# FEA IMPLEMENTION IN ANALYSIS AND OPTIMIZATION OF TOP AND BOTTOM FRAME FOR HYDRAULIC COTTON LINT BAILING PRESS

A. G. Naik, N. K. Mandavgade

A**bstract:** This paper attempts to acquire the FEA implementation for analysis and optimization of top and bottom frame for hydraulic cotton lint bailing press. Ginning is the process of separation of fiber from cottonseed. Composite ginnery performs ginning and pressing operations to convert lint cotton into a bale. In modern day, capacity of ginning plant is such that the cotton bale handled by their press system gives rise to very large forces. Frame structure like all the other equipment has to be able to withstand these forces without damage. It is essential that the calculations for mechanical strength to check the suitability of top and bottom frame.

Key words: - ANSYS, Cotton bale, FEA, Failure analysis, Frame structure, Hydraulic press, optimization,

◆

## 1 INTRODUCTION:

The hydraulic press is one of the oldest of the basic machine tools. In its modern form, is well adapted to presswork ranging from coining jewelry to forging aircraft parts. Modern hydraulic presses are, in some cases, better suited to applications where the mechanical press has been traditionally more popular. [1]The full force of a hydraulic press can be delivered at any point in the stroke. This feature is a very important characteristic of most hydraulic presses. A mechanical press usually can exert several times the rated maximum force in the event of an accidental overload. This extreme overload often results in severe press and die damage. It is essential that the calculations for mechanical strength to check the suitability of top and bottom frame. For quality compare the weight if possible. Try to determine the character of the frame construction. If a weldment, look at the plate thicknesses, extent of ribbing, and stress relieving [2].

So in this paper successful attempt to overcome different problem of top and bottom frame, which is reported by the manufacturer. By using the Pro/E wildfire 4.0 firstly we had developed the CAD model of the top and bottom frame mechanism and than by using ANSYs software the FEM analysis of it is carried out.

Due to the diversification of structural optimization problems, most structural optimization problems can be classified as size, shape and topology optimization. The main application of optimal design of steel structures is the size optimization, because this method is possible to minimize the weight of structures [4].

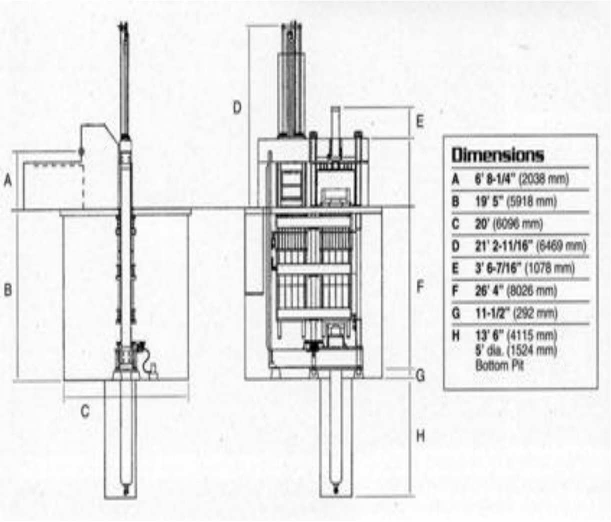

Fig. 1. Schematic view of Hydraulically operated up packing cotton lint baling press

### 1.2 Hydraulically operated up packing cotton lint baling press:-

The Jadhav Zen Door-Less Bale Press is designed to be "energy efficient". It uses a Single 2 no's x 250 mm in diameter-ram. Features include a super high capacity lint feeder and a totally

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enclosed right-angle gear drive tramper. A unique follow block and platen design enables square knot type wire to be applied manually and semi-automatically. Automatic strapping and wire tying systems are also applicable to the variable shut-height system. The Bale press consists of a frame, hydraulic rams, and a hydraulic power system [15].

### 1.3 Problem Identification

- Reduction of bending stresses causing bending of frame by optimizing the Top & Bottom frame.
- Reduction of cost and Improve safety
- Changing the geometric structure and material of the frame -Design Optimization.
- Designing an optimal thickness to minimize the maximum deflection of a frame for maximum economy - Material optimization.

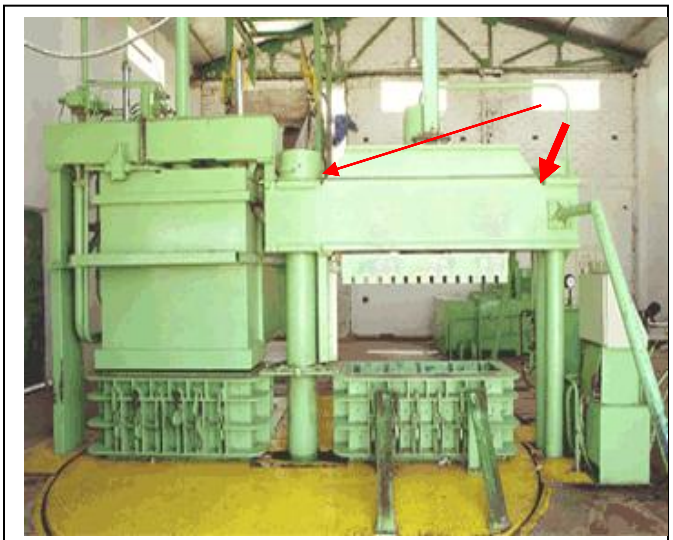


Fig. 2. Hyraulic Press with Old Top Frame & Location where the actual Failure occurs.

## 2 CALCULATION OF MECHANICAL STRESSES AND DEFLECTION BY DOUBLE INTEGRATION METHOD [6] [16] FOR BOTH BOTTOM AND TOP FRAME

- For structural steel

**IS 2062: 20006 E 250 (FE410) QA B**

- Young's modulus : 250 MPa
- Poisson's ratio : 0.3
- Density : 7850 Kg/m$^3$
- Tensile yield strength : Compressive yield strength : 310 MPa
- Tensile ultimate strength : 465 MPa [5] p.n.420]

TOTAL FORCE = Pressing Force (Fp) + Bell wt
= 325000 + 325 ∗ 9.81
= 1.59 * 10$^6$ N

SUMATIONS OF ALL VERTICAL FORCES

ΣFY=Ra-1.59 * 10$^6$-26.97* 10$^3$-1.59 * 106+Rd

Ra+Rd=3.206*10$^6$

SUMMATION OF ALL THE MOMENT OF FORCES ABOUT POINT 'A'…………By Moment Equations

ΣM=-(Rd*2.1) + (1.59 * 10$^6$*1.285) +(26.97*10$^{3*}$1.015) + (1.59 * 10$^6$*1.285)

∴ Rd=1.456* 10$^6$

Ra=1.66*10$^6$

ΣM=-(Rd* X) + [1.59 * 10$^6$*(X-0.815)] + [26.97*103*(X-1.085)] + [1.59 * 10$^6$*(X-1.355)……. (1)

**Written above equ. In differential equ. Form**

$$EI\frac{d\ y}{dx}=-\left(1.59\times10^{6}\times\frac{X^{2}}{2}\right)+\left[(1.59\times10^{6})\times\frac{(x-0.815)^{2}}{2}\right]+\left[(26.97\times10^{3})\times\frac{(x-1.085)^{2}}{2}\right]+\left[(1.59\times10^{6})\times\frac{(x-1.355)^{2}}{2}\right]+c_{1}$$

**By again integrating above Equation we get,**

$$EI\frac{d_{2}y}{dx^{2}}=-(1.59\times10^{6}\times x)+[(1.59\times10^{6})\times(x-0.815)]+[(26.97\times10^{3})\times(x-1.085)]+[(1.59\times10^{6})\times(x-1.355)]$$

**…………………………..(2)**

**Now by applying boundary condition**

E.x. y=0 & x=0 in Equ 2

We get $C_1$=2.03*10$^6$

From Equ. 2 we get $C_2$= (-2.42*10$^6$)

**Now by substituting $C_1$ & $C_2$** And boundary condition at x= 1.015

∴ EIY=-675394.02 N.m …………………………(3)

E for MS material= 2*10$^{11}$

**Moment of inertia**

I= 1/12(BD$^3$-bd$^3$)

∴ I= 4.478*10$^{-3}$ m3

**By putting all values in equ. 3**

Y=-7.5412*10$^{-4}$ m

= 0.745 mm…………Deflection

**For Bending stress**

$$\frac{M}{I}=\frac{\sigma_{b}}{Y}=\frac{E}{R}\ldots\ldots\ldots Bending-Equation$$

$$\sigma_{B}=56.28\times10^{6}\,N/m^{2}\ldots\ldots\ i.e.Indused-Stress$$

Allowable stress= 310 Mpa for ISC-20 ……..From Design data book [05]

$$fos=\frac{S_{yt}}{\sigma_{b}}=4.37$$

**By applying Max. Principal stress theory**
Syt = 0.5 Sys
246 = 0.5 Sys
Sys = 492 Mpa

For Stress σ = Sys/FOS
σ= 113.88* $10^6$

$$f_{\max} = \frac{1}{2}\left[\sigma_b + \sqrt{\sigma_b^{\,2} + 4\sigma_s^{\,2}}\right]$$

$$f_{\max} = 145.42\, N/m^2 \geq \sigma_B$$

**Total Bending Stress is Greater than the Bending strength on material Hence design is unsafe**

## 3 ANALYTICAL ANALYSIS FOR TOP AND BOTTOM FRAME WITH SHOWING THE EFFECT OF SUPPORTING PLATE (RIBS) ON FRAME

**Table1**
**Analytical analysis for Top frame**

| NO OF PLATE | MOMENT OF INERTIA | σb | F.O.S | Maximum Deflection |
|---|---|---|---|---|
| 0 | 1.45X10^10 | 55.08 | 4.53 | 0.336 |
| 2 | 1.56X10^10 | 50.97 | 4.90 | 0.33 |
| **4** | **1.68X10^10** | **47.41** | **5.27** | **0.31** |
| 6 | 1.80X10^10 | 44.35 | 5.63 | 0.29 |
| 8 | 1.91X10^10 | 41.62 | 6.00 | 0.27 |
| 10 | 2.03X10^10 | 39.23 | 6.37 | 0.25 |

**Table 2**
**Analytical analysis for bottom frame**

| NO OF PLATE | MOMENT OF INERTIA | σb | F.O.S | Maximum Deflection |
|---|---|---|---|---|
| 0 | 2.36x10^11 | 30.57 | 8.04 | 0.466 |
| 2 | 6.53X10^9 | 29.68 | 8.28 | 0.44 |
| 4 | 6.81X10^9 | 28.43 | 8.74 | 0.42 |
| 6 | 6.83X10^9 | 27.97 | 8.79 | 0.41 |
| 8 | 7.38X10^9 | 25.89 | 9 < | < 0.4 |
| 10 | 7.67X10^9 | 24.91 | 9 < | < 0.4 |

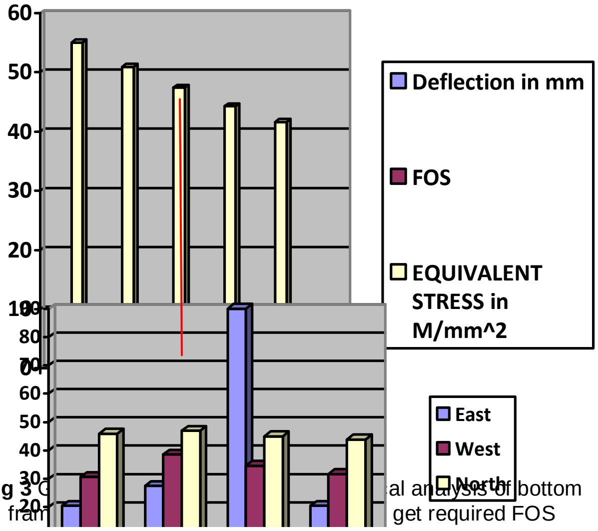


**Fig 3** C al analysis of bottom fram get required FOS

## 4. FINITE ELEMENT ANALYSIS OF TOP & BOTTOM FRAME

Finite element analysis (FEA) is a computer simulation technique used in engineering analysis, it uses a numerical technique called the finite element method (FEM). The finite element method (FEM) is one of the most used methods in engineering. These methods and programs based on it are fundamental usage in CAD. FEA/FEM are indispensable in all engineering analysis where high performance is required. The main purpose of the study is to see a practical application using FEA to improve design of a typical mechanical component. One of the major advantages of FEM is the simplicity of its basic concepts.[17] To perform a finite element analysis, the user must develop a calculus model of the analyzed structure. There are no algorithms and general methods for developing a unique model that approximate, with a known error, the real structure. The development of structure of a model is based on the intuition experience and imagination of the user. Each model consists of lines, planes or curved surfaces and volumes, created in a 3D CAD environment. In this stage of development, the model is continuous with an infinite number of points like the real structure.[17]
The main goal of FEM is to obtain the finite element mesh, transforming the continuous structure into a discrete model, model with a finite no of points. The boundary condition and external loads are applied to this system before solving. The result of the solution is available at the nodes of the elements. Finite element analysis can display them in graphical form to

analyze them, to make design decisions and recommendations. Conventional analytical method for solving stress and strain become very complex and almost impossible when part geometry is very complex and almost impossible when part geometry is intricate. In such cases finite element modeling becomes very convenient means to carry out the analysis. Finite element process allows discrediting the intricate geometries into small fundamental volumes called finite element. It is possible to write the governing equations and material properties for these elements. These elements are then assembled by taking proper care of constraints and loading, which result in set of equations .these equations when solved give the result that described the behavior of original complex body being analyzed.[6]

A structural shape optimization problem is set up to minimize total cost, subject to the limits on structural performance measures. For every design iteration, finite element analysis (FEA) is conducted to evaluate structural performance. The process is repeated until specified convergence criterion is satisfied. Application programs developed to integrate commercially available CAD/CAM/FEA/Design optimization tools enable implementation in virtual environment and facilitate automation. The application programs can be reused for similar design problems provided that the same set of tools is used.[8]

### 4.1 FEA Objective:-

Primary: - Reduction of bending stresses causing bending of frame by optimizing the frame supports.
Secondary: Reduction of cost & Improve safety
The whole objective is to use FEA based simulation, and determine which the best design solution is. Optimize the frame structure by changing the design, material, structure of that frame.

### 4.2 Element Selection

For most supports analysis, the element selection is made from three categories of elements:
1. Ax symmetric solid elements
2. shell/plate elements
3. 3-D brick elements.

Although nearly all problems can be solved using 3-D brick elements, the other two types offer significant reductions in the solution time and effort where they are applicable, Therefore a four node quadratic shell Elements is selected [11]

### 4.3 Meshing

The accuracy of the FE model is highly dependent on the mesh employed In general; a finer mesh will produce more accurate results than a coarser mesh where the increased mesh density fails to produce a significant change in the results. At this point the mesh is said to be "converged."[17]
Map meshing Method used for meshing with Quad Element with Element number 100.

### 4.4 Boundary & Loading condition

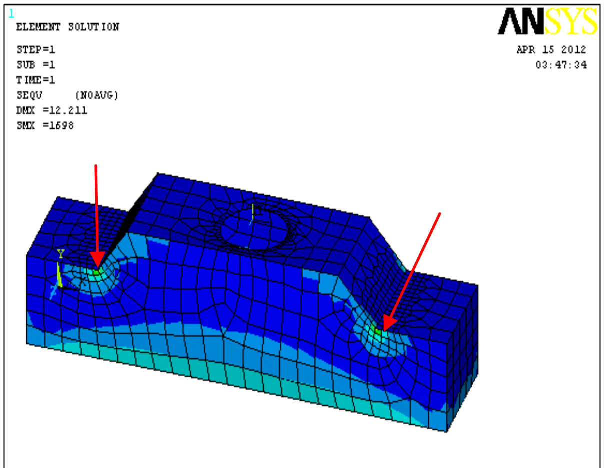
**TABLE3**
**Boundary & Loading condition For Top frame**

| Parts | force(N) due to Punching along upward direction | Self weight | Fix Diplace-ment | Weight of the Hydraulic cylinder |
|---|---|---|---|---|
| Top frame Old mod-el | 177000 | 9810mm/sec$^2$ along downward direction | At support hinged | 80kg or 784.8N |

**TABLE4**
**Boundary & Loading condition For Bottom frame**

| Parts | force(N) due to Punching along upward direction | Self weight | Fix Diplace-ment | Weight of the Hydraulic cylinder |
|---|---|---|---|---|
| Top frame Old mod-el | 177000 | 9810mm/sec$^2$ along downward direction | At support hinged | 80kg or 784.8N |

## 5 ANALYSIS RESULT WITH OLD FRAME



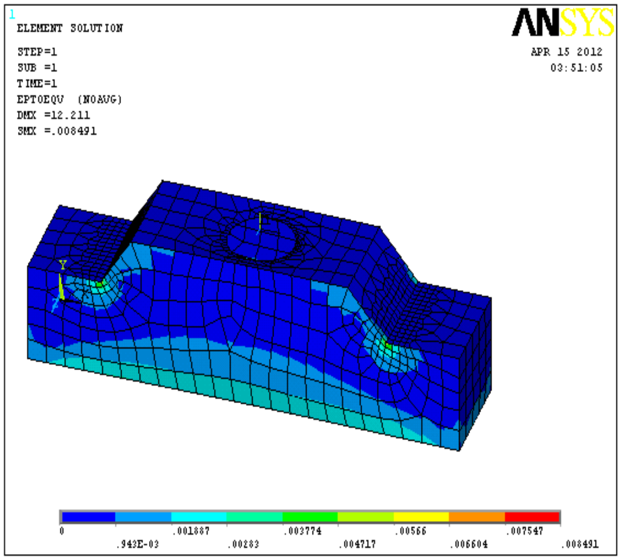


**Fig 5** Deflection occurs in OLD TOP FRAME Average value 05 mm which is undesirable

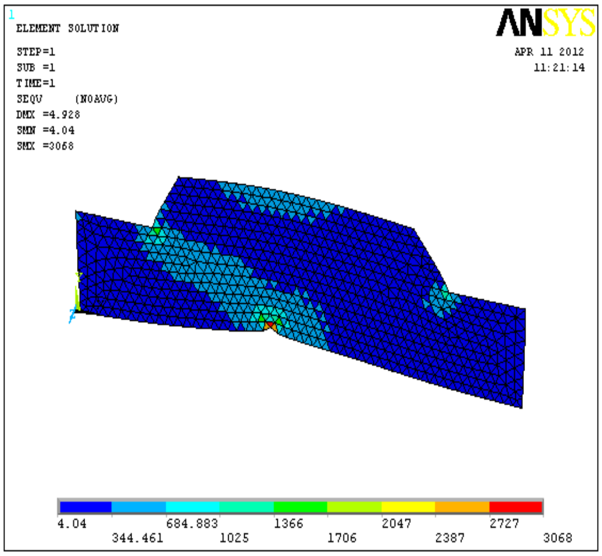


**Fig 6** Stress Distribution flow occurs in OLD TOP FRAME

REASULT CONCLUSION FROM FEA ANALYSIS

Equivalent stress observed that Equivalent stress
>> Yield strength of material
Stress concentration at the point where failure occurs

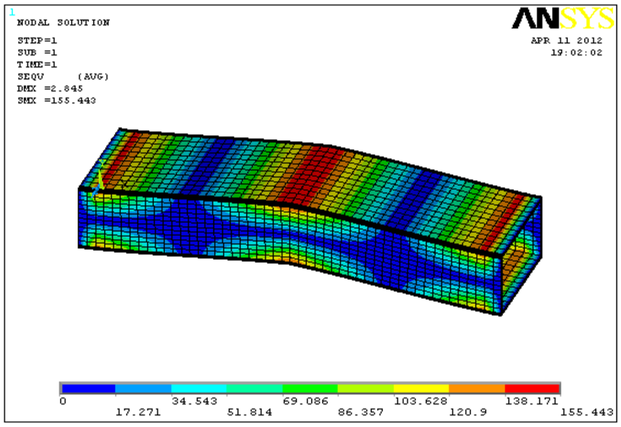


**Fig 7** Equivalent **S**tresses 155 MPa occurs in new TOP FRA with Rectangular cross sectional area

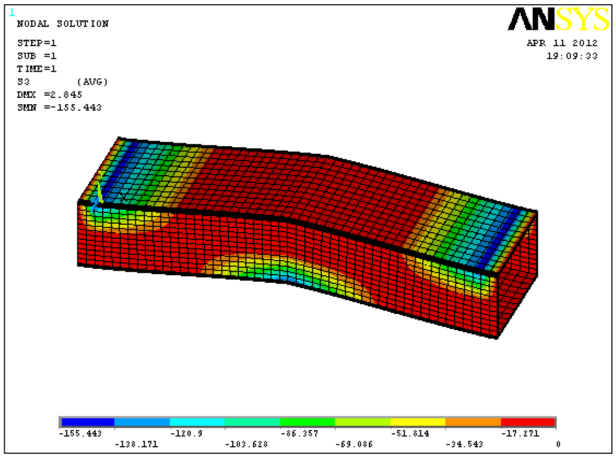
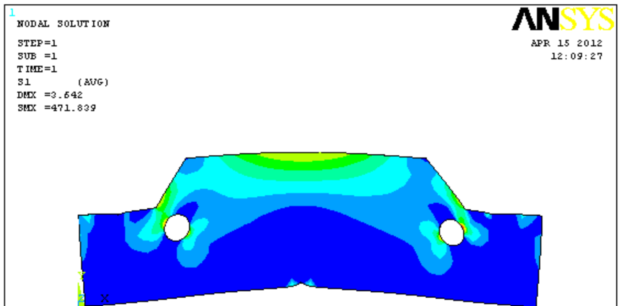


**Fig 8** Deflection occurs in NEW OLD TOP FRAME Average value 02 mm



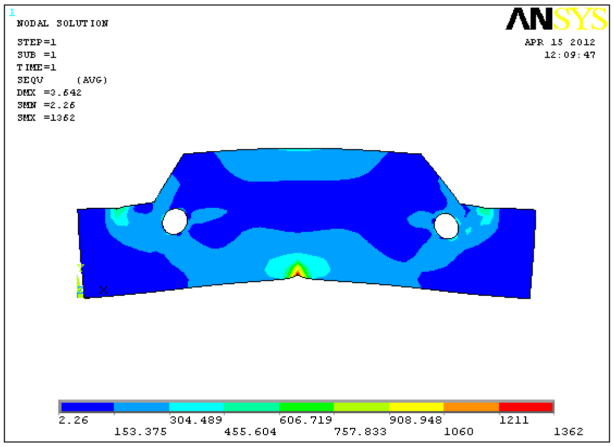


**Fig 10** Equivalent Stresses 432 MPa in old top frame with new design for avoid stress concentration

Table5
Comparison between Last three cases

| Analysis parts | Maximum stresses | Maximum deflection | Material used | Remark |
|---|---|---|---|---|
| Old frame | 1294 | 5.769 | Structural steel | Failure |
| Modified frame | 155.44 | 2.013 | Structural steel | Less than Yield Strength |
| Modified old for reduce stress construction | 432.96 | 3.642 | Structural steel IST20 | Greater than Yield strength |

Analytically It is found that Rectangular cross sectional top frame most suitable for Hydraulic press. Now Optimize the Rectangular cross sectional top frame.

## 6 FEA Optimization Processes [14]

The steps of optimization approach using topology optimization can then be stated as:

- identify the design space for the analyzed body,
- create the topology optimization model,
- formulate the optimization problem based on design requirements,
- perform topology optimization,
- create an optimized design based on the optimization results.

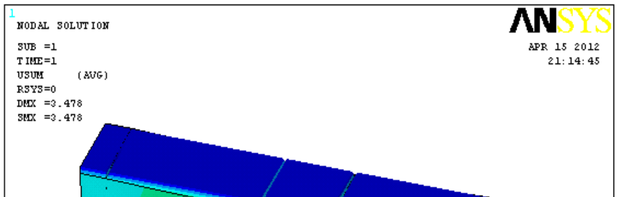
Objective function: Weight Minimization
Constraints: - Equivalent stresses i.e. Yield Strength of Material (310 Mpa) and Deformation (3 mm) [5]
Parameters: - By reducing and changing No of support plate for topology optimization Method [6][9][14]and changing the thickness of plate (size optimization) Changing the Material (Design optimization) [12][15][10]

## 7 OPTIMIZATION REASULT & DISCUSSION

TABLE6
ITERATION REASULT IN OPTIMIZATION PROCSSES

| `Result Itera ration No | Deform (mm) | Design changes | Material | Yield strength MPa | Max stress occurs | Design |
|---|---|---|---|---|---|---|
| 1 | 2.974 | 6 Plate | Str Steel | 310 | <Syt | Safe |
| 2 | 3.404 | 6 Plate 20 th upper and bottom plate | Str Steel | 310 | >Syt | Not safe |
| 3 | 3.40 | 4 plate | Str Steel | 310 | >syt | Not safe |
| 4 | 3.478 | 16 th top & bottom plate | Str Steel | 310 | >Syt | Not safe |
| 5 | 3.470 | 20 th top and bottom plate | Str Steel | 310 | >syt | Not safe |
| 6 | 2.10 | Material change | Alloy Steel, 20Mn2 | 490 | <Syt<br>E=6<br>87-<br>834 | Safe |

## 8 FEA ANALYSIS REASULT FOR OPTIMIZATION



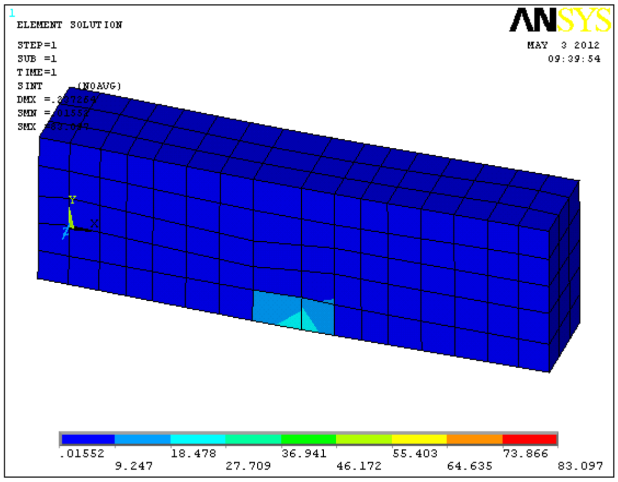


Fig 6 E New TOP FRAME

TABLE 7:
COMPARISON OF CURRENT DESIGN AND NEW DESIGN WEIGHT

| **Component** | **Current design weight (kg)** | **New design weight (kg)** | **Weight reduction (kg)** | **Weight reduction In Percentage** |
|---|---|---|---|---|
| **FRAME WEIGHT** | **2146** | **1854** | **292** | **13%** |
| **FRAME COST (Rs)** | **1,60,950** | **1,39,050** | **21,900** | **15%** |

**Considering (Material cost + Fabrication cost) = Rs 75/kg**

## 9 CONCLUSIONS

The proposed design process successfully incorporates into a structural shape optimization problem. In addition to ensuring manufacturability of the structurally optimized components, the design process delivers components with minimum cost and required performance. The trade-off between structural performance and machining cost is highlighted using these design examples. Furthermore, the process starts with preliminary information about the component and delivers optimum components at the end.

The design calculations of Hydraulic press system are playing important role as we come to know the value of total force develops in the system. The value of tensile stresses developed in the system is greater than the permissible limit. Selection of good shape provides strength to the system as the system is only undergoing through bending according to the FEA Analysis the best solution is obtained by changing the shape and design of the Top and Bottom frame structure.

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