Design of Handling System for Heavy Rocket Motor Segments

K. Eswari Bhargavi[1] P. Uma Mahesh[2] K. Mohan Krishna[3]
[1]P.G. Scholar [2,3]Assistant Professor
[1,2,3]Department of Mechanical Engineering
[1,2,3]Chadalawada Ramanamma Engineering College, Tirupathi, A.P., 517506

Abstract—For launching any launch vehicle heavy booster rockets are essential. These booster rockets are produced in the form of segments. Each segment weighs around 60T, which is currently in use at ISRO. These heavy booster segments are produced in SDSC-SHAR. For the production of the segments a series of operations are essential. A rocket booster segment is a heavy cylindrical object containing solid propellant which is highly explosive in nature. Each rocket segment is provided with an end ring on either side. These end rings are used to meet the handling needs of these segments. Heavy handling brackets are used to connect the end ring and the handling system manually. This operation demands a lot of time and effort. To overcome the above difficulties, a remotely operated handling system of grabbing type has been proposed. This project deals with the detailed design of the handling system with the help of solid works. By virtue of these tool the design of the handling system will be validated.

Key words: Handling System, Rocket Motor Segments, Solid Works

I. Introduction

Indian space research organization (ISRO) launches Remote Sensing, communication and weather forecasting satellites into space orbits using satellite launch vehicles. Launch vehicle consists of multiple number of stages, each stage being solid fuelled (Solid Rocket Motor) or liquid fuelled (Liquid Rocket Engine).The solid rocket motors required for ISRO's launch vehicle programmes are produced at Solid Propellant Space Booster Plant (SPROB) located at Sriharikota.

In Solid Propellant Plant at Satish Dhawan Space Centre, the heavy cylindrical structures of weighing maximum 60 tons. Presently these structures are being handled with '+' type tackle. Both ends of the cylindrical structure are provided with detachable end rings used for handling purpose. All the structures are having identical interface for handling with a common tackle. This tackle has two beams which are placed in the form of plus and detachable brackets on the end rings with manually locking and unlocking the pins. This tackle meets the handling requirements of the structures at different work centers. Heavy handling brackets are used to connect the end ring and the handling system. This operation demands a lot of time and effort.

In the proposed tackle the brackets are replaced with 'C' arms which are 4 in numbers, 2 for each beam which are engaged and disengaged for handling purpose. The main beams are of tapered and made with mild steel IS 2062 Gr B. The C arm which is very critical part in this tackle is made with forged mild steel material. To avoid human intervention, the pneumatic system is used to engage and disengage the C- arm and locking/unlocking of the pins remotely. This entire C arm tackle is lifted with the help of Ram's horn hook. Hence this handling system of grabbing type is safe as it handles at four points, the load gets distributed equally for each arm. Thus it will be a safe method of handling the heavy cylindrical structures and with a single person.

II. Selection of Materials

The following are the properties of materials used for handling system.

Material	Property	Value
Mild Steel (Beam and c-arm)	Young's Modulus (MPa)	210000
	Density (kg/m^3)	7850
	Poisons ratio	0.3
	Ultimate Strength (MPa)	410
	Yield stress	240
	Allowable stress (MPa)	132

Table 1: Material properties of IS 2062 Gr B

MATERIAL	PROPERTY	VALUE
En24	Young's Modulus (MPa)	210000
	Poisons ratio	0.3
	Ultimate Strength (MPa)	850-1000
	Yield stress	600
	Allowable stress (MPa)	340

Table 2: Material properties of En 24

III. Description of Handling System

The handling system comprises of:

A. C - Arm:

The critical part of the handling system is C arm. Since they should withstand load of about 37.5 t, they are to be made of a materials having high strength. Generally IS 2062 Gr B steel is best suited for this purpose. These C arms which are 4 in number are arranged vertically, 2 on each beam. These C arms are engaged and disengaged with the end rings of the segments.

B. Beams:

A Beam is a structural member, which is acted up on by transverse loads. The two beams used in the tackle are arranged in the form of '+'. The beams are generally made of mild steel having UTS 410 N/mm^2. The beams are subjected to both bending moment and shear force.

C. Bracket:

Bracket consists of two plates placed on top of the beam, which are welded to the plate. These brackets are made of mild steel having UTS (410 N/mm^2). In these Brackets, pins are provided for lifting the complete tackle with the help of Rams horn hook.

D. Pins:

Pins is a load bearing member subjected to bending and shearing stresses. So pin is made with En 24.

E. Pneumatic Actuators:

The pneumatic actuator is used to engage and disengage the C - arm.

IV. DESIGN CALCULATIONS

Design load = 75 t
Considering two point loading
Load on each C - arm = 37.5t

A. Main Beam:

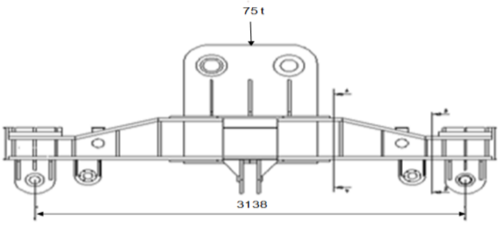

Fig 1: Main Beam

Load acting on beam = 75 t
Material: IS: 2062, Gr B Mild steel
Yield strength = 240 N/mm^2
Allowable bending stress (fb) = 0.55 Yp (As per IS: 13591)
= 132 N/mm^2
Maximum Bending Moment = 5.88 x 10^8 N - mm
Required section modulus, Z = 4.45 x 10^6 mm^3

1) *Section A-A:*

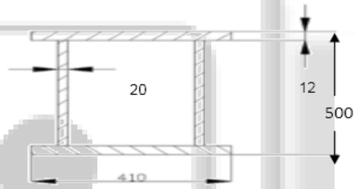

Fig 2: Section-AA of main beam

Provided section modulus, Z = 4.68 x 10^6 mm^3

$$\text{Bending stress} = \frac{5.8\times10^8}{4.68\times10^6} = 125.93 \text{ N/mm}^2$$

At end of beam, shear stress only develops
Load acting at end = 37.5 t
Considering web shear stress only

2) *Section B-B:*

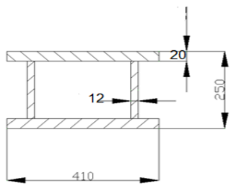

Fig 3: Section-BB of main beam

Shear stress = 74.40 N/mm^2
Allowable shear stress = 0.4 x Yp = 0.4 x 240 = 96 N/mm^2
Since the shear stress obtained is less than the maximum allowable stress. Therefore the design is valid.

B. Top Bracket and Pin:

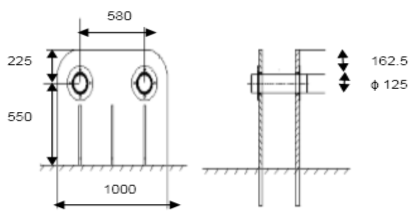

Fig 4: Top Bracket & Pin

Load on each bracket and pin = 37.5 t

1) *Pin For Top Bracket:*

Material = En24
Ultimate tensile strength = 800 N/mm^2
Factor of safety = 4
Allowable bending stress = 200N/mm^2
Maximum Bending Moment = 31.12 x 10^6 N-mm
Required section modulus, Z = 155.6 x 10^3 mm^3
Solid pin is provided with a diameter of 125mm:

Diameter (D) = 125 mm
Section modulus, Z = 191.74 x 10^3 mm^3
Bending stress = 162.30 N/mm^2

Since the bending stress obtained is less than the allowable, so the design is validated.

2) *Bracket:*

Material = I S: 2062 Gr B Mild steel
Tensile stress = 15.62N/mm^2
Shearing stress = 13.02N/mm^2

All stress values are within allowable limits.

C. Bottom Bracket and C-arm Pin:

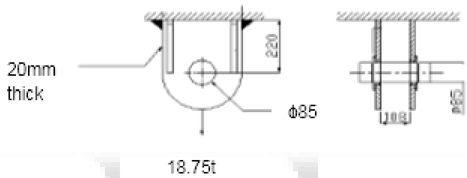

Fig. 5: Bottom Bracket & C-arm Pin

Material = En24
Ultimate tensile strength = 800N/mm^2
Factor of safety = 4
Allowable bending stress (f_b) = 200N/mm^2
Maximum bending moment (M) = 12.0 x 10^6 N-mm
Required section modulus, Z = 60000mm^3
Provided section modulus, Z = 60291.58 mm^3
Bending stress = 199.03 N/mm^2

Since the combined effect obtained is less than the maximum allowable. Therefore the design is validated.

1) *Bracket:*

Material = IS: 2062 Gr B
Tensile stress = 43.60 N/mm^2
Shear stress = 31.25 N/mm^2
All stress values are within allowable limits.

D. C- Arm Design:

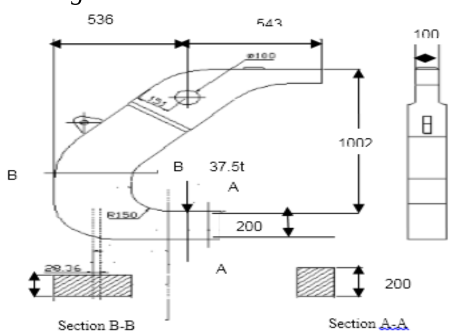

Fig. 6: C-Arm

Material = IS 2062 Gr B
Ultimate tensile strength = 410 N/mm^2

Yield strength = 240 N/mm^2
Length of the beam = 310 mm
Radius of inner fiber (R_i) = 150 mm
Radius of outer fiber (R_0) = 460 mm

We know that area of section at B-B = 40300mm^2

We know that Radius of curvature of the neutral axis, R_n = 276.63mm

And Radius of curvature of the centroidal axis, R = 305 mm

Therefore, distance between the centroidal axis and neutral axis, e = R - R_n = 305 - 276.63 = 28.37 mm

And distance between the load and the centroidal axis, x = 410mm.

Therefore, bending moment about the centroidal axis, M =153.75 x 10^6 N - mm
Tensile stress = 9.3 N/mm^2

We know that the distance from the neutral axis to the inside fibre, y_i = 126.63 mm

And distance from the neutral axis to outside fibre , y_o =183.37mm

Therefore, maximum bending stress at the inside fibre = 113.52 N/mm^2

And maximum bending stress at the outside fibre = 53.60N/mm^2

Therefore, resultant stress at the inside fibre = 122.82 N/mm^2

And resultant stress at the outside fibre = - 44.3 N/mm^2

All stresses are within permissible limits hence the design is validated.

E. Pneumatic Cylinder:

1) For C arm movement:

Parker make pneumatic cylinder of Model: 8CBB2MAR is suggested
Bore: 200 mm, double acting cylinder
Stroke: 175 mm
Quantity: 04 nos

Plain spherical bearings are used at each ends clevis mounting (ID =25mm, OD = 42mm, B= 20mm)
Swing of C-arm = 22.5 deg
C-arm weight = 475 kg
Over load factor = 1.5
Considered load on Pneumatic cylinder = 712.5 kg
Operating pressure = 6 bar
Maximum pressure = 10 bar

2) Calculations:

Piston diameter (D) = 200 mm
Rod diameter (d) = 40 mm
Area of piston for pneumatic pressure = 301.59 cm^2
Pressure required = 2.36 kgs/cm^2
Minimum pressure required to lift C arm = 2.5 kgs/cm^2
Pressure provided = 8 bar

V. GEOMETRIC MODELLING

The design of the handling system for heavy rocket motor segments is created in Solid Works software. The Following is assembled part of the handling system as shown in below figure:

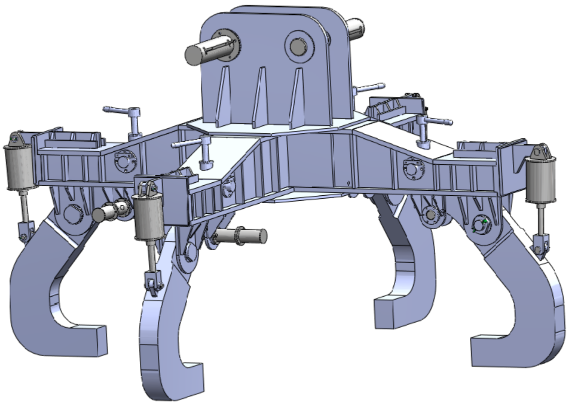

Fig. 7: assembled part of the handling system

VI. RESULTS

The various results of stresses in different components of handling system are tabulated below:

Component	Material	Parameter	Allowable value	Calculated value
Main Beam	Steel IS 2062 Gr B	Bending stress	132 N/mm^2	125.93N/mm^2
		Shear stress	96 N/mm^2	74.40 N/mm^2
C-Arm	Steel IS 2062 Gr B	Bending stress	132 N/mm^2	113.52 N/mm^2

Table 3: Design calculations of tackle

VII. CONCLUSION

Following are the conclusions from the results:

– Beam is made of IS 2062 Gr B steel and has bending stress and allowable stress values are compared and found to be same with a 5 % variation, which is well within allowable limits.
– The critical component in this tackle is C arm made with IS 2062 Gr B steel and has bending stress and allowable stress values are compared and found to be same with a 14% percentage variation within allowable limits.
– The 3 - D model of the handling system is generated by using solid works software.Hence the design is validated.

REFERENCES

[1] Dr. R.K. Bansal, 2007 "Strength of materials"4th edition.
[2] R.S.Khurmi,2010"Machinedesign"1stmulticolor edition.
[3] IS2062: Hot Rolled medium and high tensile Structural Steel- Specification.
[4] En24: BS970: Mac steel-Special Steels Catalogue.
[5] Alexander Blake, 1978 "Design of curved members for machines".

