International Journal of Multidisciplinary Research and Growth Evaluation

International Journal of Multidisciplinary Research and Growth Evaluation
ISSN: 2582-7138
Received: 29-04-2021; Accepted: 16-05-2021
www.allmultidisciplinaryjournal.com
Volume 2; Issue 3; May-June 2021; Page No. 297-301

Centrifugal pump replanning capacity of 50 liters/s of use on the unit manufacturing company regional drinking water

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Abstract
With the development of science and technology today, human needs are also increasing. For this reason, humans have created tools that can help increase human burdens, one of which is a pump. A pump is a device used to convert mechanical energy into energy hydraulic pumps, in general, to move fluid from one place to another by increasing the pressure of the fluid, and the pump provides energy to the fluid it is pumping. The working principle of the pump is to create low pressure at the inlet side of the suction so that the fluid will be sucked in and out of it on the pressure side of the exit side with higher pressure, all of this is done by using the driving pump element, namely the impeller, plunger or piston. To work, the pump requires energy obtained from outside, namely from an electric motor or combustion motor. After doing the calculation, you will get the size of the components such as impeller diameter, blade width, shaft diameter, pulley size, bearing size, and impeller peg size.

Keywords: Pump, Impeller, Diffuser, Capacity

Introduction

The need for water is significant for the life of all living things, especially humans. Human use water for various purposes in everyday life.

In general, a pump is driven by a motor engine or the like. Factors that cause different types and sizes of pumps, among others, are influenced by the type of fluid and the volume of the fluid, the height and distance of the fluid transport, and the required pressure. The working principle of the pump itself makes a difference in pressure between the suction and the discharge (Skrzypacz & Bieganowski, 2018) [11].

The pump that was used beforehand must be known characteristics in different working conditions, thus determining the limits of the working conditions at which the pump can reach maximum efficiency. This needs to be done because it is complicated to ensure the pump's performance in actual working conditions.

In a factory or industry, there is always a situation where the processed materials are transferred from one place to another or from a place of storage to a place of processing.

The transfer can also be intended to carry the material to be processed from the source from which the material was obtained. The higher liquid will flow automatically to a lower place, but if the opposite is the case, it takes effort to move or increase the fluid, then the commonly used tool is a pump (Kara Omar, Khaldi, & Ladouani, 2017; Tao & Wang, 2020) [6, 12].

Many industries use pumps as one of the essential auxiliary equipment for the production process. For example, it is used by Regional Drinking Water Companies to circulate or supply water to the community for purposes such as bathing, washing, and also for drinking.

To obtain a source of clean water supply, the use of natural resources such as rivers, lakes is an alternative that is often used. This is what underlies the use of available river water for industrial clean water to the local community.

So that to use it relatively does not require a very long process, the number is relatively stable. However, the obstacle that often arises is when the dry season hits, where the supply of clean water power is reduced, resulting in a small amount of clean water supply for the community (Yu & Liu, 2018) [15].

Identification the problem is how to redesign a centrifugal pump with a capacity of 50 liters / second for use in the production unit of a drinking water company? How is the calculation to determine the diameter and thickness of the pipe that will be used? How is the calculation of losses that occur in the design?

The limitation of the problem in this study is the analysis of pump sizes (impeller, pump housing, and pump shaft), the selection of pump specifications following the calculation analysis, focused on centrifugal pump redesign on the main components of the pump.

The purpose of this research is to re-plan the centrifugal water pump with a capacity of 50 liters / second for use in the production units of local drinking water companies, to increase knowledge of the ability to design centrifugal pumps so that the appropriate pump specifications for a capacity of 50 liters / second can determine the amount of power. The appropriate pump can determine the losses in the inflow and outflow.

2. Literature review

The systematic investigation of the influence of various design aspects of a centrifugal pump on its performance over a wide range of flow rates necessitates numerical predictions and experimentation. A pump test rig was recently designed and is now in operation at the University of Patras' Fluid Mechanics Laboratory. The test rig is currently equipped with an industrial centrifugal pump, which a laboratory pump will replace once its construction is completed. The laboratory pump volute has been specifically designed to accommodate radial impellers with the same outlet diameter but differing in crucial design parameters such as the number of blades, mean line geometry of the blade, and inlet and outlet blade angles (Bacharoudis, Filios, Mentzos, & Margaris, 2008; Perissinotto *et al.*, 2020; Verde, Biazussi, Sassim, & Bannwart, 2017) [3, 8, 13].

The laboratory centrifugal pump's volute is rectangular with rounded corners, and its diffuser extends radially. The Pfleiderer method was used to design three shrouded impellers of constant width (b=20mm) with six untwisted blades facing backward. The blade lengths of the three impellers are nearly equal (Gonza´ lez, Ferna´ ndez, Blanco, & Santolaria, 2002; Pei, Wang, Yuan, & Zhang, 2016) [5, 7].

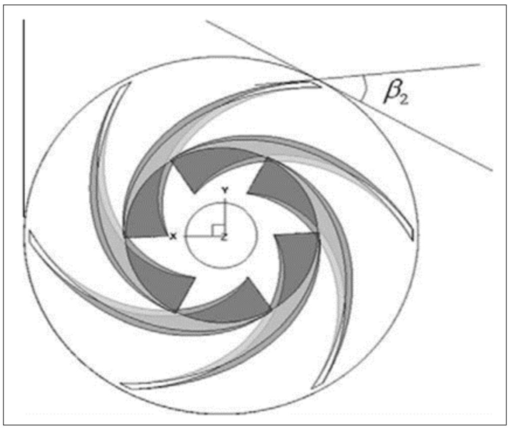

Fig 1: A view of the modeled impeller

All impellers have the same suction and pressure side diameters and the same blade's leading edge angle (1=14 deg), but they differ in the blade's trailing edge angle, which is 2=20, 30, and 50 deg, respectively. The suction and pressure side impeller diameters are D1=150mm and D2=280mm, respectively (Al-Obaidi, 2019; Bacharoudis *et al.*, 2008; Xu, Tan, Cao, & Qu, 2017) [2, 3, 14]

3. Research methods

This research was conducted at the place of use in the production unit of the local drinking water company. This study will re-plan a centrifugal pump with a capacity of 50 liters/second using the French method (analysis), before carrying out the analysis, some steps must be carried out, namely the data collection stage in the form of field data and literature related to the planning that is collected and processed by classifying it, based on their respective categories (Adamkowski, Henke, & Lewandowski, 2016; Chalghoum, Elaoud, Akrout, & Taieb, 2016) [1, 4].

The results of the analysis function to determine problems and conformity with literature data to produce good and correct planning (Sani, Rahman, Budiyantara, & Doharma, 2020; Sani, Rahman, Subiyakto, & Wiliani, 2019) [9, 10].

In this planning, planning methodology is used such as the following flowchart.

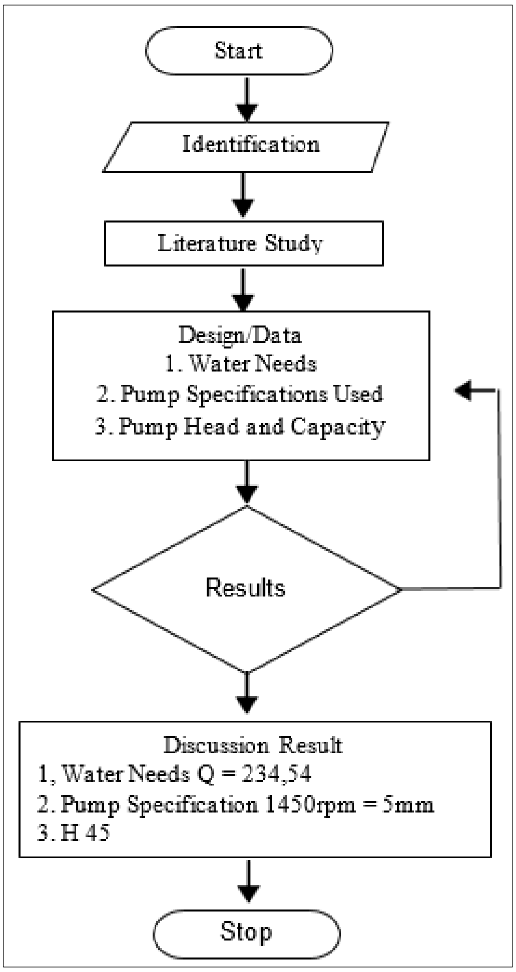

Fig 2: Research Method

4. Results and discussion

In excellent and correct planning to distribute clean water, we must know the pump power, the pump capacity of the shaft planning, the impeller, and the planning of the pump housing (casing).

The population plan for the city of Jakarta for 2022 - 2023 is drawn up based on the plan concept that has been made. The population plan for 2022 - 2023 is determined based on aspects, including the following.

1. The intensity of city activities and the structure of land use in each part of the city area
2. Accessibility between regions and service centers.

Table 1: Estimated total population in the future 2022-2023

No	Step	Years	Population
1	Step 1	2012 - 2013	219,470
2	Step 2	2017 – 2018	222,755
3	Step 3	2022 - 2023	226,092

In estimating the number of subscribers, data on the number of previous customers is used. The data on the number of customers of Regional Drinking Water Companies, the projection data, is from 2008-2012. This can be seen in the following table.

Table 2: Number of customers of the Jakarta Regional Drinking Water Company

No	Years	Customers
1	2008	14,001
2	2009	14,663
3	2010	15,781
4	2011	16,366
5	2012	17,086

The method used in estimating the number of customers.

1. Arithmetic Method

$$I = \frac{p_0 - p_t}{t} \quad \text{........................} \quad (1)$$

$$I = \frac{17.085 - 14.001}{5}$$

$$I = 617$$

So that the equation becomes

$$p_n = 14.001 + 617n$$

Where

For 2008, n = 1

For 2009, n = 2

For 2022, n = 15,

P_{15} = 14.001 + 617 (15)

p_{15} = 23.256

2. Last-Square Method

From the data on the number of customers in 2008, the number of customers was studied.

Table 3: Regression data determination

Years	X	Y	X²	Y²	X.Y
2008	-4	14,001	16	196,028,001	-56,004
2009	-3	14,663	9	215,003,569	-43,989
2010	-2	15,781	4	249,039,961	-31,562
2011	-1	16,366	1	267,845,956	-16,366
2012	0	17,086	0	291,931,396	0
Σ	-10	77,897	30	1,219,848,883	-147,921

$$a = \frac{(N)(\sum XY) - (\sum X)(\sum Y)}{(N)(\sum X^2) - (\sum X)^2} \quad \text{..................} \quad (2)$$

$$a = \frac{(5)(-147.921) - (!0)(77.897)}{(5)(30) - (100)}$$

a = 787,3 citizens

$$b = \frac{(\sum X^2)(\sum Y) - (\sum X) - (\sum XY)}{(N)(\sum X^2) - (\sum X)^2}$$

$$b = \frac{(30)(77{,}897) - (10)(-147{,}921)}{(5)(30) - (100)}$$

b = 17,154 customers

So that

Y = 787,3X + 17,154

X = 2008 – 2022 = 15,

Where x is the projected year

Y_{15} = 787,3 (15) + 17,154

Y_{15} = 28.963,5 = 28.964 customers

3. Geometric Methods

From the number of customers of the Drinking Company, we can determine the ratio of the number of subscribers to the increase in the number of customers using the formula.

$$r = \frac{p_o}{p_t}^{1/t} - 1 \quad \text{.............................} \quad (3)$$

$$r = \frac{17.086}{14.001}^{1/5} - 1$$

r = 1,0406

r = 0,0406

So that the number of customers until 2002 can be calculated using the equation.

$$p_n = p_o (1 + r)^n \quad \text{..........................} \quad (4)$$

$$p_{15} = 17.086\,(1 + 0{,}0406)^{15}$$

$$p_{15} = 31.038$$

From the results of the above calculations, that the largest estimated number of Drinking Water Companies is shown in the last - square method. The complete calculation results can be seen in Table below

Table 4: Estimated for 3 method

Year	Method		
	Arithmetic	Last-Square	Geometric
2013	17,703	21,878	21,694
2014	18,320	22,665	22,575
2015	18,937	23,452	23,492
2016	19,554	24,240	24,445
2017	20,171	25,027	25,438
2018	20,788	25,814	26,471
2019	21,405	26,602	27,545
2020	22,022	27,389	27,545
2021	22,639	28,176	29,827
2022	23,256	28,964	31,038

Educational Facilities

As it is known, the existing education facilities in the planning area consist of Kindergarten to Senior High School, namely 62 units based on technical data from Drinking Company and based on population predictions for the years 2022 - 2023 with a school age of 22,637 people. So the need for water for building facilities is as large as: 22,637 x 15L / person / day = 339,555L / person / day.

Medical Facilities

Based on the projection results of Health facilities in the city of Jakarta, there are 33 units with 613 beds based on technical data from the Drinking Company. 613 x 220 L / bed / day = 134,860

Religious Facilities

Based on the projection results of worship facilities in the city of Jakarta, there are as many as 16 units based on technical data. 16 x 1908 L / unit / day = 17,568

Office Facilities.
Based on the projection of office facilities in the city of Jakarta, there are 25 units based on the technical data of Drinking Companies. 25 x 2,097L / Unit / day = 52,425

Household Facilities
Based on the projection results of households in the city of Jakarta until the end of 2022 - 2023, there will be 30,901 units based on technical data from Regional Water Company. So the water requirement for household facilities is: 30,901 x 4 x 132L / person / day = 16,315,728L / unit / day

So the total number is as follows

∑ Household + ∑Offices + ∑Religious + ∑ Medical + ∑ Educational

30,901 + 25 + 16 + 33 + 62 = 31,037 customers

16,315,728 Ltr/day + 52,425 Ltr/day + 17,568 Ltr/day + 134,860 Ltr/day + 339,555 Ltr/day

= 16,860,136 Ltr/day = 0,195140 L

Pump Capacity
Based on the water flow that must be distributed, which is 0.2345m³/s or 20.264.3m³/day, the number of pumps used is 3 main pumps and 1 backup pump.

a. Effective discharge in pump operating hours:

Qe = 20,264.3 m³/day/50L/s

Qe = 4,690m³/s

b. Effective debit for each pump that will be used
That the pump discharge can be found by dividing the required flowrate (effective discharge) by the number of pumps to be used.

$$Q_{ep} = \frac{effective\ discharge}{number\ of\ pumps}$$

$$Q_{ep} = \frac{4{,}690}{3}$$

Q_{ep} = 1,564m³/s

c. Theoretical Discharge of Pumps

$$Q_{th} = \frac{Q_{ep}}{\eta_v}$$

Where

Q_{ep}= Effective discharge of pump = 1,564

η_v= Volumetric efficiency (0.90 - 0.98)

= taken 0.96

Then

$$Q_{th} = \frac{Q_{ep}}{\eta_v}$$

$$Q_{th} = \frac{1{,}564}{0{,}96} = 1{,}621\text{m}^3/\text{s}$$

Head Total Pump

$$H = Hs + h_l + \frac{V_d{}^2}{2g}$$

Where

V_d = 22,94

V_d = 22,94

h_1 = 21,057

g = 9,81

$$H = -3 + 21{,}057 + \frac{(22{,}94)^2}{2\ (9{,}81)} = 44{,}9 = 45\text{m}$$

Pump Impeller Design

$$n_s = \text{n}.\frac{q^{0,5}}{H^{0,75}}$$

$$n_s = 1450\ \frac{\sqrt{0{,}23M^3/S}}{45/2^{0,75}} = 67.312$$

Based on the calculation of the specific spin above, the pump used is a French pump because the specific rotation of the pump is 67, 312.

Pump Power
Three main requirements in analyzing pump power:
Water power (Pw)

Pw = p.g.Q.h

Pw = 998 × 9,81 × 0,2345 × 45

= 1033129,8495 watt

Pw = 998 × 9,81 × 0,2345 × 45

= 1033129,8495 watt

= 1033,129 kW

Pump Shaft Power

$$P = \frac{v.H.\rho.9}{\eta e.1000}$$

$$P = \frac{v\ .\ H\ .\ \rho\ .\ g}{1000.\eta e}$$

$$= \frac{0{,}2345\ .\ 45\ .\ 1000\ 9{,}81}{1000\ .\ 0{,}9}$$

= 115,022

Pump Drive Motor Power

$$Pm = \frac{Ps\ .(1 + a)}{Et}$$

$$Pm = \frac{115{,}022\ (1+0{,}2)}{0{,}96}$$

= 143,7775 Watt

= 0,143kW

Table 5: Size of the impeller on exit side

No	Item	Notation	Result
1	Hub Diameter	Dh	70.32 mm
2	Eye Diameter	Do	138.8 mm
3	Vane Inlet Diameter	D1	13.80 mm
4	Impeller Passage Width	B1	27.60 mm
5	Tangensial Speed	U1	10.54 mm
6	Impeller Entry Point	B1	15o
7	Impeller Fluid Absolute Angle	α1	90o
8	Relative velocity of fluid	V1	21,538 m/s
9	Impeller Fluid Velocity	Vo	4.572 m/s

Table 6: Size of the impeller on exit side

No	Item	Notation	Result
1	Impeller outer diameter	D2	555,51 mm
2	Impeller pass width	b2, mm	72,69 mm
3	Tangensial Speed	U2	42,153 m/s
4	Theoretical tangensial velocity	Vu2	35,178 m/s
5	Theoretical fluid angle	α2	7°.41
6	Relative Velocity of Fluid	V2	81,82 m/s
7	Theoretical Absolute Speed	V2	35,44 m/s
8	Actual tangential speed	Vu2	26,38 m/s
9	Actual fluid angle	α2	10°13 40,08
10	Absolute actual speed	V2	26,72 m/s

Calculation of Net Positive Suction Head (NPSH)

Cavitation will occur when the static pressure of a liquid flows below the saturated vapor pressure.

NPSH Available (HSV)

$$h_{sv} = \frac{Pa}{y} - \frac{p_v}{y} - h_s - h_f$$

Then

$$h_{sv} = \frac{10326{,}19}{995.7} - \frac{432{,}5}{995{,}7} - 4{,}5 - 0{,}029$$

$$= 5{,}407\text{m}$$

NPSH Required

$$H_{SVN} = n^{4/3} \bullet Qp^{2/3}$$

Then

$$H_{SVN} = 1450^{4/3} \times 140{,}7^{2/3}$$

$$= 0{,}613 \text{ m}$$

From the results of the above calculations, it can be seen that the available NPSH is greater than the NPSH needed, so the pump is declared safe against cavitation.

5. Conclusion

From the results of the re-planning analysis of the pump in order to meet the needs of clean water, drinking water companies, the following conclusions can be drawn.

1. The water capacity needed by the people of Jakarta until 2022 is 234.54 l / s, while the current production capacity is 50 l / s so that the additional capacity is 184.54 l / s.
2. Based on the results of the calculation of the total pump head, the result is 45m.
3. The pump specifications used as input are.
   Pump type = centrifugal pump

   The speed of the motor, n = 1450 rpm
   Impeller blade thickness, s = 5 mm

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