ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Failure Analysis of Rollers in mill stand using Failure mode Effect Analysis

Tadisetti Premsai, Anga Kiran Vikram Varma, S.Sivarajan *
* School of Mechanical and Building Sciences,VIT University, Chennai Campus,India
sivarajan.s@vit.ac.in

Abstract

Rolling is an important steel production process. Productivity and quality improvements in metal rolling are possible by paying a detailed attention to the various roll failure modes.A proper understanding of the causes of roll failure modes is usually complex and depends on the metallurgical quality of rolls, improper mill usage practices and abnormal rolling conditions. The work rolls operate under severe condition and should posses excellent wear resistance and very little plastic deformation to withstand mechanical and thermal shocks. The objective of this study is to analyze different failures associated with rollers in the mill stand using Failure Mode Effect Analysis (FMEA). The values of severity, probability of occurrence and detection of each failure mode are taken according to the FMEA criteria and based on these values, Risk Priority Number of each failure mode is calculated. Based on the risk levels of each failure modes, remedies for the respective failure modes are presented. Thus it results in reduced risk of process failure, improved reliability and quality of the products.

Keywords: Rollers, Failure mode Effect Analysis

Introduction

In rolling mill operation a four roll high stand tandem mills including two work rolls and two back-up rolls are used to decrease force and power of work roll as well as increase the accuracy and thickness uniformity of thin sheets. Repeated loading under bending and compressive stresses, severe friction and wear under corrosive environments at elevated temperatures are some conditions that back-up rolls should endure during mill campaign[1].

The main reason for premature failure of the forged back-up roll can be the combined effects of mechanical and metallurgical factors. Mechanical factors include rolling parameter misalignment, uneven roll surface, lubrication, bearing, rolling speed seizure, insufficient stock removal during grinding and the experience of operators [2,3]. Metallurgical factors comprise the presence of non-metallic inclusions, localized overloading, casting defects, temperature gradients due to insufficient cooling and phase transformations [3,4]. It was observed [4] that spalling, cracking, metal pick up and subsequently strip welding are three critical factors responsible for the poor service life of back-up and work rolls during milling operation.

The present work was carried out in a wire rod mill in a steel plant. The rolling mill train Is subdivided into a seven-stand roughing mill, an six-stand intermediate mill, two-stand pre finishing mill and a ten-stand rod finishing mill..In this study more than fifteen failure modes of rollers in mill stand are identified and failure analysis is carried out using Failure mode effect analysis.

Methodology

Introduction to Failure Mode Effect Analysis

Failure Mode and Effects Analysis (FMEA). involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. It assesses the risk associated with the identified failure modes, effects and causes, and prioritizes issues for corrective action. It identifies and carries out corrective actions to address the most serious concerns[5].

The ground rules of each FMEA include a set of project selected procedures; the assumptions on which the analysis is based; the hardware that has been included and excluded from the analysis and the rationale for the exclusions. The ground rules also describe the indenture level of the analysis, the basic hardware status, and the criteria for system and mission success. Every effort should be made to define all ground rules before the FMEA begins; however, the ground rules may be expanded and clarified as the analysis proceeds.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Basic Terminology in FMEA:

Failure:

The loss under stated conditions is called as failure.

Failure Mode:

The specific manner or way by which a failure occurs in terms of failure of the item (being a part or (sub) system) function under investigation; it may generally describe the way the failure occurs. It shall at least clearly describe a (end) failure state of the item (or function in case of a Functional FMEA) under consideration. It is the result of the failure mechanism (cause of the failure mode). For example; a fully fractured axle, a deformed axle or a fully open or fully closed electrical contact are each a separate failure mode.

Failure Cause and/or Mechanism:

*D*efects in requirements, design, process, quality control, handling or part application, which is the underlying cause or sequence of causes that initiate a process (mechanism) that leads to a failure mode over a certain time. A failure mode may have more causes. For example; "fatigue or corrosion of a structural beam" or "fretting corrosion in an electrical contact" is a failure mechanism and in itself (likely) not a failure mode. The related failure mode (end state) is a "full fracture of structural beam" or "an open electrical contact". The initial cause might have been "Improper application of corrosion protection layer (paint)" and /or "(abnormal) vibration input from another (possibly failed) system".

Severity:

Severity is an assessment of the seriousness of the effect of the potential failure mode after it has occurred. Severity is a ranking number associated with the most serious effect for a given failure mode. It is based on the criteria from a severity scale. It is a relative ranking within the scope of the specific FMEA. It is determined without regard to the likelihood of occurrence or detection.

Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, system damage and/or time lost to repair the failure.

Table 1 : Severity Evaluation Criteria

Effect	Criteria: Severity of Effect	Rank
Hazardous	Failure is hazardous, and occurs without warning	10
Serious	Failure involves hazardous outcome and/or noncompliance with government regulations or standards	9
Extreme	Product is inoperable with loss of primary function. The system is inoperable	8
Major	Product performance is severely affected but functions.operate The system may not operate	7
Significant	Product performance is degraded. Comfort or convince functions may not operate	6
Moderate	Moderate effect on product performance. The product Requires repair	5
Low	Small effect on product performance. The product does not Require repair	4
Minor	Minor effect on product or system performance	3
Very Minor	Very minor effect on product or system performance	2
None	No effect	1

Occurrence:

Occurrence is a ranking number associated with the likelihood that the failure mode and its associated cause will be present in the item being analyzed. It is based on the criteria from the corresponding occurrence scale. It has a relative meaning rather than absolute value, determined without regard to the severity or likelihood of detection.

It is necessary to look at the cause of a failure mode and the likelihood of occurrence. This can be done by analysis, calculations / FEM, looking at similar items or processes and the failure modes that have been documented for them in the past.

Table 2. Occurrence Criteria Table

Probability of failure	Effect	Ranking
Very High:	failure is almost inevitable	10
		9

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

High:	Repeated Failures	8
		7
Moderate	Occasional Failures	6
		5
		4
Low	Relatively few failures	3
		2
Remote	Failure is unlikely	1

Detection:

Detection is a ranking number associated with the best control from the list of detection-type controls, based on the criteria from the detection scale. It considers the likelihood of detection of the failure mode/cause, according to defined criteria. It is a relative ranking within the scope of the specific FMEA. It is determined without regard to the severity or likelihood of occurrence.

The means or method by which a failure is detected, isolated by operator and/or maintainer and the time it may take. This is important for maintainability control and it is specially important for multiple failure scenarios. It should be made clear how the failure mode or cause can be discovered by an operator under normal system operation or if it can be discovered by the maintenance crew by some diagnostic action or automatic built in system test.

Table 3. Detection Criteria Table

Detection	Criteria	Ranking
Absolute uncertainty	Design control will not snd/or cannot detect a Potential cause/mechanism and subsequent failure mode	10
Very remote	Very remote chance the design control will detect a potential Cause/mechanism and subsequent failure mode.	9
Remote	Remote chance the design control will dtect a potential cause/mechanism And subsequent failure mode	8
Very low	Very low chance the design control will detect a potential cause/mechanism And subsequent failure mode	7
Low	Low chance the design control will detect a potential cause/mechanism And subsequent failure mode	6
Moderate	Moderate chance the design control will detect a potential cause/mechanism And subsequent failure mode	5
Moderately high	Moderate chance the design control will detect a potential cause/mechanism And subsequent failure mode	4
High	High chance the design control will detect a potential cause/mechanism And subsequent failure mode	3
Very high	Very high chance the design control will detect a potential cause/mechanism and Subsequent failure mode	2
Almost Certain	Design control will almost certain detect a potential cause/mechanism and Subsequent failure mode	1

Risk Priority Number:

The product of severity, occurrence, and detection gives Risk Priority Number (RPN). RPN cannot be calculated without the awareness of severity, detection and occurrence values. The values of severity, occurrence and detection are taken from the respective criteria tables. The value of RPN varies from 1 to 1000.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Risk priority Number (RPN) = Severity(S) * Occurrence (O) * Detection (D)

Results and discussion

Failure Modes Of Rollers:

Eighteen failure modes of Rollers are identified and their description and origin are given below

Saddle Spalls:

These are characteristic "saddle" shaped fatigue spalls originating in the core material below the shell/core interface and breaking out to the barrel surface. Variable intensity of fatigue lines may be seen in the deep areas of the spall indicating the propagation direction from the core to the barrel surface.

Spalling is caused by high cyclic loads due to large reductions when rolling thin gauge and hard materials. These loads induce high alternating stresses on the core material, beyond the fatigue limit, and many micro cracks begin to form causing a progressive weakening of the core material. In the second stage these micro cracks join together and propagate to and through the shell to the barrel surface giving rise to the large and typical "saddle" spall.. This is usually a roll fault.

Pressure Cracks:

In the first stage, one or more pressure cracks is formed in an area of local overload, at or near to the barrel surface. Such a crack is usually oriented parallel to the roll axis but propagates in a non-radial direction. In the next phase, a fatigue, cat's tongue like fracture band propagates progressively in a circumferential direction running more or less parallel to the barrel surface. The direction of propagation is opposite to the direction of roll rotation. High local loads at leading edges, or doubling of the strip end exceed the shear strength of the shell material and initiate the crack. Subsequent rolling fatigues the material and the crack propagates until a massive spontaneous spall occurs. This is a mill fault.

Shell Core Interface/ Bond related Spall

A large area of shell material separates from the core following the weakly bonded interface until an area of full metallurgical bond is reached. At this point the fracture propagates rapidly towards the barrel surface resulting in a large spall.

During casting of rolls, the aim is to achieve full metallurgical bond between the shell and the core metal. Disbonding of the shell from the core during operation is favoured by any reason which reduces the strength of the bond such as:

- residuals of oxide layer between shell and core,
- presence of flux or slag at the interface,
- excess of carbides, microporosities, graphite flakes or non-metallic inclusions such as sulphIdes.

***Shell Core Interface/Insufficient Shell Depth*:**:

The interface between the shell metal and the core is completely welded but the depth of shell is insufficient to reach scrap diameter. The core material which contains more graphite and less alloy is much softer than the shell material. As the interface follows the solidification front of the shell metal, the areas of soft core metal showing at the barrel surface, will be patchy and not continuous.. This is a roll fault.

Barrel Edge Spalls:

Surface cracks and associated spalls form on the work roll barrel approximately 100-300mm from the end of the barrel in a circumferential direction. These cracks are extended towards the freeboard of the barrel surface. In extreme cases, these cracks can enter into the neck radius. This cracked edge may either stick to the roll body or break out as a large spall.This is a mill fault.

Band Fire Cracks:

It corresponds to the strip width and to the contact arc between work roll and strip. The appearance of these cracks is the usual mosaic type, but of larger meshes size than a conventional fire crazing pattern.

In the case of a mill stop, the strip can remain in contact with the work rolls for a considerable time. The temperature of the roll surface increases rapidly in the contact area and heat penetrates deeper into the roll body. The thermal stresses induced exceed the hot yield strength of the roll material. When the strip is removed and the rolls lifted, the roll surface cools down and due to the contraction of this localized area, the surface starts cracking. . This is a mill fault.

***Ladder Fire Cracks*:**

Within a circumferential band on the barrel, the roll shows longitudinal oriented cracks which propagate in radial planes. This type of fire cracking can be initiated due to a lack of cooling, for instance by blocked cooling nozzles. Due to pronounced heat penetration into the roll body, these fire cracks are much deeper than usual fire crazing. This is a mill fault.

***Localised Fire Cracks*:**

The barrel shows local areas of firecracks, sometimes together with indentations or even local spalling. These cracks occur when the combination of mechanical and thermal stresses within these local areas pass over the yield strength of the barrel

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

material and are exaggerated during subsequent cooling.

Journal Failure from Shock Overload:

The journal suffers a cross section failure usually starting at the bottom of the radius adjacent to the barrel. The fracture face follows the radius and then continues into the side of the barrel, and shears away a portion of the barrel end face.

Under shock load conditions the peak load can exceed the ultimate bending strength of the core material and fracture occurs, usually at the most highly stressed cross section area. In the case where a roll has been miss-handled by being dropped or by incorrect use of the porter bar during roll changes, roll necks will either crack or more often fail by fracture. The fact that a piece of the barrel is attached to the journal indicates a misuse failure. This is a mill fault.

Journal Failure from Bending Fracture:

Fracture lines start from the outside and spread over the whole cross section, particularly starting in the fillet area and very often after a fatigue crack propagation. This failure arises from high bending loads which exceed either the ultimate bending strength or fatigue strength of the journal. It is generally limited to 2-Hi work rolls of any grade in hot mill stands.

This kind of breakage can be caused by:

- High rolling loads combined with a weak roll design.
- Rolling accidents with extreme bending forces,
- Inadequate roll quality as far as journal strength is concerned,
- A notch effect as a consequence of too small a fillet radius, circumferential grooves, fatigue cracks induced by corrosion etc.

This is either a mill or roll fault.

Journal Failure from Drive End Torque:

The torque on the drive end has exceeded the torsional strength of the journal material. The strength of the journal will also be affected by the notch effect of sharp radii, i.e. in the split ring recess, or any other stress raisers such as radial bore-holes. The load can be normal for the design and operation of the mill, in which case the roll material requires upgrading or the load can be in excess of standard mill operation, which in turn is higher than the torsional resistance of the roll material.

Overloads are experienced through a variety of circumstances:

- a mill stall due to a “slab sticker”,
- rolling accidents such as strip welding, wrong pre-set of the roll gap etc.
- incorrect drive shaft fitting, either by the mill, or by incorrect machining of the drive end.

This is normally a mill fault.

Journal Failure from worn and Seized Bearings:

Score marks or deep scratches occur on the journal in the area of the bearing, either along the axis or in the circumferential direction. There can also be indentations and inclusions of fragments of mill scale or other extraneous materials. Other damage can include oxidation and erosion of the ground surface underneath the bearing. Rotational marks and firecracks may be evident in the bearing areaand in extreme cases thermal breakage of the neck can result. Cracks may propagate from the oil injection holes.

Inadequate, damaged or even missing seals allow intrusion of water, scale and other foreign particles into the gap between the inner bearing race and the journal. The deep scratches along the axis are caused by debris between the bearing and the journal digging into the surface when the bearing is removed for roll grinding. Grease viscosity which is too low and wrong clearance between bearing and journal together with foreign particles cause surface damage and wear when the inner bearing ring moves around the roll journal due to micro slippage. This can even induce cold welding and cohesion between the journal and the bearing plus blockage of lubrication holes. The result can include high frictional loads, firecracks from the heat produced and a seized bearing. Excess wear on the journal as described above, lack of lubrication, elliptical machining or incorrect fitting of the neck ring or any other lack of sealing will allow the mill cooling water to penetrate under the bearing and cause corrosion.

This is a mill fault.

Thermal Breakage:

The barrel is broken showing radial oriented fracture lines whose origin is at or near to the axis of the barrel. The fracture is perpendicular to the roll axis and usually occurs close to the centre of the barrel length. This kind of fracture is generally known as thermal breakage. These defects are considered as a roll fault

Inclusions:

Non-metallic inclusions may be of different size and appearance.:Different sources are possible, such as slag or flux entrapment or foreign particles coming from the mould or casting equipment. This is always a roll fault and threatens surface quality but does not normally lead to massive roll failures.

Hard and Soft Spots:

These surface and/or subsurface defects appear as circular or semicircular, white or grey spots

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

within the shell material and are either harder or softer than the surrounding base metal. They normally do not appear as a localised single defect but generally affect a large part of the roll body.

Hard spots present a concentration of segregated iron carbides where as soft spots show carbide depleted or graphite enriched areas. One cause is probably the segregation effect triggered by a gas bubble, which is pushed by centripetal force, through the shell metal just before final solidification. The gas originates from sudden decomposition of the water of crystallisation contained in the binder of the coating material.

Peeling:

During rolling, a thin layer of oxide is formed on the roll surface within the rolling width. Partial removal of just this oxide layer is known as peeling. This peeling can be easily identified when observed as silvery circumferential streaks of parent roll material, intermingled with blue/black oxide streaks still adhering to the roll surface.

The oxide layer on the roll surface grows as a function of the roll surface temperature when leaving the roll bite and time of exposure to air at elevated temperature. This oxide layer is submitted to alternating shear stresses due to the difference of surface speed of strip and roll. Once the fatigue strength of this oxide layer is exceeded, peeling of this layer starts. Peeling is characterised as long as only the oxide layer is sheared away while the basic roll material remains intact and continues resisting the shear forces.

Banding:

Heavily peeled bright areas appear on the work roll oriented in the circumferential direction and very often in the form of bands with a very rough surface. Banding typically appears on ICDP work rolls in the early finishing stands of hot mills, even after rather short campaign times. Banding is also possible, when high chrome work rolls are used after longer run times in the same critical stands and positions.

Calculation of Risk Priority number

The Risk Priority number is calculated by multiplying the severity, occurrence and Detection values. The Table 4 gives the Risk priority number of the eighteen identified failure modes.From the table it was observed that Journal failure from drive end torque,Journal failure from beding fracture, journal failure from shock overloads, Saddle spalls and bond related spalls are risky failure modes when compared with other failure modes.

Table 4.Severity,Occurrence and Detection Criteria Ranking and Risk Priority number

S. No	Failure	Severity	Occurrence	Detection	RPN
1	Saddle spalls	10	5	8	400
2	Pressure Cracks	8	5	7	280
3	Bond related spalls	7	7	8	392
4	Insufficient shell depth	7	4	5	140
5	Barrel Edge Spalls	6	6	4	144
6	Band Firecracks	4	6	7	168
7	Ladder Firecracks	4	5	5	100
8	Localized Fire Cracks	5	3	6	90
9	Journal failure from shock over load	9	4	8	288
10	Journal failure from bending fracture	9	6	7	378

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

11	Journal failure from drive end torque	10	5	9	450
12	Journal failure from worn and seized bearings	7	5	4	140
13	Thermal breakage	10	4	5	200
14	Pinholes and Porosites	2	2	3	12
16	Inclusion s	6	5	4	120
16	Hard and soft Spots	2	4	9	72
17	Peeling	2	8	4	64
18	Banding	3	7	5	105

Remedies of Failure modes:

Saddle Spalls:

Correct information about rolling loads (t/m of strip width) and previous experience of roll failures should be advised to the roll supplier who will then specify a core material for the work rolls with higher strength properties appropriate for highly loaded mill.

Pressure Cracks:

Regular crack detection (ultrasonic, eddy current, dye penetrant) after each roll change will identify dangerous cracks and avoid major failures if such cracks are completely removed prior to the next campaign. Immediate roll change is strongly recommended after a severe mill incident with subsequent 100% crack detection and appropriate roll dressing before the next campaign. Additional measures such as controlled campaign length, adequate stock removal, correct roll camber, prevention of cobbles etc., are necessary to prevent as many causes of local overloads as possible. The roll user can prevent this type of heavy roll damage by applying the correct roll inspection and mill operation.

***Shell Core Interface – Bond Related Spalls*:**

Ultrasonic testing can identify and quantify the degree of welding and shows possible propagation of bonding defects during roll life. Catastrophic failures of this type can be prevented normally if ultrasonic testing during roll life is applied and rolls are taken out of service before any critical stage of disbonding has appeared.

Shell Core Interface – Insufficient Shell Depth:

Adapt casting parameters to suit shell depth requirements.

Barrel Edge Spalls:

Ensure back up rolls have correct barrel and relief. Avoid high stress concentrations at the ends of the work roll barrel. Ensure good control of roll bending. Pay attention to correct alignment and profiles of work and back up rolls.

Band Fire Cracks:

Prevent the mill stalling and the bar from sticking. In the event of a stall, immediately open the roll gap and turn off the cooling water. Remove the strip and give the rolls time to equalise the surface temperature without getting into contact with cooling water in order to prevent severe cracking. Turn on the water when the rolls have cooled to a more even temperature. For finishing rolls, a roll change will almost always be required. Rolls have to be redressed until the surface does no longer show visible open cracks. Perform ultrasonic testing in order to make sure that there are no fire cracks that propagate into a surface parallel direction.

Ladder Fire Cracks:

Ensure efficiency of the water cooling system and verify if the volumes and pressures are correct. Inspect roll cool headers and nozzles for blockage and before rolls are inserted, turn cooling water on to check nozzle spray pattern.

***Localized Fire Cracks*:**

Improve rolling conditions to avoid mill incidents of this kind. Remove rolls immediately after an occurrence for close inspection and appropriate dressing.

***Journal Failure from Shock Overload*:**

Careful handling is needed in the roll shop. Correct alignment of the porter bar during roll changes is essential for those mills without automatic roll change. Avoid shock loading and high overloads during mill operation.

Journal Failure from Bending Fracture:

Avoid excessive bending loads. Select the correct roll design and/or material. Reduce notch effects from circumferential grooves by cross polishing the fillet area. Protect the journal fillets against corrosion. Arrange regular inspection of roll journals.

***Journal Failure from Drive and Torque*:**

Guarantee stable rolling conditions. Avoid sharp radii and radial bore holes in highly loaded sections, i.e. such as split ring recesses, spade or wobbler drive ends. Avoid excess torque e.g. by installing shear pins. Ensure correct tolerances in the drive and coupling systems.

Journal Failure from Worn and Seized Bearings:

Ensure that there is adequate grease and lubrication at all times. Avoid cooling water and mill scale from entering the bearing area by preventive maintenance of the seals. Increasing the surface hardness of roll necks is not an adequate remedy.

Thermal Breakage:

Good roll cooling is the best guarantee that the maximum possible temperature difference will never be critical. If, for example, the maximum roll temperature at the end of the rolling campaign will not exceed 65°C there is normally no danger of thermal breakage during start-up, even in the case of high rolling pace from the beginning of the rolling campaign. In the case of poor roll cooling conditions, safety measures have to be respected, for instance:

- Reduction of the rolling throughput at the start-up phase,
- Preheating of the work rolls before start-up,
- The roll should be mounted only if it is at least at room temperature,
- Use of high strength core material (SG-Iron core metal instead of lamellar/flake grey cast iron),

***Pinholes and Porosities*:**

The roll maker has to improve mould preparation, melting and casting operations. From a certain size, defects can be detected by ultrasonic inspection before delivery.

Inclusions:

The roll maker has to pay particular attention to cleanliness of the liquid metal before casting and the integrity of the casting mould as well as a good foundry environment. From a certain size, defects of this type can be detected by ultrasonic inspection before delivery.

***Hard and Soft Spots*:**

The roll maker should ensure good mould condition and coating preparation and avoid excessive vibration of the mould during spin casting.

Peeling:

Control the strip surface temperature by optimising rolling temperature, interstand cooling, skin cooling and roll cooling. Campaign length must be adjusted to rolling conditions as well as grades of strip and roll.

***Banding*:**

Adjust the campaign length to change work rolls before appearance of banding.

Factors of importance are:

- Roll grade
- Lubrication
- Reduction
- Roll cooling
- Rolling pace

Conclusion

The failure modes are controlled and the remedy actions are planned to reduce or eliminate the risk associated with each potential cause of the failure mode. Those failure modes should be prevented or detected at the product development stage to reduce or eliminate the production or process lag.

More than 15 failure modes of rollers in mill stands are identified and FMEA was conducted for each failure mode to calculate the risk of respective failure mode. FMEA identified the potential failure modes, their causes, and the effects on the system for a given process. Based on RPN calculation spalling, journal failure from shock overloads, drive end torques had maximum risk when compared to other failure.

References

[1] Hamid Reza Bakhsheshi Rad , Ahmad Monshi Mohd Hasbullah Idris , Mohammed Rafiq Abdul Kadir ,Hassan Jafari , "Premature failure analysis of forged cold back-up roll in a continuous tandem mill", Materials and Design 32 (2011) 4376–4384

[2] Wu Q, Sun DL, Liu CS, Li CG. Analysis of surface and sub-surface initiated spalling of forged cold work rolls. Eng Fail Anal 2008;14:401–10

[3] Li H, Jiang Z, Tieu KA, Sun W, Analysis of premature failure of work rolls in a cold strip plant. Wear 2007;263:1442–6.

[4] Ray AK, Mishra KK, Das G, Chaudhary PN. Life of rolls in a cold rolling mill in a steel plant operation versus manufacture. Eng Fail Anal 2000;7:55–67

[5] EFFECTIVE FMEAs, by Carl S. Carlson, published by John Wiley & Sons, 2012

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

[6] *Ford Motors FMEA Reference Manual, Automobile Industry Action Group, 3rd Edition.*
[7] *www.effectivefmeas.com*

Author Biblography

	**Tadisetti Premsai** Tadisetti Premsai is a Final year student of SMBS, VIT Uiversity, Chennai Campus
	**Anga Kiran Vikram Varma** Anga Kiran Vikram Varma is a final Year student of SMBS, VIT University, Chennai Campus
	**S.Sivarajan** S.Sivarajan obtained his Bachelors degree in Mechanical Engineering from Coimbatore Institute of Technology and Masters degree in Advanced Manufacturing Engineering from Indian Institute of technology, Chennai. He has 17 years of teaching experience. He has published around fifteen papers in International Conferences /Journals