Problem1: Milling Support:

a. Rationale for selecting range & step size:

   For the fast results, varying the base thickness from min. 0.3in to max. 0.75in which is the maximum allowable range with a step size of 0.15in to get at least 4 variations. The vertical leg width is varied from 0.25in to 1in with step of 0.25in to get 4 variations. Horizontal leg width varied from 0.5in to 1.25in with step of 0.25in to get 4 variations. Hypotenuse leg width varied from 0.25in to 1in with step of 0.25in to get 4 variations. Overall, all ranges are set to cover a broader range of dimensions, and each is set to have a step size to enable at least 4 variations for the fast results.

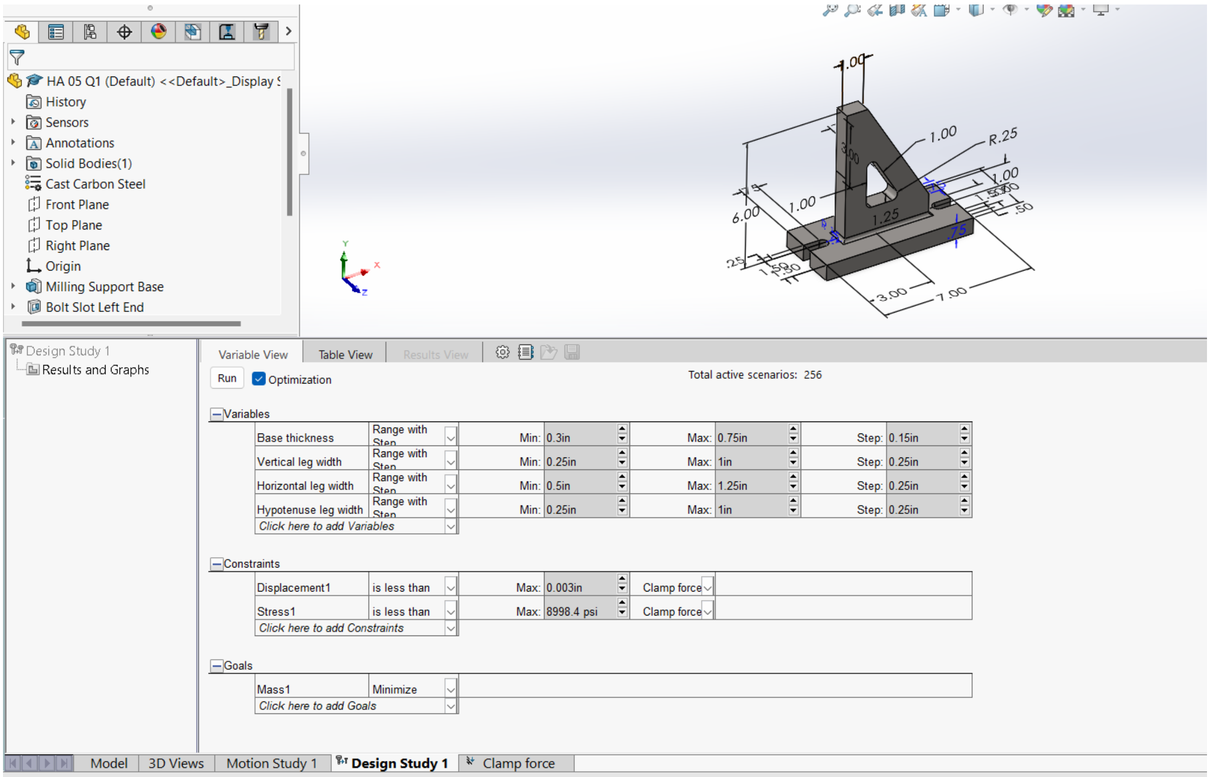
   For the high-quality results, based on the output from fast results, we decide range for each parameter to be slightly above and below the optimised solution from fast results. Optimised fast result for base thickness is 0.3in, vertical leg width is 0.75in, horizontal leg width is 0.5in, hypotenuse leg width is 0.25in. Also, when we look at other solutions from the fast results, it is clear that vertical leg width is a sensitive parameter, the base thickness is not affecting much and 0.3in seems to be the lowest safe option. So, the base thickness is varied from 0.3in to 0.4in with step of 0.1in to get 2 variations. The vertical leg width is varied from 0.5in to 0.8in with step of 0.06in to get 6 variations. Horizontal leg width varied from 0.4in to 0.6in with step of 0.1in to get 3 variations. Hypotenuse leg width varied from 0.2in to 0.3in with step of 0.05in to get 3 variations. Overall, the idea was to keep a smaller range and small step size to fine tune the optimal result.

   Final optimal result, base thickness is 0.3in, vertical leg width is 0.68in, horizontal leg width is 0.5in, hypotenuse leg width is 0.3in. Optimal mass being 3.35lb.

b. Variables & Results:

For fast results –

i. Variable table:



Total active scenarios: 256

Variables

Base thickness	Range with Step	Min: 0.3in	Max: 0.75in	Step: 0.15in
Vertical leg width	Range with Step	Min: 0.25in	Max: 1in	Step: 0.25in
Horizontal leg width	Range with Step	Min: 0.5in	Max: 1.25in	Step: 0.25in
Hypotenuse leg width	Range with Step	Min: 0.25in	Max: 1in	Step: 0.25in

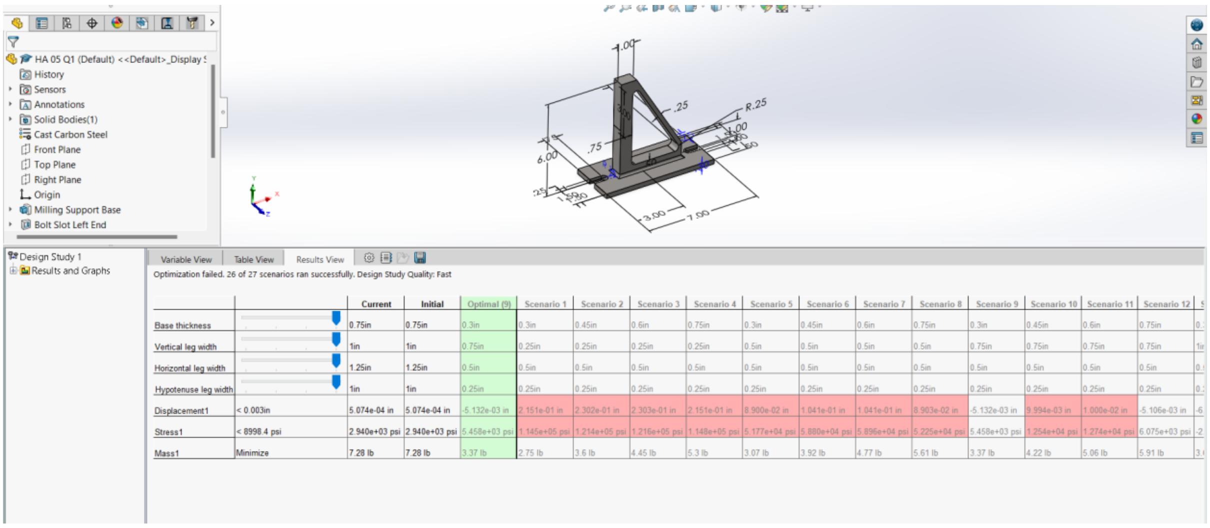
Constraints

Displacement1	is less than	Max: 0.003in	Clamp force
Stress1	is less than	Max: 8998.4 psi	Clamp force

Goals

Mass1	Minimize

ii. Results table:

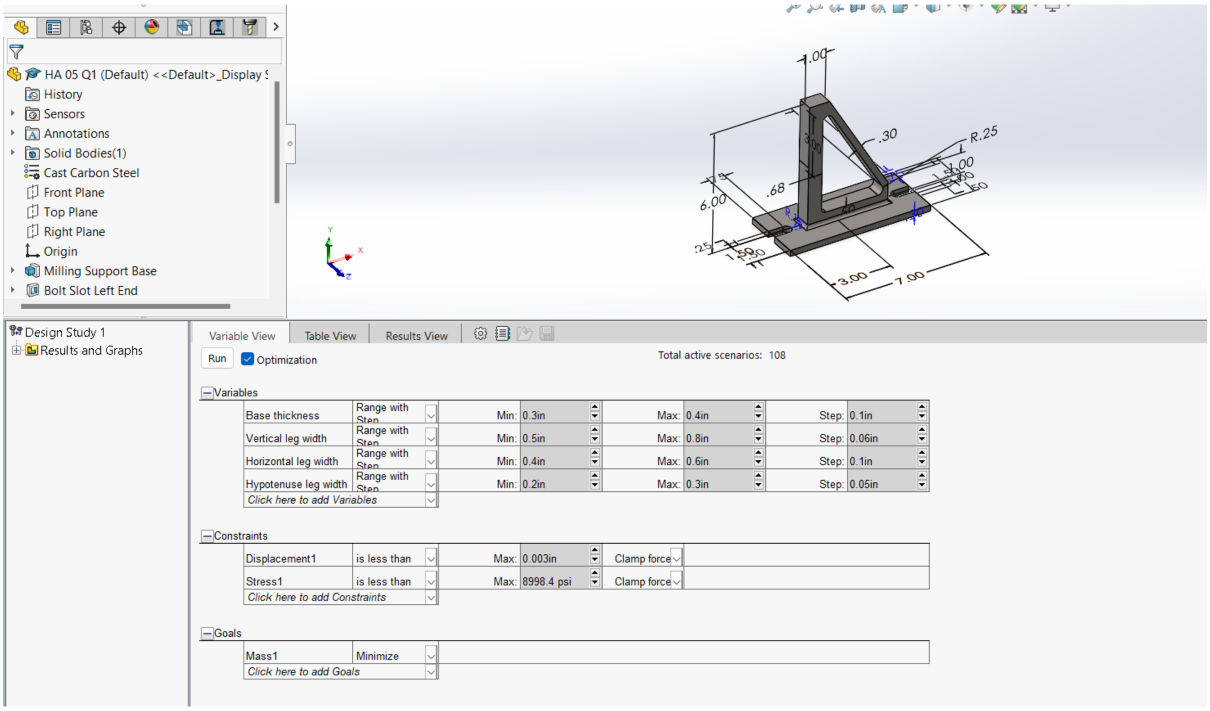


Optimization failed. 26 of 27 scenarios ran successfully. Design Study Quality: Fast

		Current	Initial	Optimal (9)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
Base thickness		0.75in	0.75in	0.3in	0.3in	0.45in	0.6in	0.75in	0.3in	0.45in	0.6in	0.75in	0.3in	0.45in	0.6in	0.75in
Vertical leg width		1in	1in	0.75in	0.25in	0.25in	0.25in	0.25in	0.5in	0.5in	0.5in	0.5in	0.75in	0.75in	0.75in	0.75in
Horizontal leg width		1.25in	1.25in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in	0.5in
Hypotenuse leg width		1in	1in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in
Displacement1	< 0.003in	5.074e-04 in	5.074e-04 in	-5.132e-03 in	2.151e-01 in	2.302e-01 in	2.303e-01 in	2.151e-01 in	8.900e-02 in	1.041e-01 in	1.041e-01 in	8.903e-02 in	-5.132e-03 in	9.994e-03 in	1.000e-02 in	-5.106e-03 in
Stress1	< 8998.4 psi	2.940e+03 psi	2.940e+03 psi	5.458e+03 psi	1.145e+05 psi	1.214e+05 psi	1.216e+05 psi	1.148e+05 psi	5.177e+04 psi	5.880e+04 psi	5.896e+04 psi	5.225e+04 psi	5.458e+03 psi	1.254e+04 psi	1.274e+04 psi	6.075e+03 psi
Mass1	Minimize	7.28 lb	7.28 lb	3.37 lb	2.75 lb	3.6 lb	4.45 lb	5.3 lb	3.07 lb	3.92 lb	4.77 lb	5.61 lb	3.37 lb	4.22 lb	5.06 lb	5.91 lb

For high-quality results –

iii. Variable table:



Variables

Base thickness	Range with Step	Min: 0.3in	Max: 0.4in	Step: 0.1in
Vertical leg width	Range with Step	Min: 0.5in	Max: 0.8in	Step: 0.06in
Horizontal leg width	Range with Step	Min: 0.4in	Max: 0.6in	Step: 0.1in
Hypotenuse leg width	Range with Step	Min: 0.2in	Max: 0.3in	Step: 0.05in
Click here to add Variables				

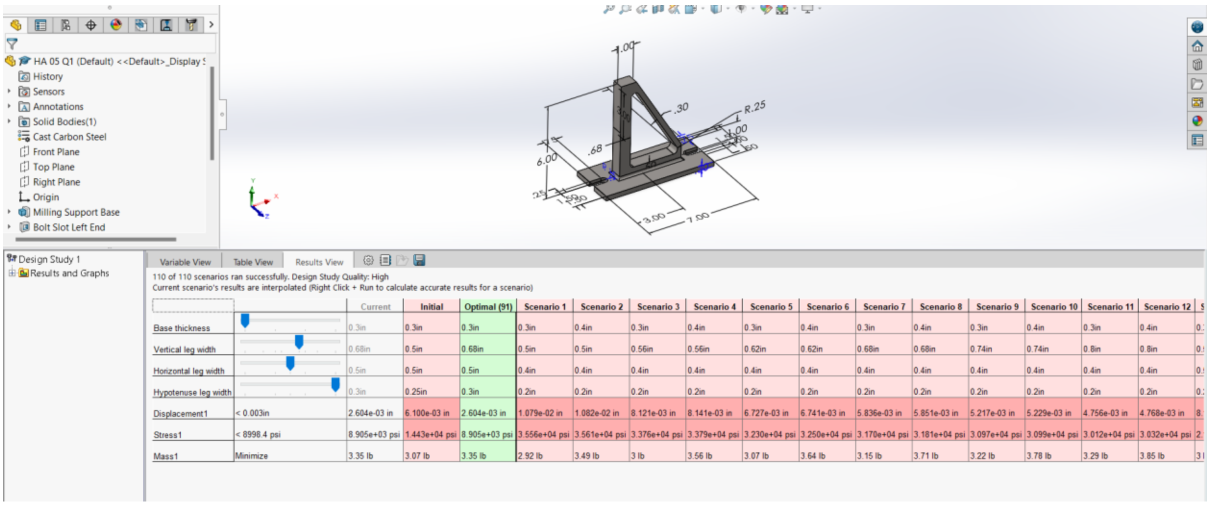
Constraints

Displacement1	is less than	Max: 0.003in	Clamp force
Stress1	is less than	Max: 8998.4 psi	Clamp force
Click here to add Constraints			

Goals

Mass1	Minimize
Click here to add Goals	

iv. Results table:

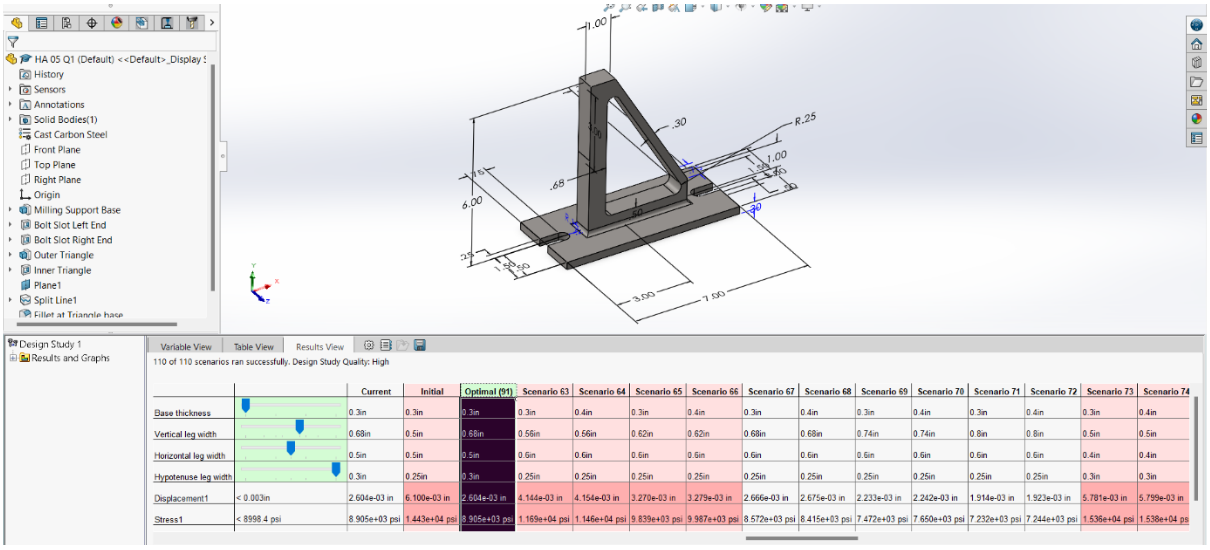


110 of 110 scenarios ran successfully. Design Study Quality: High
Current scenario's results are interpolated (Right Click + Run to calculate accurate results for a scenario)

		Current	Initial	Optimal (91)	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Base thickness		0.3in	0.3in	0.3in	0.3in	0.4in	0.3in	0.4in	0.3in	0.4in
Vertical leg width		0.68in	0.5in	0.68in	0.5in	0.5in	0.56in	0.56in	0.62in	0.62in
Horizontal leg width		0.5in	0.5in	0.5in	0.4in	0.4in	0.4in	0.4in	0.4in	0.4in
Hypotenuse leg width		0.3in	0.25in	0.3in	0.2in	0.2in	0.2in	0.2in	0.2in	0.2in
Displacement1	< 0.003in	2.604e-03 in	6.100e-03 in	2.604e-03 in	1.079e-02 in	1.082e-02 in	8.121e-03 in	8.141e-03 in	6.727e-03 in	6.741e-03 in
Stress1	< 8998.4 psi	8.905e+03 psi	1.443e+04 psi	8.905e+03 psi	3.556e+04 psi	3.561e+04 psi	3.376e+04 psi	3.379e+04 psi	3.230e+04 psi	3.250e+04 psi
Mass1	Minimize	3.35 lb	3.07 lb	3.35 lb	2.92 lb	3.49 lb	3 lb	3.56 lb	3.07 lb	3.64 lb

	Scenario 7	Scenario 8	Scenario 9	Scenario 10	Scenario 11	Scenario 12
Base thickness	0.3in	0.4in	0.3in	0.4in	0.3in	0.4in
Vertical leg width	0.68in	0.68in	0.74in	0.74in	0.8in	0.8in
Horizontal leg width	0.4in	0.4in	0.4in	0.4in	0.4in	0.4in
Hypotenuse leg width	0.2in	0.2in	0.2in	0.2in	0.2in	0.2in
Displacement1	5.836e-03 in	5.851e-03 in	5.217e-03 in	5.229e-03 in	4.756e-03 in	4.768e-03 in
Stress1	3.170e+04 psi	3.181e+04 psi	3.097e+04 psi	3.099e+04 psi	3.012e+04 psi	3.032e+04 psi
Mass1	3.15 lb	3.71 lb	3.22 lb	3.78 lb	3.29 lb	3.85 lb

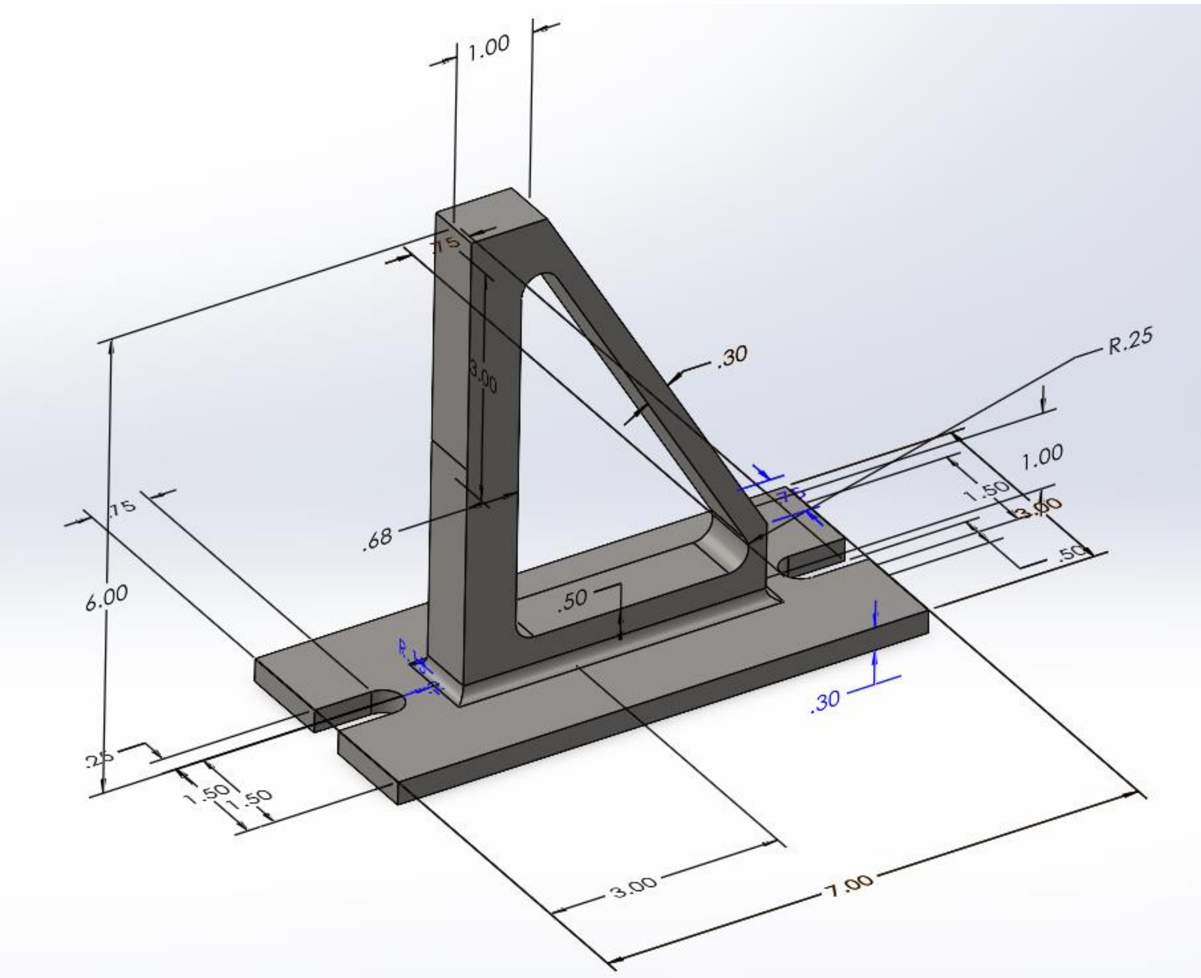
c. Optimal design after high-quality results:



110 of 110 scenarios ran successfully. Design Study Quality: High

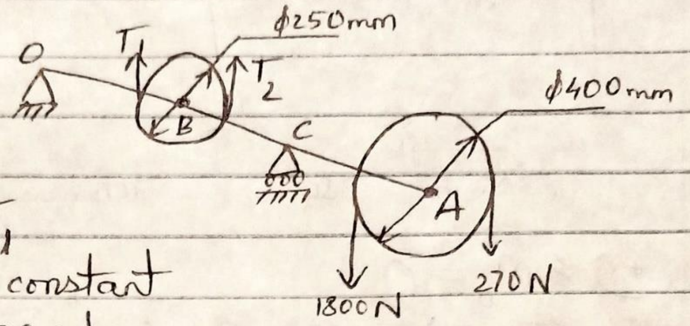
		Current	Initial	Optimal (91)	Scenario 63	Scenario 64	Scenario 65	Scenario 66	Scenario 67	Scenario 68	Scenario 69	Scenario 70	Scenario 71	Scenario 72	Scenario 73	Scenario 74
Base thickness		0.3in	0.3in	0.3in	0.3in	0.4in	0.3in	0.4in	0.3in	0.4in	0.3in	0.4in	0.3in	0.4in	0.3in	0.4in
Vertical leg width		0.68in	0.5in	0.68in	0.56in	0.56in	0.62in	0.62in	0.68in	0.68in	0.74in	0.74in	0.8in	0.8in	0.5in	0.5in
Horizontal leg width		0.5in	0.5in	0.5in	0.6in	0.6in	0.6in	0.6in	0.6in	0.6in	0.6in	0.6in	0.6in	0.6in	0.4in	0.4in
Hypotenuse leg width		0.3in	0.25in	0.3in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.25in	0.3in	0.3in
Displacement1	< 0.003in	2.604e-03 in	6.100e-03 in	2.604e-03 in	4.144e-03 in	4.154e-03 in	3.270e-03 in	3.279e-03 in	2.666e-03 in	2.675e-03 in	2.233e-03 in	2.242e-03 in	1.914e-03 in	1.923e-03 in	5.781e-03 in	5.799e-03 in
Stress1	< 8998.4 psi	8.905e+03 psi	1.443e+04 psi	8.905e+03 psi	1.169e+04 psi	1.146e+04 psi	9.839e+03 psi	9.987e+03 psi	8.572e+03 psi	8.415e+03 psi	7.472e+03 psi	7.650e+03 psi	7.232e+03 psi	7.244e+03 psi	1.536e+04 psi	1.538e+04 ps

CAD model with optimal dimensions shown below:



Problem 2: A countershaft carrying two V-belt pulleys:

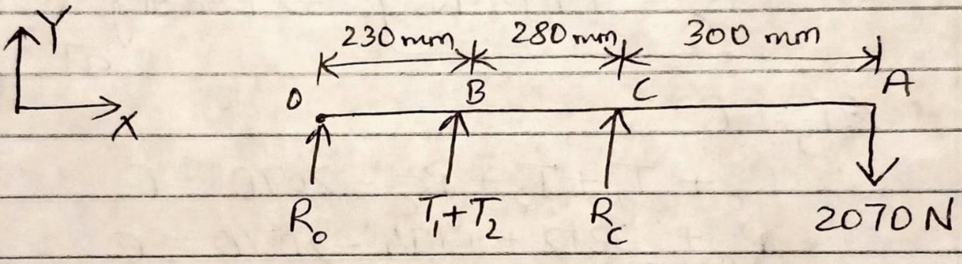
Q.2.



Given:

$T_2 = 0.15 T_1$

Shaft at constant speed



a. Torque at A = Torque at B

$$(1800-270)\times \frac{400}{2} = (T_1 - T_2)\times \frac{250}{2}$$

$$\therefore \frac{1530 \times 400}{250} = T_1 - 0.15T_1 = 0.85\,T_1$$

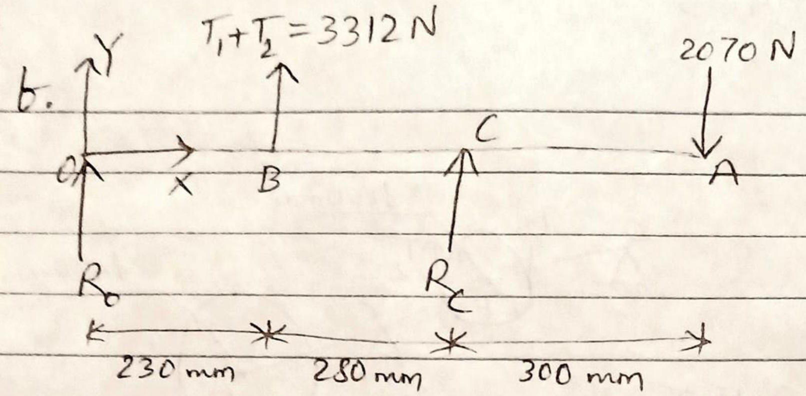
$$\therefore \boxed{T_1 = \cancel{280}\ 2880\ N}$$

$$T_2 = 0.15\,T_1$$

$$\therefore \boxed{T_2 = 432\ N}$$

Tensions in belt on pulley B

b.



$+\circlearrowleft \Sigma M_O = 0$

$\therefore (T_1+T_2)\times 230 + R_C \times (230+280) - 2070 \times (230+280+300) = 0$

$\therefore 3312 \times 230 + R_C \times 510 - 2070 \times 810 = 0$

$\therefore \boxed{R_C = 1794 \text{ N}} \Rightarrow$ Bearing reaction force at C.

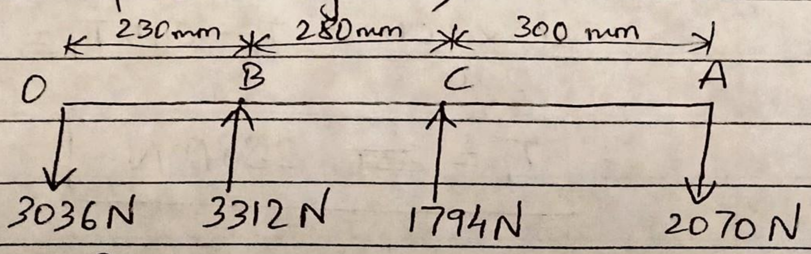
$\Sigma F_y = 0$

$\therefore R_O + T_1 + T_2 + R_C - 2070 = 0$

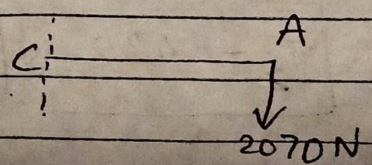
$\therefore R_O + 3312 + 1794 - 2070 = 0$

$\therefore \boxed{R_O = -3036 \text{ N}} \Rightarrow$ Bearing reaction force at O.

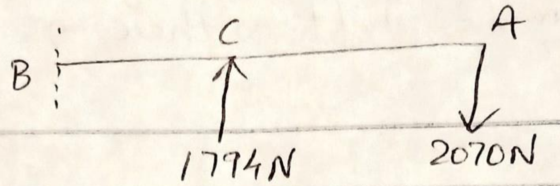
c. For force diagrams,



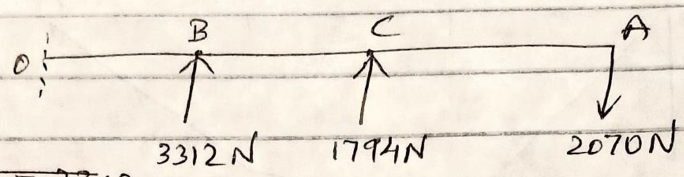
Shear force diagram,



$F_{SC} = -2070$ N

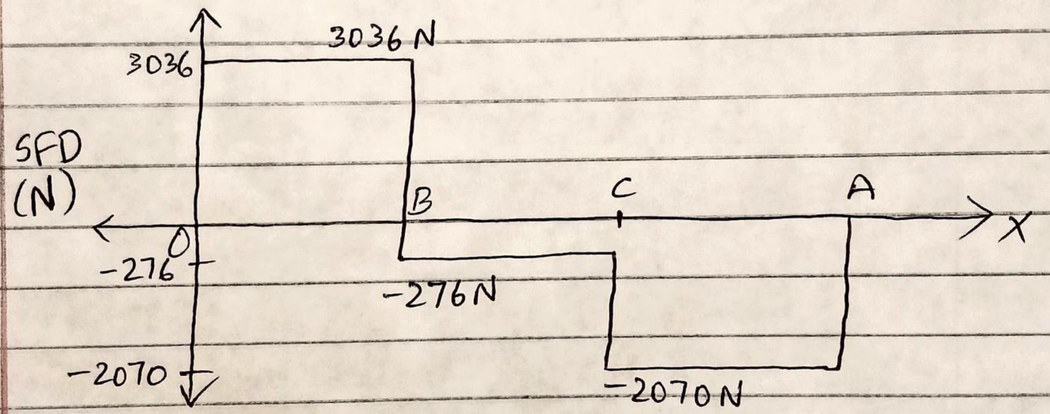


$$F_{SB} = 1794 - 2070 = -276 \text{ N}$$

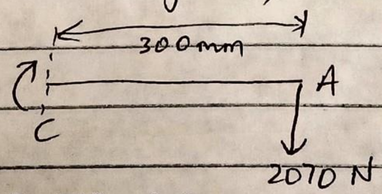


$\cancel{F_{SO} = 3312}$

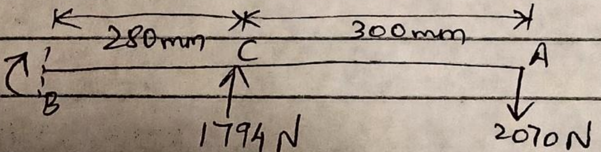
$$F_{SO} = 3312 + 1794 - 2070 = 3036 \text{ N}$$



Bending moment diagram,

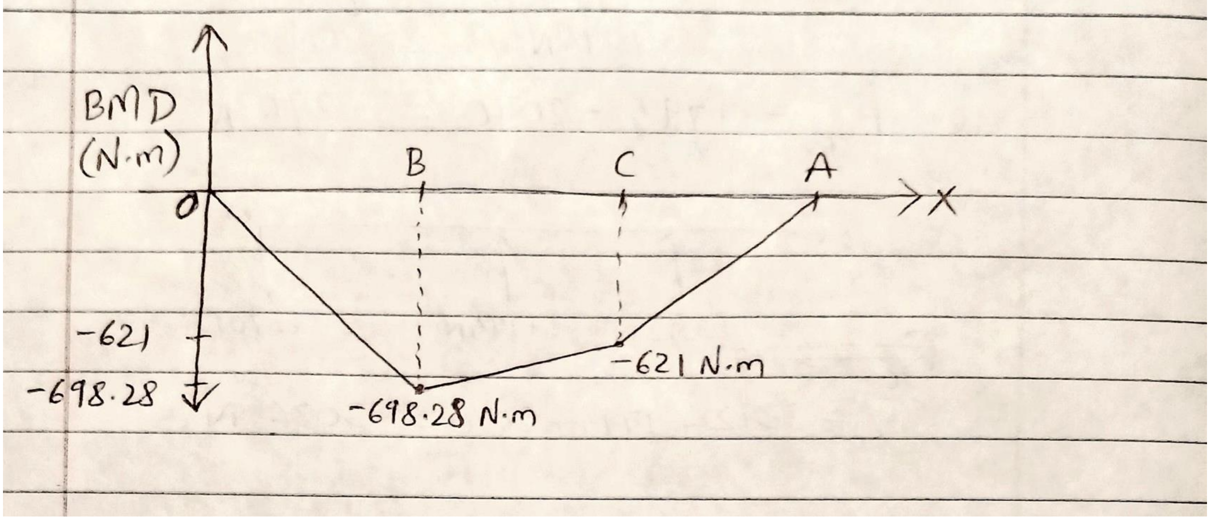


$$M_C = -2070 \times 0.3 = -621 \text{ N.m}$$



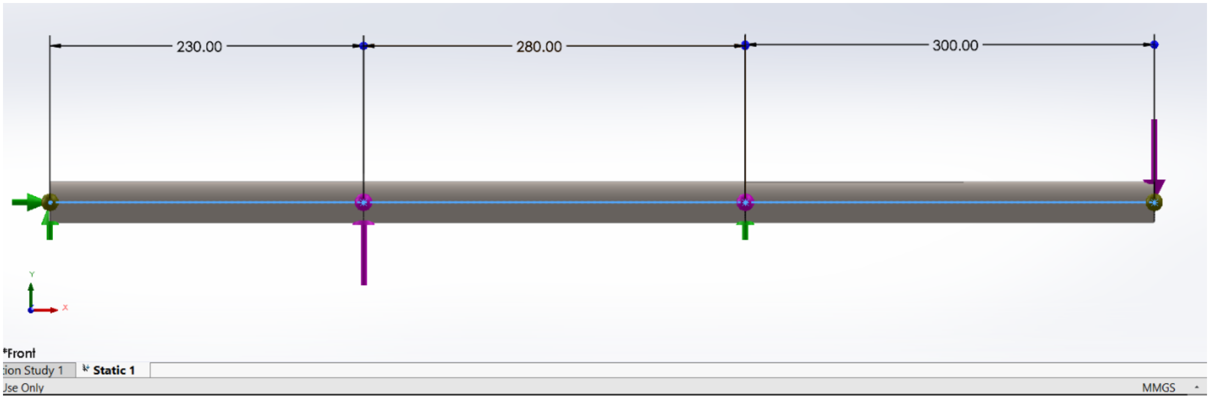
$$M_B = 1794 \times 0.28 - 2070 \times (0.28 + 0.3) = -698.28 \text{ Nm}$$

Bending force varies linearly between bearing & pulleys on the shaft as there are no other loads.

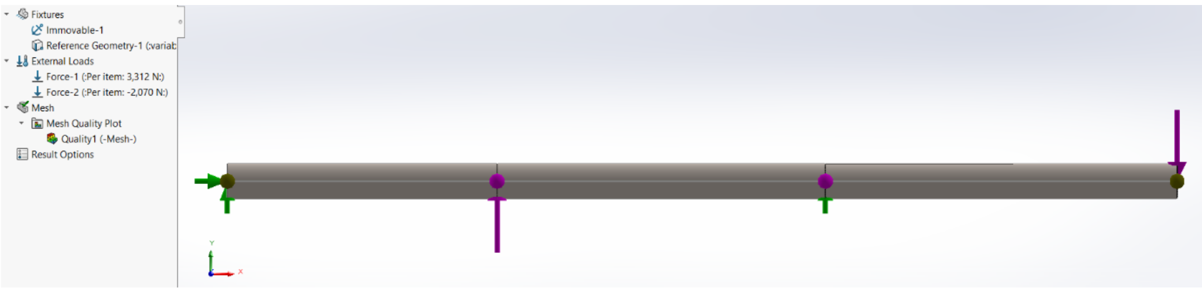


d. Model with boundary conditions:

Below model using weldment with boundary conditions:

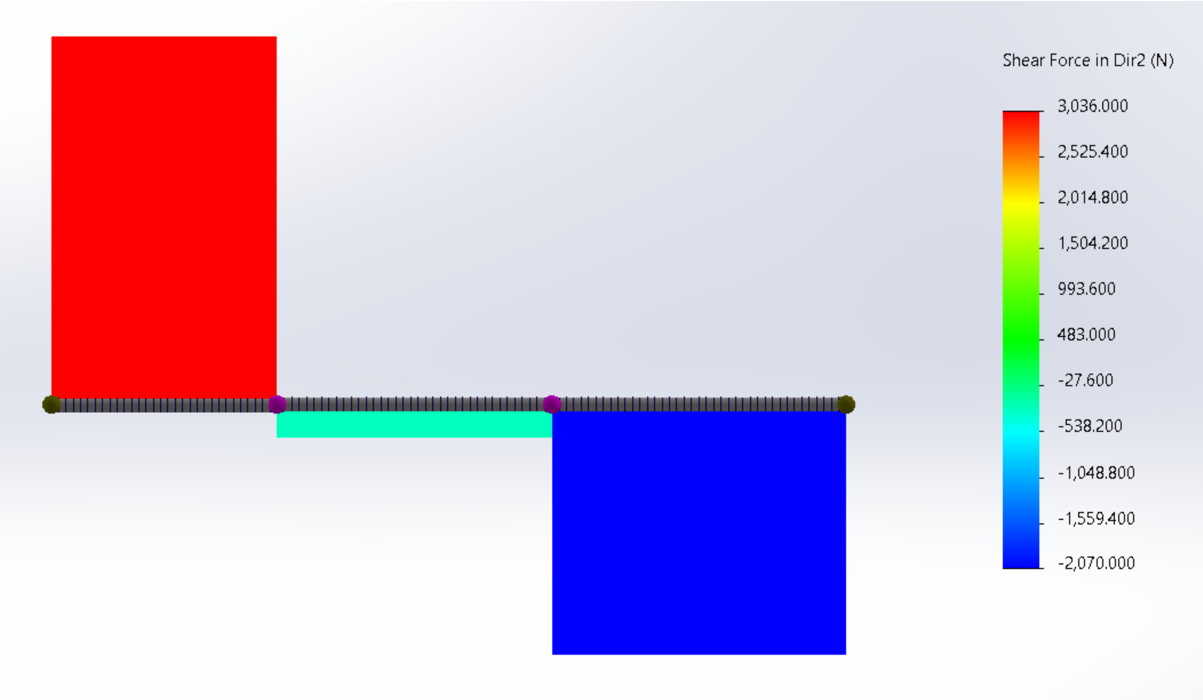


Below image shows the force values:

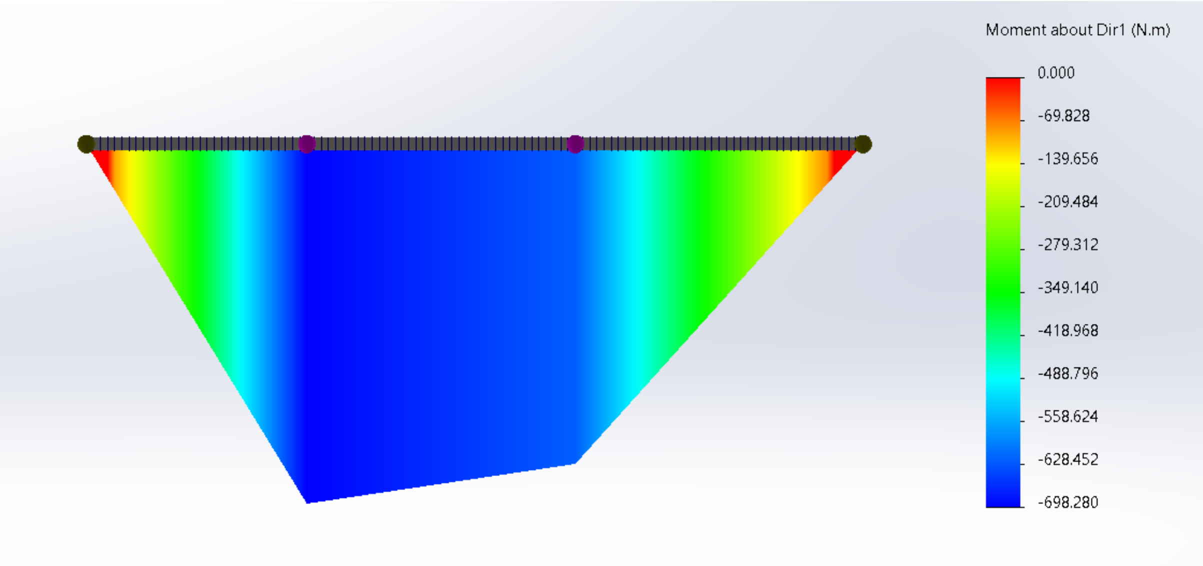


e. Plots from FEA:

Shear force diagram below:



Bending moment diagram below:



f. Comparing FEA with classical solution:

The FEA results and classical solutions completely match with **0% error**, both for the shear forces and the bending forces. Given below values for force:

Min. bending moment = 0 N.m & Max. bending moment = – 698.28 N.m.
Min. shear force = – 2070 N & Max. shear force = 3036 N.