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# Nonlinear Finite Element Buckling Analysis of Arm Stand of Dynamic Compaction Machinery

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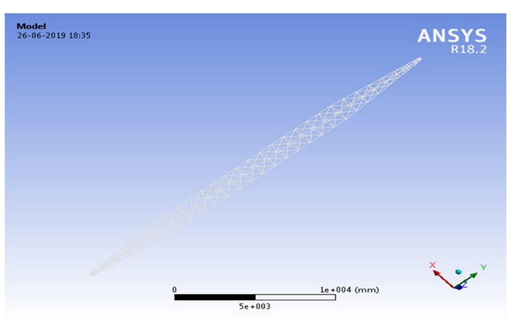
***Abstract: The arm stand of dynamic compaction machinery is a large space of statically indeterminate truss structure welded by steel pipe. Its stability calculation is always difficult to calculate and design for the arm stand. Use FEA software ANSYS to establish a overall elastic-plastic FEA model of the arm stand of dynamic compaction machinery in working condition. The eigenvalue buckling analysis and nonlinear buckling analysis of the arm stand was conducted and the buckling modal and the load-displacement curve of the arm stand was obtained. Nonlinear buckling analysis use arc length method which is in control of displacement to load the structure of the equilibrium path. The arm stand of dynamic compaction machinery with initial geometric imperfections has been adopted in the analysis. Through the analysis of instability characteristic points' load-displacement curve, the arm stand of dynamic compaction machinery's ultimate bearing capacity in working condition is obtained. Model and calculation method used in this paper provide a basis for improved partly of strong tamping machine arm stand.***

## I. INTRODUCTION

Arm stand is the main load bearing components of the dynamic compaction machine and its structure is increasingly more and larger, tall, gentle and fine rack .It has improved the structural strength, while filling the structural stability more obvious each day because of using high strength steel. At present, the stability of the calculation method of the arm stand of dynamic compaction machinery including specification method, the eigenvalue buckling analysis and nonlinear buckling analysis. The specification method is in accordance with the specification manual checking of design of steel structures , Steel Design Manual , Crane Design Manual etc,to ensure that the size of the arm stand of dynamic compaction machinery to meet the stability of the design requirements .This method cannot explore the arm stand of dynamic compaction machinery and it will not be able to get the buckling safety factor. Eigen value buckling analysis is able to get the buckling coefficient and buckling modes of the structure .However, this method does not consider the structure of the deformation under load , and the initial geometric imperfections on equilibrium , it only be used for the structure of the theory of an ideal linear elastic buckling analysis .A lot of complex structures is not occur in the theory of elastic buckling at buckling, and actually there is a big difference because of initial defects and non-linear .Nonlinear analysis of the initial imperfections considers the nonlinear characteristics of the material plasticity , large deformation response , so it is more accurate than the eigen value buckling analysis . In addition, the nonlinear buckling analysis using arc length control method loads can also track structure the post-buckling behaviour, the results of its analysis is more in line with the practical engineering.

## II. METHODOLGY

Structure of arm stand is constructed in design modeller on ansys workbench 18.2 as a wireframe model and different sections have been taken for different members of the structure. Meshing has been done in ansys mechanical using BEAM element to get the full structure. Model analysis has been carried out to find the model frequencies of the arm stand. Static analysis was carried out to fine the strength of the beam under static loading and buckling analysis is carried out to find the maximum load carrying capacity of the arm stand in vertical position.




Final geometry of the arm stand

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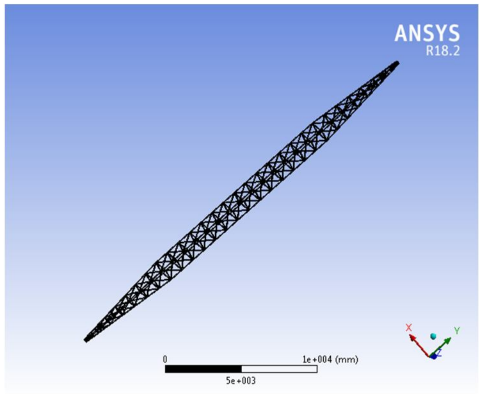
### *A. Finite Element Analysis*

After adding the cross sections to the wireframe model of the arm stand, we take the beam element for meshing the structure. And the meshing is done by using refined global settings. Since the structure is too large, mesh quality does not play significant role in the analysis.




Meshing

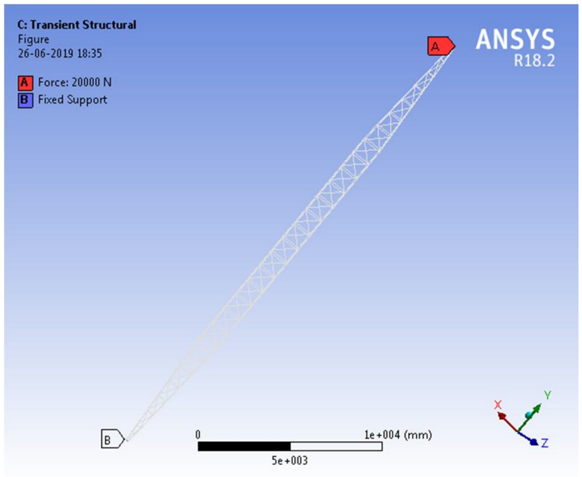
Mesh settings are given in the table below

| Statistics | |
|---|---|
| Nodes | 1576 |
| Elements | 892 |

Mesh stats

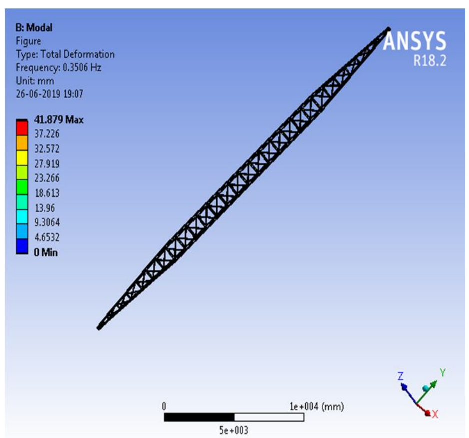
| Model (C3) > Mesh | |
|---|---|
| Object Name | Mesh |
| State | Solved |
| **Display** | |
| Display Style | Body Color |
| **Defaults** | |
| Physics Preference | Mechanical |
| Solver Preference | Mechanical APDL |
| Relevance | 0 |
| Element Order | Program Controlled |
| **Sizing** | |
| Size Function | Uniform |
| Relevance Center | Fine |
| Max Face Size | Default (409.930 mm) |
| Mesh Defeaturing | Yes |
| Defeature Size | Default (2.04970 mm) |
| Transition | Fast |
| Growth Rate | Default (1.850 ) |
| Bounding Box Diagonal | 28080 mm |
| Minimum Edge Length | 150.0 mm |
| **Quality** | |
| Check Mesh Quality | Yes, Errors |
| Error Limits | Standard Mechanical |
| Target Quality | Default (0.050000) |
| Smoothing | Medium |
| Mesh Metric | None |
| **Inflation** | |
| Use Automatic Inflation | None |
| Inflation Option | Smooth Transition |
| Transition Ratio | 0.272 |
| Maximum Layers | 5 |
| Growth Rate | 1.2 |
| Inflation Algorithm | Pre |
| View Advanced Options | No |
| **Advanced** | |
| Number of CPUs for Parallel Part Meshing | Program Controlled |
| Straight Sided Elements | No |
| Number of Retries | 0 |
| Rigid Body Behavior | Dimensionally Reduced |
| Mesh Morphing | Disabled |
| Triangle Surface Mesher | Program Controlled |
| Topology Checking | No |
| Pinch Tolerance | Default (3.68940 mm) |
| Generate Pinch on Refresh | No |

1) *Transient Analysis:* In our model we have taken time dependant loads which vary from 0 to 20000 N over 4 seconds with time interval of 0.2 seconds. To reduce the complexity of the FE problem and to find the maximum value of the load that the structure can carry, the vertical position is carried out in the FE model. Fixed support is given at the bottom and vertical transient load is being applied at the top of the arm stand.

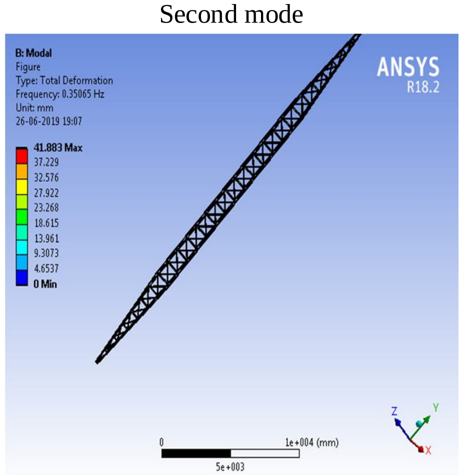



2) *Modal Analysis:* Model analysis is carried out to determine the fundamental frequency and higher nodes of frequencies.

First mode




Second mode



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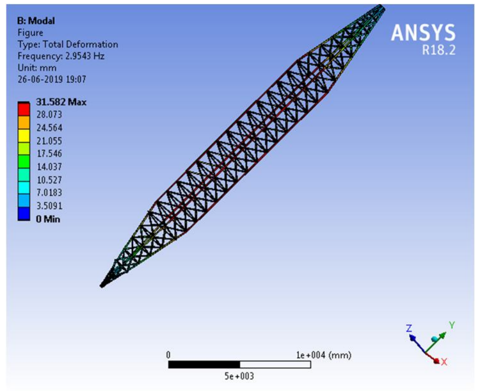
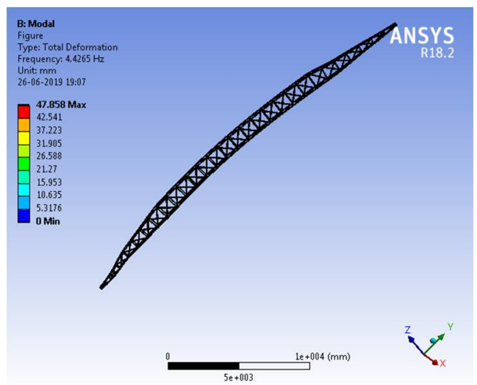
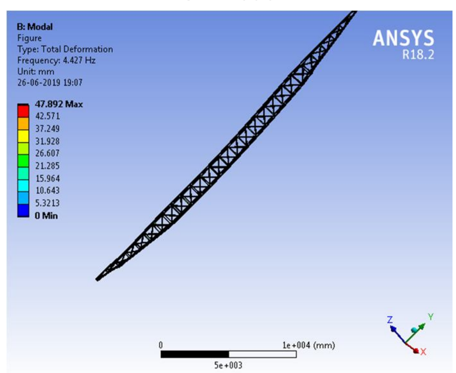
Third mode



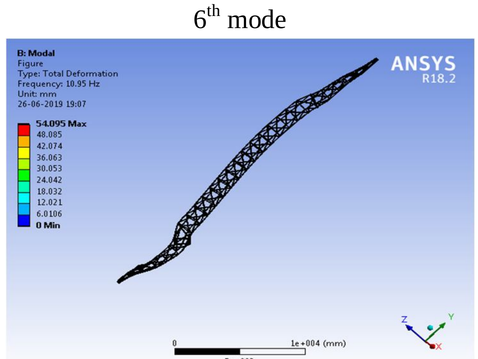

Fourth mode




$5^{th}$ mode




$6^{th}$ mode



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Modal frequencies of first modes are

| Mode | Frequency [Hz] |
|---|---|
| 1. | 0.3506 |
| 2. | 0.35065 |
| 3. | 2.9543 |
| 4. | 4.4265 |
| 5. | 4.427 |
| 6. | 10.95 |

Since the working frequency and load values are very high when compared to the model frequencies of the structure, there is no chance for the occurrence of resonance in the arm stand.

3) *Buckling Analysis:* In buckling analysis of the structure, we have considered 6 mode shapes of buckling to find the maximum load that the structure can carry under buckling.

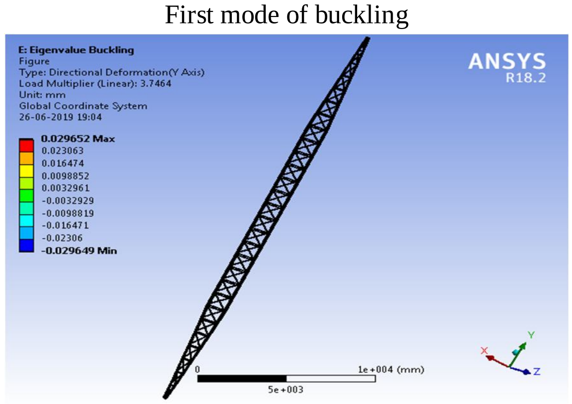
Maximum load that can be carried by the structure = safe load multiplier X applied load

Load multiplier values are

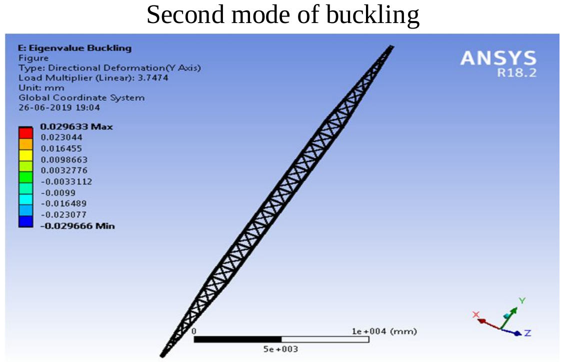
| Mode | Load Multiplier |
|---|---|
| 1. | 3.7464 |
| 2. | 3.7474 |
| 3. | 63.364 |
| 4. | 63.368 |
| 5. | 67.094 |
| 6. | 67.104 |

Therethe maximum safe load under buckling is 20000 X3.7474 = 75KN

First mode of buckling




Second mode of buckling



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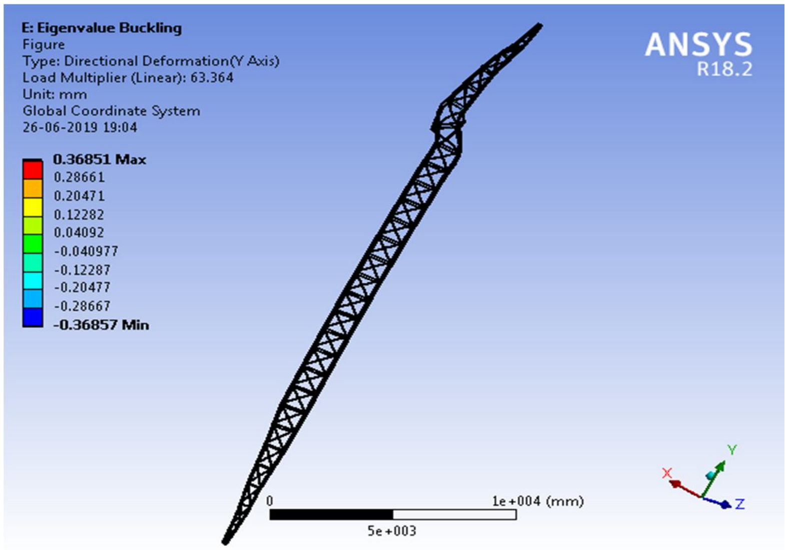
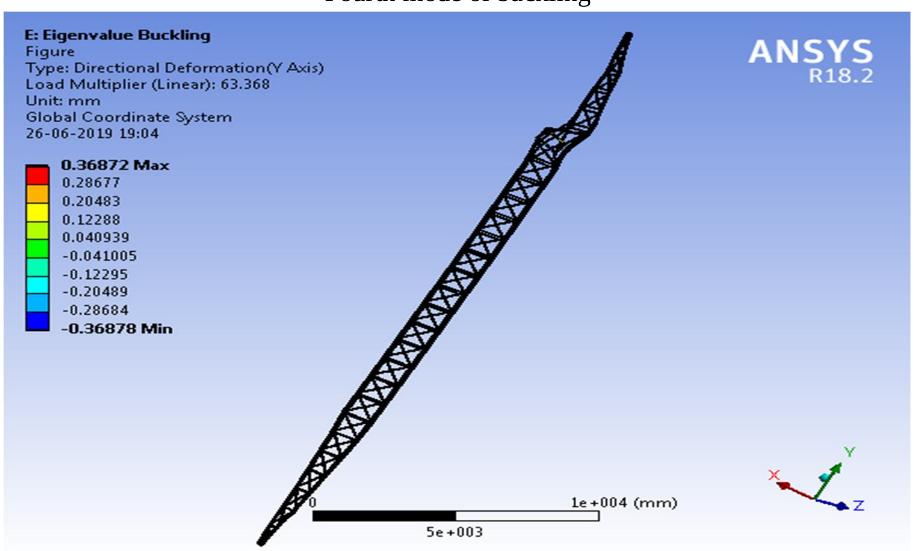
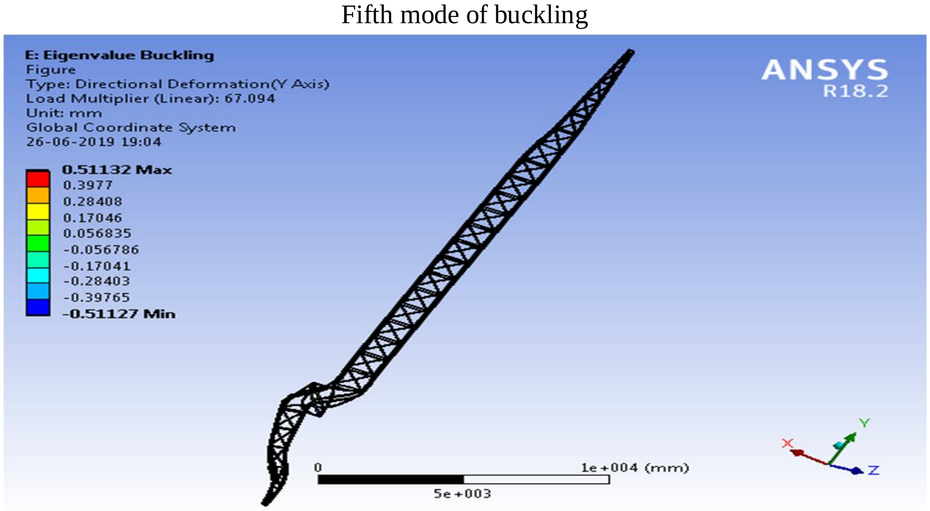
Third mode of buckling



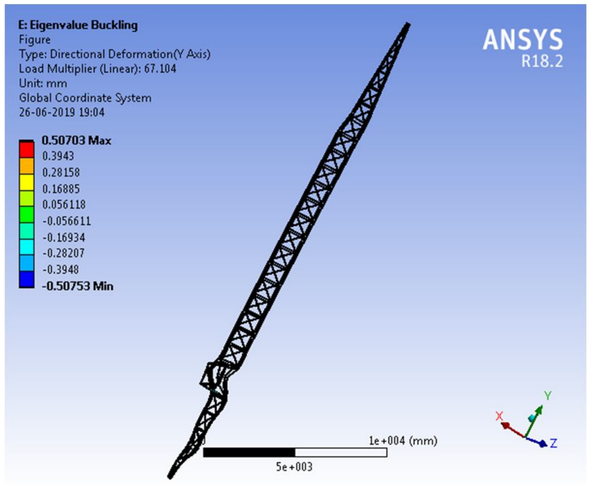

Fourth mode of buckling




Fifth mode of buckling



Sixth mode of buckling




## III. CONCLUSION

*A.* From transient analysis, the maximum value of the bending stress is 1.7 mpa which is well below the permissible value of the steel.

*B.* Total axial force is 5000N compressive load under which is way below 20000N.

*C.* Maximum deformation is 2.6 mm which well below the maximum allowable value i.e 1/350 time of the span i.e 1500 mm.

*D.* From the model analysis, we can conclude that the working frequency and load values are very high when compared to the model frequencies of the structure, there is no chance for the occurrence of resonance in the arm stand.

*E.* From the buckling analysis, we can conclude that the maximum load carrying capacity under buckling is 75KN. Which is well above the applied load of 20000N. So, the structure is safe under buckling.

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