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DESIGN OF FRAME FOR THE PUMP PERFORMANCE TEST EQUIPMENT USING VDI 2221 METHOD

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Abstract

Pumps in modern human life have become a major need, and their use is very wide, therefore pump learning is indispensable for mechanical engineering students. For pump performance learning media, pump performance test equipment (PPTE) is needed. The test equipment requires a strong frame and meets the requirements to be able to withstand the load, not only the equipment load but also the water weight used as the working fluid on the performance test equipment which is very large. This study aims to design a frame that can withstand the entire load of the PPTE. The design is done by calculating the load experienced by the frame when the test equipment is operated. The design of this pump performance test framework uses the VDI 2221 method, which includes several stages: task clarification, design concepts, concept embodiment, and design details. The results obtained from the use of the VDI 2221 method are variation 1, with a frame of 1000mm length, 1200mm width, and 1140mm height. The frame specifications using 4x4 hollow steel size with a thickness of 2mm and 4x6 size with a thickness of 3mm, and using a wheel type with a lock that can withstand the load. maximum up to 600kg.

Keyword: PPTE, Frame, VDDI 2221 Method

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1. Introduction

Water is a primary human need that must be met at all times. To be usable, the water needs to be moved from a low place (such as from the ground) to the top so that it can be utilized, for that a pump is needed. Therefore, the pump in modern human life has become a major necessity, and its use is very wide. One of the commonly used pumps is the centrifugal pump[1]. A centrifugal pump is a pump that utilizes the rotational speed of the impeller to increase the pressure in the fluid[2], so that water can be raised from a low place to a high place.

Along with the very high demand and very wide use, the problems caused by the pump are also increasingly diverse. Therefore, pump learning is very necessary for students, especially mechanical engineering students[1,2].

For pump performance learning media, PPTE has been created and designed. This tool requires a strong frame and meets the requirements to be able to withstand loads, not only the burden of the tool but also the weight of the water used as the working fluid on the test equipment. The frame is the most important part in the construction of a tool or vehicle because all the load will rest on this frame [3,4]. The frame is a structure in which all components of the test equipment consisting of a pump engine, water reservoir, pipes are added with a load of water weight as the working fluid[2].

This study aims to design a frame that can withstand the entire load of the Pump Performance Test Equipment (PPTE). A systematic design method is needed in the process of designing a product to fulfill several aspects such as convenience, practicality and ease of use, maintenance, repair, and security/safety. Likewise with the design of this frame, therefore the VDI 2221 method is used, which includes: task clarification, design concepts, concept embodiment, and design details. This method helps simplify the process of designing a product and facilitates the learning process for beginners and can optimize the productivity of designers to find the most optimal problem solving [2,5]. The design is done by calculating the load experienced by the frame when the test equipment is operated.

In previous studies, research has been carried out on PPTE. However, that research is only limited to testing the performance of centrifugal pumps but does not discuss the specifics of the frame design [2,6].

2. Experimental procedures

The research flow of "designing the frame of PPTE using the VDI 2221 method" is shown in Fig. 1. After literature study, the design of the frame was conducted using VDI 2221 method[7], which was followed by design calculations and selection of the

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specifications until meet the requirement. Then, the frame design drawings were made based on this.

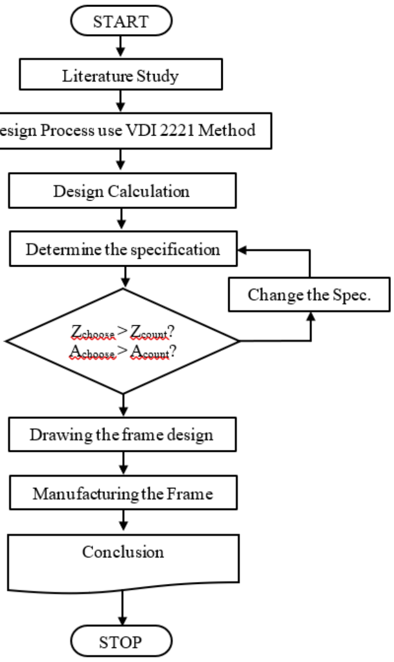


Fig. 1. Research flowchart

The systematic VDI 2221 design method is expected to make it easier for designers to master the design system without having to master it in detail. This method helps simplify the process of designing a product and can optimize designer productivity to find the most optimal problem solving [8-10].

3. Results and Discussion

From the results of the first stage of research is the process of designing and selecting variants on the frame of the PPTE. Then from the results of the planning, the design and frame of the PPTE will be carried out.

3.1. Design

The frame of this PPTE is made of hollow profile steel and is connected one part to another using welding techniques so that it gets maximum strength to support the load of the supporting equipment components and can dampen vibrations when the simulation tool is working.

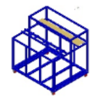
3.2. Solution Principles

The solution principles were to fulfill the main function. Solution principles are combined using a classification scheme. Due to space limitations, only the most important sub-functions of the solution principles are included. By looking for some of the solution principles, a combination of structure functions will be obtained, which in principle can carry out the sub-functions[6].

3.3. Solution Matrix

From the solution principles, it can be studied and described in matrix columns such as Table 1 as follows:

Table 1: Solution matrix

Sub Function \ Solution Principles		1	2	3
1	Frame	Frame 1 	Frame 2 	Frame 3 
2	Frame material	Hollow 	Stainless 	wood 
3	wheel	Wheel completed with lock 	Wheel without lock 	Plastic wheel with plate lock 

3.4. Module structured

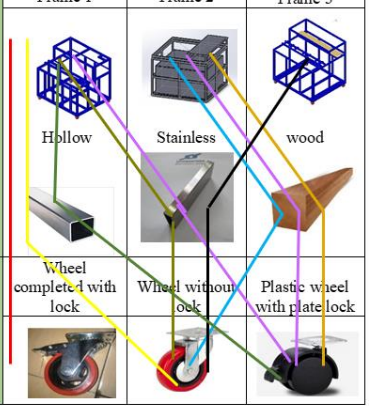
A system consisting of the basic parts of the basic form to form a work organ arrangement or is a regulator/compiler of several solution principles, so that it has alternative combinations which are then re-selected to be realized in the right choice.

3.5. Solution Principles Combination Diagram

Below are alternative combinations which are then selected again to be realized in finding the right choice as shown in Table 2 as follows:

Table 2: Combination of principal solution

Sub Function \ Solution Principles		1	2	3
1	Frame	Frame 1	Frame 2	Frame 3
2	Frame material	Hollow	Stainless	wood
3	wheel	Wheel completed with lock	Wheel without lock	Plastic wheel with plate lock



3.6. Solution Principles combination Alternative

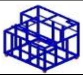
From Table 2, the solution principles combination diagram shows 2 kinds of variants as follows:

1. Variant 1 (red): 1.1 – 2.1 – 3.1
2. Variant 2 (yellow): 1.1 – 2.1 – 3.2
3. Variant 3 (green): 1.1 – 2.1 – 3.3
4. Variant 4 (purple): 1.1 – 2.2 – 3.1
5. Variant 5 (brown): 1.1 – 2.2 – 3.2
6. Variant 6 (pink): 1.1 – 2.2 – 3.3
7. Variant 7 (blue): 1.1 – 2.3 – 3.1
8. Variant 8 (black): 1.3 – 2.2 – 3.2
9. Variant 9 (Orange): 1.2 – 2.3 – 3.3

3.7. Variant Shape Concept

1. Variant 1 (red): 1.1 – 2.1 – 3.1, as shown in Table 3 below is a table of variants selected for frame creation.

Table 3: Variant 1

Sub Function \ Solution Principles		1	2	3
varian 1	Frame	Frame 1		
				
2	Material Frame	Hollow		
				
3	Wheel	Wheel with lock		
				

From the alternative combination of existing solution principles, It can be considered the following factors:

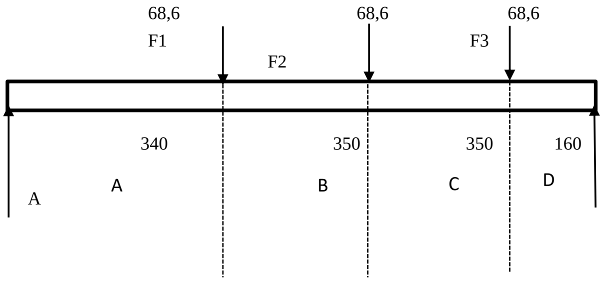
1. Availability of materials/materials.
2. Strength of the material.
3. Safety when operating
4. Ease of maintenance.
5. Meet the requirements of the wish list.

3.8. Calculation of rod and wheel selection

The calculation of the choice of variant aims to get the right rod specifications to be used based on the load it supports, because if the rod specifications are lacking then the frame is feared not to be strong enough to withstand the load.

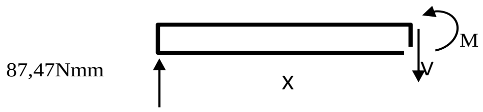
3.8.1. Calculation of rod 13 experiencing bending load

Rod 13 has a load of 3 pumps weighing 21 kg, rod 13 consists of 2 parallel rods, the load is assumed to be evenly distributed so that only 1 rod is analyzed.



ΣMA = 0 +
F1 (a) + F2 (a+b) + F3 (a+b+c) - B (a+b+c+d) = 0
68,6 x 340 x 68,6 x 340 +350 + 68,6 x 340 + 350 + 350 - B x 340 + 350 + 350 + 160 = 0
68,6 x 340 + 68,6 x 690 + 68,6 x 1040 - B x 1200 = 0
1200 B= 142.002 Nmm
B= 118,34 Nmm

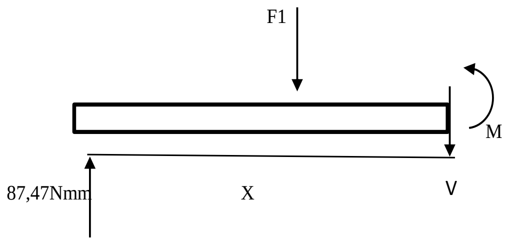
∑FY = 0
A – F1 – F2 – F3 + B = 0
A - 68, 6 - 68,6 - 68, 6 + B = 0
A - 68,6 - 68,6 - 68,6 + 118,34 = 0
A = 205,8 - 118,34 = 0
A = 87,47 Nmm



∑FY = 0
A - V = 0
87,47 – V =0 ↑
V = 87,47

∑MA= 0 +
V (X) - M =0
87,47X - M =0
M = 87,47 X
$0 \le X \le 340$
X= 0 mm → M= 0 N/mm
X= 340 mm → M= 29.738,1 N/mm

Left B Section



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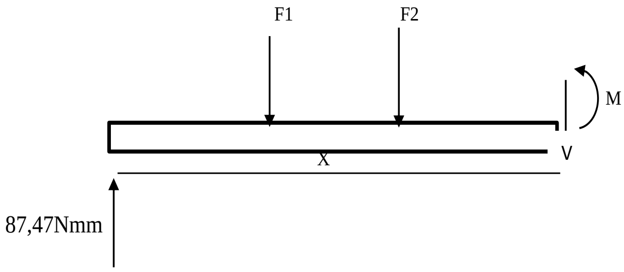
∑FY = 0+
A – F1 – V = 0
87,47 - 68,6 - V = 0
V = 18,87

F1(a) + V(x) – M = 0
68,6 x 340 + 18,87X - M=0
23.324 + 18,87 X – M=0
M= 23.324 + 18,87 X
340≤ X ≤ 690

X= 340 mm → M = 29.738,1 Nmm
X= 690 mm → M = 363.40,85 Nmm

Left C Section

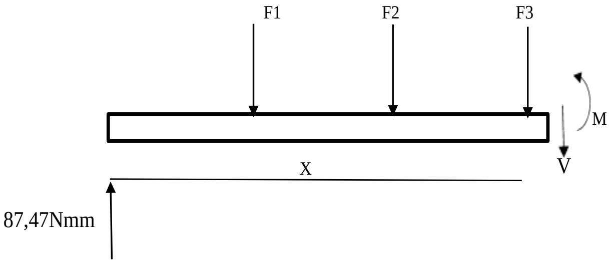


∑FY = 0 +
A – F1 – F2 – V = 0
87,47 - 68,6 - 68,6 - V = 0
V= -49,74

∑MA = 0 +
F1(a) + F2 (a+b) – V(x) –M = 0
68,6 x 340 + 68,6 x 340 + 350 - -49,74X -M =0
23.324 + 68,6 X 690 - -49,74 X – M =0
M = 70.658 + 49,74 X
690≤ X ≤ 1040

X= 690 mm → M = 104.975,2 Nmm
X= 1040 mm → M = 122.382,4 Nmm

Left D Section



∑FY = 0 +↑
A - F1 – F2 - F3 - V = 0
A - 68,6 - 68,6 - 68,6 - V = 0
87,47 - 68,6 - 68,6 - 68,6 - V = 0
V = -118,34

∑MA = 0 +
F1(a) + F2 (a+b) + F3 (a+b+c) – V(x) – M = 0
68,6 x 340 + 68,6 x 340 + 350 + 68,6 x 340 + 350 + 350 - VX - M =0
23324 + 68,6 x 690 + 68,6 x 1040 - VX - M = 0
23324 + 47.334 + 71.344 - -118,34 X - M = 0
M= 142.002 + 118,34 X
1040≤ X ≤ 1200

X = 1.040 mm → M = 265.070,4 Nmm
X = 1.200 mm → M = 284.004 Nmm

Table 4. Bending moment

X mm	M Nmm
0	0
340	29738.1
630	36340.85
630	104975.15
920	12382.4
920	265070.4
1200	284004.00

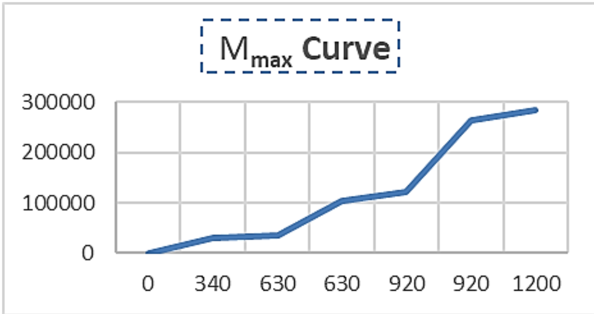


Fig. 2. The maximum moment (Mmax) graph

Z = Mmax/σi
i = y/FS
i = 345 MPa / 4 (FS 4 because the frame will experience a shock load)
i = 86.25 MPa
i = 86.25 N/mm²
Z_{calc} = 3,292.80 mm³
Z_{calc} = 3.29 cm³
Z_{table} = 3.47 cm³
Z_{table} is greater than Z_{calc}, then bar 13 is safe to use.

3.8.2. Calculation of bars 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 subjected to axial load

The calculation of this rod is experiencing a direct load from rod 13, so the load is taken from the Mmax of rod 13, which is 118.34 N.

3 rod

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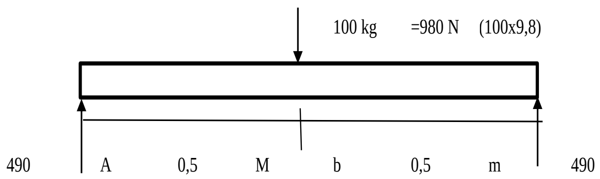
Conclus i = F/A A=F/σi
y = 345 MPa
i = y/FS
345 4
86.25 MPa

A = F/σi = 118.34 N / 86.25 MPa = 118.34 N
A = 1.37 mm²
A = 0.01 cm²
$A_{calculation}$ = 0.01 cm²
A_{table} = 2.94 cm²ions
Description:
FS 4 because the frame will experience a shock load
F is taken from the heaviest load of the 13. bar

Taking into account the availability of stock in the materials visited, then rod 3 was selected hollow with a size of 40x40 with A table 2.94, also taking into account the price, then purchased the same rods in large quantities for rods 1, 2, 4, 5, 6, 7, 8,9, 10, 11, 12.

$A_{table} > A_{calculation}$, then the rod used is safe.

3.8.3 Calculation of rods 17, 18, 19, 20, 21, 22, 23 subjected to bending loads



From the simple beam table, we get:
Mmax = Pab/L = (980 x 0.5 x 0.5/1)
= 245 Nm

i =Mmax/Z Z = Mmax/ i
i = y/FS = 345 : 4 = 86.25 MPa
Z_{calc}: Mmax/σi = 245 Nm : 86.250.000 MN/m³ = 2.84 x 10-6 m³
Z_{calc} = 2.84 cm³
Z_{table} = 6.95 cm³

From the table, it is found that the sizes for rods 20, 21, 22, 23 are 60x40 with Z_{table} 6.95 cm3 because the rods look more aesthetically pleasing and support larger loads.

To simplify the calculation and price efficiency, rods 17, 18, 19 use the same rod specifications as rods 20, 21, 22, 23 using the maximum load calculation. Z_{table} is greater than Z_{calc} then the rod is safe to use.

3.8.4 Wheel selection calculation

In selecting the wheel, the wheel specifications are selected with a maximum load that the wheel can hold 150 kg per 1 wheel, so when multiplied by 4 the total load that the wheel can withstand is 600 kg.

From the data above, we can determine the best variant, namely variant 1 with a frame length of 1000 mm, a width of 1200 mm and a height of 1140 mm, the frame specifications use 4x4 hollow steel with a thickness of 2 mm and a size of 4x6 with a thickness of 3mm, and use a wheel type. with a lock which can withstand a load of 600kg. as shown in Fig. 3 below.

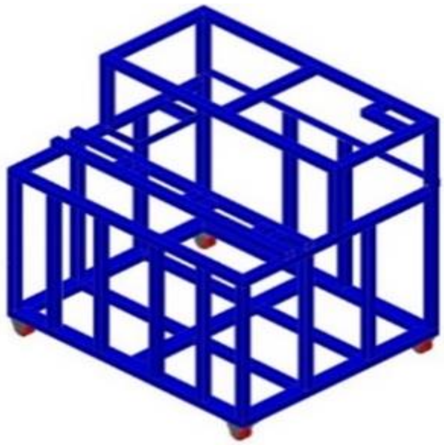


Fig. 3. Chosen variant

4. Conclusions

From the results of the research conducted, the following conclusions can be drawn:
1) The frame of the PPTE that is designed shows that the frame is safe when the tool is operated to test the performance of the pump either singly, in series, or parallel.
2) The results obtained from the use of the VDI 2221 method to determine the safe frame specifications are (i) the frame uses the first model, (ii) the frame material with hollow iron, (iii) uses a wheel with lock.

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