Elimination of Tool Failure in Edge Cutting Machine using Quality Tools and Techniques

D. Sakthimurugan, L. Antony Michael Raj, V. Antony Aroul Raj, K. Thavasilingam, N. Bharath

Abstract*— Increasing cost of consumable materials has put an enormous pressure on the estimating as well as the cost-effectiveness of an organization. Therefore, without any conciliation on quality, the unpredictable cost has to be reduced. This demands novel intellectual and creativity for constant improvement in manufacture, resulting in good earnings. Rim is an important component for any wheel and manufacturing of rim involves various stages with each stage involving different machines. The basic idea of the research is to identify the causes of tool failure in edge machine and to find solution for the identified causes. Edge cutting machine is specially used in earthmovers unit for the production of rims for earthmover wheels. The existing tool was replaced with the new tool made of shearing resistant material. The new tool is designed and analysed for production purpose and cost variation are successfully compared.

***Keywords*— Quality Tools, PDCA, Activity Chart, Causes and Effect diagram.**

I. INTRODUCTION

Maintain leadership in the national market and presence in export market. Ensure customer satisfaction through delivery of quality product and services, at viable prices. Continuously improve & innovative product design, process technology and working environment to offer enhanced products. Bring about participation of all employees in achieving the above objectives. "Totality of features and characteristics of a product or service that bears on its ability to meet stated or implied needs" –ISO. The tools are cause-and-effect diagram, check sheet, histogram, pareto chart, scatter diagram and stratification. It is an iterative four-step management method used in business for the control and continuous improvement of processes and products. It is also known as the Deming cycle/ plan-do-check-act (PDCA).

II. QUALITY TOOLS AND TECHNIQUES

a. Seven Basic Quality tools

It is a designation given to a fixed set of graphical techniques identified as being most helpful in troubleshooting issues related to quality. The tools are,

- Cause-and-Effect Diagram.
- Check sheet.
- Control charts.
- Histogram.
- Pareto chart.
- Scatter diagram.
- Stratification

The need for tools to promote innovation, communicate information and successfully plan major projects. A team researched and developed the seven new quality control tools, often called seven management tools.

- Affinity diagram.
- Relations diagram
- Tree diagram:
- Matrix diagram:
- Matrix data analysis:
- Arrow diagram:
- Process decision program chart (PDPC)

b. PDCA (Plan –Do–Check–Act)

It is an iterative four-step management method used in business for the control and continuous improvement of processes and products. It is otherwise known as the Deming wheel, shewhart circle, control circle or plan-do-study-act (PDCA).

III. ACITIVITY CHART

The sequence of process carried out throughout the project is depicted in the activity chart. It includes step by step process to analyze and eliminate the failure.

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		January			February		March	
S. No.	Activity	W 1	W 2	W 3	W 4	W 5	W 6	W 7
1	Define the project							
2	Study the current situation							
3	Analyze the potential causes							
4	Develop the solution							
5	Analyze the results							
6	Standardize the improvement							
7	Establish future plans							

IV. LITERATURE SURVEY

Before Narasimha et al., worked on the ways of improving the tool life by various coatings on tool steels. The coatings like TiN, Al2O3 , TiN-Al2O3 are extends`tools steels are investigated in dry condition. For comparison uncoated tool steels are tested under same condition. Surface roughness of the coated tool steel was greater than uncoated tool steel. Paliska et al., studied about the universality systematic in application of seven basic quality tools. The research was carried out in different areas of the manufacturing industry. The extend of selected tool in usage and the reasons for avoiding in broader application are studied. Also the core relation between the formal quality management system and seven basic quality tools is researched. Elmagrabi et al., studied many classification of tool materials. In most cases the tool manufacturers provide tools made of the proper material for each given application. In some particular application higher price material will be justified. The optimum tool is not necessarily the least expensive or the most expensive. The best tool is the one that has been carefully chosen to get the job done quickly, efficiently and economically. This paper shows that the response surface methodology can be used in design of experiment to develop tool life models for several materials and the same approach can be used for modeling other machineability performances such as surface roughness. Kumbhar et al., studied about tool failure and surface roughness prophecy. Taguchi approach is used to find the optimal process parameter for cutting semi hard steel. An orthogonal array, ANOVA and signal to noise ratio are used to study performance characteristics of machining parameters such as cutting speed with consideration of surface finish and tool life. The conclusions exposed that the feed rate is the most influential factor on the surface roughness and tool life.

V. DEFINE THE PROBLEM

A. Edge cutting machine

Generally a pair of tool is mounting on the either side of the tool holder. Tool used in edge cutting process is rectangular in shape with three counter bores provided for mounting the tool in the holder. The tool is mounted to the holder using allen bolt. The holder tightly holds the tool and it can move both horizontally and vertically. Only two counter bores are used to mount the tool and the other one remains free and is utilized in mounting other direction. The edge cutting tool has eight edges but only two edges are used for cutting process.

Fig 1: Edge cutting machine

B. Edge cutting tool

The The tool used in the Edge Cutting process is a 2 profile rectangular High Carbon High Chromium (HcHcr) tool with 3 M12 Counter bore. The tool is attached to a tool holder. The issue is that it fails often with severe damages for every 1000 to 1200 rim productions

Fig 2 : Edge cutting machine

C. Impact of the Problem

Positioning Authors and Affiliations Tool change loss is the time lost while changing tools either due to breakage of tool or once the life of the tool is reached. Rim line is tool intensive lines in which around 200 types of tools are used. They are producing more than 1000 wheels per day. It means 1000 Edge cutting process is performed by the tool every day. Tool change loss due to edge cutting tool and holder breakage = **55 minutes/month**

- Total tool change loss per month = 0.92 hours
- Scheduled hours per day = 20.33 hours
- Cost of rectangular type tool (one set) = Rs.4000
- Number of set used per month = 4 set

- Frequency of change due to failure per month = 4*4000*12 = Rs.1,92,000
- So total cost of rectangular cutting tool per year for edge cutting operation is Rs. 1, 92,000.

D. Edge cutting loss trend

The time loss due to tool failure for a period of nine months is plotted using a run chart. And it is found that time loss varies between 40-65 minutes. So on an average the time loss is 55 minutes per month.

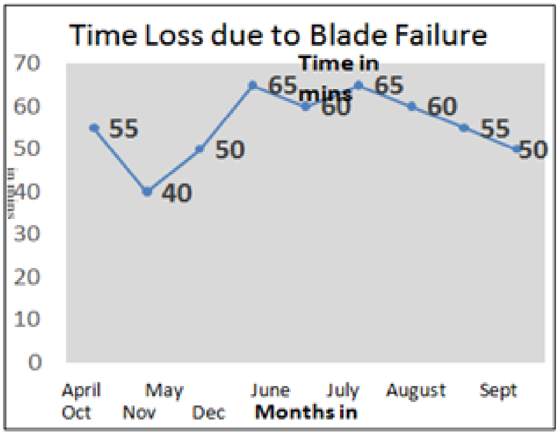

Fig 3: Edge cutting time loss trend

VI. IDENTIFING THE CAUSES

The causes for the problems can be identified by brainstorming techniques

A. Brainstorming

It is a group or individual person, creativity technique by which efforts are made to find a conclusion for a specific problem by gathering a list of ideas impulsively contributed by its members. The following are the possible causes find by brainstorming techniques for edge cutting tool failure,

- Excess stress at cutting edge
- Weak design for blade
- Improper material for blade
- Improper fixing of blade holder
- Hardness in tool is insufficient
- Mill scales get trapped inside the tool
- Insufficient cutting pressure
- Excess stress concentration in tool

B. Fishbone diagram

It used to determine major causes for an effect and sorts ideas into useful meaningful categories namely - man, machine, material, method. The possible causes of tool failure identified by brainstorming is sorted into four categories using the cause and effect diagram.

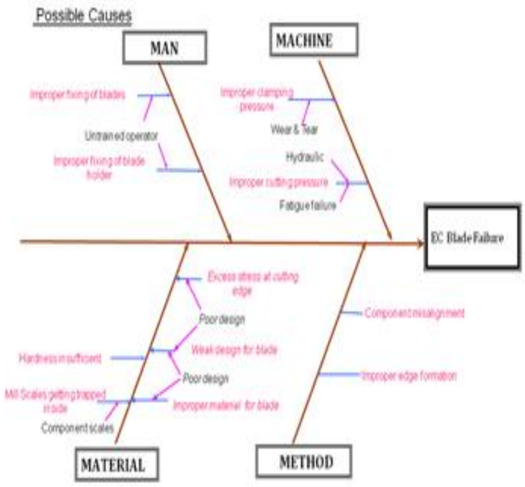

Fig 4 : Edge cutting time loss trend

C. Validating the possible causes

Table- II: Validation of causes of tool failure

Causes	Considered/ Not Considered	Reasons for Eliminating the Causes
1. Excess stress at cutting edge	Considered	NA
2. Weak design for blade	Considered	NA
3. Improper material for blade	Considered	NA
4. Improper fixing of blade holder	Not considered	Only Skilled technicians are involved in tool change over in Edge cutting machines
5. Hardness in tool is insufficient	Not considered	The blade hardness is observed to be 52-54 HRC which is sufficient for the operation
6. Mill Scales get trapped inside the tool	Not considered	Blade is bolted with blade holder. Space is minimal for scales to enter
7. Insufficient cutting pressure	Not considered	The cutting pressure was observed to be 60 bar which is sufficient for the cutting off the edges

8. Existing blade width is high	Not considered	Blade failure at the vertical section not observed after analysis of tool
9.Insufficient clamping pressure	Not considered	Clamping pressure is 50 bar
10.Component misalignment	Not considered	Component fed through automation and width is sufficient for component alone
11. Improper edge formation	Not considered	The size of edge variation was observed between 0.5 to 2 mm only
12. Improper fixing of blade	Not considered	Only Skilled technicians are involved in tool change over in Edge cutting machines

VII. ANALYSIS THE ROOT CAUSES OF TOOL FAILURE

The root causes are analyzed individually with the help of ANSYS work bench software.

A. Calculation of stress

Cutting force, F = A × Tβ

A = Shear area

A = L × S

L = Total cutting length

S = Material thickness

Tβ= shear strength

Note: Shear strength = 80% of tensile strength So,

Tensile strength σ =258Mpa

Shear strength Tβ =0.80×258

Shear strength, Tβ = 207 Mpa = 207 N/mm2

Material thickness, S = 3.5 mm

Total cutting length, L = 10 mm

Shear area, A = L × S

= 10 × 3.5

Shear area, A = 35 mm2

Cutting force, F = A × Tβ

= 35 × 207

Cutting force = 7245 N

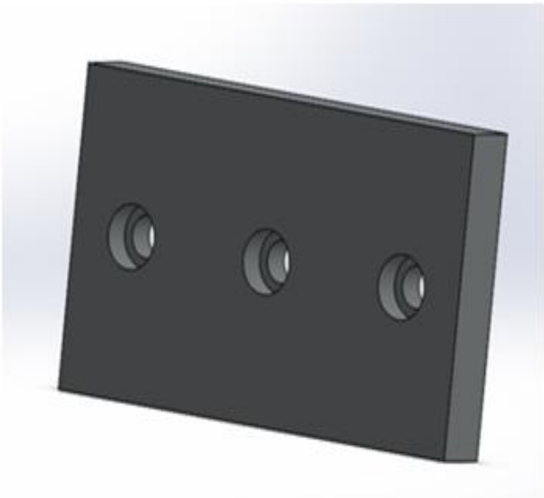

Fig 5: 3D view of old tool

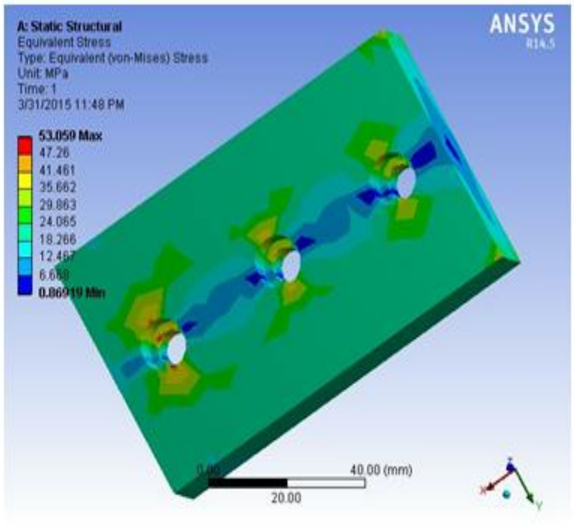

Fig 6: Von – Mises stress

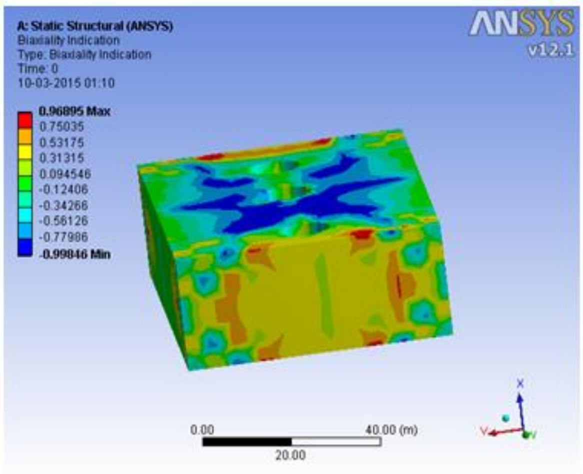

Fig 7 : Biaxial Indication

B. Calculation of volume

Volume = (l × b × t) – 3(volume of the drill)

C. Volume of the drill

Radius of the outer drill (R) = 6mm

Radius of the inner drill (r) = 4mm

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Height of the drill (h) = 12.5mm
Volume of the drill = $(\pi \times R2\times h) + (\pi \times r2 \times h)$
Volume of the drill = $(\pi \times 62\times 12.5) + (\pi \times 42 \times 12.5)$
$= (\pi \times 36 \times 12.5) + (\pi \times 16 \times 12.5)$
$= (\pi \times 450) + (\pi \times 200)$
$= \pi (450 + 200)$
$= \pi \times 520$
Volume of the drill = 204mm^3

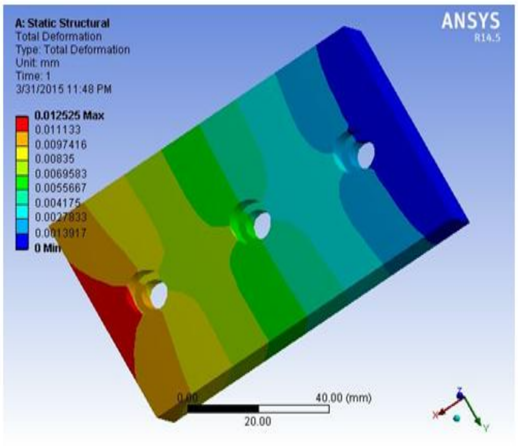

Fig 8: Total deformations due to stress

D. Volume of the Old Tool

Length of the old tool (l) = 100mm
Breadth of the old tool (b) = 70mm
Thickness of the old tool (t) = 25mm
Volume of the drill = 2041mm3
Volume of the old tool= (l × b × t) – 3(volume of the drill)
= (100 × 70 × 25) – 3(2041)
= 175000 – 6123
Volume of the old tool = 168877 mm3

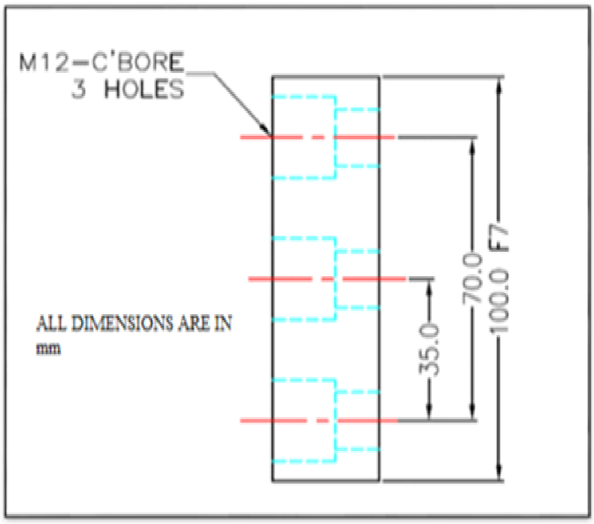

Fig 9: Side view of old tool

The 3 Counter bores covers a significant volume in the tool, which reduces the strength of the tool.

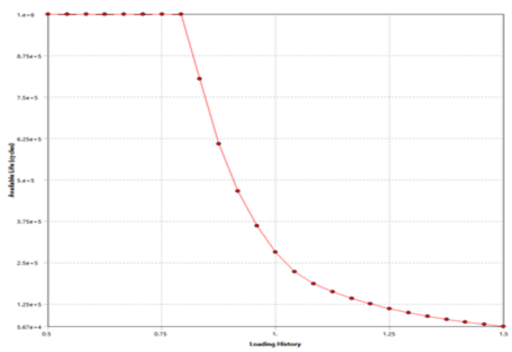

Fig 10: Fatigue sensitivity curve

E. Improper material for Tool

Existing tool is made up of high carbon high chromium D2 steel.

Table- II: Chemical composition of HCHCR

S. No	Element	Content %
1	Carbon (C)	1.4-1.60
2	Manganese (Mn)	0.60
3	Silicon (Si)	0.60
4	Cobalt (Co)	1.00
5	Chromium (Cr)	11-13
6	Molybdenum (Mo)	0.70-1.20
7	Vanadium (V)	1.10
8	Phosphorous (P)	0.03
9	Nickel (Ni)	0.30
10	Copper (Cu)	0.25
11	Sulphur (S)	0.03

High carbon high chromium steels usually contain high carbon content (1.4 to 1.60 %). Hence they are not suitable for shearing operations well. So we have planned to find another material that suits for shearing operation.

Load calculation for the existing Tool

Factor of Safety = 3
Ultimate Tensile Strength = 258 MPa
P tool = σ ultimate× Area of tool (A)
P tool = σ ultimate× 7000
P tool = 258 × 7000
= 1806000 N
P tool = 1806.000KN
Safety load that can be applied on the old tool is 1806 KN

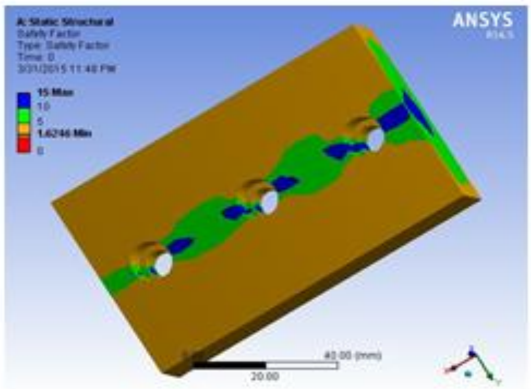

Fig 11: Safety factor

F. Existing Tool holder

The existing old tool is mounted on a holder, which holds the tool during the cutting operation.

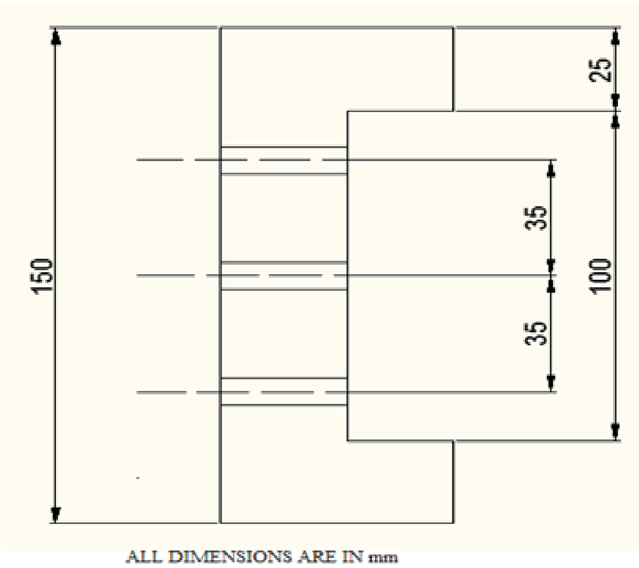

Fig 12: Existing Tool holder

Volume of the existing holder in mm3 =Area × Height
Area of the holder (A1) = l × b = 150 × 25
Area of the holder (A1) = 3750mm2
Area2 (A2)
= 15 × 15
Area2 in mm2
=225mm2
(A3)
= 15*15
Area3 in mm2
= 225mm2
Total Area (A) = A1 + A2 + A3
=3750+225+225
Total area in mm2 =4200 mm2
Volume of the holder = Area × Height
Height of the holder = 70mm
= 4200 × 70
Volume of the holder = 294000mm3

VIII. DEVELOPING THE SOLUTION

A. Increasing work Area

There is insufficient area for load at cutting edge, so we suggested changing the front fixing to rear fixing so that sufficient area for load at the cutting edge is achieved. Since the old tool is rectangular in shape, it can be used only on two cutting edges, but if the tool is in square shape it can be used on four sides, which will eventually decrease the tool change loss.

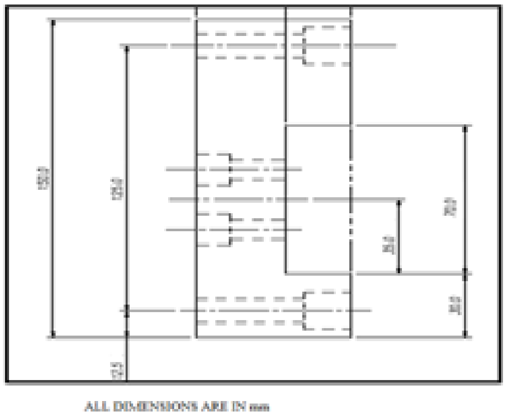

Fig 13: Rear Fixing

B. Alternate Design

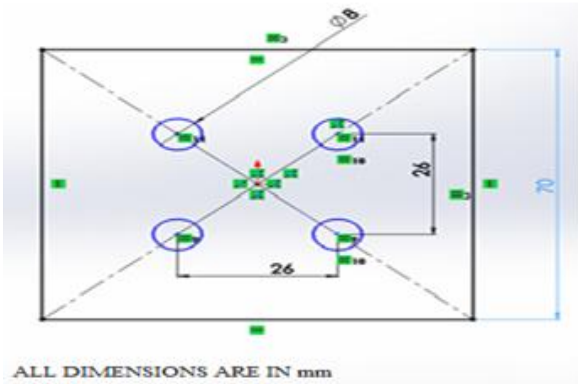

Fig 14: 2D sketch of modified tool

Since the old tool has 3 M12 counter bores which occupies a significant area in the tool, it was decided to change the counter bores into 4 M8 tap holes. Now the counter bore is shifted to the holder. The advantage is that now the tool can be used on 8 edges compared to 2 edges in old rectangular tool.

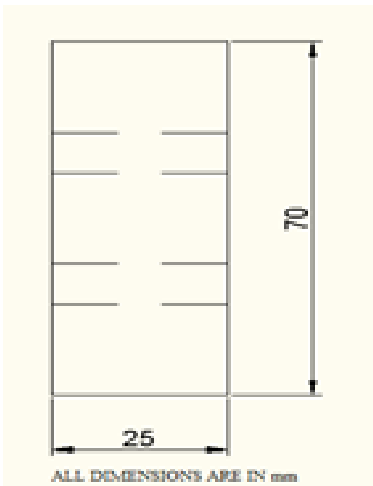

Fig 15 Side view of modified tool

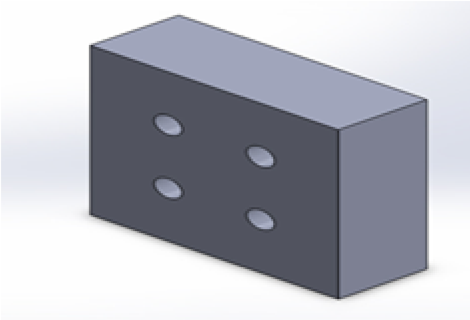

Fig 16 3D model of new tool

C. Alternate Material

With reference to ASM specialty handbook: Tool Materials we decided to choose S-7 tool material. As compared to HcHcr D2, S7 material has low carbon content. It contains only 0.55% of carbon. So it offers high roughness to endure chipping and breaking combined with high possible hardness (58 HRC) and fine wear resistance. Hence S7 material was chosen and the tool is designed and analysed.

Table- II: Chemical composition of S7 material

S. No	Element	Content %
1	Carbon (C)	0.55
2	Manganese (Mn)	0.70
3	Chromium (Cr)	3.25
4	Molybdenum (Mo)	1.40
5	Vanadium (V)	0.25
6	Silicon (Si)	0.35

As per new design and dimension, the new edge cutting tool was developed. This new tool was made of S7 material. When compared to old tool material, S7 material tool is smaller in size and the three tap holes occupies only little area. So the working area is larger when compared to old tool. Since it is square shaped all the eight edges can be mounted as working edge one after another.

S7 material has incomparable collision properties in addition with highest hardenability of shock resisting grades of tool steel. It also possesses fine softening resistance at high temperatures which gives it hot work capabilities. Because of its unusual combination of properties, S7 is suitable for a wide range of tool applications. S7 has good polish ability in the hardened and tempered condition. S7 offers roughness to endure chipping and breaking, combined with high achievable hardness and good wear resistance.

Fig 17 New tool developed using S7 material

IX CALCULATION AND ANALYSIS FOR NEW TOOL

A. Volume of new tool

Volume of the new tool in mm^3 = Casting volume of the tool-Volume of tap holes.

Casting volume of the tool

Length of the side of the tool

= 70 mm

Casting Volume of the new tool in mm^3 = a^3

= 70× 70 × 70

Casting volume of the new tool in mm^3 = $343000 mm^3$

Volume of the hole

Diameter of the hole = 8mm

Radius of the hole = 4mm

Height of the hole = 25mm

Volume of the single hole = $\pi r^2 h$

Volume of the single hole = $\pi \times 4^2 \times h$

= $\pi \times 16 \times 25$

= $\pi \times 320$

Volume of the single hole = 1005.30mm2

Volume of four holes = 4 × 1005.30

Volume of four holes = 4021.2mm3

Volume of the new tool = Casting volume of the tool – Volume of the tap holes

= 343000 – 4021.2

Volume of the new tool = 338978.8 mm^3

B. Load that tool can be with stand and by the tool

Load applied on the new tool

Factor of Safety = 3

Ultimate Tensile strength of the tool material (UTS) = 780 MPa

P tool = σ ultimate× Area of tool (A)

P tool = σ ultimate× 4900
P tool = 365 × 4900
= 1788500 N
Ptool = 1788.5 KN

Safety load that can be with stand by the new tool is 1788.5 KN.

C. Volume of new tool holder

Since the tool is changed, we have to change the dimensions of the holder so that the new tool can be fixed.

Area of the holder (A1) = l × b
= 150 × 25
Area of the holder (A1) = 3750mm2
Area of the holder (A2) = 45 × 15
Area of the holder (A2) = 675mm2

Area of the holder (A3) = 15×15
Area of the holder (A3) = 225mm2
Total area of the holder (A) = A1 + A2 + A3
= 3750 + 675 + 225
Total area of the holder (A) = 4650mm3
Volume of the new holder = Area × height
= 4650 × 70
Volume of the new holder = 325500mm3

D. Load that tool can be with stand and by the tool

The new tool is analyses after the design is changed using ANSYS work bench software.

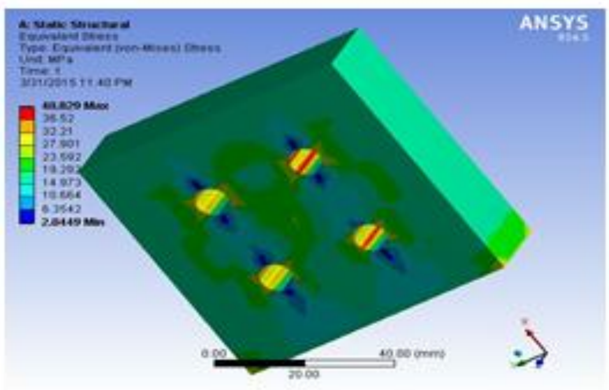

Fig 18 Von-mises analysis of new tool

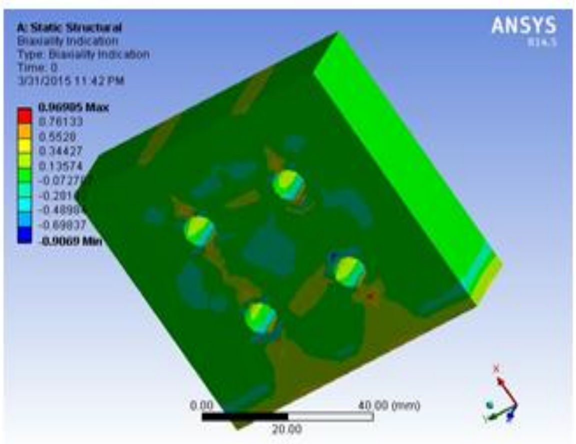

Fig 19 Biaxiality indication

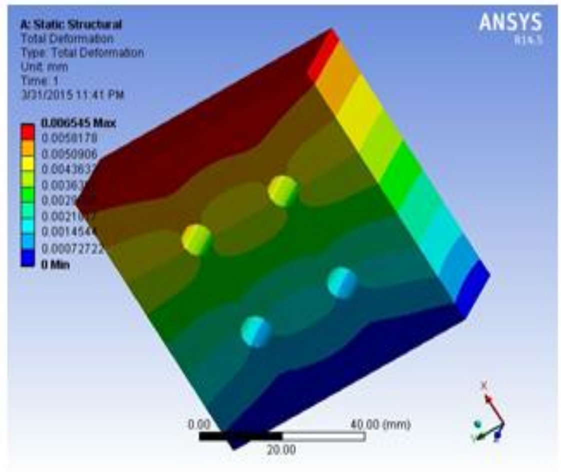

Fig 20 Deformation of new tool

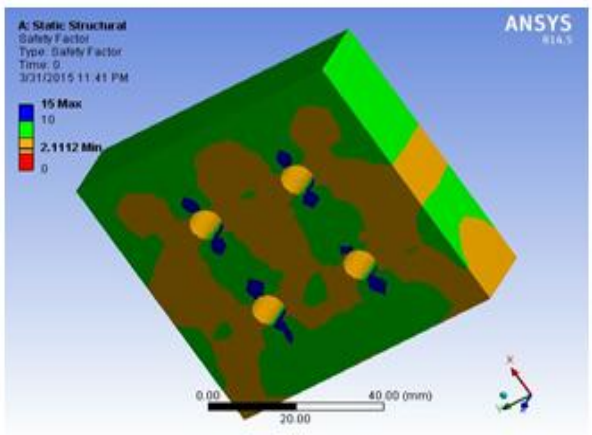

Fig 21 Safety factor of new tool

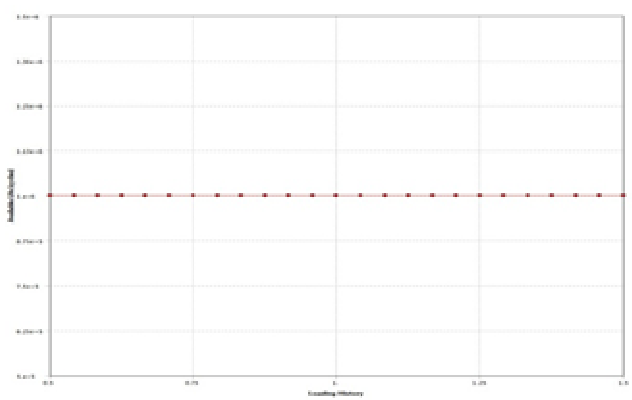

Fig 22 Fatigue sensitivity curve for new tool

X. FORESEEING BENEFITS & RESULTS

A. Tangible Benefits

The productivity improvement after eliminating the tool failure is shown in the table. It is observed that the productivity is increased to 8 to 10 wheels per month.

Table- II: Productivity improvement due to new tool

Tool change loss due to EC blade and holder breakage	55	Min/Month
Total Tool change loss per month	0.92	Hours
Scheduled hours per day	20.33	Hours
Current wheel productivity achieved per month	3462	Wheels
Extra wheels produced due to elimination of TC loss	8-10	Wheels(appx)

Cost savings

Extra wheels produced due to elimination of tool change loss

= 8 wheels

Opportunity cost of the wheel = 2600/wheel

Per day opportunity cost =792 Rs/day

Cost benefits per annum = 2.5lakhs

B. Intangible Benefits

Safety

- Handling reduced which improves safety.
- Frequent adjustments eliminated.

Morale

- Fatigue reduced
- Operator morale improved.

Comparison of productivity between old tool and new tool

Tool modification cost

- Cost of old rectangular tool (two sides) per set = 0.04 lakhs
- Frequency of change due to failure per month = 4 set
- Total cost per annum = 4×0.04×12
- Total cost per annum = 1.92 lakhs
- Approximate cost of new square tool per set = 0.03 lakhs
- Frequency of change for new tool (approximate) = 1 set /4 months
- Total cost of new square type tool for one year = 0.03×0.25×12
- Total cost of new square type tool for one year = 0.09 lakhs
- Saving in tool cost due to tool modification = 1.92-0.09
- Estimated tool cost that can be saved = 1.83 lakhs.

Thus the tool modification cost is reduced from 1.92 lakhs to 0.09 lakhs per annum.

XI. CONCLUSION

Thus the project on "Elimination of tool failure in edge cutting machine using quality tools and techniques" is successfully carried out in the earthmovers rim unit of Wheels India, Padi .Without compromising on quality a new tool has been designed with alternate material which is both cost efficient and productive than the old tool. The new tool can be implemented in other rim lines with necessary analysis in similar edge cutting machines. The project has been done with sufficient quality tools and problem solving techniques used commonly in industries. By eliminating the tool change loss for a particular month, the productivity is improved upto 8-10 wheels a month. Apart from tangible benefits, it helps to achieve many intangible benefits. On completion of this project, it helped us to gain industrial knowledge on manufacturing process, quality assurance, tool design, engineering materials.

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