

Minimize vibration
Minimize noise
Minimize structural stress
Minimize operator fatigue and annoyance
Increase machine life
Increase bearing life
Increase product quality
Increase personnel safety
Dangers associated with machine failure are minimized.
Increase productivity
Lower operating costs
Extra machines are not required "just in case" of breakdowns. Spare capacity is kept to a minimum. Energy consumption is reduced.

So it is a universal saying that everything that rotates needs to be in a state of balance to ensure smooth running when in operation. Precision balancing is essential to the manufacture of rotating equipment and to the repair and renovation of installed machines. As machine speeds increase, the effects of unbalance become more detrimental. Modern technology allows for accurate balancing to be performed both in the field and in the workshop. Increased time between outages and availability for production is the prime benefit.

3. Result Analysis

Product of the company on which RCA applied is tubular strander. One of the problems observed during present work is

3.1 Crack Occurring In Cradle Tube

By analyzing the RCA sheet, many brainstorming session and technical discussion with the team members, the following root causes of the above said problem was found

- Crack in tubular strander occurred due to internal residual stresses generated by prior fabrication process.
  Solution of the problem

From brainstorming, RCA sheet and literature reviews following solution was find out of the above stated root cause.

- Internal residual stresses generated in pipe due to fabrication process can be removed by stress relieving.

SR can be done either by heat treatment or by Resonant Vibration Method. Management decided to carry out SR by heat treatment as it was available locally i.e.in Ajmer itself before taking a decision to buy a heat treatment arrangements. As the result are likely to come in 4-5 months so at that time final decision will be taken.

3.2 Vibration in machine

Second problem generated is Vibration in machine.

In the Tubular strander vibration is the second major problem. By analyzing the RCA the following root cause of the above said problem is found:

- Vibration is occurring due to eccentric running of cradle i.e. complete balancing of the rotor is not done.

Solution of the problem

From RCA and literature reviews following solution was find out of the above stated root cause.

Eccentric running of tubular strander machine can be avoided by complete dynamic balancing of pipe by fully automatic balancing machine so that vibration as well as quality of the product can be improved. This will also be helpful in reducing the formation of cracks.

KAIZEN ACTIVITY

Numbers of Kaizen activities were taken up for improvement in quality. Some of these activities are discussed below:

Switch over from metallic supporting rollers to Hylem rollers

Steel rollers cause a huge noise when rotor rotates at high speed (750 rpm) because there is metal to metal to contact between cradle and supporting rollers.

To reduce the noise a layer of hylem is used on the steel roller. Circular shape of hylem is cut from hylem sheet. Hylam Sheet also known as Phenolic Laminated Sheets, Bakelite Sheet, Tufnol Sheet. Phenolic Resin Bonded Cotton Fabric Laminates (SRBF) has an exhaustive range of Industrial Laminates Paper & fabric base Bakelite Sheets in electrical & mechanical variety.

Phenolic Resin Bonded Cotton Fabric Laminates are used where mechanical strength, wear resistance and resilience are more important than electrical insulation. Typical applications of fabric laminates are gears, textile shuttles, bearings, pickers, bushes and marine application. Different grades are offered to suit specific applications. Hylem grade F107 is used in the industries.

So the results of a RCA are typically utilized to guide and direct changes to processes, the environment, and human behavior in order to prevent or reduce the probability that the adverse event will occur in the future.

5. Conclusion

The conventional Root Cause AssesmentTools and Methods provide some structure to the process of human event problem solving. This empirical study shows as to how they can be used and how it can be communicated to others with full appreciation. How the solutions will prevent the problem from recurring. The Root Cause Tools and Methods could be utilized according to prevalent conditions and situations of Man, Material, Machines, Systems and Processes.

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