Design and Analysis of Clamping Rod for Injection Mold

Ms. Udawant Amruta Prakash [1], Prof.R.R.Kharde [2]
[1, 2] Department of Mechanical Engineering
[1, 2] Pravara Rural Engineering College,Loni
Savitribai Phule Pune University,Pune

Abstract- *There is a problem faced by Larsen and Toubro (L & T) Ahmednagar .The tie bar or clamping rod which is used to lift the mold gets bend after frequent use, because it doesn't have a proper design with respect to varying weight of mold. On the basis of weight of mold weight proper design of tie bar that is specific length (L), breadth (B), and width (W) is done for injection mold DCB50304/1A1. Analysis of newly design component is done using HYPERMESH software.*

Keywords- Arduino,RF Reader, UART and MATLAB

I. INTRODUCTION

Weight of mold core and cavity is not even which causes tilting of tie bar when it is lifted and after repetitive use it causes bending of tie bar.

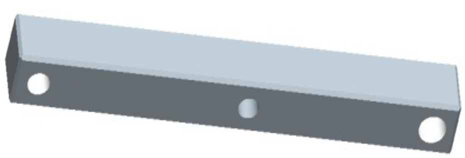


Fig. 1 Tie bar or clamping rod to be design

Mold consists of-

(i) cavity, is the female portion of the mold, gives the molding its external form.

(ii) Core, is the male portion of the mold, forms the internal shape of the molding.(shown in fig.2).

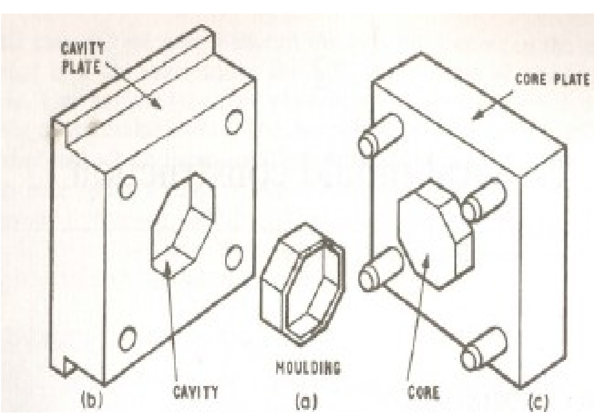


Fig. 2 - Basic mold consisting of cavity and core plate

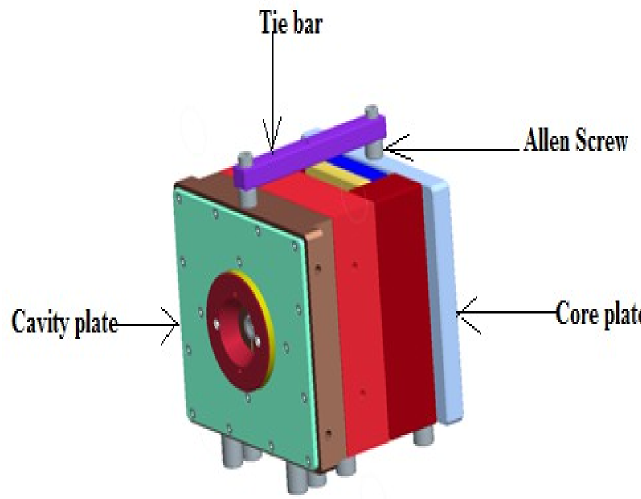


Fig. 3. Mold core and cavity

Mold assembly lifting using tie bar is shown in the fig.3.

Material selection -

Material used for tie bar is mild steel material (ASTM A36). This is most commonly used mild steel.

TABLE I
MECHANICAL PROPERTIES OF ASTM A36-

Mechanical properties	**Metric**	**Imperial**
Tensile strength , Ultimate	400-550 Mpa	58000-79800 Psi
Tensile strength , Yield	250 Mpa	36300Psi
Elongation at break(in 200mm)	20.0%	20.0%
Elongation at break(in 50mm)	23.0%	23.0%
Modulus of elasticity	200 Gpa	29000 Ksi
Bulk modulus(typical for steel)	140 Gpa	20300 Ksi
Poisson's ratio	0.260	0.260
Shear modulus	79.3 Gpa	11500 Ksi

Material used for eye bolt is forged carbon steel C15. This is having its mechanical properties as follows:

TABLE II
MECHANICAL PROPERTIES OF C15-

Mechanical property	Value
Young's modulus	200000Mpa
Tensile strength	650-880Mpa
Elongation	8-25%
Fatigue	275Mpa
Yield strength	350-550Mpa

1. Design calculations-

A. To find lifting force (F) –

Known values are –

Weight of Cavity (W_1) = 188Kg = 188*9.81 = 1844.28 N

Weight of Core (W_2) =159Kg = 159*9.81 = 1559.59N

Length of tie rod (L) = 398.5mm.

So, lifting force can be calculated by, calculating summation of forces in Y direction.

$\Sigma F_Y = 0$

-1844.28-1559.79 + W = 0

W = 3404.07N

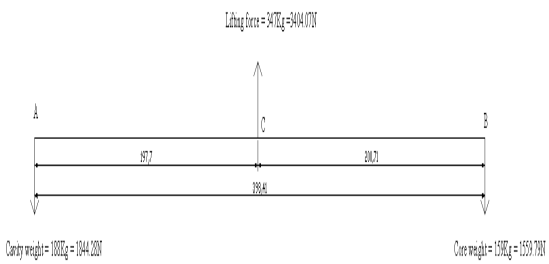


Fig.4 Free Body Diagram of tie bar

To find mass center of tie bar for locating eye bolt –

To find the correct position of eyebolt based on mold weight; it is essential to find the mass center of body i.e. of tie bar.

Here, m_1 = 188Kg = 1844.28 N

m_2 = 159Kg = 1559.79N

To find mass center,

$m_1r_1 = m_2r_2$

1844.28*r_1 =1559.79(398.5 – r_1)

$r_1 + r_2$ = 398.5

r_2 = 398.5 - r_1

1844.28*r_1 = (1559.79*398.5) – (1559.79*r_1)

1844.28*r_1 + 1559.79*r_1 = 1559.79*398.5

3404.07*r_1 = 621576.315

r_1 = 182.5979mm

Therefore, r_2 =398.5 – 182.5979

r_2 = 215.9020mm

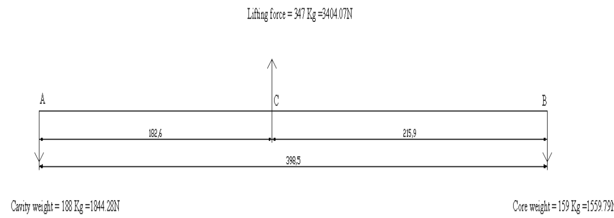


Fig. 5 Free Body Diagram for mold core and cavity along with tie bar with new position of eye bolt.

B. To find dimensions of tie bar –

Shear force calculations -

S_{FAL} = 0N

S_{FAR} = -1844.28N

S_{FCL} = -1844.28N

S_{FCR} = -1844.28+3404.07N = 1559.79N

S_{FBL} = 1559.79N

S_{FBR} = 1559.79-1559.79 = 0N

Bending moment calculation –

B_{MA} = 0 Nmm

B_{MC} = -1844.28*182.5979 = -336761.655Nmm

B_{MA} = -(1844.28*398.5)+3404.07(398.5-182.5979)Nmm

B_{MA} = 0.81547 Nmm

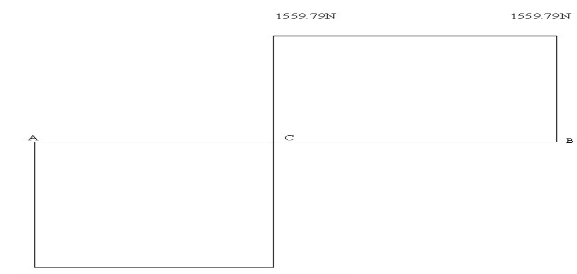


Fig. 6 Shear force diagram

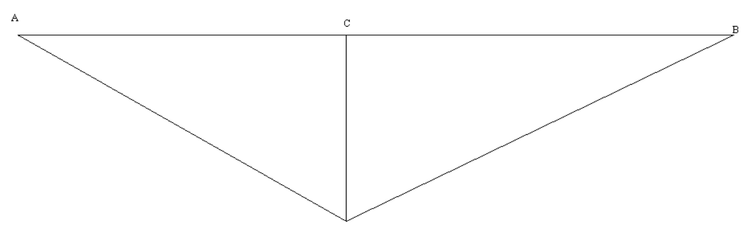


Fig. 7 Bending moment diagram

C. Area moment of inertia –

Case –I

I_1 = bd^3/12

= 36*25^3/12

= 46875mm^4

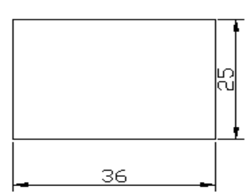


Fig.8 Area moment of inertia for Case – I

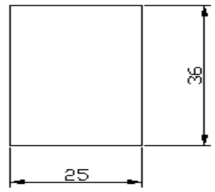


Fig.9 Area moment of inertia for case –II

Case –II

I_2 = bd^3/12

= 25*36^3/12

= 97200mm^4

From above calculations, I2> I_1

So that, application of second case will give more moment of inertia to tie bar.

D. Calculation for allowable bending stresses of ASTM A36–

Yield stress of mild steel (ASTM A36) = 250 Mpa with allowable stresses in

Tension, 0.6 F_Y = 150 Mpa

Bending, 0.66 F_Y = 165 Mpa

Calculation of σ for I_1 –

We know that,

M/I = σ/Y

In this application of tie bar load is applied suddenly i.e. it is the case of sudden loading.

Therefore, σ = 2σ

M/I = σ/Y

Y = d/2

-336761.655/46875 = σ/(25/2)

7.1842 = 0.08 σ

σ = 89.8025 N/mm^2

But, σ = 2σ

Therefore, σ = 2*89.8025 = 179.605 N/mm^2

Calculation of σ for I_2 –

M/I = σ/Y

Y = d/2

-336761.655/97200 = σ/(36/2)

3.464626 = 0.055 σ

σ = 62.42 N/mm^2

But, σ = 2σ

Therefore, σ = 2*62.42 = 124.84 N/mm^2

Stresses are observed lesser in the second case so, second case where, I_2 = = 97200mm^4

safe for design.

E. Shear stress calculation for tie bar–

τ=SAȳ/Ib

I = I_2 = 97200mm^4

Y = d/2 = 36/2 =18

ȳ = Y/2 = 18/2 = 9

A = (d/2)*b = (36/2)*25 = 450 mm^2

S = 3404.04 N

τ=SAȳ/Ib

τ = (3404.07*450*9)/(97200*25)

τ = 5.67345 N/mm^2

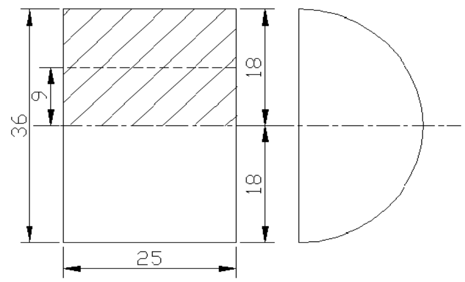


Fig.10 Shear stress distribution diagram

F. Selection of eyebolt based on total weight of mold core and cavity –

Shear stress calculations for bolt –

Factor of safety is considered as 6 for eye bolt ---------

(V .B. Bhandari Design of machine elements pg.232)

Step I - Permissible tensile stress –

Factor of safety for eye bolt is(F_s) = 6

(σ_t =S_{yt}/F_s = 350/ 6 = 58.33 Mpa (C15)

Step II – Size of bolt -

σ_t = Force/ (Area) = P/(π /4*$d_c^{\wedge 2}$)

58.33 = 3404.07/ (π /4*$d_c^{\wedge 2}$)

d_c = 8.62mm

d = d_c / 0.8 = 8.62/ 0.8 = 10.77 mm

From the table (L&T), the standard size of bolt is M12[10].

Threads used are metric threads of corse type.

Stress area formulae –

D = Basic diameter

P = Screw thread pitch

L_e = Length of thread engagement

A_t = The screw thread tensile area

d_p = Pitch circle diameter of thread

A_{SS} = The thread shear area

A_t = (π/4)(D-0.938194.p)^2

This is based on ISO 898 Part 1.

d_p = Pitch circle diameter of thread

d_p = (D - 0.64952.p)

d_p = (12 - 0.64952*1.75)

d_p = 10.86

A_t = (π/4)(D-0.938194.p)^2

A_t = (π/4)(12-0.938194*1.75)^2

A_t = 84.26mm^2

Allowable shear stress ($\tau_{allowable}$) = (0.5* S_{yt}) /F_s

= (0.5 * 350) / 6

= 29.16 N/mm^2

Induced shear stress ($\tau_{induced}$) = P/ A

($\tau_{induced}$) = 3404.07/84.26

($\tau_{induced}$) = 40.39 N/mm^2

As, ($\tau_{allowable}$) < ($\tau_{induced}$) bolt M12 will not be safe to use.

d_p = (D - 0.64952.p)

d_p = (16 - 0.64952*2)

d_p = 14.70

$A_t = (\pi/4)(D-0.938194.p)^2$

$A_t = (\pi/4)(16-0.938194*2)^2$

A_t = 156.66mm^2

Allowable shear stress ($\tau_{allowable}$) = (0.5* S_{yt}) /F_s

($\tau_{allowable}$) = (0.5 * 350) / 6

($\tau_{allowable}$) = 29.16 N/mm^2

Induced shear stress ($\tau_{induced}$) = P/ A

= 3404.07/156.66

= 21.72 N/mm^2

As, ($\tau_{allowable}$) > ($\tau_{induced}$) bolt M16 will be safe to use.

TABLE III
METRIC COARSE THREAD

Size of screw	M	M3	M4	M5	M6	M8	M10	M12	M16	M20	M24
Body dia	d1?	3	4	5	6	8	10	12	16	20	24
Head dia	D1?	5.5	7	8.5	10	13	16	18	24	30	36
Height of head	H1	3	4	5	6	8	10	12	16	20	24
Length of thread portion	b(upto 130mm)	12	14	16	18	22	26	30	38	46	54
	b(Above 130-200mm)	-	-	-	-	28	32	36	44	52	60
Drill size(MS)	C	2.5	3.3	4.2	5.0	6.8	8.5	10.2	14.0	17.5	21.0
Drill size(Alloy steel)		2.6	3.4	4.3	5.1	6.9	8.6	10.4	14.2	17.8	21.3
Clear hole size	d2?	3.5	4.6	5.6	6.8	8.8	10.8	12.8	16.8	21.0	25.0
C'bore size	D2?	6.0	7.5	9.0	11.0	14.0	17.0	18.0	25.0	31.0	37.0
C'bore depth	H2	3.5	4.5	6.0	7.0	9.0	11.0	13.0	17.0	21.0	25.0
Pitch	-	0.5	0.7	0.8	1.0	1.25	1.5	1.75	2.0	2.5	3.0
Depth of thread	-	0.33	0.46	0.52	0.65	0.81	0.97	1.14	1.30	1.62	1.95
Core dia	-	2.34	3.08	3.96	4.70	6.38	8.06	9.72	13.40	16.76	20.10
Tensile stress	-	-	8.78	14.20	20.10	36.60	58.00	84.30	157	245	353

Shear stress calculation for tie bar at a region of eye bolt –

I. *For eyebolt M16 –*

Area (A) = 9*36 = 324 mm^2

τ = P/A = (3404.07/324) =10.50 N/mm^2

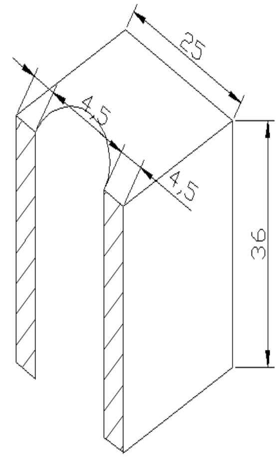


Fig.11 Sectional view of tie bar when M16 bolt is used

Clearance is 4.5mm from both sides; which may cause failure of component. So width is increased from 25mm to 30mm.Calculations for area moment of inertia and stresses is done below -

I_2 = bd^3/12

= 30*36^3/12

= 116640mm^4

Stress calculation -

M/I = σ/Y

Y = d/2

-336761.655/97200 = σ/(36/2)

σ = 52.4943 N/mm^2

But, σ = 2σ

Therefore, σ = 2*52.4943 = 104.98 N/mm^2

Above calculation shows that, this cross section is more safe to use in practical application.

G. Experimental testing –

Fig.12 Testing component

Fig.12 Testing method using actual application for which design is done.

Each of the three components was tested for frequent application till it bents.

i) Results for rod width 25mm, depth 36mm and eyebolt are as follows-

H. Modelling and analysis –

Analysis is done by using HYPERMESH software.

***Preprocessing*:**

Altair Hypermesh software is used for Preprocessing. Meshing of tie bar is done with Hex elements & Eye bolt meshing is done with second order tetra elements.

Nastran BEAM elements used to represent the Bolts & Rigid Body Elements (RBE2) elements used to connect the bolts.

Solution:

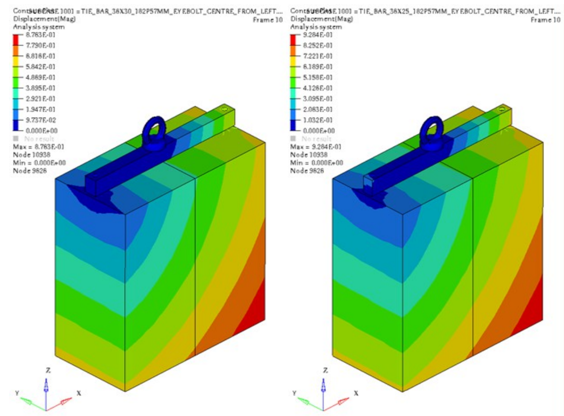
MSC Nastran software used as FE Solver.

Boundary conditions & Loads:

Eyebolt surface where the hook will be anchored is fixed in ALL DOF. Gravity loading considering the impact load with factor of 2 is applied in 'Z' direction downwards.

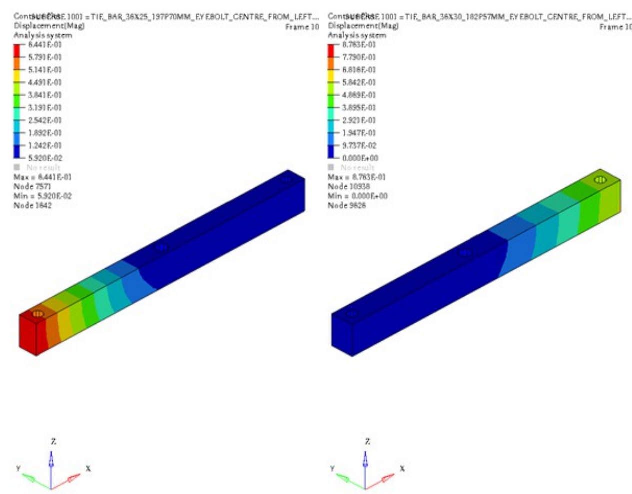
Post processing:

Altair Hyperview is used for Post-processing the results. Displacement & Stresses are plotted.



i)Tie bar 36x30mm & 182.59 mm from left end ii)Tie bar 36x25mm & 182.59 mm from left end

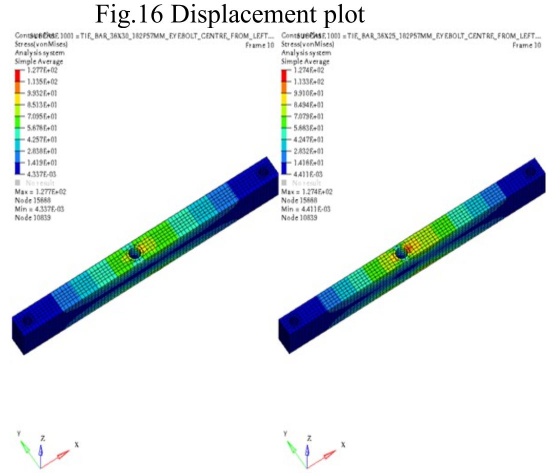
Fig.15 Displacement plot



Max. Disp. – 0.87mm Max. Disp. – 0.92mm

i)Tie bar 36x30mm ii)Tie bar 36x25mm

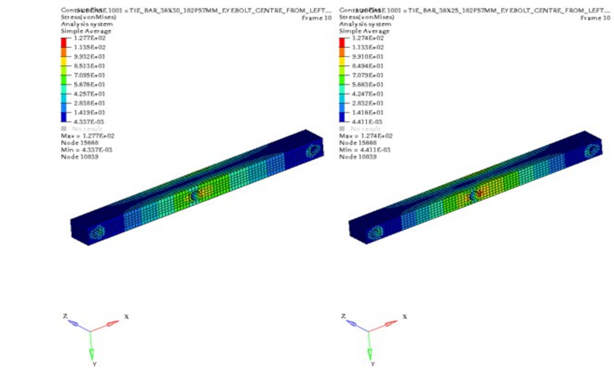
Fig.16 Displacement plot



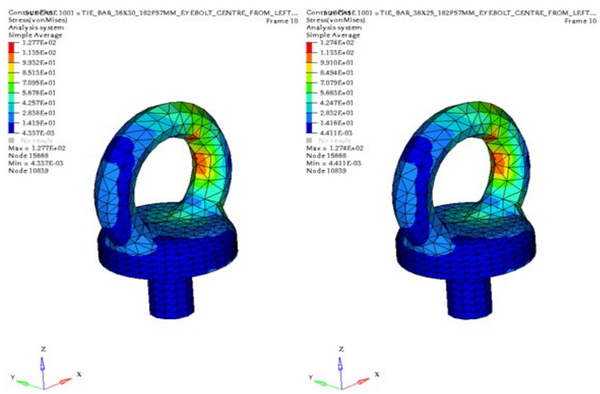
Max. Disp. – 96Mpa Max. Disp. – 109Mpa

i)Tie bar 36x30mm ii)Tie bar 36x25mm

Fig.16 Von Misses stress plot(Top location)



Max. Disp. – 96mm Max. Disp. – 109 Mpa
i)Tie bar 36x30mm ii)Tie bar 36x25mm
Fig.17 Von Misses stress plot(Bottom location)



Max. Disp. –127Mpa Max. Disp. – 127Mpa
i)Tie bar 36x30mm ii)Tie bar 36x25mm
Fig.18 Von Misses stress plot

RESULTS

- By doing calculations for mass center of tie rod new position for locating an eyebolt is obtained which are r_1 = 182.5979mm at heavier side and r_2 = 215.9020mm at lighter side.
- By the calculation of area moment of inertia of body proper dimensions of tie bar are obtained i.e. length 398.5mm, depth 36mm and width 25 mm.It gives higher area moment of inertia than its previous dimensions and having safe values for bending and shear stresses with respect to material strength.
- Selection of eye bolt based on total weight of mold core and cavity is done and it is having safe shear stress values with respect to material strength.
- From stress analysis results of HYPERMESH software ,stresses in 2- proposed tie-bar designs is well below the material yield limit of 250 MPa. Design is safe for impact loading factor ‘2’.
-

CONCLUSION

From above calculations it is concluded that,

1. Tilting of tie bar is prevented by locating the position of eyebolt correctly by finding its mass center.

2. Moment of inertia of body is more when its depth is kept larger than its width.

3. From bending stress and shear stress calculations it is found that, failure of tie bar occurs mainly due to bending stresses.

4. From stress analysis results of HYPERMESH software ,stresses in 2- proposed tie-bar designs is well below the material yield limit of 250 MPa. Design is safe for impact loading factor ‘2’.

ACKNOWLEDGMENT

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