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DESIGN FRAME OF HEAD LOSS TESTING EQUIPMENT USING MATERIAL STRENGTH ANALYSIS METHOD

Abstract

Pipes are tools used to move fluids. In the application process there is a flow of losses that occur. The frame is the main part of the head loss testing equipment which functions to support the components of the head loss testing equipment such as pipes, valves, taps, connections, elbows, reducers and so on. -others. The frame used is a framework that is simple and strong in structure. This final manufacturing task was carried out for the purpose of designing and fabricating a frame for a head loss testing equipment at Mercu Buana University. Perform an analysis of the load received and the maximum load that the frame can withstand, and a sturdy frame to withstand the installation of Head loss testing equipment. The purpose of this design is to calculate the loading force, design the frame, and create a load design simulation on the frame design of the head loss testing equipment with solidworks 2017. The method used is the method of material strength analysis. The results obtained from this design are the first frame loading of 71.06 N, from the first frame set then 83.47 N from the 2nd frame set, 13 kg from the pump and 250 kg from the water in the tub. The results of the design of the frame obtained that the material used is ASTM A500 with a hollow size of 20 x 20 x 1.6 mm for the first frame, then hollow 35 x 35 x 1.6 mm for the second and third frames. The results of the loading design simulation on the frame design of the head loss testing equipment tool using Solidworks 2017 show that the safety factor value is 2 with the material strength analysis method, safe to use in the design frame of the head loss testing equipment.

Keywords: Head loss testing equipment, frame, ASTM A500, safety factor, solidworks 2017

1. Introduction

Piping systems as fluid distributors are very helpful in everyday life, because they are very efficient in distributing fluids to their destinations. In general, a simple single piping system or a very complex branched pipe system requires various kinds of connections such as filters, valves, taps, joints, bends (elbows), magnifiers or reducers (dampers), and so on. Disturbances or obstacles often occur and cannot be ignored in the flow using pipes, causing a loss of energy. For this reason, a tool is needed to test the flow of losses in pipe installations, namely using a head loss testing equipment [1].

In the head loss testing equipment, the load is supported by the frame, so that the frame must have greater strength than the load that occurs in the installation of the head loss testing equipment which has a tub. The design of the frame aims to determine the maximum point that the frame can withstand when loaded with the installation of a head loss testing equipment. From the formulation of the problem, a discussion has been obtained regarding the maximum load and bending moment received on the frame [2]. The frame construction must meet several requirements, which include being strong and sturdy, so that it is able to support the load of the installation of head loss testing equipment, along with other

equipment, without experiencing damage or deformation. The frame must be light, so that it does not overload the head loss testing equipment system, is able to withstand the maximum load, and has a balance [3]. The design of the frame, starting from determining the design of the frame, the materials used, taking into account the strength and balance of the frame [4]. Many methods are used in product or machine design, including the VDI 2221 method [5] [6], material strength analysis method [7], or software simulation [8] [9].

2. Experimental and Procedures

The experimental procedures are as follow :

a. Counting loads

Calculate the amount of load that occurs on the frame

b. Calculating the Magnitude of the Focus Reaction

From the results of the loading that occurs, then calculate the magnitude of the support reaction that occurs in the frame

c. Calculating the Magnitude of the Bending Moment

Calculate the value of the bending moment from the loading that occurs on the frame [10] [11]

d. Calculating Zcalculation

After obtaining the value of the bending moment, then the value of Zcalculation can be

determined by dividing the bending moment with the allowable stress [10]

e. Determine the value of $Z_{table} \geq Z_{calculation}$

Determine Z_{table} values based on Appendix 1 Dimensions and properties of hollow pieces [12] [13]

f. Obtain Hollow Section Dimensions

Get the dimensions of the hollow cross section from the previously determined Z_{table}

g. Design Simulation

Performing a design simulation of a head loss testing equipment framework using solidworks 2017 [14]

h. Results Analysis

Describes the results of the design analysis of existing problems, analysis of problems, and discussion of problems that arise as well as the final results of processing design data.

3. Results and Discussion

3.1 Frame sketch

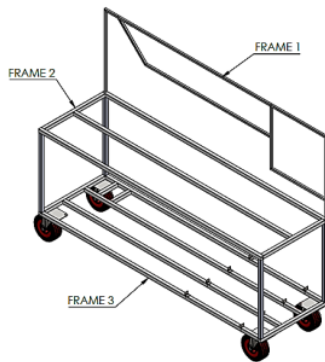


Fig. 1. frame design

3.2 Loading mass

3.2.1 mass per unit length of hollow

- Hollow 20 x 20 x 1,6 = 0,87 kg/m
- Hollow 35 x 35 x 1,6 = 1,63 kg/m

3.2.2 mass per unit length of pipe

- Galvanized Pipe (\varnothing 1") = 2,50 kg/m
- Stainless steel Pipe (\varnothing 1") = 1,30 kg/m

3.2.3 mass per unit length of pvc

- $M_{pvc} = 0,315$ kg/m

3.2.4 mass from the water bath

- $M_{bak} = \rho \cdot V_{bak}$
- $M_{bak} = 997 \cdot 0,25 = 249,25$ kg

3.2.5 mass of the component

- Pump = 13 kg
- Pressure gauge = 0,75 kg
- Tee = 0,105 kg
- Valve = 0,220 kg
- fountain = 0,650 kg
- Elbow = 0,070 kg
- Reducer = 0,110 kg

3.3 Frame 1

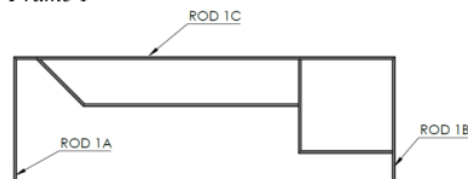


Fig. 2. Frame 1

a. sketch of vertical rod loading (1A & 1B)

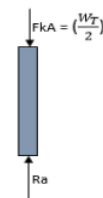


Fig. 3. sketch of vertical rods loading (1A & 1B)

Is known :

- $W_T = 7$ elbow + 8 tee + 1 gate valve + 2 ball valve + 2 x 1.5 inch pipe (0,13 m) + 2 x 1 inch pipe (0,42 m) + Water mass
- $W_T = 7 (0,07) + 8 (0,105) + 0,220 + 2 (0,650) + 2 (0,1) + 2 (0,132) + \pi \cdot 0,125^2 \cdot 58,2 \cdot 1,328 = 7,1060$ kg
- $\sigma_y = 315$ N/mm²

- $F_s = 2$

Answer:

- $F_k A = \left(\frac{7,1060}{2}\right) \cdot 10 = 35,53 \text{ N}$
- $\sigma_{\text{allowed}} = \frac{315}{2} = 157,5 \text{ N/mm}^2$

Hollow cross-sectional area calculation:

- $157,5 = \frac{35,53}{A_{\text{calculated}}}$
- $A_{\text{calculated}} = \frac{34,81}{157,5} = 0,2210 \text{ mm}^2$

So, the selected A_{table} is 102 mm^2 with a hollow size $20 \times 20 \times 1.6$ SHS (Square Hollow Section) from catalog of "Fourth Edition Cold Formed Structural Hollow Sections & Profiles" [13]

b. sketch of horizontal rod loading 1C

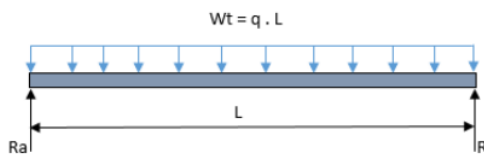


Fig. 4. sketch of horizontal rods loading

Is known :

- $W_T = 7,1060 \cdot 10 = 71,060 \text{ N}$
- $L = 2600 \text{ mm}$

Finding the bending stress value [15] [10]:

- $M = \frac{1}{8} \cdot W_T \cdot L$
- $M = \frac{1}{8} \cdot 71,060 \cdot 2600$
- $M = 23094,5 \text{ N.mm}$

Finding cross sectional modulus

$Z_{\text{calculated}}$:

- $Z_{\text{calculated}} = \frac{M}{\sigma_{\text{allowed}}}$
- $Z_{\text{calculated}} = \frac{23094,5}{157,5} = 146,6317 \text{ mm}^3$

So, the selected Z_{table} is $0,570 \times 10^3 \text{ mm}^3$ with a hollow size $20 \times 20 \times 1.6$ SHS (Square Hollow Section) from catalog of "Fourth Edition Cold Formed Structural Hollow Sections & Profiles".

3.4 Frame 2

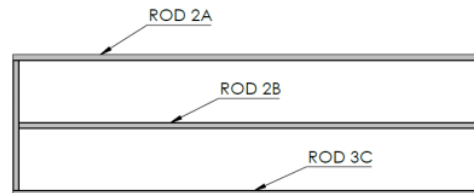


Fig. 5. Frame 2

a. sketch of horizontal rod loading 2A (pvc pipe)

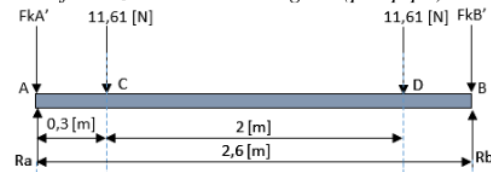


Fig. 6. sketch of horizontal rods loading

Is known :

- $q_{\text{pipe PVC}} = 0,00315 \text{ N/mm}$
- Volume of water in pipe = $\pi \cdot 0,125^2 \cdot 26 = 1,275 \text{ l}$
- Mass of water in pipe = $1,275 \cdot 1,328 = 1,6932 \text{ kg}$
- $L = 2000 \text{ mm}$
- $F_k A' = \frac{4,73 \text{ m} \cdot 0,87 \text{ kg/m} + 7,061 \text{ kg}}{2} \cdot 10 \text{ m/s}^2 = 55,876 \text{ N}$

Calculation step:

- $\Sigma M_b = 0$
- $R_a \cdot 2,6 - F_k A' \cdot 2,6 - 11,61 \cdot 0,3 - 11,61 \cdot 2,3 = 0$
- $R_a = 67,4830 \text{ N}$
- $\Sigma F_y = 0$
- $60,4830 + R_b = 11,61 + 11,61 + 55,876 + 55,876$
- $R_b = 67,4830 \text{ N}$
- $M_c = R_a \cdot 0,3 = 20,2449 \text{ N.m}$
- $M_d = R_b \cdot 0,3 = 20,2449 \text{ N.m}$

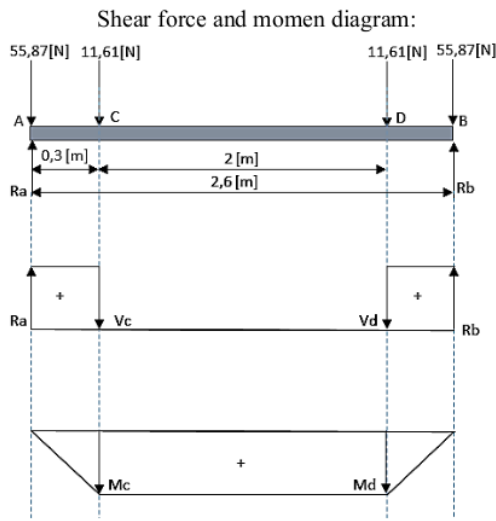


Fig. 7. shear force and momen diagram

Finding cross sectional modulus $Z_{\text{calculated}}$:

- $Z_{\text{calculated}} = \frac{20,2449 \times 10^3}{157,5} = 0,1285 \times 10^3 \text{ mm}^3$

So, the selected Z_{table} is $2.00 \times 10^3 \text{ mm}^3$ with a hollow size $35 \times 35 \times 1.6$ SHS (Square Hollow Section) from catalog of "Fourth Edition Cold Formed Structural Hollow Sections & Profiles"

b. sketch of horizontal rod loading 2B (galvanis pipe)

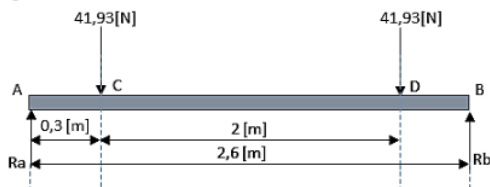


Fig. 8. sketch of horizontal rods loading

Is known :

- $q_{\text{pipe galvanis}} = 0,0250 \text{ N/mm}$
- Volume of water in pipe = $\pi \cdot 0,125^2 \cdot 2,6 = 1,275 \text{ l}$
- Mass of water in pipe = $1,275 \cdot 1,328 = 1,6932 \text{ kg}$
- $L = 2000 \text{ mm}$

calculation step:

- $\sum Mb = 0$
 $Ra \cdot 2,6 - 41,93 \cdot 0,3 - 41,93 \cdot 2,3 = 0$
 $Ra = 41,93 \text{ N}$
- $\sum Fy = 0$
 $Ra + Rb = 41,93 + 41,93$
 $Rb = 41,93 \text{ N}$
- $Mc = Ra \cdot 0,3 = 12,5796 \text{ N.m}$
- $Md = Rb \cdot 0,3 = 12,5796 \text{ N.m}$

Shear force and momen diagram:

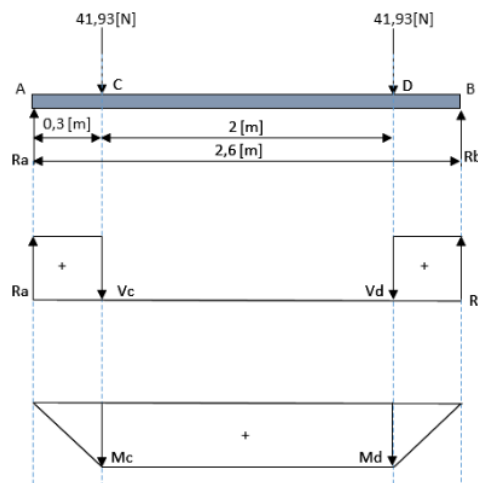


Fig. 9. shear force and momen diagram

- $Z_{\text{calculated}} = \frac{12,5796 \times 10^3}{157,5} = 0,0798 \times 10^3 \text{ mm}^3$

So, the selected Z_{table} is $2.00 \times 10^3 \text{ mm}^3$ with a hollow size $35 \times 35 \times 1.6$ SHS (Square Hollow Section) from catalog of "Fourth Edition Cold Formed Structural Hollow Sections & Profiles"

c. sketch of horizontal rod loading 2C (aluminium pipe)

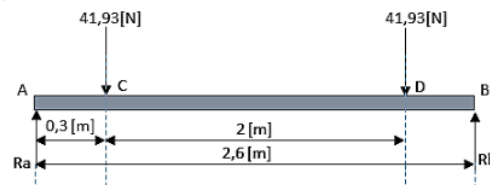


Fig. 10. sketch of horizontal rods loading

Is known :

- $q_{\text{pipe aluminium}} = 0,0130 \text{ N/mm}$
- Volume of water in pipe = $\pi \cdot 0,125^2 \cdot 2,6 = 1,275 \text{ l}$
- Mass of water in pipe = $1,275 \cdot 1,328 = 1,6932 \text{ kg}$
- $L = 2000 \text{ mm}$

calculation step:

- $\Sigma M_b = 0$
 $R_a \cdot 2,6 - 41,93 \cdot 0,3 - 41,93 \cdot 2,3 = 0$
 $R_a = 41,93 \text{ N}$
- $\Sigma F_y = 0$
 $R_a + R_b = 41,93 + 41,93$
 $R_b = 41,93 \text{ N}$
- $M_c = R_a \cdot 0,3 = 12,5796 \text{ N.m}$
- $M_d = R_b \cdot 0,3 = 12,5796 \text{ N.m}$

Shear force and momen diagram:

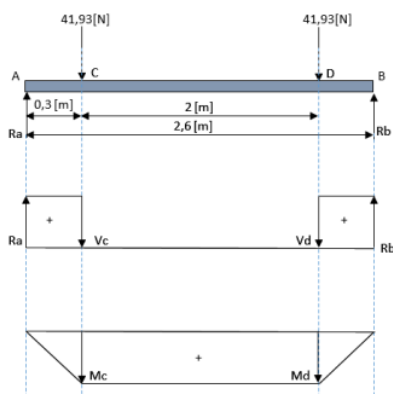


Fig. 11. shear force and momen diagram

Finding cross sectional modulus $Z_{\text{calculated}}$:

- $Z_{\text{calculated}} = \frac{12,5796 \times 10^3}{157,5} = 0,0798 \times 10^3 \text{ mm}^3$

So, the selected Z_{table} is $2,00 \times 10^3 \text{ mm}^3$ with a hollow size $35 \times 35 \times 1,6 \text{ SHS}$ (Square Hollow Section) from catalog of "Fourth Edition Cold Formed Structural Hollow Sections & Profiles"

e. sketch of vertical rod loading for frame 2

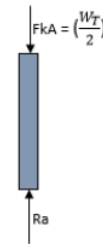


Fig. 12. sketch of vertical rods loading

Is known :

- $W_T = W_{\text{frame installation 1}} + W_{\text{pvc}} + W_{\text{galvanized}} + W_{\text{aluminum}} + W_{\text{frame 2}}$
- $W_T = 7,1060 \text{ kg} + 4,73 \text{ m} \cdot 0,87 \text{ kg/m} + 2,32 \text{ kg} + 8,33 \text{ kg} + 5,98 \text{ kg} + 1,63 \text{ kg/m} \cdot 9,4 \text{ m}$
- $W_T = 43,2001 \text{ kg}$
- $\sigma_y = 317 \text{ N/mm}^2$
- $F_s = 2$

Answer:

- $F_{kA} = \left(\frac{43,2001}{4}\right) \cdot 10 = 108 \text{ N}$
- $\sigma_{\text{allowed}} = \frac{315}{2} = 157,5 \text{ N/mm}^2$

Hollow cross-sectional area calculation:

- $157,5 = \frac{108}{A_{\text{calculated}}}$
- $A_{\text{calculated}} = \frac{108}{157,5} = 0,6857 \text{ mm}^2$

So, the selected A_{table} is 189 mm^2 with a hollow size $35 \times 35 \times 1,6 \text{ SHS}$ (Square Hollow Section) from catalog of "Fourth Edition Cold Formed Structural Hollow Sections & Profiles"

3.5 Frame 3

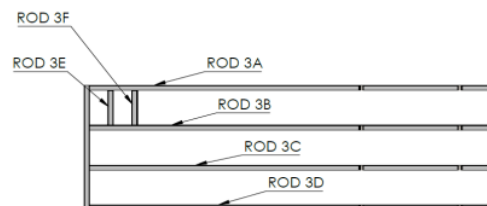


Fig. 13. Frame 3

a. sketch of horizontal rod loading

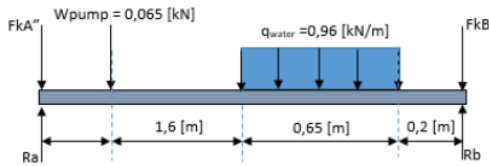


Fig. 14. sketch of horizontal distributed load rods

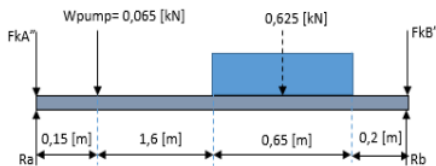


Fig. 15. sketch of horizontal concentrated load rods

Is known :

- $FkA'' = FkB''$

$$FkA'' = \frac{26,9515 [kg] + 1,63 [kg/m] \cdot 3,2 [m] \cdot 10 \left[\frac{m}{s^2} \right] \cdot 1000 \left[\frac{kN}{N} \right]}{4}$$

$$FkA'' = 0,080418 \text{ kN}$$

- $\Sigma M_A = 0$
 $R_b (2,6) - 0,625 (2,175) - 0,065 (0,15) - FkB'' (2,6) = 0$
 $R_b = 0,6069 \text{ kN}$

- $\Sigma F_y = 0$
 $R_a + 0,6069 - 0,065 - 0,625 - 0,080418 - 0,080418 = 0$
 $R_a = 0,2439 \text{ kN}$

Calculation step of section:

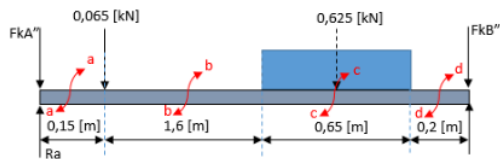


Fig. 16. sketch of horizontal rods with Election

1. Section a-a

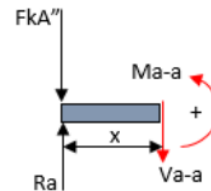


Fig. 17. section a-a

calculation step:

- $\Sigma F_y = 0$
 $R_a - FkA'' - V_{a-a} = 0$
 $V_{a-a} = R_a - FkA'' = 0,2439 - 0,080418 = 0,1634 \text{ kN}$
- $\Sigma M_a = 0$
 $M_{a-a} - V_{a-a} (x) = 0$
 $M_{a-a} = 0,1634 (x)$
 $(0 \leq x \leq 0,15) \text{ m}$
- $x = 0$; $M_{a-a} = 0,1634 (0) = 0$
- $x = 0,15$; $M_{a-a} = 0,1634 (0,15) = 0,02451 \text{ kN.m}$

2. Section b-b

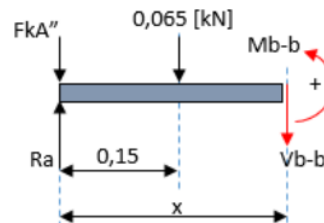


Fig. 18. section b-b

calculation step:

- $\Sigma F_y = 0$
 $R_a - FkA'' - V_{b-b} - 0,065 = 0$
 $V_{b-b} = 0,2439 - 0,080418 - 0,065$
 $V_{b-b} = 0,0984 \text{ kN}$
- $\Sigma M_a = 0$
 $M_{b-b} - V_{b-b} (x) - 0,065(0,15) = 0$
 $M_{b-b} = 0,0984 (x) + 0,00975$
 $(0,15 \leq x \leq 1,75) \text{ m}$
- $x = 0,15$; $M_{b-b} = 0,0984 (0,15) + 0,00975 = 0,02451 \text{ kN.m}$

- $x = 1,75$; $M_{b-b} = 0,0984 (1,75) + 0,00975 = 0,18195 \text{ kN.m}$

3. Sectionn c-c

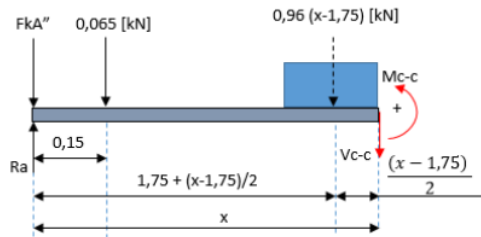


Fig. 19. section c-c

calculation step:

- $\Sigma F_y = 0$
 $R_a - F_{kA''} - V_{c-c} - 0,065 - 0,96 (x-1,75) = 0$
 $V_{c-c} = 0,0984 - 0,96 (x-1,75) = 0$
 $(1,75 \leq x \leq 2,4) \text{ m}$
- $x = 1,75$; $V_{c-c} = 0,0984 - 0,96 (1,75-1,75)$
 $x = 1,75$; $V_{c-c} = 0,0984 - 0,96 (0) = 0,0984 \text{ kN}$
- $x = 2,4$; $V_{c-c} = 0,0984 - 0,96 (2,4 - 1,75)$
 $x = 2,4$; $V_{c-c} = 0,0984 - 0,624 = - 0,5256 \text{ kN}$
- $\Sigma M_a = 0$
 $M_{c-c} - V_{c-c} (x) - 0,96(x-1,75) \left(1,75 + \frac{x-1,75}{2}\right) - 0,065 (0,15) = 0$
- $x = 1,75$; $M_{c-c} = (0,0984 - 0,96 (1,75-1,75)) (1,75) + 0,96 (1,75-1,75) \left(1,75 + \frac{1,75-1,75}{2}\right) + 0,00975$
 $M_{c-c} = (0,1722) + 0,96 (0) \left(1,75 + \frac{0}{2}\right) + 0,00975$
 $M_{c-c} = 0,18195 \text{ kN.m}$
- $x = 2,4$; $M_{c-c} = (0,0984 - 0,96 (2,4-1,75)) (2,4) + 0,96 (2,4-1,75) \left(1,75 + \frac{2,4-1,75}{2}\right) + 0,00975$
 $M_{c-c} = (0,0984 - 0,624) (2,4) + 0,96 (0,65) \left(1,75 + \frac{0,65}{2}\right) + 0,00975$
 $M_{c-c} = 0,04311 \text{ kN.m}$

Finding the value (x) for the Maximum Moment :

- $M_{c-c} = (0,0984 - 0,96 (x-1,75)) (x) + 0,96 (x-1,75) \left(1,75 + \frac{x-1,75}{2}\right) + 0,00975$
 $M_{c-c} = (- 0,48x^2 + 1,7784x - 1,46025)$
 $M_{c-c}' = (- 0,96x + 1,7784)$
 $0 = (- 0,96x + 1,7784)$
 $x = \frac{1,7784}{0,96} = 1,8525 \text{ m}$

Finding the Maximum Moment :

- $\Sigma M_a = 0$
 $x = 1,8525$; $M_{c-c} = (0,0984 - 0,96 (1,8525-1,75)) (1,8525) + 0,96 (1,8525-1,75) \left(1,75 + \frac{1,8525-1,75}{2}\right) + 0,00975$
 $x = 1,8525$; $M_{c-c} = 0,177243 + 0,00975 = 0,186993 \text{ kN.m} = 0,186993 \times 10^6 \text{ N.mm}$

4. Sectionn d-d

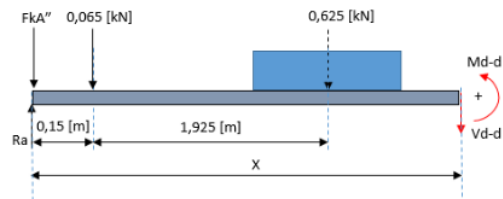


Fig. 20. section d-d

calculation step:

- $\Sigma F_y = 0$
 $R_a - F_{kA''} - 0,065 - 0,625 - V_{d-d} = 0$
 $V_{d-d} = - 0,5265 \text{ kN}$
- $\Sigma M_a = 0$
 $M_{d-d} - V_{d-d} (x) - 0,625 (0,15 + 1,925) - 0,065(0,15) = 0$
 $M_{d-d} = - 0,5265 (x) + 1,306625$
 $(2,4 \leq x \leq 2,6) \text{ m}$
- $x = 2,4$; $M_{d-d} = - 0,5265 (2,4) + 1,306625 = 0,0429 \text{ kN.m}$
- $x = 2,6$; $M_{d-d} = - 0,5265 (2,6) + 1,306625 = - 0,0622 \text{ kN.m}$

Shear force and momen diagram:

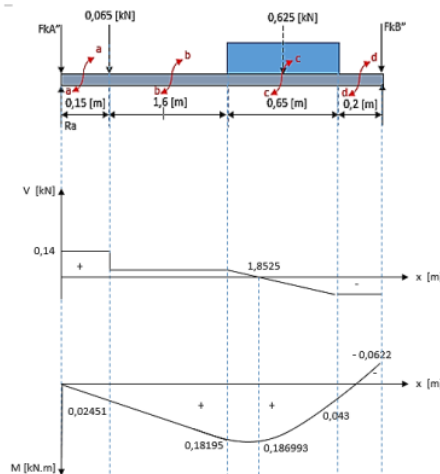


Fig. 21. shear Force and momen diagram

finding allowed stress strength:

$$\sigma_{\text{allowed}} = \frac{\sigma_y}{F_s}$$

$$\sigma_{\text{allowed}} = \frac{315}{2} = 157,5 \text{ N/mm}^2$$

finding cross sectional modulus $Z_{\text{calculated}}$:

$$\sigma_{\text{cal}} = \frac{M_{\text{max}}}{Z_{\text{cal}}} = \frac{186993}{157,5} = 1,187 \times 10^3 \text{ mm}^3$$

So, the selected Z_{table} is $2.00 \times 10^3 \text{ mm}^3$ with a hollow size 35 x 35 x 1.6 SHS from catalog of "Fourth Edition Cold Formed Structural Hollow Sections & Profiles"

3.6 Design Simulation

a. Frame design simulation on yield strength values

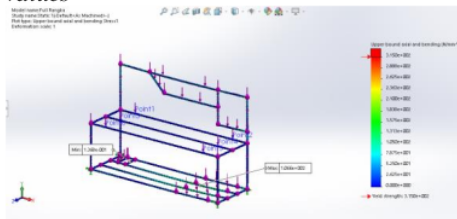


Fig. 22. Frame design simulation on yield strength values

The results of the loading simulation that occurs in the design of the frame for the yield strength as shown in fig. 22. obtained the minimum stress that occurs is 13.68 N/mm^2 on frame 3 with a hollow size of 35 x 35 x 1.6 mm SHS taking into account the proportionality with the size the outer diameter of the pipe being loaded, optimizing the use of hollows for 6 m/stem, and reducing variations in the use of hollow dimensions on the frame of the Head loss testing equipment, and the maximum stress is 106.6 N/mm^2 on frame 3 with a hollow size of 35 x 35 x 1.6 mm SHS.

b. Frame design simulation on the value of the factor of safety

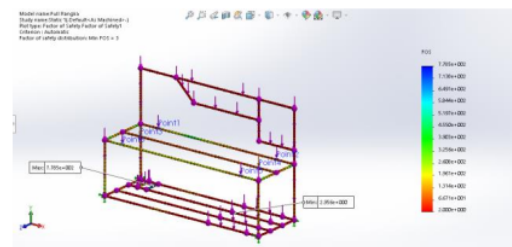


Fig. 23. Frame design simulation on the value of the factor of safety

The loading simulation results that occur in the design of the frame against the safety factor are shown in fig. 23.. obtained a minimum safety factor of 2.956 on frame 3 with a hollow size of 35 x 35 x 1.6 mm SHS, and a maximum safety factor of 7.785×10^2 on frame 3 with a hollow size of 35 x 35 x 1.6 mm taking into account proportionality with the size of the outer diameter of the pipe being loaded and optimizing the use of hollows for 6 m/stem, and reducing variations in the frame of the Head loss testing equipment.

3.6 Loading sketch for wheel

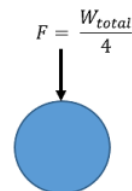


Fig. 24. loading sketch for wheel

Calculation Step:

$$\begin{aligned} W_T &= 4,11 \text{ kg} + 3,314 \text{ kg} + 15,32 \text{ kg} \\ &+ 10,63 \text{ kg} + 5,21 \text{ kg} + 20,26 \text{ kg} + \\ &13 \text{ kg} + 250 \text{ kg} \end{aligned}$$

$$W_T = 321,844 \text{ [kg]}$$

$$F \text{ on wheel} = \left(\frac{321,844}{4} \right) = 80,461 \text{ kg}$$

So, the selected wheel is a PU type with a size of 4" for a load of 100 kg from catalog of toko roda jaya [16].

3.6 Head loss testing equipment



Fig. 25. Head loss testing equipment

3.7 Research Finding

This research found that :

1. For the vertical rod loading, 1A & 1B, A_{table} is 102 mm^2 with hollow size $20 \times 20 \times 1.6$ SHS, and vertical rod loading frame 2, A_{table} is 189 mm^2 the proper hollow size $35 \times 35 \times 1.6$ SHS.
2. For the horizontal rod loading 1C, Z_{table} is $0,570 \times 10^3 \text{ mm}^3$ with hollow size $20 \times 20 \times 1.6$ SHS, and the horizontal rod loading 2A, Z_{table} is $2 \times 10^3 \text{ mm}^3$, rod loading 2B, Z_{table} is $2 \times 10^3 \text{ mm}^3$, rod loading 2C, Z_{table} is $2.00 \times 10^3 \text{ mm}^3$, rod loading frame 3, Z_{table} is $2.00 \times 10^3 \text{ mm}^3$, the proper hollow size $35 \times 35 \times 1.6$ SHS.
3. The results of the loading simulation obtained the minimum stress occurred on frame 3 i.e. : 13.68 N/mm^2 with the maximum stress is 106.6 N/mm^2
4. The loading simulation obtained a minimum safety factor of 2.956.

5. The load occurred on wheel is 80.461 kg and the selected wheel is a PU type with a size of 4" for a load of 100 kg.

4. Conclusions

From the results of the design of the head loss testing equipment tool it can be concluded that:

1. The design results have obtained the loading forces that occur on the frame of the Head loss testing equipment is 71.06 N from the first frame series. 11.61 N from 1 inc pvc pipe, 41.93 N from 1 inc galvanized pipe, 29.93 N from 1 inc aluminum pipe from The second frame, then 13 kg from 108 bit shimizu pump and 250 kg of water in sump.
2. The results of the design of the frame for the head loss testing equipment show that the material used is ASTM A500 with a hollow size of $20 \times 20 \times 1.6 \text{ mm}$ for the first frame, then a hollow of $35 \times 35 \times 1.6 \text{ mm}$ for the second and third frame.
3. The results of the loading design simulation on the frame design of the head loss testing equipment using Solidworks 2017 show that the safety factor value for dynamic loads is 2, it is safe to use in the design of the Head loss testing equipment frame.

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