Practice 1.1 Report

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1, The Task:

Design a road, that will connect the points 1 and 2 (in fig.1) and transfer the load P=105kN (105000N).

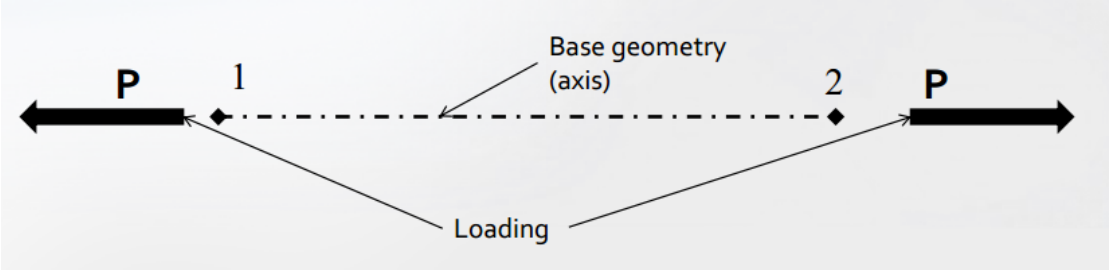

Fig. 1 Force analysis of the task

In this task, only consider cross-sectional area and material as independent variables, ignore the other factors (such as the shape). So, use L-shape for all variants.

Geometry: The cross-section all along the rod is constant.

Loads: Pure tension load P leads to constant internal axial load N in the rod.

Requirements: no additional requirements.

Three material are allowable: Aluminum alloy D16T, Steel 30ХГСА and Titanium alloy BT20. Their ultimate tensile strength and density are as followed:

Table 1 material parameters

Material	Ultimate tensile strength σ_B, MPa	Proof strength σ_{02}, MPa	Shear strength* τ_B, τ_{02} (% of tensile strength)	Modulus of elasticity E, GPa	Shear modulus G, GPa	Density, ρ g/cm^3
30ХГСА	1100	850	63	210	78	7,85
Д16Т	450	300	50	72	28	2,8
ВТ20	1000	910	50	110	44	4,5

2, Stress analysis

In pure tension case applied stresses are:

$$\sigma = \frac{N}{F}$$

where F is the area of the section.

In this task N=105000N.

Assessment of the solution is based on safety factor and weight of the structure. The safety factor:

$$\eta = \frac{[\sigma]}{\sigma}$$

where $[\sigma]$ is the ultimate tensile stress.

The weight of the length unit:

$$G = \rho * F$$

When $\eta \approx 1.1$ it is optimum safety factor, $\eta < 1.1$ is not satisfactory design, $\eta > 1.1$ is overdesign. So the aim of the task is to find an appropriate group of material and shape such that the $\eta \approx 1.1$ and the weight is as small as possible.

3, Variants design

Using L-shape for all the variants. Firstly, design some L-shape cross section with different area. The shapes and geometry parameters are as followed:

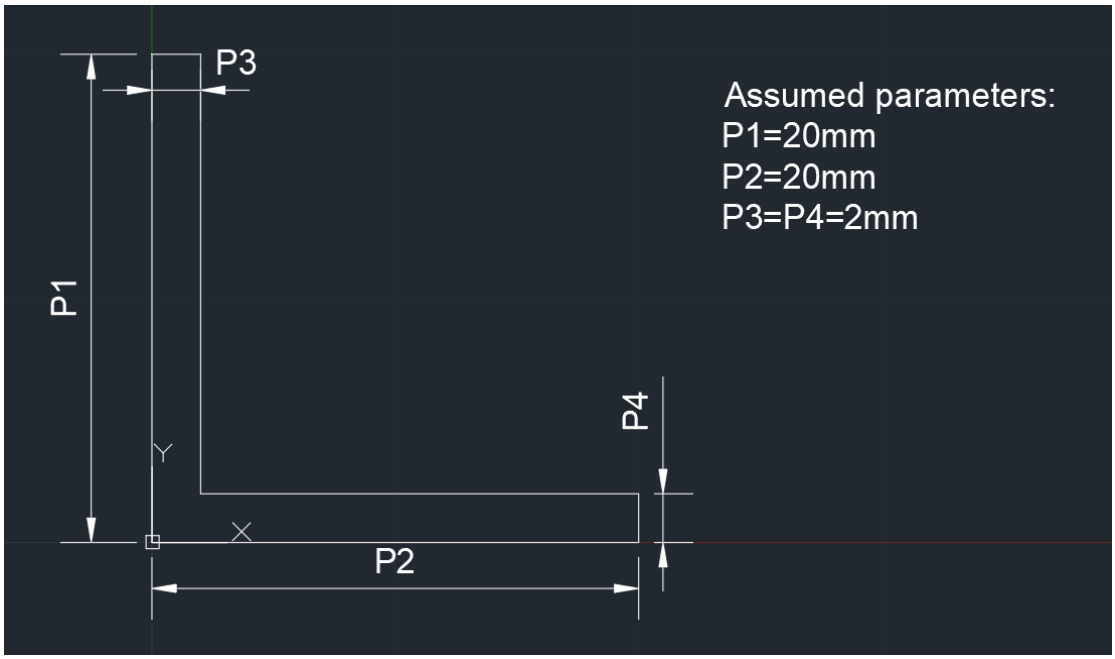

Fig. 2 L-shape 1

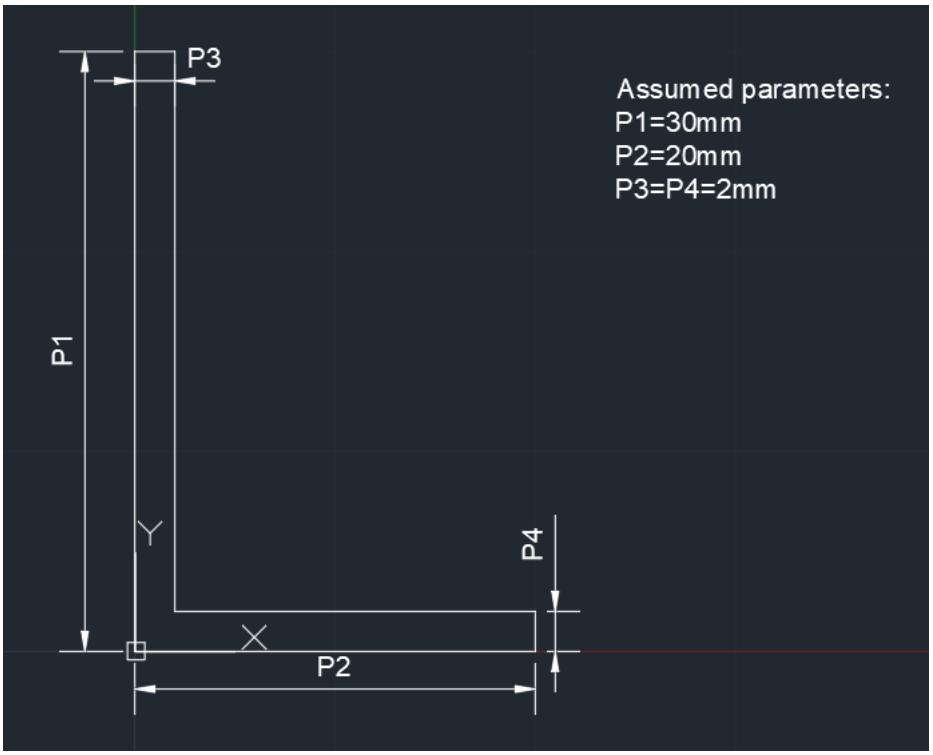

Fig. 3 L-shape 2

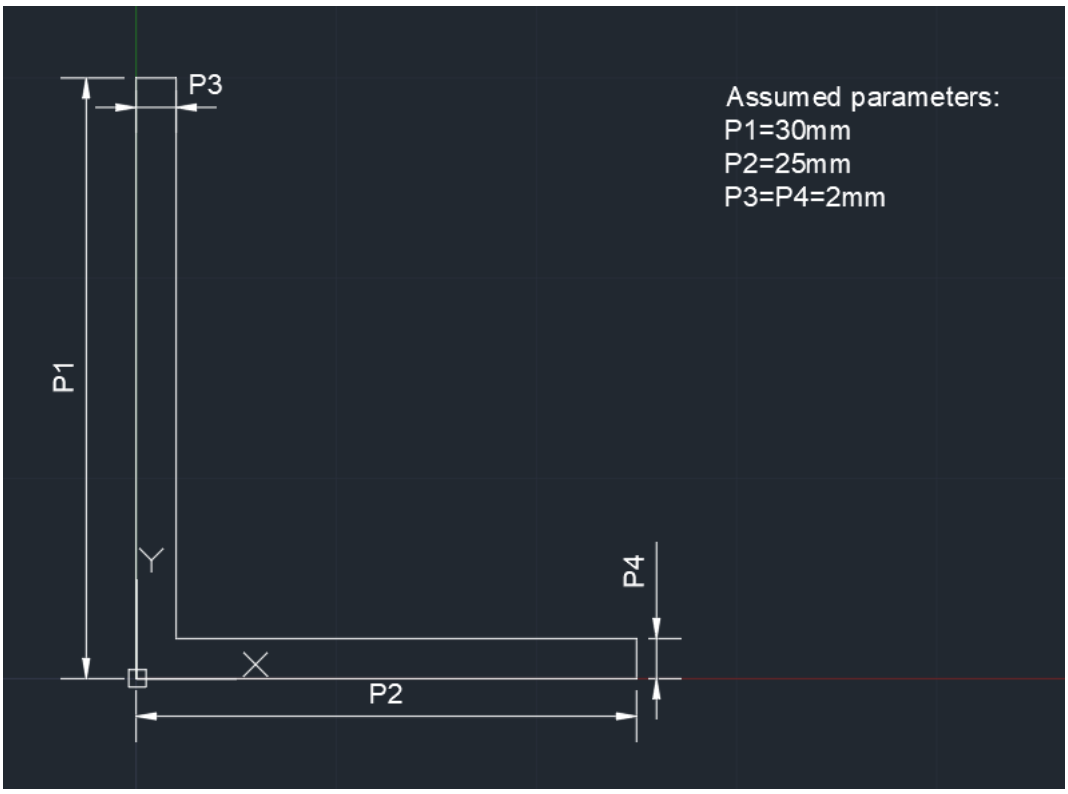

Fig. 4 L-shape 3

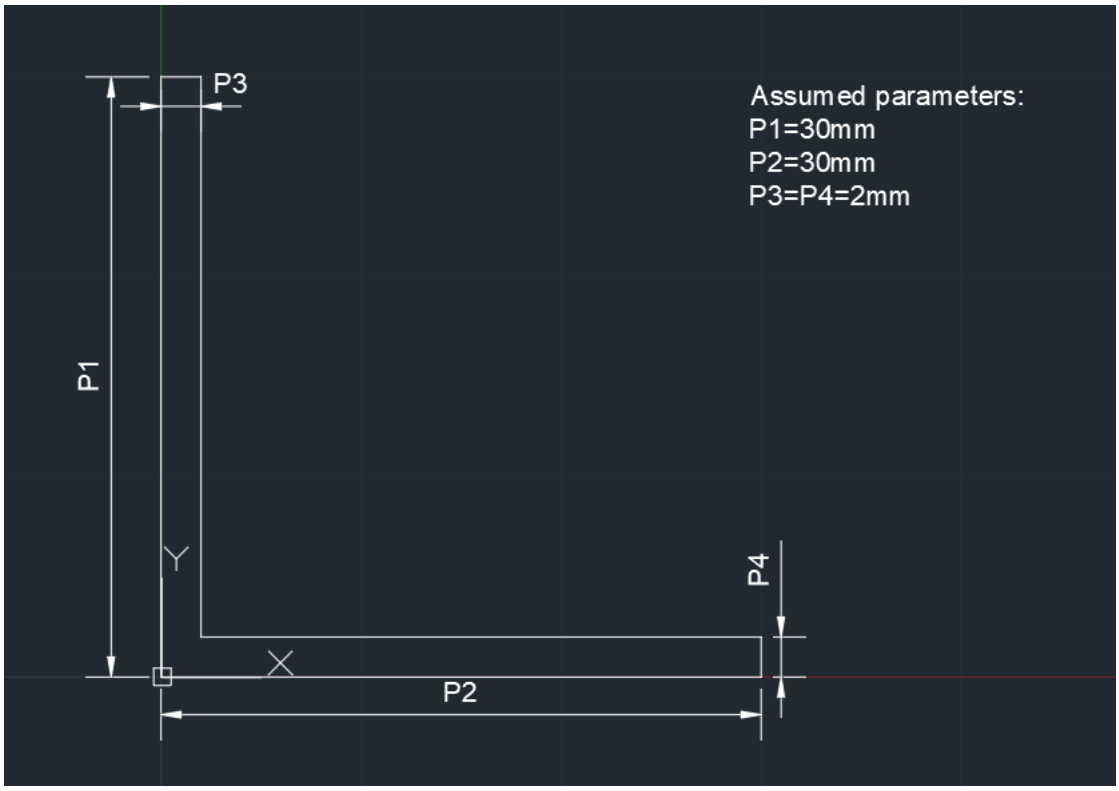

Fig. 5 L-shape 4

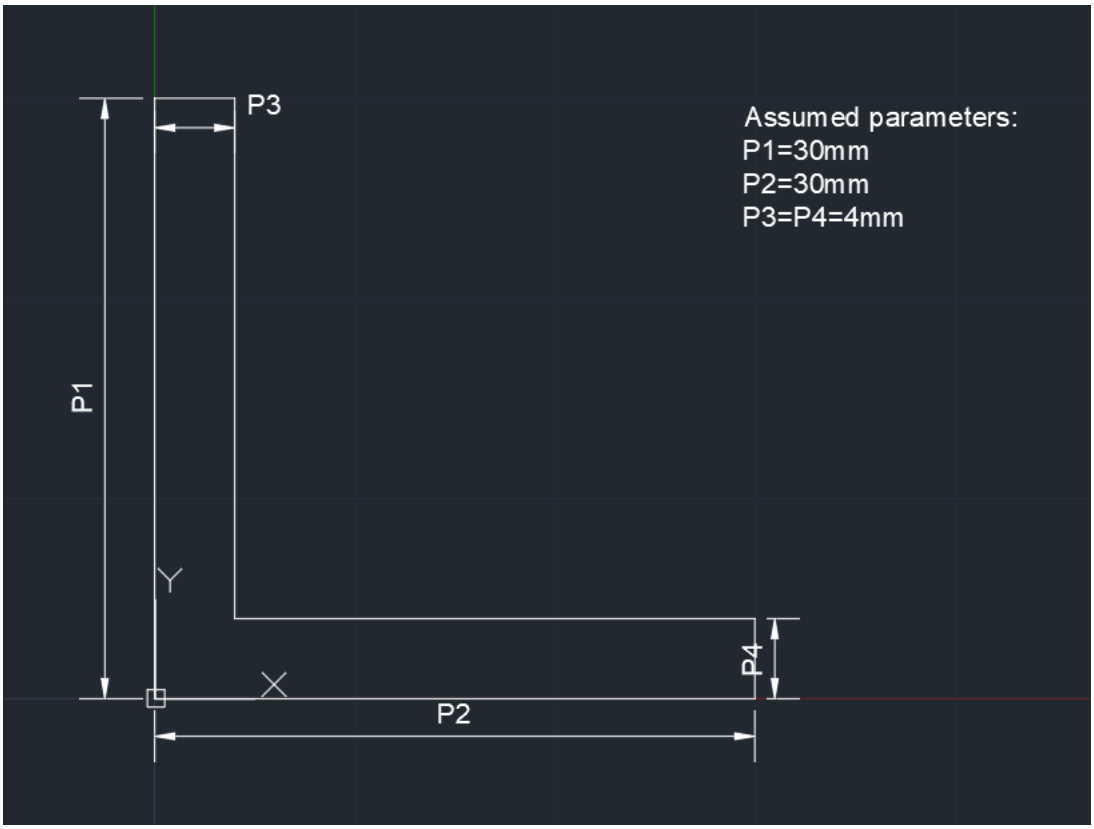

Fig. 6 L-shape 5

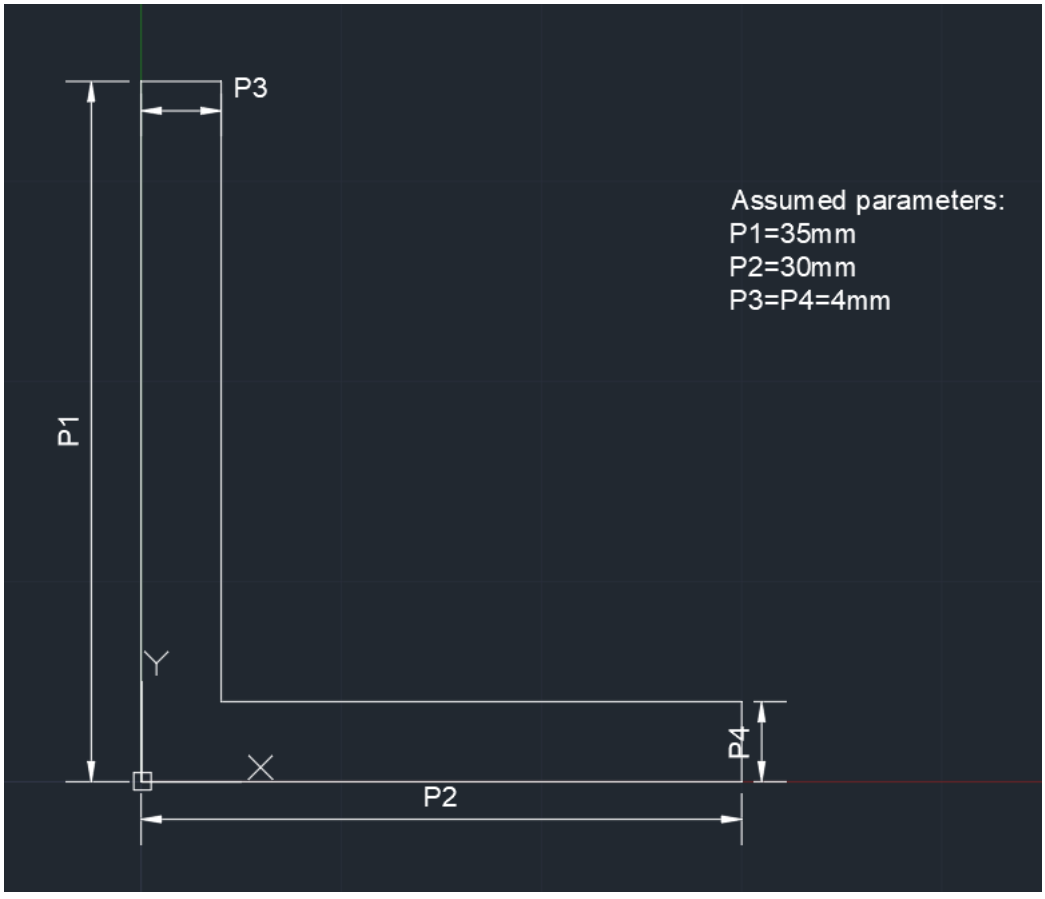

Fig. 7 L-shape 6

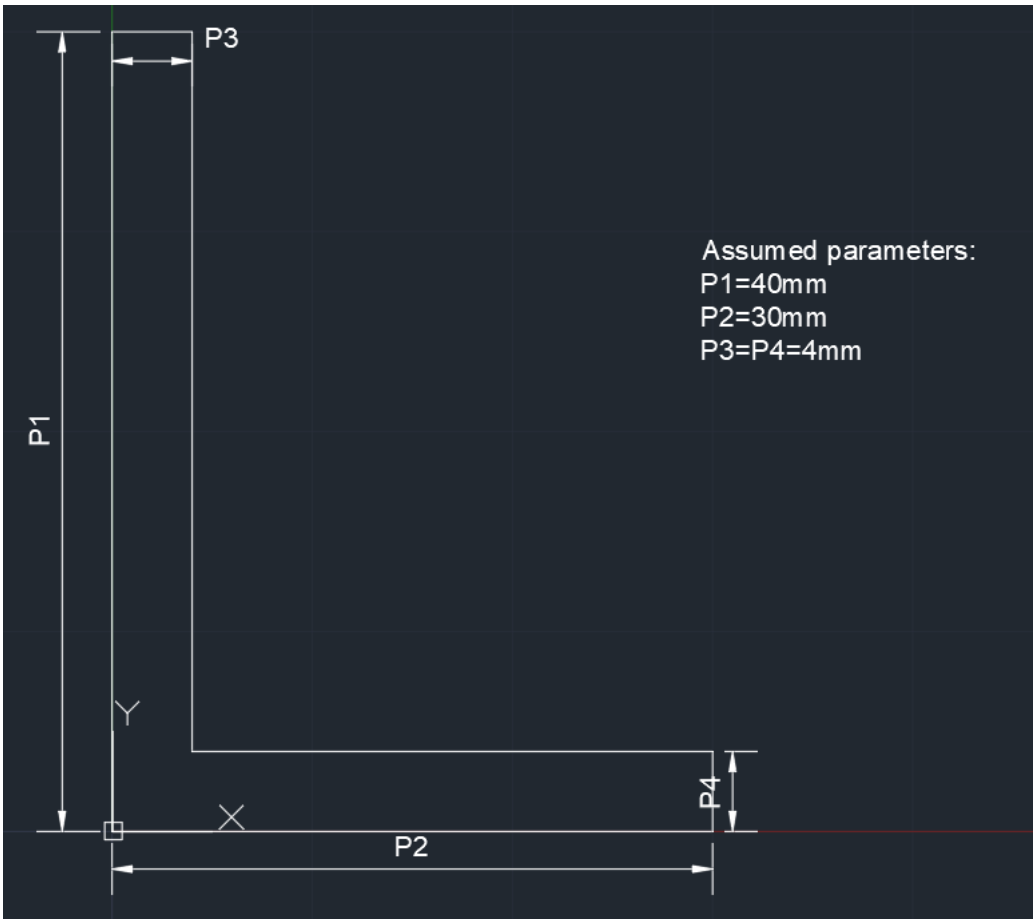

Fig. 8 L-shape 7

Then arrange the variants with different materials and shapes. Calculate the cross-sectional area, safety factor and weight.

The results are as followed:

Table 2 Results table

No.	Material	Shape	Section area, mm^2	Applied stress, MPA	Safety factor	Density, g/cm^3	Weight, kg/m
1	30ХГСА	L-shape 1	76	1381.6	0.79619	7.85	0.5966
2	30ХГСА	L-shape 2	96	1093.8	1.005714	7.85	0.7536
3	30ХГСА	L-shape 3	106	990.6	1.110476	7.85	0.8321
4	30ХГСА	L-shape 4	116	905.2	1.215238	7.85	0.9106
5	30ХГСА	L-shape 5	224	468.8	2.346667	7.85	1.7584
6	ВТ20	L-shape 1	76	1381.6	0.72381	4.5	0.342
7	ВТ20	L-shape 2	96	1093.8	0.914286	4.5	0.432
8	ВТ20	L-shape 3	106	990.6	1.009524	4.5	0.477
9	ВТ20	L-shape 4	116	905.2	1.104762	4.5	0.522
10	ВТ20	L-shape 5	224	468.8	2.133333	4.5	1.008
11	Д16Т	L-shape 4	116	905.2	0.497143	2.8	0.3248
12	Д16Т	L-shape 5	224	468.8	0.96	2.8	0.6272
13	Д16Т	L-shape 6	244	430.3	1.045714	2.8	0.6832
14	Д16Т	L-shape 7	264	397.7	1.131429	2.8	0.7392

Through the table can find that the variant No.9 is the ideal case, with area $116mm^2$, safety factor 1.104762 and weight 0.522kg/m.

4, The optimum variant

As we get the ideal area by calculation, the next step is to find the standard variant, which is chosen after standard higher value of area F of the optimum section $116mm^2$. As it has a higher area, the safety factor would not be smaller than the former one.

Check the table of the standard variant:

Table 3 Standard Variant Table

Rectangular Profile Angle Section made of Aluminium Alloys (inequal flanges) ГОСТ 13738 - 91												
No	Number of profile	H	B	S	S1	R	R1	R2	Cross-sectional Area, mm2	Veight, kg/r	Moment of Inertia, cm4	
		mm									Ix	Iy
1	410535	20,0	8,0	2,0	2,0	0,5	0,0	0,0	52.1	0,148	0,05	0,04
2	410517	16,0	13,0	1,6	1,6	1,6	0,8	0,8	44.1	0,126	0,15	0,13
3	410549	20,0	15,0	2,0	1,5	2,0	0,7	1,0	60	0,171	0,24	0,10
4	410596	25,0	18,0	2,5	2,0	2,5	1,0	1,2	94.3	0,269	0,59	0,22
5	410600	25,0	20,0	1,2	1,2	2,0	0,5	0,5	53.3	0,152	0,34	0,19
6	410640	30,0	18,0	3,0	2,5	3,0	1,2	1,5	128.6	0,367	1,16	0,28
7	410650	39,0	20,0	2,5	2,0	3,0	1,2	1,5	111.1	0,317	1,02	0,32
8	410661	30,0	25,0	3,0	2,5	3,0	1,2	1,5	146.1	0,416	1,31	0,75
9	410721	35,0	22,0	3,5	3,5	3,5	1,7	1,7	188.6	0,538	2,28	0,69
10	410765	38,0	25,0	6,0	3,0	4,0	0,0	0,0	288.4	0,822	4,18	0,95
11	410772	38,0	32,0	5,0	5,0	4,0	2,5	2,5	325.8	0,928	2,38	2,81
12	410809	40,0	25,0	4,0	3,0	4,0	1,5	2,0	225.1	0,642	3,66	0,94
13	410824	40,0	30,0	4,0	3,0	4,0	1,5	2,0	240.1	0,684	3,90	1,61

Through the table, can determine the final optimum variant and its geometry parameters.

Then draft the optimum section with dimensions:

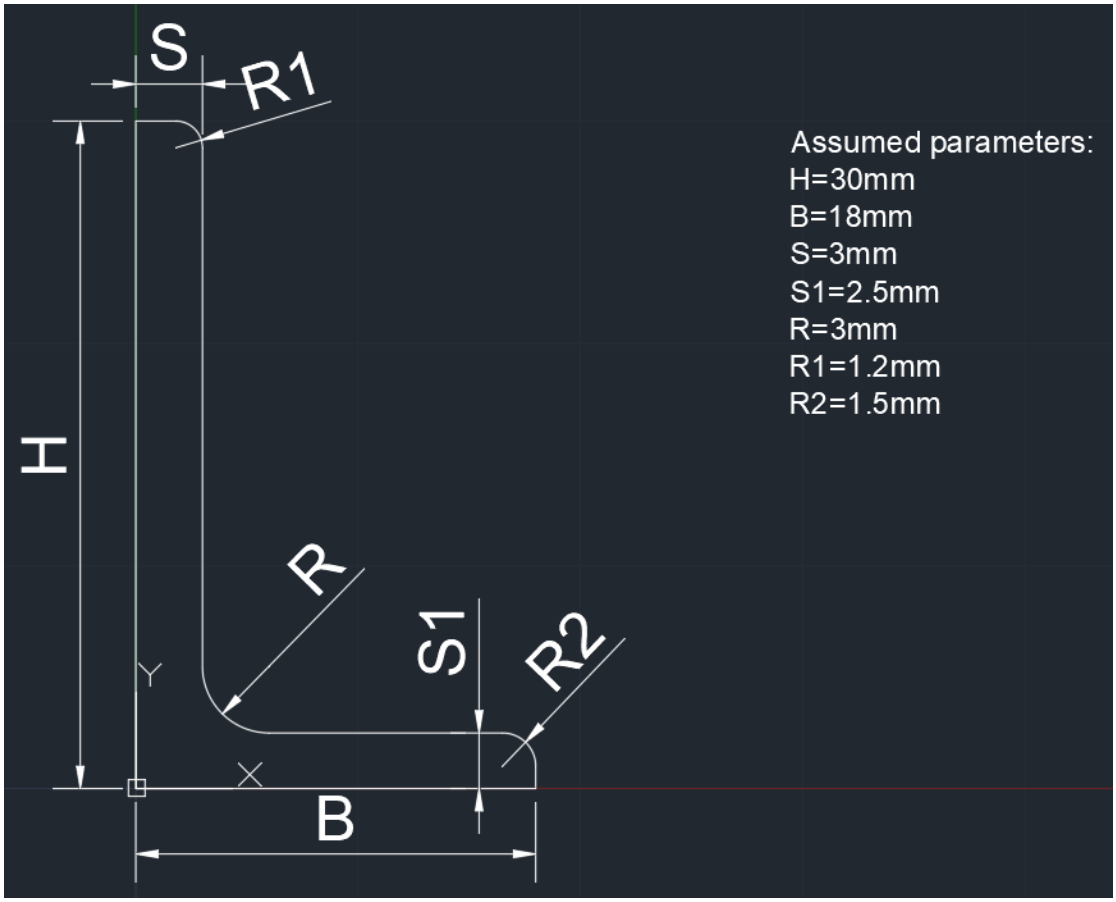

Fig. 9 L-shape 8 (optimum)

And calculate the final safety factor and weight for the optimum variant:

Table 4 The optimum variant

Material	Shape	Section area, mm^2	Applied stress, MPA	Safety factor	Density, g/cm^3	Weight, kg/m
BT20	L-shape 8	128.6395	816.2	1.225138	4.5	0.578878

In the conclusion, the optimum variant is made with material Titanium alloy BT20, and its safety factor is 1.225138, its weight is 0.578878kg/m. Its shape is as the L-shape 8 shown in Fig.9.