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FEA Analysis And Optimization of Headstock Used For Diameter Φ 50"X Φ 100" Sugarcane Mill

Authors

Yogini .V. Deore[1], Prof. Jitendra. R.Mahajan[2], Vinay Patil[3]

[1]M.E Student, Department of Mechanical Engineering, L.G.N.S.C.O.E, Nasik,

[2]Asst. Professor, Department of Mechanical Engineering, L.G.N.S.C.O.E,Nasik,

[3]C.E.O, Vaftsy CAE, Pune

Email: *yogini.deore454@gmail.com, jitendramahajan264@gmail.com, vinaaypatil@gmail.com*

ABSTRACT

Sugarcane crushing is an important activity and maximum insistence nowadays is on speed, maximum extraction without losses, and easy collection of residual material which can be used as organic compost. Speed is essential, because after cutting, the rate of sugar quantity deterioration is directly proportional to the time. Hence cane needs to be processed immediately. The cost of extraction and sugar is so competitive that wastage is not desirable, furthermore the waste now finds good usage as an organic fertilizer which means that waste collection needs to be efficient. Keeping this entire in mind, a new head stock has been designed, which included 3 Stage crushing in it, incorporated with higher speeds. However the entire assembly is manufactured using casting, and typically these brittle materials have a high chance of failure if there is a stress concentration at certain locations. Material used for casing is cast Iron and for pins it is structural steel. Hence, FEA analysis is performed on the headstock of diameter ϕ50"X ϕ 100" sugarcane mill. The shear stresses and total deformation are found out from software. The thickness is optimised by varying thickness values. Finally an optimum thickness value is selected on the basis of stress concentration which is below maximum shear stress i.e. 125 MPa. Thus the weight optimization is carried out with varying thicknesses and a safe stress value. As a result, this will reduce the material thus reducing its cost.

Keywords*-FEA, Knuckle joint analysis, Headstock stress analysis by FEA component.*

I. INTRODUCTION

In tropical and subtropical regions, sugar cane is a grass of the genus Saccharinwhich is grown approximately producing 4000 lakh metric tons of raw sugar worldwide. For extraction of juice, the three roller mills are which consists of three rollers i.e. Top, Feed and Discharge rollers. These rollers are carried on heavy shafts running in their bearing placed in pair of headstocks or casing, which are bolted on a bed plate. These three rollers are housed in a heavy cast steel frame known as "Mill Head stock" or "Mill housing".

The bearings are supported in sugar mill head stocks in which rollers rotate at various speeds. The size of the head stocks is important as they have to carry the forces experienced by the rollers for different capacities. In the Factory, sugar cane are placed and fitted on the elevator which takes them to the cane crushing mill where the juice is squeezed out. The cane mill consists of two parts: the crushing rollers & squeezing rollers. [1]

The revolving knives are sometimes followed by crushing rollers. The crushing rollers are arranged in pairs and the squeezing rollers in three-one at top and two at bottom. At the start of the season, the three rollers of a mill are fixed relative to each other and their positions in the housing are adjusted. The grooving of squeezing rollers is done to grip the cane and to allow passage ways to juice. The bearing which carry the rollers are able to slide andthe rollers are pressed together by hydraulic pressure so that each top roller exerts constant pressure on the lower roller. The pressure developed during milling depends on the layer of bagasse.

Generally in sugar plant sugar cane passes from first mill to last mill to provide maximum extraction of juice from bagasse. In larger mills the total pressure will be distributed over a large area of the bagasse. [11]

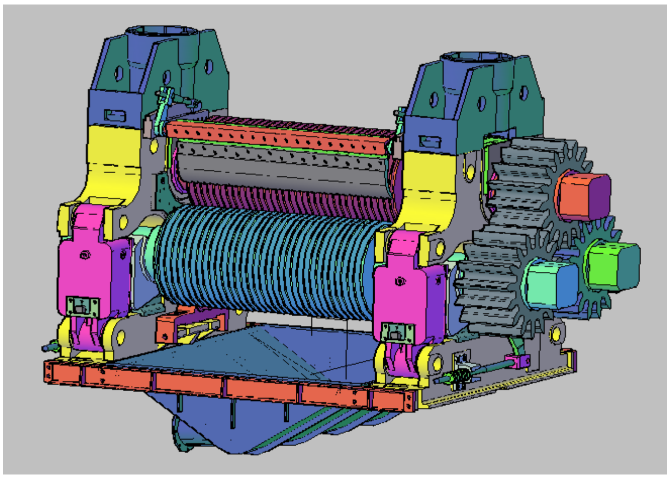

Fig 1. Conventional Three Roller mill Assembly [1]

It is highly desirable that the structural integrity of mill head stock should be maintained as they play an important role in the sugar industry. The finite element method is a powerful tool to furnish an accurate solution to a large class of engineering structural problems, which involve considerable geometric complexity and various load types. However finite element models of various levels of sophistication depend on the requirement of the problem considered. The accuracy of a good Finite Element model should be validated with the experimental values. Upon satisfaction the model can be used for further design development with confidence. Considering the above three roller mill can prove the best option because it requires trash plate. Hydraulic load is transferred & distributed to the Mill head stock in different section.[12]

This has been shown in the Fig.1. Three rollers have better drainage capacity because of its high extraction efficiency & less juice absorption by bagasse, easy operation & maintenance, simple horizontal adjustment of mill setting, large bearingjournals which provides acceptance of high mill loads. Therefore in sugar industry it is very essential to design three roller conventional mills as it has got above advantages. [13]

II. LITERATURE REVIEW

It depicts attempt towards research work carried out in the area of analysis and feature driven optimization of Headstock of Sugar mill, it is found that an evolutionary research has been done and keeps on expanding in this topic. A quite good amount of research work is found available on various areas of Headstock analysis and optima-zation.

The advantages of using Ø40”X80” mill head stocks by designing & analysis by ANSYS software. [1] In this study theoretical study has been done considering the Bending moment & force polygon diagrams. Bending moment factor which helps in finding actual results. By changing various parameters the performance of mill headstocks is studies using static structural analysis & the same are compared with above theoretical results. Based on results the optimum design is proposed. ANSYS software is used to calculate principal stresses, deformation of mill head stock. The stress values calculated theoretically as well as ANSYS is nearer and that too much less than the principle & tensile stress value. From above results & mill head stock parameters is safe. Therefore the conventional sugar mill head stock is suitable for Dia. 40”x80” mill size.

The advantage of using two roller sugar mill over three roller sugar mill by designing and analysing it with FEA techniques. The roller mill needs to be designed in order to satisfy the condition of keeping number of stages same while maintaining optimum crushing rate. In this study theoretical analysis has been done considering simply supported beam with two conditions i.e. determinate beam and indeterminate beam. By comparing results of above two conditions one factor has been calculated i.e. Bending moment factor which helps in finding actual results. By changing various parameters the performance of roller mill is studied using FEA software and the same is compared with above theoretical results. Based on results the optimum design is proposed. ANSYS software is used to calculate stress-strain state of roller mill. The stress value calculated theoretically as well as from FEA are nearer and that too much less than the allowable stress value. From above results and discussions it is concluded that two sugar roller mill for above same parameters is safe. Based on the above advantages it is proposed to have two roller sugar mill. [2]

Sugarcane roller mill is the vital part of sugar industry. The main objective of milling is to separate the sucrose-containing juice from the cane. The extraction of juice in a mill is achieved by squeezing prepared cane between two rolls. Finite Element Method is a numerical technique used to carry out the stress analysis. In this method the solid model of the component is subdivided into smaller elements, constraints and loads are applied to the model. Geometrical model is created using 3D modelling software CATIA V5. The static analysis of each component is carried out using analysis software ANSYS WORKBENCH. The results for maximum shear stress on the top, feed, discharge roller are calculated analytically and compared with the results from software. Static analysis of all three rollers is done using different materials for analysing the variation in results. Maximum shear stress value for top, feed and discharge roller is less than yield strength in shear of material so, all three shafts are safe. As the value of maximum Shear stress is very less than yield strength in shear of material, so there is scope for weight optimization. [3]

The basic three-roller mill designed and developed in early 1900s incorporated two compressions in the mill with high frictional work between compressions over the trash plate. Three roller mills which are used for extraction of juice consist of three rollers i.e. Top, Feed and Discharge rollers. Sugarcane is being fed into top and feed rollers which further passes through top and discharge roller along with trash plate. This trash plate is having a downside that 25% of total hydraulic load is shared by this trash plate in overcoming friction and remaining 75% only the useful one, i.e. 25% hydraulic load is shared by feed roller and 50% is shared by discharge roller. Today, heavy-duty shredders and fibrizors prepare the sugarcane with up to 90% open cells before it is fed to the mills. As a result, frictional work over the trash plate is no longer necessary, so eliminating the trash plate was an obvious choice for engineers. Considering above pitfalls two roller mills can be the best option because it doesn't require trash plate and any trash plate adjustment and replacement. Two roller mills consist of only two rollers i.e. top and bottom roller. 100% of hydraulic load is available for compression at bottom roller. Hydraulic load required is 70% of same size conventional 3-roller mill which is not shared and directly transferred to the bottom roller. 2-roller has better drainage because of its simplicity; capital cost is 12% less than traditional mill, no slippage and less juice absorption by bagasse. In this, shaft of bottom roller is a critical part which should be designed. From results that Weight of Solid Shaft= 14087 kg , Weight of Hollow shaft = 10721 kgand discussions it is concluded that two sugar roller mill with hollow shaft is preferable one and it offers much greater safety factors against failures.[4]

The material optimum distribution paths and the topology optimization results are obtained by Opti-Struct software which meets the engineering constraints. The analysis provides optimization methods and ideas for the headstock of rotation mechanism. The material optimum distribution paths and material optimum thickness is calculated here by software, but there are many issues to be considered in the actual project, such as the casting technology, the installation requirements and so on. So it is needed to continue on studying.

There are many external causes of shaft failure which can be eliminated by changes in mill design and operation, such as an improvement in the tailbar coupling, and limitation of the hydraulic loading. But in the final analysis, it is evident that the major causes of failure originate on the surface of the roll shaft. "Tender Loving Care" of the surface of the shaft can therefore be rewarded by a much longer life for the shafts. One of the areas in which this care can be applied with great effect is in adequate planning of the roll repairs and reshell programme for the annual off crop. Whenever the persons involved in repair and machining are pressed for time, mistakes which escape notice until a failure occurs can easily be made. Provided all the precautions enumerated in this paper are carefully observed there is no reason why every roll shaft should not give a minimum life of 10 million tons of cane. Theoretical analyses of shaft stresses and fatigue stress concentration factors have been carried out to determine whether present shaft design, machining practices, material specifications and shell assembly techniques are satisfactory and whether they can be improved. The feasibility of using adhesive to fix the shell to the shaft is discussed and some recommendations to users and manufacturers on roll shaft and shell specification, design, assembly and operation are given. [5]

Residual stress measurement is of critical significance to in-service security and the reliability of engineering components, and has been an active area of scientific interest. It offers review of several prominent mechanical release methods for residual stress measurement and recent developments, focusing on the hole-drilling method combined with advanced optical sensing. Some promising trends for mechanical release methods are also analysed. Non-destructive methods include several well established techniques that are all relatively expensive. X-ray diffraction can only be used as a surface measurement technique for certain crystalline materials and is sensitive to surface preparation. Magnetic testing methods can only be used on magnetic materials and are based on the changing relationship between stress and the magnetization curve in the process of ferromagnetic saturation. And ultrasonic testing is simple in principle, and is suitable for depth varying residual stress measurements although there are still some difficulties to overcome such as distinguishing sound velocity changes caused by materials defects or stress. [6]

The premature failure of journal bearings encountered in sugar mills has been analysed. The causes of bearing failure are identified by simulating the operating conditions and conducting controlled experiments on a fully automated Journal Bearing Test Rig with provisions for varied combination (i.e. load, speed, and lubricating oil) of operating conditions. The results of performance behaviour (i.e. coefficient of friction, change in surface roughness and weight loss) of the bearings as observed in these experiments have been reported. The theoretical and experimental results indicate the existence of boundary lubrication conditions in sugar mill journal bearings. To mitigate the problem of relatively high wear, lubricating oil with boundary additives have been tried and results are reported. [7]

In the present work ANSYS 13 has been used for analysis of knuckle joint with modified material and varying loads. Many systems used in industries use knuckle joint which is combination of two materials: cast iron and stainless steel. Here we are proposing the modification of one of the material that is changing cast iron into a composite polymer material. The proposed system has many advantages over other system such as making the device, simpler and having maximum safety and is eco friendly. The analysis of the system proves all the above features mention above. The reason for considering polymer is that property of polymer is mostly similar to the property of metal. Composite polymers are characterized by a high flexibility material. The revolutionary evolution in technologies in last year allowed reducing stress and strain. [8]

The overall subject is the frequent failure analysis of output shaft of gear motor used for cold rolling mill to drive the Pay-off Four-HI (Horizontally inserted). One end of that shaft is connected to the claw coupling to the drive of the Pay-off four-HI .By considering the drive system forces and torque acting on the output shaft are determine using which the stresses occurring at the failure section are calculated . Stresses analysis is also carried out with analytical method and comparing these results with the software results that is done using the ANSYS software after getting all the different parameter redesign of shaft is done and again analysing the shaft using ANSYS and hope that shaft may torsional Rigid. [9]

III. COMPANY SURVEY

The survey was carried out in Kadwa sugar factory located at Nashik, Maharashtra, India. Fig 2, Fig 3 and Fig 4 shows side view, front view and Top view of actual Headstock in Kadwa Sahakari Sakhar Karkhana, Nashik respectively.

Fig 2. Side view of ϕ50"X ϕ 100" Sugar mill

Fig 3. Front view of ϕ50"X ϕ 100" sugar mill

Fig 4. Top view of ϕ50"X ϕ 100" sugar mill

IV. METHODOLOGY AND 3-D MODEL OF HEADSTOCK USING FINITE ELEMENT SOFTWARE

Fig 5 shows complete methodology of work .FEA consists of a computer 3 D model of a material or design that is stressed and then it is analysed for particular results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case there is structural failure, FEA may be used to help to determine the design modifications to meet the new design condition. There are generally two types of analysis that are used in industry: 2-D modelling, and 3-D modelling. While 2-D modelling has simplicity in nature and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modelling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively.

Within each of these modelling schemes, the algorithms (functions) can be put which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture. FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which have large amounts of stress usually have a higher node density than those which experience little or no stress. The mesh acts like a web of spider in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors carries the material properties to the object, creating many elements. A Finite Element analysis consists of three stages; Pre-processing, processing, and post processing. A complete finite element analysis software is a logical interaction of these three stages. [10]

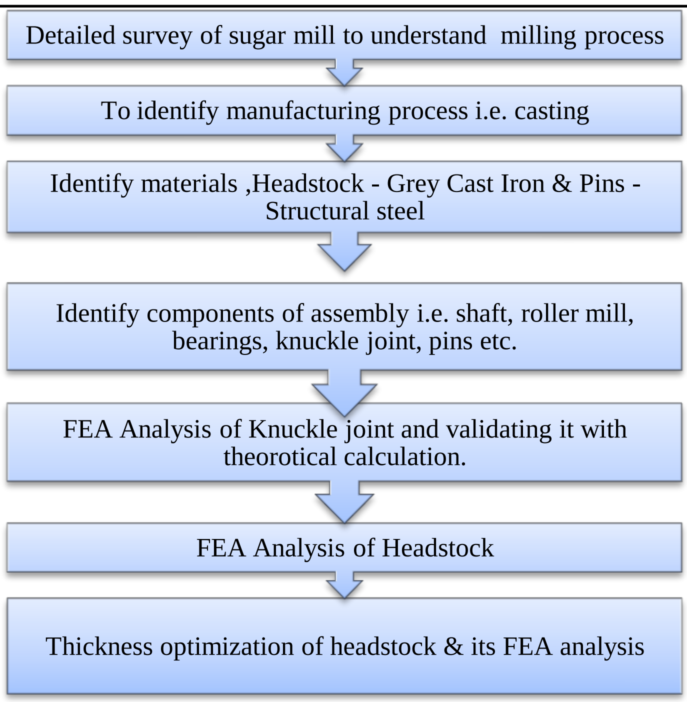

Fig 5. Methodology for work

1) Pre-processing:

Pre-processing is something which is done before processing your analysis. The processes such as nodal coordinates, finding out of the connectivity, boundary conditions, loading and information of material comes under Pre-processing. The preparation of data require considerable effort if all data are to be handled manually. If the model is small, the user can often just write a text file and feed it into the processor, but as the complexity of the model grows and the number of elements increase, writing the data manually can be very time consuming and error-prone. Therefore it is necessary with a computer pre-processor which help with mesh plotting and boundary conditions plotting. We can change loads, boundary conditions, mesh and element properties and material. All this is done graphically to minimize the chance of error. The only limitation is that you cannot draw geometry by your own; you have to select one of the pre-generated geometries.

2) Processing

The processing stage involves stiffness generation, stiffness modification, and solution of equations, resulting in the evaluation of nodal variables. This is a typical "black box"-operation, as the user will see little of what is going on. We feed data from the pre-processor, and get data out.

3) Post processing:

The post processing stage deals with the representation of results. Typically, the deformed configuration mode shapes, temperature, and stress distribution are computed and displayed at this stage.

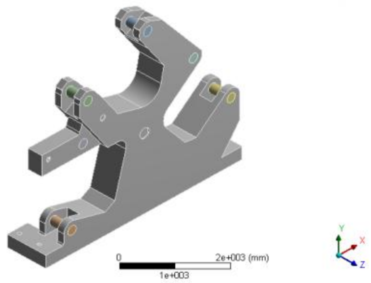

Fig 6. 3D Model of Sugarcane Mill Headstock

The 3 D model shown in Fig 6 is made by actual dimensions given in AutoCAD design. The model is divided into two parts. One is body and one is pins. The body is made of Grey cast Iron and pins are made of structural steel and mass of original headstock is 40468 kg.

V. MESHING OF 3D MODEL

Meshing is divided into two parts.

1) Body

2) Pins

Fig 7. Meshing of Headstock

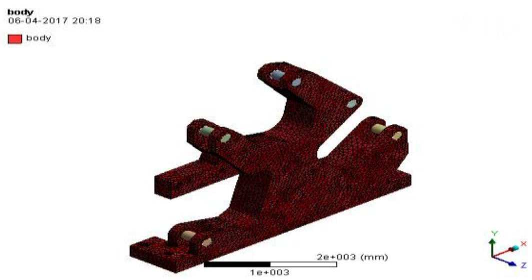

Fig 8. Meshing for body.

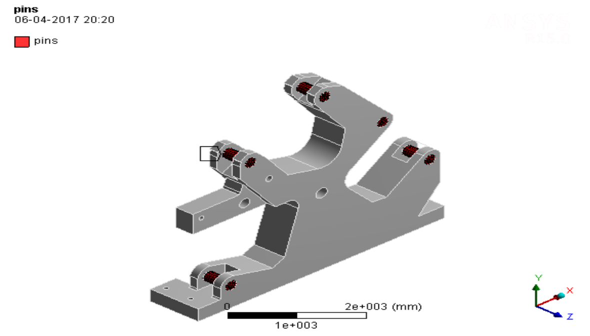

Fig 9. Meshing for pins.

Fig 7 shows complete meshing of Headstock. The scoping method used is Named selection which is divided in body and pins. Thus, Fig 8 shows the Meshing of Body of Headstock made of Grey Cast Iron. In Fig 9, the Meshing of pins is shown which is made of structural steel. Table 1 depicts the Meshing method used i.e. Tetrahedrons, where the size of body is 65mm and pins is 25mm.The no. of nodes are 212663 and no. of elements is 123475. The behaviour of Meshing is soft.

Table1. Details of Meshing

Scoping Method-Named Selection		
Body		Pins
Method	Tetrahedrons	
Behaviour	Soft	
Element Size	65 mm	25 mm
Nodes	212663	
Elements	123475	
Mesh Metric	None	

VI. BOUNDARY CONDITIONS & LOADS

The three coordinate systems are generated. The remote force of 50 KN is applied on them in outward direction. Then the graph is plotted of displacement versus force which holds a linear relationship. Condition for analysis is fix + frictionless.

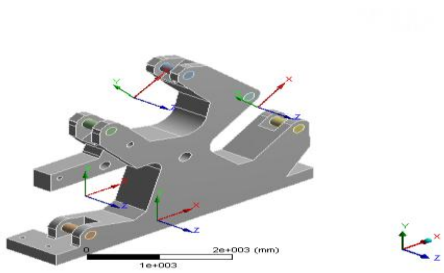

Fig 10. Coordinate systems for Headstock

Fig 12 shows Headstock with; remote force applied is 50 KN in outwards in X direction with certain angle. Fig 13 shows Headstock with, remote force applied is 50 KN in outwards in Y direction with certain angle. Fig 14 shows Headstock with remote force applied is 50 KN in outwards in negative or opposite X direction.

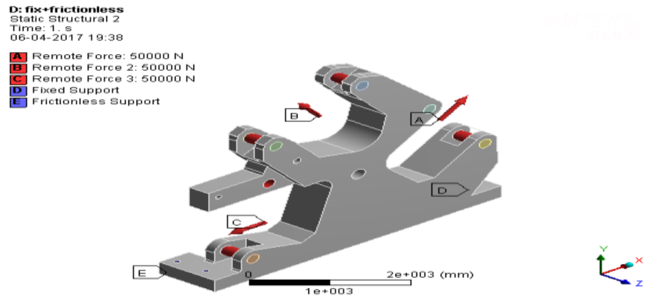

Fig 11. All Remote forces applied on headstock assembly

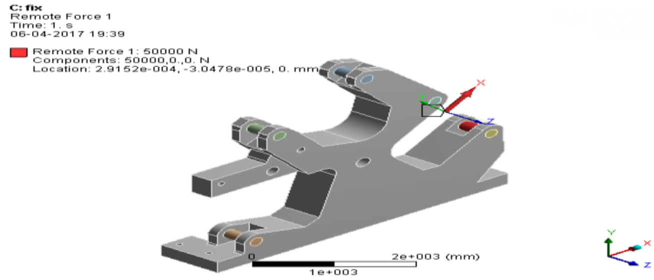

Fig 12. Headstock with, remote force applied is 50 KN in outwards in X direction with certain angle

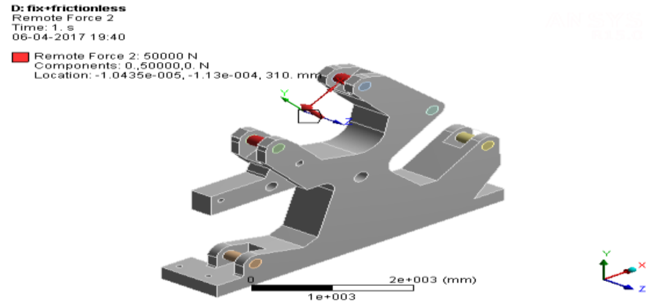

Fig 13. Headstock with, remote force applied is 50 KN in outwards in Y direction with certain angle.

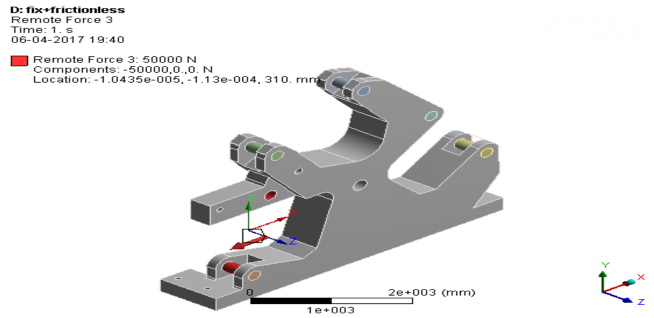

Fig 14. Headstock with remote force applied is 50 KN in outwards in negative or opposite X direction

VII. THICKNESS OPTIMIZATION

The mass of original Headstock is 40468 Kg. This mass is quite large, due to which the material required is also very high, because of which the ultimate cost is high. Hence we carried out much iteration of various thickness sizes to find out the stress which the headstock can sustain and whose value is below maximum shear stress of cast iron material. This stress is 125 MPa .The original thickness of headstock is 620 mm. Thus, we started thickness from 60 mm and reduced it by 5 mm. simultaneously the stress and deformation was increasing. At thickness of 20 mm, the stress came to be 132.14 MPa which is greater than maximum shear stress and hence it is not acceptable. So we select thickness of 21 mm with stress of 92.545 MPa , which is safe . The mass for 21 mm thickness is 6286.4 Kg.

Table 2 shows various thicknesses with their mesh sizes, number of nodes, elements, and corresponding deformation and equivalent (von-mises) stress values.

VIII. RESULTS AND DISCUSSIONS

a) Stresses and deformation for Original Headstock Assembly.

Fig 15 shows Maximum shear stress which is 1.7101 MPa. Von –Mises or Equivalent stresses for pins which are made up of structural steel material, with maximum value of 2.9628 MPa and minimum of 0.014489 MPa is shown in Fig 16. Total Deformation of Headstock, with maximum deformation of 0.06491 mm and minimum deformation of 0 mm as seen in Fig 17. Fig 18 shows equivalent stress for Headstock which is 2.9628MPa.

b) Stresses and deformation for optimized thickness of 21mm for the Headstock Assembly.

Maximum shear stress for headstock body is 52.368 MPa as seen in Fig.19. Equivalent stresses (Von –Mises) for pins is 4.7058 MPa as seen in Fig.20. Total deformation of Headstock is 2.6754 mm as shown in Fig 21. Fig.22 shows Equivalent stress for optimized Headstock is 92.545MPa which is less than maximum shear stress.

Table 2. Results of Thickness optimization

				MESH SIZE				RESULTS	
SR NO	FORCE(KN)	THICKNESS(mm)	MASS(KG)	BODY(mm)	PINS(mm)	NODES	ELEMENTS	DEFORMATION(mm)	STRESS(MPa)
1	50	60	15131.0	58	50	187348	100748	0.33219	13.8
2	50	55	14138.0	70	25	197386	116819	0.34871	14.637
3	50	50	13046.0	70	25	195051	115061	0.45008	14.534
4	50	45	12925.0	70	25	194309	114460	0.54901	20.67
5	50	40	10797.0	70	25	195153	114853	0.68492	26.197
6	50	35	9640.6	65	25	210334	122359	0.90685	37.952
8	50	25	7262.1	70	25	197132	115792	1.7859	81.345
9	50	23	7303.3	65	25	212143	123222	1.2044	80.376
10	50	22	6531.7	68	25	203797	119063	2.3596	84.959
11	50	21	6286.4	65	25	212663	123475	2.6754	92.545
12	50	20	6040.4	70	25	198609	116449	2.8433	132.14

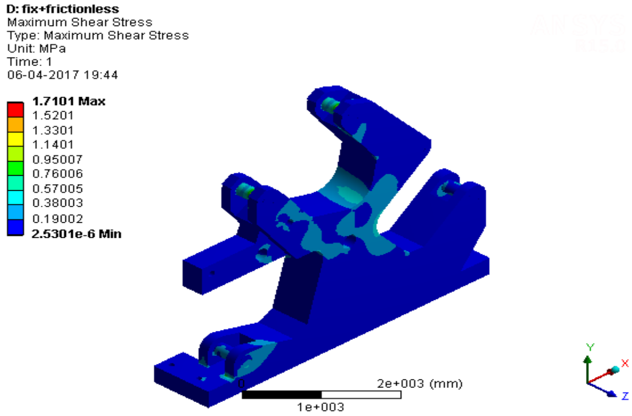

Fig 15 .Maximum shear stress

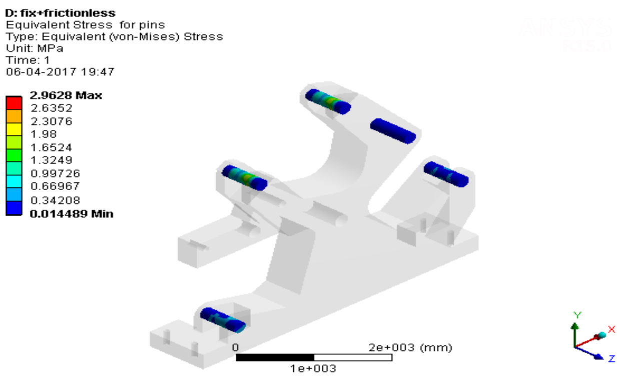

Fig 16. Von –Mises or Equivalent stresses for pins

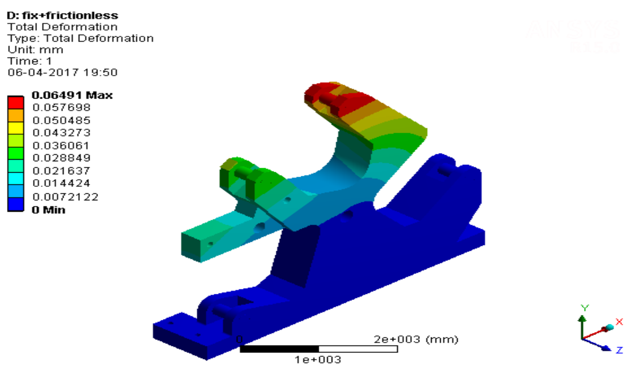

Fig 17. Total Deformation of Headstock in mm.

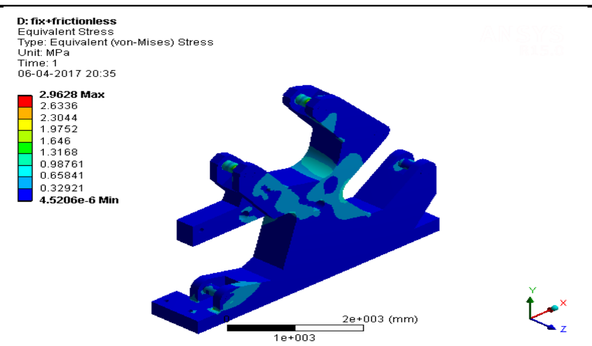

Fig 18. Equivalent stress for Headstock

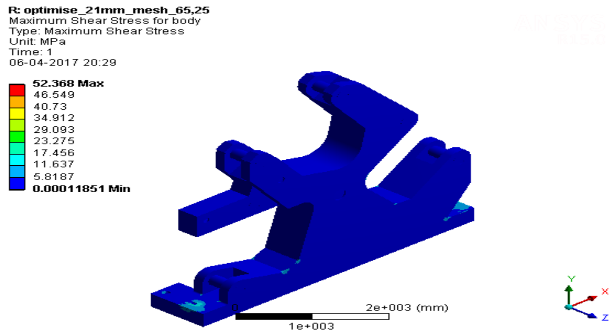

Fig 19. Maximum shear stress for headstock body

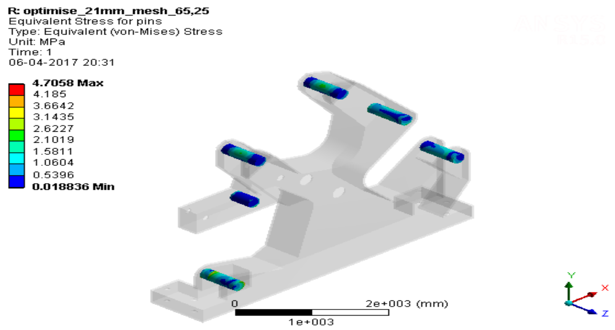

Fig 20. Equivalent stresses(Von –Mises) for pins

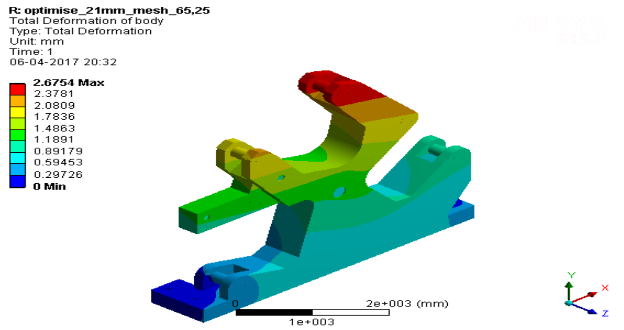

Fig 21. Total deformation of Headstock

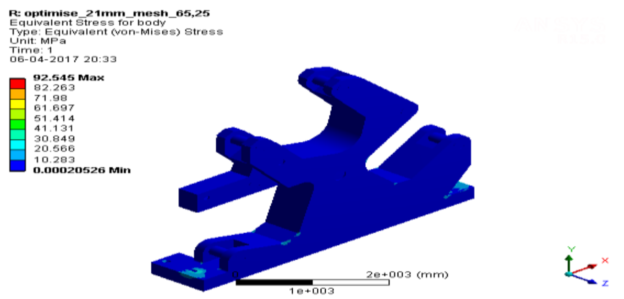

Fig 22. Equivalent stress for Headstock

Table 3. Comparison of original and optimized headstock.

Sr. No	Parameter	Original Headstock	Headstock with 21 mm thickness
1	Thickness (mm)	620	21
2	Mass(Kg)	40468	6286.4
3	Maximum shear stress(MPa)	1.7101	52.368
4	Total Deformation of Headstock(mm)	0.06491	2.6754
3	Von Mises stress for pins(MPa)	2.9628	4.7058
5	Von Mises stress for Headstock(MPa)	2.9628	92.545
6	Remote force applied(KN)	50	50

Table 3 is showing comparison of parameters for both i.e. original headstock and headstock with optimized thickness of 21 mm.

IX. CONCLUSION

The FEA Analysis is carried on sugarcane headstock and following conclusions are found out.

1. The Von Mises stress for original headstock is 2.9628 MPa whereas for headstock with 21 mm thickness is 92.545 MPa. This shows that the optimized headstock has high stress which is less than the Maximum shear stress i.e. 125 MPa. Hence the optimized Headstock is safe.
2. The maximum shear stress for original headstock is1.7101 MPa, whereas for optimized headstock is 52.368 MPa which is less than maximum shear stress calculated by shear stress failure criteria i.e. 125 MPa.
3. The Von Mises stress for pins made by steel is 4.7058 MPa, which is less than 125 MPa i.e. Maximum shear stress for failure. Hence pins are also safe.
4. The weight for original Headstock is 40468 Kg, whereas for the optimized headstock weight is 6286.4 Kg. This shows that there is considerable weight reduction which is safe with respect to stresses calculated.
5. Thus as the weight is reduced from 40468 Kg to 6286.4 Kg, the material required will be less.

6. Ultimately the cost required for cast iron material is optimized.

REFERENCES

1. Santosh Y Salunkhe, "Design & Analysis of Ø40" x Ø 80" Conventional Sugar mill head stock",*International Journal of Scientific Engineering and Technology*, ISSN :2277-1581,Volume No.4 Issue No.7, pp: 397-400,01 July 2015.
2. Chetan T Rathod, Walmiki S Rathod, "Design and Analysis of Two Roller Sugar mill using FEA Techniques", *International Journal of Scientific Engineering and Technology* ,(ISSN : 2277-1581) , Volume No.1, Issue No.3, pg : 148-152 01 July 2012.
3. Jitendra S. Khot, Prof. M. B. Mandale ,"Static Structural Analysis of Crushing Rollers of Three Roller Sugar Mill", *International Journal of Engineering Research & Technology* , Vol. 4 Issue 05, May-2015.
4. Shinde V. V,Prof. M. S. Bidve ,"Weight Reduction and Analysis of Sugar Mill Roller Using FEA Techniques", *International Journal of Latest Trends in Engineering and Technology*,Vol. 5, Vol. 5 Issue 1 January 2015.
5. M. J. REID,"Analysis Of The Causes Of Recent Roll Shaft, Failures In Natal Sugar", *Proceedings of The South African Sugar Technologists' Association - June Sugar Milling Research Institute, 1988*
6. Xianfu Huang1, Zhanwei Liu1, Huimin Xie2," Recent Progress In Residual Stress Measurement Techniques",*ActaMechanicaSolidaSinica*, Vol. 26, No. 6, December, 2013 Issn 0894-9166 ,.
7. S.M. Muzakkir , Harish Hirani , G.D. Thakre , M.R. Tyagi , "Tribological failure analysis of journal bearings used in sugar mills", Engineering Failure Analysis 18 (2011) 2093–2103,Sciencedirect.org.
8. NishantVibhavSaxena, "Study & Analysis of Knuckle Joint with the Replacement of Material by Using Teflon". Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 5, Issue 3, (Part -4) March 2015, pp.67-72 ,
9. D .K Padhal, "Analysis and Failure Improvement of Shaft of Gear Motor in CRM Shop".*International Journal Of Engineering And Science*, Vol.3, Issue 4 (July 2013), PP 17-24 Issn(e): 2278-4721, Issn(p):2319-6483.
10. S.SekharBabu,Y.venu "Design Optimization Of Excavator Bucket Using Finite Element method", *International Journal of Research and Innovation in Mechanical Engineering* ,Vol.1,issue 4, pp:76-84,Dec 22,2014.
11. E.Hugot (1986) Handbook of cane sugar engineering third edition, Elsevier science publishers.
12. Design of Machine elements by V.B.Bhandari, 4th edition.
13. Patent Application number-PCT/IN2013/000489, "An improved two roller sugarcane crushing mill", India, Publication date-March 6, 2014