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Design and Structural Optimization of Multiple Bush Pressing Machine

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ABSTRACT

A Multiple Bush Pressing Machine structure has been cad modeled using Solid works and the same is exported to Hypermesh, a meshing tool for quality mesh. The geometry is split and two types of mesh are used in the problem based on the regularity of the components. The regular components with constant cross sections are grouped to separate components and irregular components grouped to three dimensional components. Shell mesh is used for regular components and three dimensional brick elements are used for irregular members. Calculations are carried out to find the bush pressing load acting on the cam bush pressers. Initially analysis is carried out to check finite element results with theoretical calculations. Two critical members are checked and results are found to have error variation less than 15%. So, Finite element analysis can be carried out for the full machine structure.

Keywords - *Multiple Bush Pressing Machine, FEM, Pascal's law, Hydraulic System.*

1. INTRODUCTION

Hydraulic power has been used since Aristotle time. Lot of research has been done on the properties of fluid in using for agricultural work and military purpose. In the initial days, water equipment is used for agricultural purpose and later applied to bigger applications like clamping the members and driving the machinery. Hydraulic machinery pumps provide more power when comparatively with electric motors. The important benefit of hydraulic system is it can drive bigger force through coupling the hydraulic pumps. Hydraulic systems work by Pascal's law.

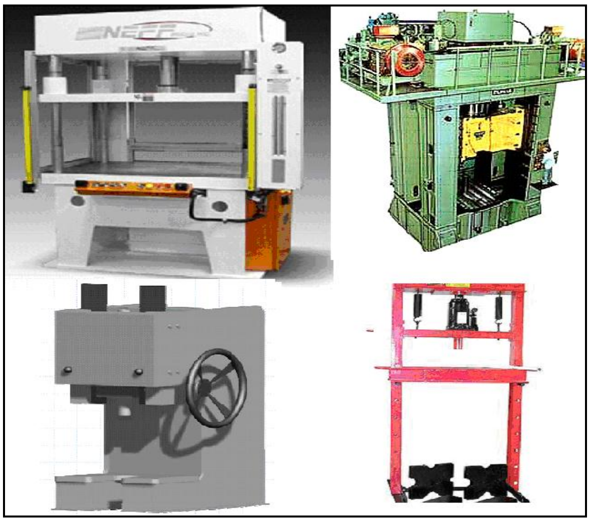


Fig 1: Hydraulic Machinery.

- Design calculations for force requirements for pressing operation.
- Structural design and analysis of the machine.
- Finding structural stability of the problem.

2. SCOPE OF WORK

The pressing operation is common application in the industrial applications. Manual pressing is limited to certain applications. Due to higher growth of automobile and manufacturing sector, manual pressing can't be carried out on the bigger machines. Higher turning and direct forces are required for pressing or clamping of the components with hydraulic power system. In the present work for cam bush pressing which is used to plug the holes of engine block requires high capacity for pressing. So a special purpose machine is required to do the same.

3. THEORETICAL CALCULATIONS FOR RAM POST

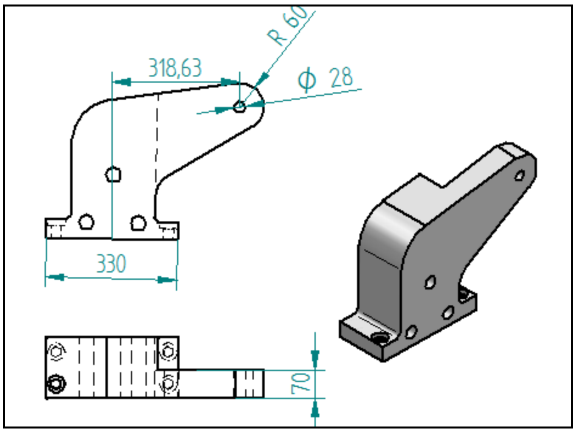


Fig 2: Ram Post Dimensions.

Theoretical Calculations:

Moment calculation, M $= F * L$

$= 11940*319$

$= 3808860$ N-mm

Moment of inertia, I $= \frac{B * h^3}{12}$

$= \frac{120 * 70^3}{12} = 3430000\text{mm}^4$

Section Modulus, Z $= \frac{B * h^2}{6}$

$= \frac{120 * 70^2}{6} = 98000\text{mm}^3$

Stress development, σ $= \frac{M}{z}$

$= \frac{3808860}{98000} = 38.86$ N/mm2

Unsupported free length, $l = \frac{(318 - 220)}{2} = 208$ mm

Here bottom support hole distance = 220mm

Approximate displacement based on cantilever formula, $\delta = \frac{Pl^3}{3EI}$

$$= \frac{11940 * 208^3}{3 * 2E5 * 3430000}$$

= 0.0522mm

Error Percentage for stress $= \frac{(38.86 - 33.46) * 100}{38.86}$ = 13.89%

Error percentage for deflection = $\frac{(0.0595 - 0.0522) * 100}{0.0595}$ =12.3%

Since percentage of error is less than 15% of theoretical solution, the results can be accepted.

4. GEOMETRY AND MATERIAL SELECTION

3.1 Material Properties

Engine Block Material: St42 (Structural Steel 42)

Sl No	Description	Value
1	Young's Modulus	$200* 10^3$ N/mm^2
2	Yield stress	$420 *10^6$ N/mm^2
3	Poison's ratio	0.3
4	Density	7800 Kg/m^3

Table 1: Properties of Structural Steel 42.

Bush Pressing Machine Material: Cast Iron

Sl No	Description	Value
1	Young's Modulus	0.75* 105 N/mm^2
2	Yield stress	420 *106 N/mm^2
3	Poison's ratio	0.3
4	Density	7800 Kg/m^3

Table 2: Properties of Cast Iron.

3.2 Geometry

The geometry is built using Solid works software and imported to Hypermesh in 'step' file format. All the theee dimensional modeling software has option of model geometry to export in desired format. Generally 'step' file format is the best when compared to 'iges' format, as it is free of data loss which is more with 'iges' file format.

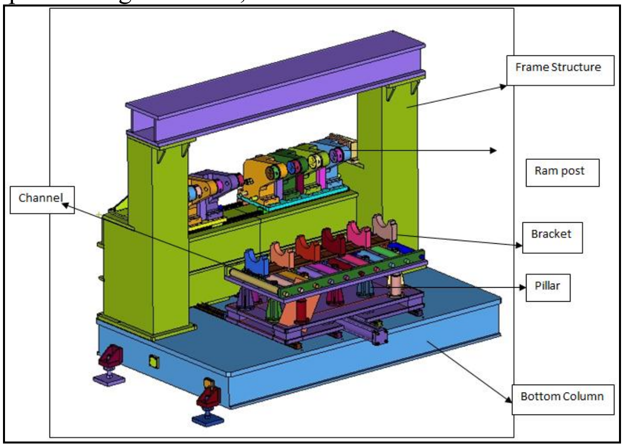


Fig 3: Three Dimensional Representation of the Pressing Structure.

3.3 FE Modeling

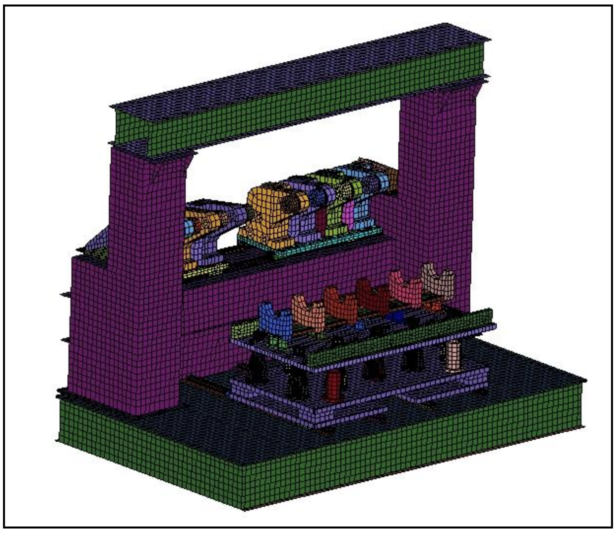


Fig 4: Mesh Model.

Whole assembly is meshed with good quality of brick and prism elements in order to avoid deviation of results due to poor quality mesh. Here 32400 elements with 37734 nodes are used for meshing.

3.4 Boundary Condition

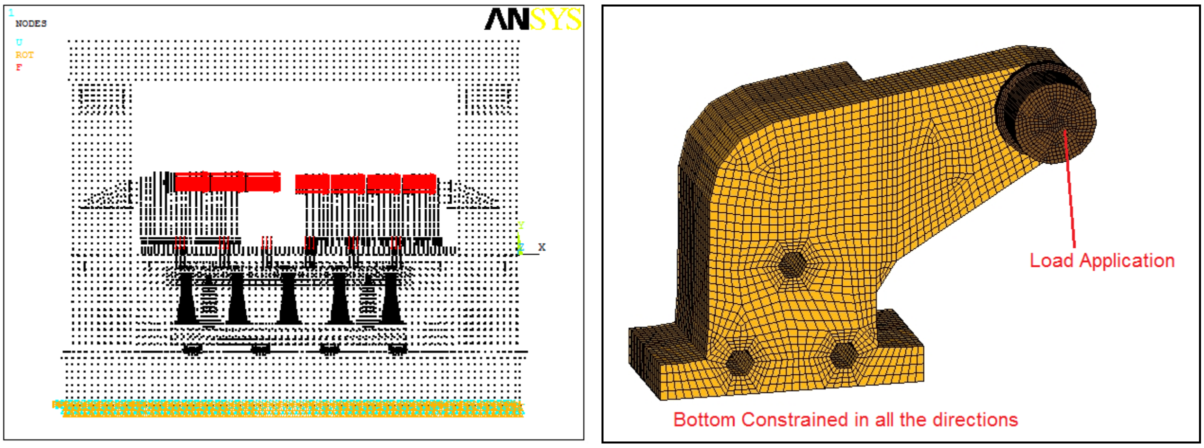


Fig 5: Boundary Conditions for the Problem.

Bottom of the Ram Post is fixed in all the directions and pressing load of 11940 N is applied at the hole region where hydraulic machinery set up will be done for pressing operation.

5. RESULTS AND DISCUSSION

4.1 Stress Analysis for Ram post

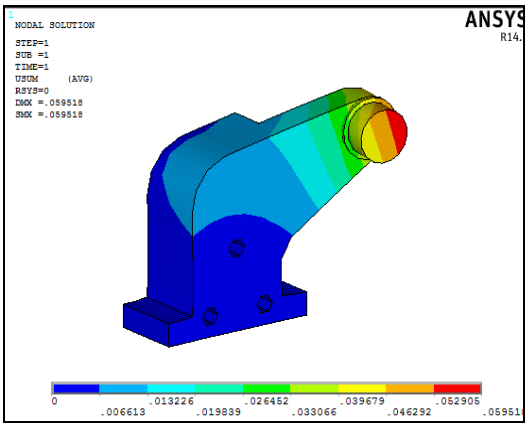


Fig 6: Max Displacement in Ram Post.

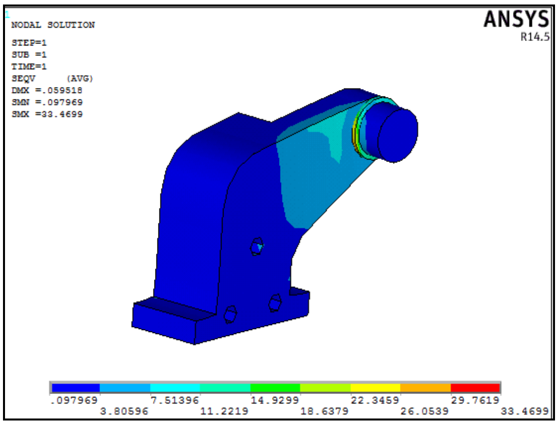


Fig 7: Maximum von-Mises Stress in Ram Post.

Above Fig shows developed stress of 33.4699MPa which is less than the allowable stress of the material (140MPa). So structure is safe for the given loading conditions.

4.2 Design Optimization in the problem

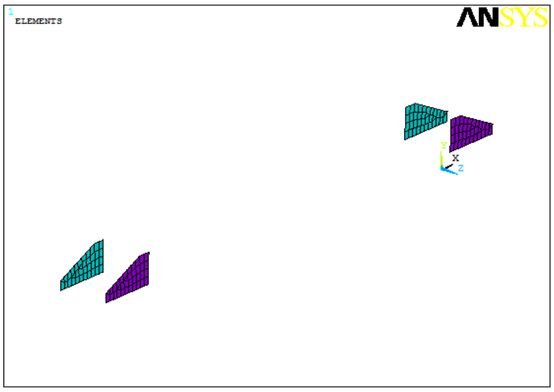


Fig 8: Design Parameter 1- Rib plates of 15mm thick.

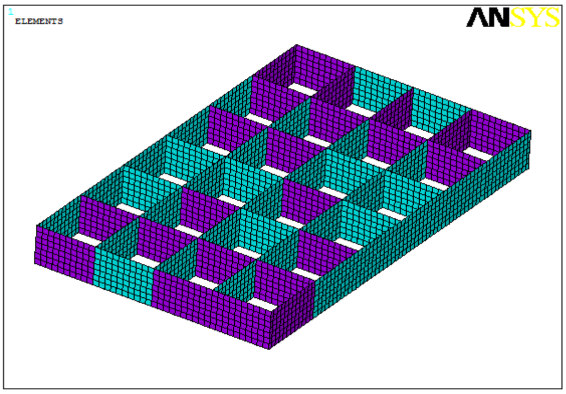


Fig 9: Design parameter 2- 16mm Column Rib plates.

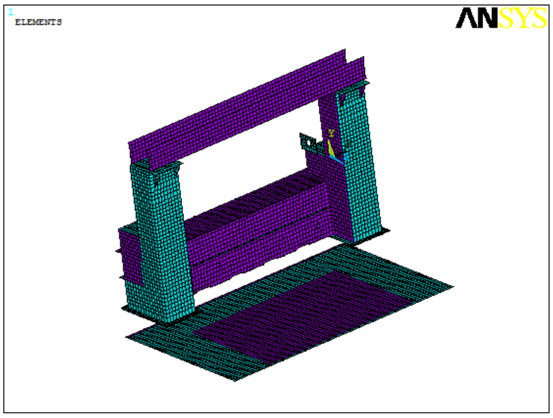


Fig 10: Design Parameter 3- 20mm Frame Structure.

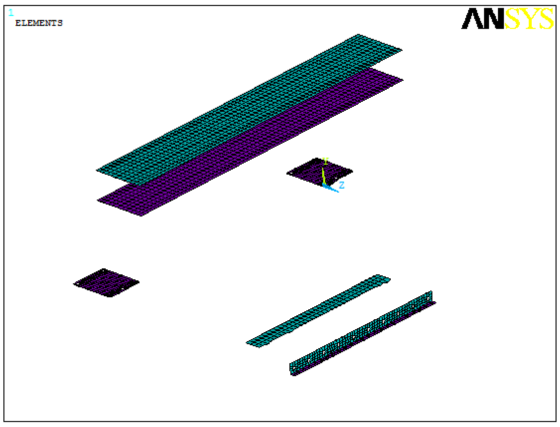


Fig 11: Design Parameter 4- 30mm Support Plates.

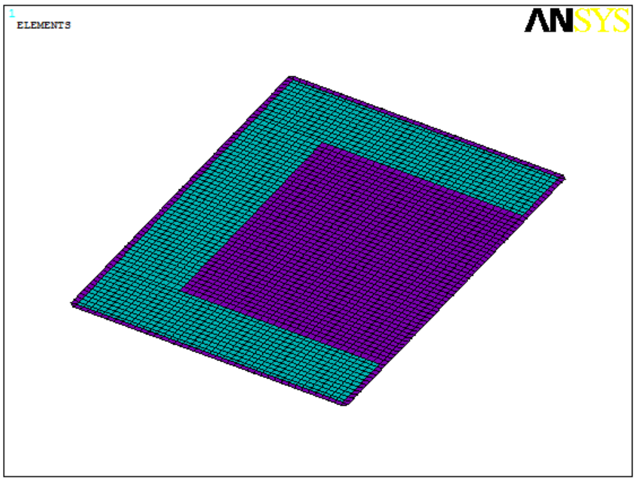


Fig 12: Design Parameter 5- 40mm Base Plate.

Design optimizer in Ansys requires both geometrical or design variables (DV) and state variables (SV). The design variables include geometrical dimensions like length; thickness etc and state variables include stress and deformation in the problem. Finally objective function with convergence limits need to be specified for the problem. Sub problem approximation is used in the problem for faster and accurate convergence. Analysis file has been created and executed using design optimizer tool and weight optimization results are presented as follows.

LIST OPTIMIZATION SETS FROM SET 1 TO SET 11 AND SHOW ONLY OPTIMIZATION PARAMETERS. (A "*" SYMBOL IS USED TO INDICATE THE BEST LISTED SET)

		SET 1 (FEASIBLE)	SET 2 (FEASIBLE)	SET 3 (FEASIBLE)	SET 4 (FEASIBLE)
MAXD	(SV)	0.14828E-03	0.15687E-03	0.16435E-03	0.15301E-03
MAXS	(SV)	0.77640E+08	0.85655E+08	0.89148E+08	0.81910E+08
T1	(DV)	0.15000E-01	0.14236E-01	0.13090E-01	0.13964E-01
T2	(DV)	0.16000E-01	0.12743E-01	0.15087E-01	0.13493E-01
T3	(DV)	0.20000E-01	0.13880E-01	0.10033E-01	0.16951E-01
T4	(DV)	0.30000E-01	0.23847E-01	0.19382E-01	0.11400E-01
T5	(DV)	0.40000E-01	0.26127E-01	0.19609E-01	0.20418E-01
WT	(OBJ)	8286.3	6570.7	5803.2	6577.4

		SET 5 (FEASIBLE)	SET 6 (FEASIBLE)	SET 7 (FEASIBLE)	SET 8 (FEASIBLE)
MAXD	(SV)	0.14974E-03	0.15507E-03	0.15342E-03	0.16645E-03
MAXS	(SV)	0.77746E+08	0.84706E+08	0.81651E+08	0.88925E+08
T1	(DV)	0.10562E-01	0.13860E-01	0.10591E-01	0.13071E-01
T2	(DV)	0.13178E-01	0.13328E-01	0.14554E-01	0.11038E-01
T3	(DV)	0.19895E-01	0.14776E-01	0.17136E-01	0.10023E-01
T4	(DV)	0.22633E-01	0.26085E-01	0.21816E-01	0.12696E-01
T5	(DV)	0.14527E-01	0.35093E-01	0.11901E-01	0.12274E-01
WT	(OBJ)	7009.6	7112.8	6570.3	5161.8

		SET 9 (FEASIBLE)	SET 10 (FEASIBLE)	*SET 11* (FEASIBLE)
MAXD	(SV)	0.16717E-03	0.16738E-03	0.16743E-03
MAXS	(SV)	0.88845E+08	0.88821E+08	0.88815E+08
T1	(DV)	0.10298E-01	0.13162E-01	0.13126E-01
T2	(DV)	0.10290E-01	0.10081E-01	0.10029E-01
T3	(DV)	0.10021E-01	0.10020E-01	0.10020E-01
T4	(DV)	0.10726E-01	0.10180E-01	0.10081E-01
T5	(DV)	0.10588E-01	0.10169E-01	0.10082E-01
WT	(OBJ)	5012.7	4976.2	4967.9

		SET 11 (FEASIBLE)
MAXD	(SV)	0.16743E-03
MAXS	(SV)	0.88815E+08
T1	(DV)	0.13126E-01
T2	(DV)	0.10029E-01
T3	(DV)	0.10020E-01
T4	(DV)	0.10081E-01
T5	(DV)	0.10082E-01
WT	(OBJ)	4967.9

Fig 13: Optimization Parameter Sets Obtained from Ansys.

4.3 Modal Analysis Results

Modal analysis is very important in the dynamic analysis and is the beginning for the important analysis of harmonic, transient and spectrum. Through modal analysis, modal frequencies can be obtained by which natural frequencies can be calculated. Through natural frequencies mode shapes can be obtained. Mode shapes are useful for finding the regions of weakness in the structure along with the constraint directions. Modal analysis has been done for problem, and modal frequencies are obtained. Maximum operational range in the problem is corresponding 2400rpm of the mounted motors.

Set No	Frequency(Hz)
1	51.076
2	66.293
3	85.404
4	94.05
5	116.77

Table 3: Modal Frequencies.

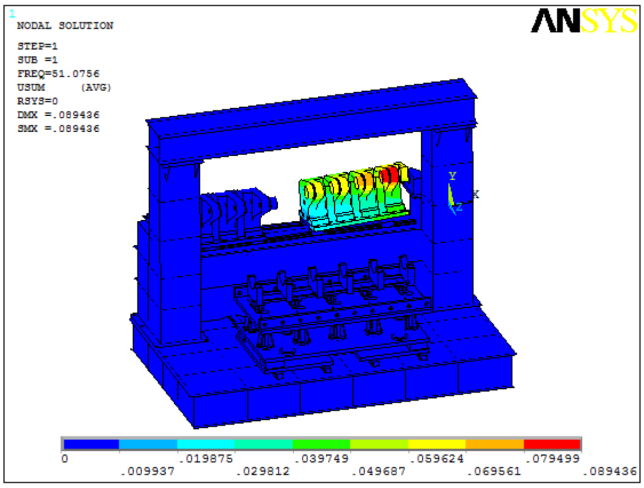
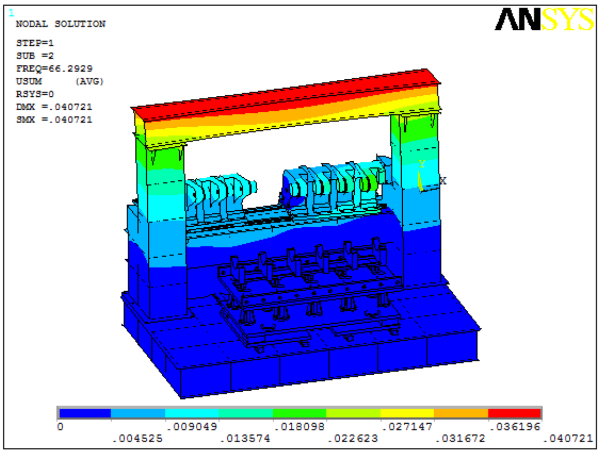


Fig 14: Mode Shape corresponding to fundamental frequency 51.0756Hz.

Mode shapes are obtained for each natural frequency. Mode shapes are nothing but vibration nature of the system under resonance. The mode shapes may be axial, lateral, torsional or mixed mode type. In a bigger assembly, mode shapes shows weak regions in the problems. Also to check connectivity of the mesh, modal analysis is done which shows improper connections in the problem. Mode shapes helps in providing constraints to prevent possible damage to the surrounding structures. The status bar shows proportional displacements in the problem. A modal analysis problem has one equation lesser than number of equations by which solution is not unique.



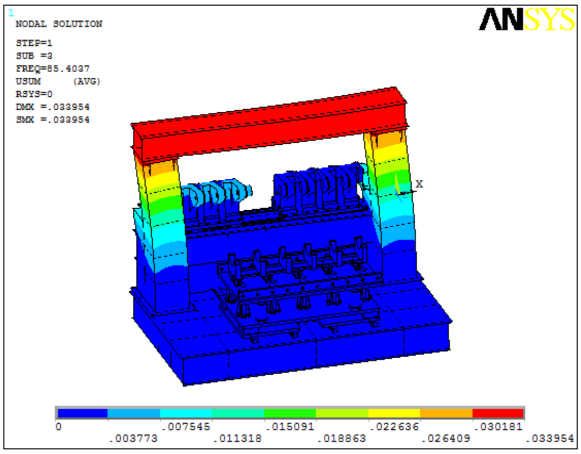
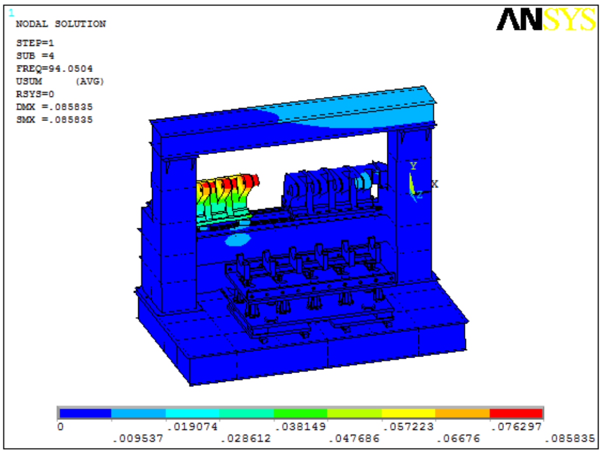


Fig 15: Mode Shape corresponding to frequency 66.29Hz Fig 16: Mode Shape corresponding to frequency 85.4Hz



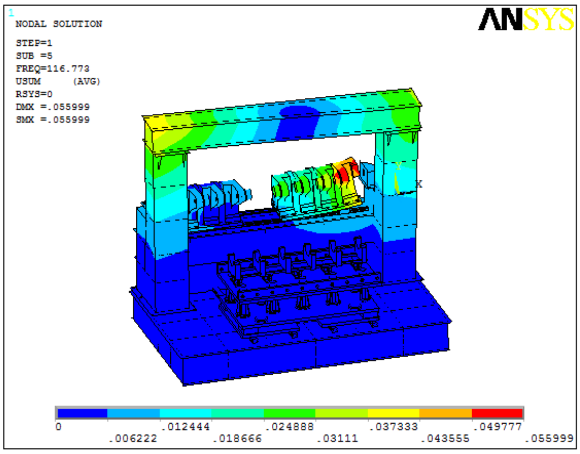


Fig 17: Mode Shape for frequency 94.05 Hz Fig 18: Mode Shape for frequency 116.77Hz

6. CONCLUSION

The results show excellent matching of theoretical and finite element results. So finite element procedure can be adopted for further analysis and from the obtained FE results fallowing conclusion can be made.

The bush pressing machines is designed and analyzed for the external load to evaluate the structural stability of the pressing machine. From the results it is reveals that design is safe and also has potentials to optimize its weight.

The design optimization iterations are carried out to reduce the overall weight of the machine. The best optimum design is suggested. Total weight is reduced by 40%. The stress level in the optimized design is meeting the design requirements. From analysis it is clear that optimized design is safe and can be used.

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