Design, Analysis & Optimization of Feed Roller Mounting Cradles to address the Field Failures of Vehicle

Amol V Majgaonkar, Arun Bhosale, U. Saindane

Abstract— **The objective of this paper is to design Modifications of Feed Roller Mounting Cradles to address the field failures of cradle getting cracked during harvesting. This is regarding the Sugarcane harvester, during harvesting around 1000 hours it has been observed that there are cracks on the feed roller mounting cradles, due to continuous hitting on stopper plate. The breaking of Cradle will jam the entire machine and which creates tremendous load on engine also causes choking of Sugarcane vehicle so, in order to run it smoothly the Dynamic Components should be designed in such a way that it should have more life than actual vehicle life so, critical breakdown can be avoided.**

***Index Terms*—ABAQUS, Hypermesh Altair Sugarcane Harvesters Feed Rollers Mounting Cradles.**

I. INTRODUCTION

Nowadays due to advancement of technologies there are couple of off Highway vehicles and utility machines for Crop Harvesting Such as Sugarcane harvester, Combine Harvester, tractors , Balers Etc., also Marine Application, Construction Equipment like Wheel Loader , Tower Cranes , Backhoe Loader which need Robust Design and Higher torque to operate to get the things done in Shorter time to increase productivity. The Sugarcane harvester vehicle is more complex due to its operating crop condition, the cane forces during harvesting are very high which creates tremendous forces on related mechanisms, so the mechanisms are needs to be designed in such a way that it should support 15G loading conditions and an ran in worst fields.

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In India Sugarcane harvester usually run in 1.1 meter Row which cuts the cane just above the root of crop to make sure the next couple of seasons, after cutting of cane the Feed Rollers acts as a Conveyors to convey the cane to Chopper gear box where the chopper chops the cane in 6" billet approximately and delivered to elevator to convey the same to infielder Van which deliver the crop to Sugar factory for making sugar.

A. *Problem Statement*

In this Project A Sugarcane harvester machine have feeding system of billets of sugarcane, during harvesting cane push the rollers up to increase the flow and get better output, the floating roller mounting cradles are the structural frames n vehicles which carries rollers and motors, due to constant up and down moment with restriction of stopper there is impact load which cracks the frame of cradle badly and once the cradle broken will stop the function of machine and finally reduce the productivity.

B. *Objectives*

1. To design a cradles which meets the dynamic condition, which will have good structural strength and fatigue life more than machine life to make it more robust.
2. To perform FEM analysis of cradles and take baseline results, compare with new design results to see the new design virtual validation.
3. Improve the Fatigue life of components

C. *Methodology*

Obtain the optimal design solution by using Engineering calculations, endurance limit theory which gives fatigue life of a component. FEA software through perform the design solution, and finally optimal design solution manufacturing and testing. Use Creo 3 to Model the part and ANSYS for Meshing and results.

II. LITERATURE REVIEW

Richard Budynas , J Keith Nisbett, design and to analyze the structural strength of sheet metal parts , Roller mounting Cradle to find out the high tensile strength material and better section modulus, they were resulted in remarkable achievements in automobile industry because of its greater specific strength and specific modulus, improved fatigue and corrosion resistances and reduction in energy requirements due to reduction in weight as compared to Mild Steel. The modeling and analysis of floating roller mounting cradle using Sailma 450 Material and as a base material and to improve section module the thickness of plate, section of roller plate have been changed. Modeling is done using Creo 3.0 software and Analysis is carried out by using ABACUS 6.4 software for easy understanding. The New modified Cradle Design increased weight by 3 kg and improved the stiffness. [1]

Joseph E Shigley , Charles Mischke, design and analyzed a structural strength of medium carbon steel material which composite structure is better than the mild steel construction part and the grain structure is substituted in such a way that the stress flow will be smooth and will have tensile and shear properties. The three major fatigue life methods used in design and analysis are the stress-life method, the strain-life method, and the linear-elastic fracture mechanics method. These methods attempt to predict the life in number of cycles to failure, N, for a specific level of loading. Life of $1 \leq N \leq 103$ cycles is generally classified as low-cycle fatigue,
Whereas high-cycle fatigue is considered to be $N > 103$ cycles. The stress-life method, based on stress levels only, is the least accurate approach, especially for low-cycle applications. However, it is the most traditional method, since it is the easiest to implement for a wide range of design applications, has ample supporting data, and represents high-cycle applications adequately. The strain-life method involves more detailed analysis of the plastic deformation at localized regions where the stresses and strains are considered for life estimates. This method is especially good for low-cycle fatigue applications. In applying this method, several idealizations must be compounded, and so some uncertainties will exist in the results. For this reason, it will be discussed only because of its value in adding to the understanding of the nature of fatigue. The fracture mechanics method assumes a crack is already present and detected. Itis then employed to predict crack growth with respect to stress intensity. It is most practical when applied to large structures in conjunction with computer codes and a periodic inspection program.

III. ROOT CAUSE ANALYSIS

As shown in Fig 1 the Roller Cradle failed in 44 machine with average failure hours are 1176, the Suspected Root causes will be the Section Modulus of Part, Excessive Play due to heavy Wear and tear of Cradle, Due to Sudden heavy actuation load the heavy impact force been generating in field on Cradle which causes the creation of localized stresses on parts at weak sections. Solution to be identified.

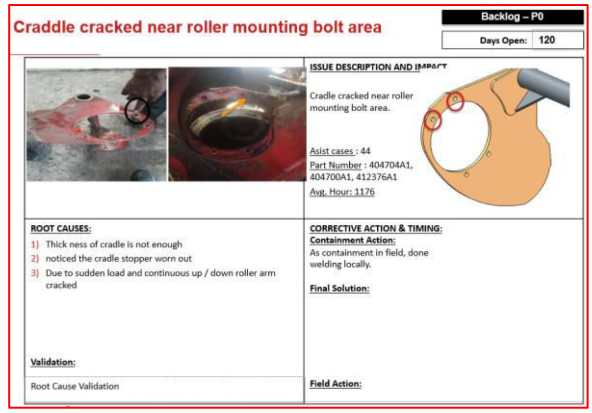

Fig 1 One Pager Analysis of Roller Cradle Crack

IV. DESIGN OF ROLLER MOUNTING CRADLE FRAME

A. Model selection and Properties

The Cradle weight should not increase above 60Kg, which may start failing the Vehicle Chassis, wall thickness of roller can be increased by 10mm not more than that because of packaging constraints.
Model Sugarcane Series

Sr.No.	Particular	Value	Unit
1	Thickness of Plate	8	mm
2	Diameter of plate	790	mm
3	Weight of Roller with Cradle	54.5	Kg
4	Floating Cycles	10^6	Numbers
5	Surface Area of cradle plate	50449	mm2

Table 1: Specification of selected model

Mechanical properties	Symbol	Units	Steel
Young's Modulus	E	GPa	210
Shear modulus	G	GPa	80
Poisson's ratio	μ	-	0.3
Density	ρ	Kg/mm3	7.85e-06
Yield Strength	Sy	MPa	450

Table 2: Design properties of model Sailma 450

B. Mathematical Calculations

- **Stress Range:** $\Delta\sigma = \sigma_{\max} - \sigma_{\min}$
- **Stress amplitude:** $\sigma_a = \frac{1}{2}(\sigma_{\max} - \sigma_{\min})$
- **Mean stress:** $\sigma_m = \frac{1}{2}(\sigma_{\max} + \sigma_{\min})$
- **Load ratio:** $R = \frac{\sigma_{\min}}{\sigma_{\max}}$

We have
Thickness of Plate t = 9.81mm ~ 10mm

V. DESIGN OF ROLLER CRADLE FRAME

A. Raw Material Selection

Following are the features of Sailma 450 Composite Material, the reason for which it is chosen.
A high strength structural steel supplied in quenched and tempered condition. The steel is designed to provide excellent welding and bending properties and it offers substantial possibilities for savings in material costs, processing and handling. Due to its high strength, it enables design of lighter, more durable and efficient products and structures

1. High tensile Strength - 450Mpa Minimum
2. Lighter in weight -
3. Medium steel carbon content.
4. Better fatigue, wear and corrosion resistant.
5. Less elongation – 18%

B. Combination of Loading Modes

It may be helpful to think of fatigue problems as being in three categories:
• Completely reversing simple loads
• Fluctuating simple loads
• Combinations of loading modes
The simplest category is that of a completely reversed single stress which is handled with the S-N diagram, relating the alternating stress to a life. Only one type of loading is allowed here, and the midrange stress must be zero. The next category incorporates general fluctuating loads, using a criterion to relate midrange and alternating stresses (modified Goodman, Gerber, ASME-elliptic, or Soderberg). Again, only one type of loading is allowed at a time. The third category, which we will develop in this section, involves cases where there are combinations of different types of loading, such as combined bending, torsion, and axial.
This type of loading introduces few complications in that there may now exist combined normal and shear stresses, each with alternating and midrange values, and several of the factors used in determining the endurance limit depend on the type of loading. There may also be multiple stress-concentration factors, one for each mode of loading. The problem of how to deal with combined stresses was encountered when developing static failure theories. The distortion energy failure theory proved to be a satisfactory method of combining the multiple stresses on a stress element of a ductile material into a single equivalent von Mises stress.

C. Material Properties and behaviors

The Sailma 450 material comes from the SAIL Industries, this immaterial is very strong material with fewer heaviness , carries toughness , resistance to wear and tear , excellent composition of steel and other chemicals, gives 18-21% elongation with keep elasticity same as existing , twist moment supportive , hi fatigue and endurance life.

Chemical Properties of Sailma 450 High Tensile Structural Steel Plates								
Grade	C max %	Si max %	Mn max %	P max %	S Max %	AL min %	Nb + V + Ti max %	Deoxidation
SAILMA 450	0.25	0.4	1.5	0.055	0.055	0.01	0.2	Killed
SAILMA 450 HI	0.25	0.4	1.5	0.055	0.055	0.01	0.2	Killed

Table 1: Chemical Properties of Sailma 450 High Tensile Structural Steel Plates

Mechanical Properties of Sailma 450 High Tensile Structural Steel Plates			
Grade	Yield strength MPa	Tensile Strength MPa	Elongation
SAILMA 450	450 min	570 – 720	18
SAILMA 450HI	450 min	570 – 720	19

Table 2: Mechanical Properties of Sailma 450 High Tensile Structural Steel Plates

ABAQUS 6.14, PRE-post

Finite element analysis is a computer based analysis technique for calculating the strength and behavior of structures. The complete structure analysis of the Roller Cradle in present case follows there major steps: preprocessor, solutions and post-processor. Preprocessor involve CAD geometry, Meshing and Boundary conditions.

D. Layout of Vehicle

Sugarcane Harvester Vehicle Terminology

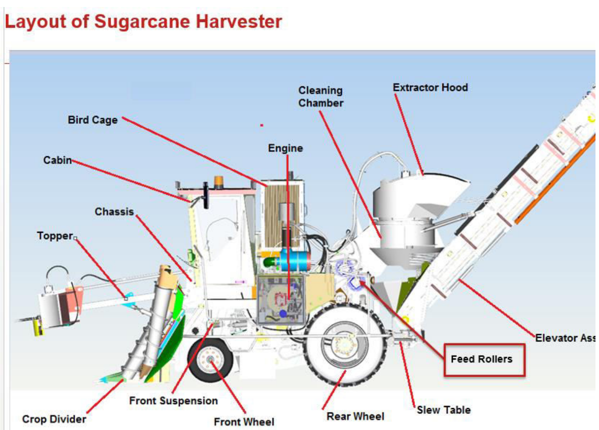

Fig 2. Shows the Layout of Sugarcane Harvester Vehicle

Fig 2 shows the typical layout of Sugarcane Harvester, which mainly includes Topper , Crop Divider, Cabin , Front Suspension & Steering , Chassis , Feed Roller Mechanisms, Engine , Bird cage , Slew Table , Feed Rollers , Extractor hood and Elevator assemblies.

Topper Assembly trims the knives of Sugarcane to avoid wastage in crop , Crop Divider, External Auger divides the crop and internal Auger pull the Crop for Harvesting which is there in 1.1 meter Row Spacing, the knockdown roller bow down the Sugarcane which can easily late down for better insertion for cutting operation, Finned Roller Segregate the Mixed crop in to 4 Rows , base cutter will cut the base of cane which is 6" above from Root to take new Crop on same plant in future , the cut sugarcane conveyed through feed rollers and send to chopper gear box which cuts the cane in equal billets and drop down in cleaning chamber where the extractor fan sucks the trash present in crop and throw out from extractor and finally cleaned billets of sugarcane conveyed to Infielder van through elevator to send to Sugar factory for post processing.

E. CREO 3.0

The modelling performed by using CREO 3 to design the 3d model gives packaging feasibility, dynamic relationship and finally support FEM

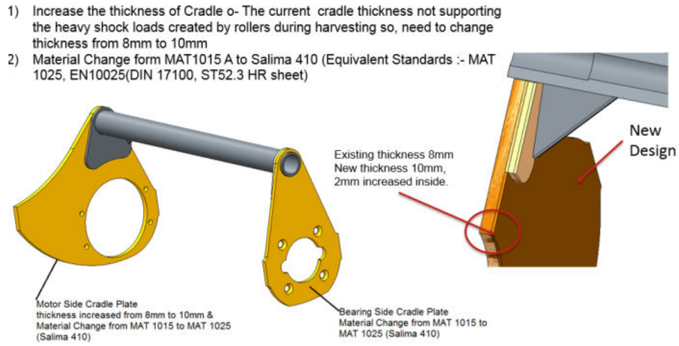

Fig. 3: CAD geometry and boundary conditions

F. ABAQUS 6.14 COMPOSITE PRE-POST

ANSYS Composite Prep-Post training is geared towards engineers who are designing and analyzing layered composites. The training will cover the correct and efficient use of this technology for the purpose of overcoming some of the inherent challenges in composite modeling - such as capturing fiber orientation, model inspection, and failure analysis.

The Pivot Point of Cradle assembly shaft constrained as a fix point and 6 G Load applied on the Pivot pin of 360Kg, set material property and solved.

G. Result

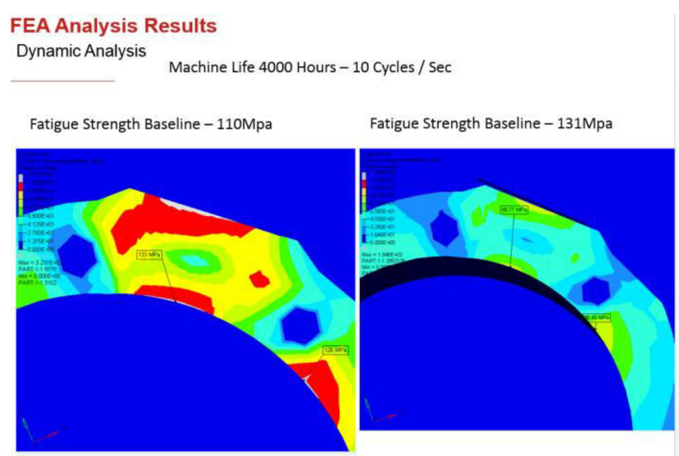

Fig 4: Result obtain form FEA

VI. MANUFACTURING PROCESS AND TESTING

A. Manufacturing Process

In most conventional materials, there is a having very close

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relation between the manufacture of a composite material and it is use. The manufacture of the material is often actually part of the fabrication process for the structural element or even the complete structure. The selection of a fabrication process obviously depends on the constituent materials in the composite, with the matrix material being the key (i.e. the process for polymer matrix, metal matrix and ceramic matrix composites are generally quite different).

Some of the more popular techniques are described in follows.

- Laster Cutting of Plates
- Obtain Standard Pipe with designed length
- Filament Winding
- MIG Welding Setup

MIG welding we used to get desired weld penetration

After the manufacturing the weight of assembly is 54.5 Kg including roller assembly, and cradle weight is 10.3 Kg

B. Validation

Vehicle level validation has been completed, the overall defined vehicle life is 4000 hours, out of which 3200 hrs. has been completed and remaining hours are in progress , since this is critical issue , the cradle assemblies are getting monitored every 100 hours , no failure reported yet, earlier average failure hours was 444 so, design is much better and Robust.

Rig Testing not done , vehicle level validation required to justify the FEA Results , please refer the following testing set up gives the idea of validation and testing

Fig. 5: No Failure after 3200 hrs.

C. Result

- No Failure reported after 3200 Hours out of 4000 Hrs.'

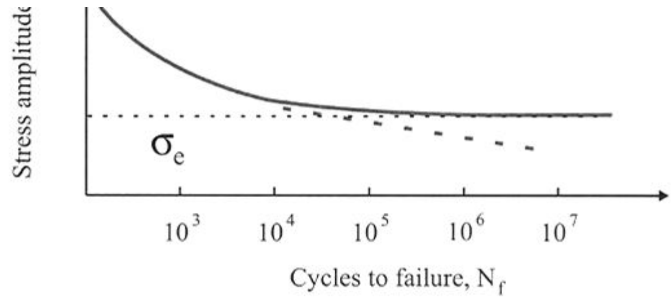
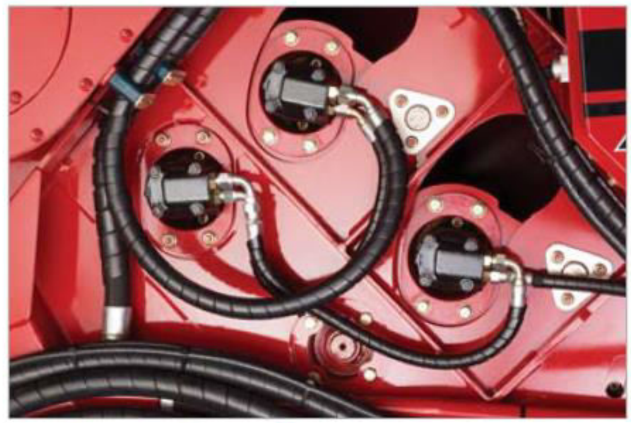


Fig. 5: Endurance Curve



Top floating feed rollers

The above results shows validation, done for 1.44x10^5 Cycles, as per endurance curve the fatigue life of said component is infinite.

VII. CONCLUSION

The FEA Analysis Shows the Design of Roller Mounting Cradles are not meeting the Fatigue Strength of Engineering acceptance Criteria and FEA Analysis Captured the location which is very close to actual failure location hence design has been changed and validated more than 80% , no failure reported. The new Design meets engineering acceptance criteria.

REFERENCES

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[3] V B Bhandari (2005) Design of Machine Element 5.9: 134

[4] A4000 Sugarcane harvester vehicle brochure page 4, 5, and 6.