

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

Structural Design and Analysis of a Launcher for Sounding Rockets

Neeraja Unni¹, Lakshmi G Das²

P.G. Student, Department of Civil Engineering, Indira Gandhi Institute of Engineering and Technology,
Kothamangalam, Kerala, India¹

Assistant Professor, Department of Civil Engineering, Indira Gandhi Institute of Engineering and Technology,
Kothamangalam, Kerala, India²

ABSTRACT: This paper deals with the structural design and analysis of a launcher for sounding rockets. Detailed FE modelling and analysis of the launcher configurations are carried out to arrive at a mass optimized configuration which meets the specifications. The loads are estimated based on IS 875 code considering the wind loads applicable for Trivandrum. The frequencies, displacements, stresses are estimated from the finite element analysis. The masses of two configurations are also compared. Accordingly two different configurations are arrived. Initially, a truss and then a machined configuration is designed with the suitable specifications. Design includes dimensions of launcher boom, drive shaft and rocket. The components are meshed and the member and material properties are assigned to the model, the composed model is then analysed with finite element software, NISA.

KEYWORDS: Launcher, Boom, Drive Shaft.

I. INTRODUCTION

Launchers are the interface unit between rockets and externally or internally carried store, not necessarily with propulsion. In other words, they are container of tubes for firing unguided rockets carried as external store. In the present context, launcher can be defined as launching structures for the sounding rockets of 300mm diameter class. Launchers are made using reinforced thin-walled structures that are very complex and must survive under severe loading conditions. Therefore, it is necessary to develop advanced numerical tools to reduce the computational cost of the complex experimental activities that are required during structural design.

The basic design goals for a launcher are as follows:

- Adequate base structure
- Proper trunnion locations
- Optimum stiffness, damping, inertia and mass placements.
- Adequate clearance to ensure a clean launch
- Proper load balance to minimize aim changes
- Reloading access
- Adequate alignment and straightness of the launcher guidance device
- Proper type of launch device (rail, tube, etc.)
- Minimize rocket induced launcher reactions
- Provide adequate launch attitudes and rates.

The objective of this work is to carry out the detailed structural design and analysis of a launcher for sounding rockets of 300 mm diameter class and to arrive at a mass optimized configuration meeting the design specifications. Two different configurations i.e., truss based and machined constructions are studied for the given geometric configuration and specifications. Finite elements models of configurations are generated in a commercial FE package. The required

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

geometrical and material properties are applied and meshing is generated for finite element analysis. Analysis of the structure under the given load combinations is carried out. Static analysis is done for determination of stresses and displacement. Determination of natural frequencies is done through free vibration analysis. Paper is organized as follows. Section II describes Geometric configuration and design specifications and accordingly structural load estimation is carried out. After that, finite element modelling is done which is given in section III. Section IV presents the results obtained through structural analysis. Finally, Section V presents conclusions.

II. GEOMETRIC CONFIGURATION AND DESIGN SPECIFICATIONS

The configuration of launcher being considered is as follows:

- Launcher consists of a boom of length 14 m and a rail length of 13 m for rails.
- The boom is having a tapered cross section of 800 mm x 400 mm at hinge which is being tapered to 400 mm x 400 mm to the boom tip.
- Desirable working height is 1.5 m from ground.

The following are the various structural and functional requirements:

- Rocket loading is being provided as under slung configuration.
- It has to withstand the wind loads (applicable for Trivandrum) without any failure.
- The maximum deflection shall not be excessive so as to cause any functional damage to the system. Deflection shall not more than L/900.
- The structure should withstand both static and dynamic loadings during prelaunch and launch conditions.
- Natural frequency of boom in the assembled configuration should be greater than 2.3 Hz.
- Material for launcher shall be preferably Mild steel or SS 304L.
- Ultimate load factor of 1.5 shall be used for design, being a ground structure.
- Mass shall be minimum with C.G location close to hinge point.

The loads are estimated for launcher based on the wind load computation procedure defined in IS 875: Part 3. The structural loads taken into account is with respect to **Launcher assembled with 300 mm diameter class rocket in horizontal condition**

Basic wind, $V_b = 39$ m/s (for Trivandrum)

Probability factor, $k_1 = 1.0$

Terrain, height and structural size factor, $k_2 = 1.05$

(Terrain with no obstructions, wind speed variation for height upto 10m, Class A i.e. structure size < 20m)

Topography factor, $k_3 = 1.0$

$$\begin{aligned} \text{Design wind speed, } V_z &= V_b \cdot k_1 \cdot k_2 \cdot k_3 \\ &= 39 \times 1.0 \times 1.05 \times 1.0 \\ &= 41 \text{ m/s} \end{aligned}$$

$$\begin{aligned} \text{Design wind pressure, } P_z &= 0.6 \cdot V_z^2 \\ &= 0.6 \times 41^2 \\ &= 1010 \text{ N/m}^2 \end{aligned}$$

Normal force co-efficient, $C_{fn} = 1.68$

Normal force on windward side, $F_n = C_{fn} \cdot P_z \cdot K \cdot (l \times b)$

For $l/b = 8/0.225 = 35.55$

$K = 0.86$

$$\begin{aligned} \text{Pressure on windward side, } P_{\text{windward}} &= C_{fn} \cdot P_z \cdot K \\ &= 1.68 \times 1010 \times 0.86 \end{aligned}$$

$$= 1459.248 \text{ N/m}^2$$

For frame spacing ratio = 600/400 = 1.5, shielding factor = 0.7

$$\begin{aligned} \text{Pressure on leeward side, } P_{\text{leeward}} &= \text{shielding factor} \times P_{\text{windward}} \\ &= 0.7 \times 1459.25 \end{aligned}$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

$$\begin{aligned}
 &= 1021.5 \text{ N/m}^2 \\
 \text{Transverse force on foreside, } F_t &= C_{ft} \cdot P_z \cdot K \cdot (l \times b) \\
 \text{Pressure on fore side, } P_{fore} &= C_{ft} \cdot P_z \cdot K \\
 \text{Normal force co-efficient, } C_{ft} &= 2.0 \\
 \text{For } l/b = 8/0.225 = 35.55 \\
 K &= 0.86 \\
 \text{Pressure on fore side, } P_{fore} &= C_{ft} \cdot P_z \cdot K \\
 &= 2 \times 1010 \times 0.86 \\
 &= 1737.2 \text{ N/m}^2 \\
 \text{Pressure on aft side, } P_{aft} &= 1737.2 \text{ N/m}^2 \\
 \text{For roof having slope, } \alpha = 0^\circ \\
 h/w = 225/225 = 1, \text{ Pressure coefficient, } C_p &= 1.1 \\
 \text{Pressure on top side, } P_{top} &= 1111 \text{ N/m}^2 \\
 \text{Pressure on bottom side, } P_{bot} &= 1111 \text{ N/m}^2
 \end{aligned}$$

III. STRUCTURAL DESIGN

1. In the study, two types of configurations are attempted to arrive at a mass optimized design. They are the following:

- i. Design Option 1: Truss Construction
- ii. Design Option 2: Machined Construction

2. Loading Conditions

- i. Dead Load i.e., Self weight of the structure
- ii. Wind Load

3. Materials Used

The mechanical properties of materials of structural components used in design of launcher are given in the following table.

Table 1 Mechanical properties of materials of structural components

Component	Material	Thickness	Modulus of elasticity N/mm ²	Poisons ratio	Density	Yield strength N/mm ²
Launcher boom Aft segment Mid segment Fore end segment	Mild steel	Machined model: 16 8 6 Truss model: 50 mm x 50 mm	200	0.3	7800	240
Rocket	15CDV6 steel	3 mm thick	200	0.3	33936	835
Shaft	15CDV6 steel	320mm 260mm 220 mm	200	0.3	7800	835

International Journal of Innovative Research in Science, Engineering and Technology

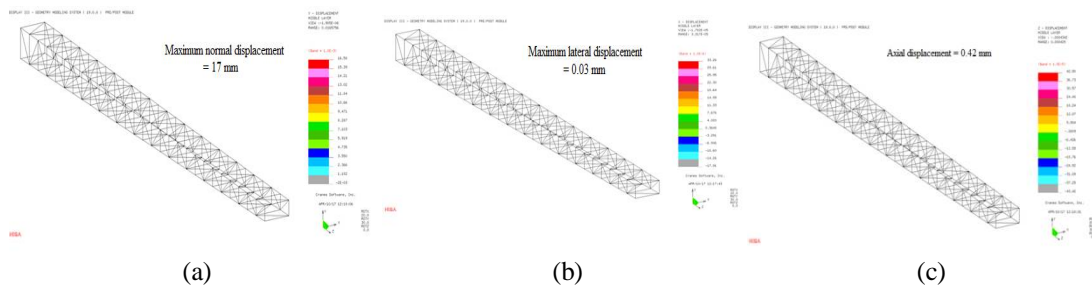
(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

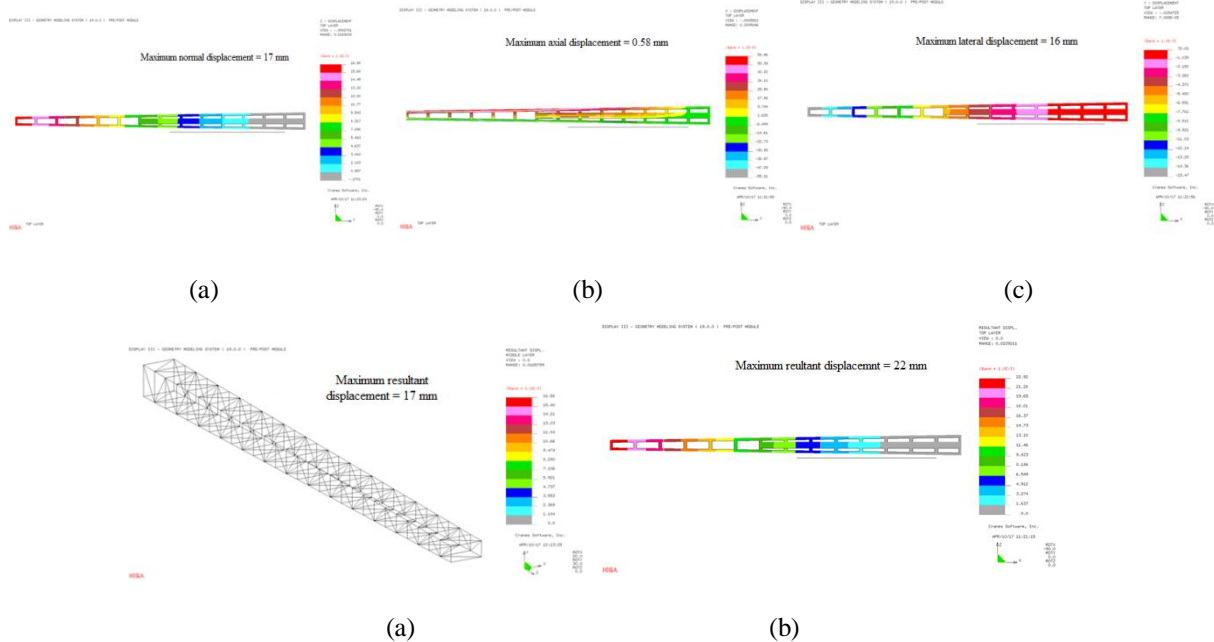
Vol. 6, Issue 5, May 2017

IV. STRUCTURAL ANALYSIS

Figures show the results of displacement and Von Mises Stresses acting on the launcher structure obtained through static analysis. Figures. 1. (a),(b),(c) shows the directional displacements obtained for truss model of launcher.



Similarly, figures 2. (a),(b),(c) shows the directional displacements obtained for machined model of launcher. The resultant displacements obtained for the truss and machined configurations are shown in figures 3. (a) and (b).



The first 4 natural modes of the launcher are extracted from free vibration analysis and the corresponding frequencies are reported. The mode shapes for the configurations are also obtained and are shown in figures 4 (a),(b),(c),(d). Table 2 (a) and (b) shows the natural frequencies obtained for truss and machined configurations respectively.

MODE	FREQUENCY(HZ)
1	3.55
2	11.41
3	19.01
4	24.97

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

MODE	FREQUENCY(HZ)
1	2.4
2	8.1
3	12.1
4	13.2

DISPLAY 111 - GEOMETRY MODELING SYSTEM V. 18.0.0.1 - PRE-POST MODEL

Frequency = 3.5 Hz

MODE SHAPE PLOT
NO. DEFN = 4.28E+02
MODE NO. = 120019
SCALE = 1.0
(MAPPED SHAPE)

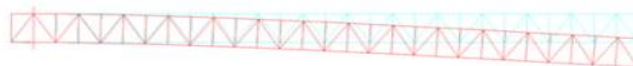


Crioste Software, Inc.
APR18/17 12:10:09
MODE NO. 120019
SCALE 1.0
MAPPED SHAPE

DISPLAY 111 - GEOMETRY MODELING SYSTEM V. 18.0.0.1 - PRE-POST MODEL

Frequency = 11.41 Hz

MODE SHAPE PLOT
NO. DEFN = 6.00E+02
MODE NO. = 120020
SCALE = 1.0
(MAPPED SHAPE)



Crioste Software, Inc.
APR18/17 12:10:09
MODE NO. 120020
SCALE 1.0
MAPPED SHAPE

DISPLAY 111 - GEOMETRY MODELING SYSTEM V. 18.0.0.1 - PRE-POST MODEL

First frequency = 2.4 Hz

MODE SHAPE PLOT
NO. DEFN = 1.00E+02
MODE NO. = 120001
SCALE = 1.0
(MAPPED SHAPE)

DISPLAY 111 - GEOMETRY MODELING SYSTEM V. 18.0.0.1 - PRE-POST MODEL

Frequency = 8.1 Hz

MODE SHAPE PLOT
NO. DEFN = 5.00E+02
MODE NO. = 120018
SCALE = 1.0
(MAPPED SHAPE)



Crioste Software, Inc.
APR18/17 12:10:01
MODE NO. 120001
SCALE 1.0
MAPPED SHAPE

MODE NO. = 2 FREQUENCY = 2.280000 Hz



Crioste Software, Inc.
APR18/17 12:10:16
MODE NO. 120018
SCALE 1.0
MAPPED SHAPE

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 5, May 2017

V. CONCLUSION

From the above results, it is obtained that minimum frequencies are obtained as in the case of machined construction. Also, the shell model can be optimized by reducing the frequency. Mass is higher in the machined construction. For a design, where frequency is primarily important as a functional requirement, the truss construction with (3.5 Hz first mode) is superior and has lowest mass of 2358 kg. It can be seen that, the truss construction is better for a mass optimised design, which meets the frequency requirements.

The future scope of the project is that moving load analysis of the launcher for the launch conditions may be carried out for all the designed configurations with the time history of rocket velocity and acceleration and the response shall be studied in future.

REFERENCES

- [1] **Bathe, K J. 2006.***Finite Element Procedures.* 2006.
- [2] **Bathe, Klaus- Jurgen. 1982.***Finite Element Procedures in Engineering Analysis.* s.l. : Prentice Hall, 1982.
- [3] **Beaufait, Fred W. 1970.***Computer Methods of Structural Analysis.* s.l. : England Cliffs, N S Preautia Hall, 1970.
- [4] **Gokhale, S Nithin. 2007.***Practical Finite Element Analysis.* s.l. : K Joshy and Co, 2007.
- [5] **Klaus-Jurgen Bathe, EDward L Wilson. 1976.***Numerical Methods in Finite Element Analysis.* s.l. : Prentice Hall, 1976. pp. 6-12. Vol. 1.
- [6] **Lakshminarayanan, H V. 2004.***Finite Element Analysis: Procedures in Engineering.* s.l. : Universities Press/ Orient Blackswan Pvt.Ltd., 2004.
- [7] **Timoshenko, S. 1940.***Theory of Plates and Shells.* 1940.
- [8] **Robert D. Cook,** *Finite Element Modelling for Stress Analysis,* University of Winconsin- Madison, Hamilton Printing, 1995
- [9] **Nithin S. Gokhale,** *Practical Finite Element Analysis,* First Edition, K. Joshi & Co. Anil Joshi & Team, 2007.
- [10] NISA-Civil, *Choice of Civil and Structural Engineers World Wide,* Cranes Software International Ltd, 2005
- [10] NISA II Users Manual, *Choice of Civil and Structural Engineers World Wide,* Cranes Software International Ltd, 2001.