Series and parallel relationship pump performance in FT. Unitas's practicum tools

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Abstract. Basically, the variation of the pump arrangement in the piping installation is done to get the performance / flow characteristics needed in a particular usage according to the needs, namely the need for a head height that is higher than the flow rate (capacity) or vice versa. Flow regulation method with variations of valve openings (Senen 2004), which is applied in this study with consideration of energy use efficiency, it can be stated that the pump efficiency range of the parallel circuit is high to get a larger flow rate than the series circuit pump. To get the head maximum, the pump efficiency series is smaller than the pump efficiency of the parallel circuit, so that it does not provide an illustration that the optimum pump work has been achieved, so that further research needs to be carried out research with variations in pump rotation (Mastur and Warso 2015) below or above the standard round. But based on the purpose of this study in terms of pump performance, to meet the needs of a high head, the pump installation is arranged in series and vice versa if what is needed in the pump installation system is a high flow rate, the pump is arranged in parallel, so the results of this study have been can meet the needs of practicum for students of Mechanical Engineering Study Program FT. Unitas in terms of how to get the performance of a centrifugal pump installation.

1. Introduction

Basically the variation of the pump in the piping installation is done to get the flow characteristics needed in a particular usage according to the needs of the need for a head height that is higher than the capacity or vice versa. There are several research results on this subject, as has been done by Senen, 2004; Mastur and Warso, 2015, but still limited to showing a linear pattern in terms of the relationship between discharge and head in series or parallel pump circuits is not linear because each machine has minimum and optimum work. With this last consideration, this research really needs to be carried out.

From the two main literature which based on this research, the design of research tool was the same type as that done by Senen (2004) where the main variables of the study were valve openings 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, 90° for each installation circuit. The design of this study is identical to the low tower electric water pump installation model with a series and parallel pump arrangement. In the pump discharge position there is a pipe, pressure gauge and rotameter that will flow fluid from a higher water source or parallel to the pump to a reservoir. The components of the piping component that will drain the water can be seen from the scheme (Figure 1) and the dimensions of the piping components (Table 1).
Figure 1 Description:
1. Pump 4. Pressure Gauge
2. Piping 5. Rotameter
3. Tank 6. Primary Valve

Table 1. Type, size and number of piping components

| Lane     | Channel | Type of Piping Components | Size                  | Amount |
|----------|---------|---------------------------|-----------------------|--------|
| A – B    | Inlet   | Pipe PVC AW               | DN. 25.4 cm, \( L = 163 \) cm |        |
|          | Parallel Series | Bend 90°            | DN. 25.4 cm          | 3      |
|          |                     | Clutch 1°             | DN. 25.4 cm          | 1      |
| C – D    | Outlet Inlet | Clutch 1°              | DN. 25.4 cm          | 1      |
|          | Inlet    | Pipe PVC AW              | DN. 25.4 cm, \( L = 134 \) cm | 3      |
|          | Parallel  | Bend 90°                 | DN. 25.4 cm          | 1      |
| B – D    | Series   | Pipe PVC AW              | DN. 25.4 cm, \( L = 79 \) cm | 2      |
|          |          | Valve                    | DN. 25.4 cm          | 1      |
|          |          | Tee                      | DN. 25.4 cm          | 1      |
| B – E    | Parallel | Pipe PVC AW              | DN. 25.4 cm, \( L = 29 \) cm | 1      |
|          |          | Valve                    | DN. 25.4 cm          | 1      |
|          |          | Tee                      | DN. 25.4 cm          | 1      |
| D – E    | Inlet    | Pipe PVC AW              | DN. 25.4 cm, \( L = 52 \) cm | 3      |
|          | Parallel  | Clutch 1°                | DN. 25.4 cm          | 2      |
|          | Series   | Tee                      | DN. 25.4 cm          | 1      |
| E – F    | Outlet Inlet | Bend 90°              | DN. 25.4 cm          | 1      |
|          | Outlet   | Pipe PVC AW              | DN. 25.4 cm, \( L = 234 \) cm | 6      |
|          | Parallel Series | Bend 90°            | DN. 25.4 cm          | 1      |
|          |          | Valve                    | DN. 25.4 cm          | 1      |
|          |          | Valve ½°                 | DN. 25.4 cm          | 3      |
|          |          | Tee                      | DN. 25.4 cm          | 7      |
|          |          | Rotameter                | DN. 25.4 cm          | 3      |

2. Research Method
From the research model that has been realized into a tool (Figure 2), the stages or procedures of the research are prepared. The stages in the research carried out in order to collect data are as follows:

1. Calculating pump installations in series and parallel with the data in Table 1.
2. Determine the research variables
   - Fixed variables are: Pump Standard Round & Static Head Pump (ha) (m).
   - Non-fixed variables, namely: Exhaust Valve Openings (°)
   - The measured variables are: Pressure (bar), Flow Rate (l/men), Voltage (V) and Current (I)

3. Check the condition of the pump to be operated.
4. Checking / recording voltage (V) and current (I) entering the pump.
5. Record the Pressure Gauge on the pump.
6. Record the rotameter stand
7. Calculating Head, Flow Debit and Pumping Effectiveness

![Figure 2. Installation of a low tower electric water pump](image)

Test results data in the form of measuring pressure, discharge, voltage and current are labelled, followed by quantitative calculations to find the Head variable, flow rate and pumping efficiency and pour the relationship between head (H), Debit (Q) and efficiency (ƞ) of the valve openings and the relationship of the head to the flow discharge in the series and parallel arrangement pumps, as outlined in the graph, then carried out a qualitative analysis of the relationships.

3. Results and Discussion

3.1. Results
Data processing results can be seen in Tables 2 and 3. Data processing is carried out by calculation based on the provisions in the description below.

3.1.1. Static Head System. The static head is obtained by subtracting the output head with the input head based on Figure 1

3.1.2. Calculation of Reynolds Numbers. As a benchmark whether a flow is laminated or turbulent, Reynolds numbers (equation 1) are used (Sularso, 2000: 29):

$$ Re = \frac{\nu D}{\nu} $$  \hspace{1cm} (1)

Where : 
- $ Re $ = Reynolds Numbers  
- $ \nu $ = Average flow rate (m/s)  
- $ D $ = Diameter in the pipe (m)  
- $ \nu $ = Kinematic viscosity (m²/s)

Dynamic viscosity and water density at a temperature of 27 °C is 0.862 x 10^-6 m² / s and 9.7722 kN / m³ (Munson, BR., Young, DF. & Okiishi, TH.2002)
3.1.3. Pump Head. The pump head is the energy per unit weight that must be provided to drain the planned amount of liquid in accordance with the pump installation conditions or pressure to drain a certain amount of liquid which is generally expressed in units of length (m). According to Bernauly’s equation there are three kinds of head fluid from the flow installation system, namely pressure energy, kinetic energy and potential energy. This can be stated in the equation 2 (Munson, BR., Young, DF. & Okiishi, TH. 2002: 305):

\[ H_{tot} = h_a + \Delta h_p + h_l + \frac{v^2}{2g} \]  

(2)

Where:
- \( H_{tot} \): The total pump head (m)
- \( h_a \): Static head (m)
- \( \Delta h_p \): Difference in pressure head (m)
- \( P_{abs} \): Absolute pressure (N/m²);
- \( \gamma \): Specific gravity (N/m³)
- \( h_l \): Head losses (m)
- \( \frac{v^2}{2g} \): Head out speed (m)

3.1.4. Calculation of System Head Loses. Minor Losses show by equation 3 (Sularso,2000)

\[ h_f = f \frac{v^2}{2g} \]  

(3)

Where:
- \( h_f \): head loss (m)
- \( f \): coefficient of loss
- \( v \): speed (m/s)
- \( g \): gravitational acceleration (m/s²)

Mayor Losses show by equation 4

\[ h_f = \frac{10,666 Q^{1.85}}{C^{1.85} D^{4.85} x L} \]  

(4)

Where:
- \( h_f \): head loss (m)
- \( Q \): flow (m³/s)
- \( L \): Long pipe (m)
- \( D \): Diameter in the pipe (m)
- \( C \): pipe coefficient

3.1.5 Pump Efficiency. Pump efficiency is a factor used to calculate this loss.

Pump efficiency consists of:
- a) Hydraulic efficiency, taking into account losses due to friction between the liquid and the impeller and losses due to sudden changes in direction on the impeller.
- b) Volumetric efficiency takes into account losses due to recirculation in the ring, bush and others.
- c) Mechanical efficiency takes into account losses due to friction in seals, packing, glands and bearings.

Pump efficiency is the ratio between hydraulic power and pump shaft power show by equation 5 (Church, A.H. 1972: 35).

\[ \eta = \frac{P_h}{P_m} \times 100 \% \]  

(5)
Where:
\[ \eta = \text{pump efficiency (\%)} \]
\[ P_h = \text{hydraulic power (kW)} \]
\[ P_m = \text{drive motor power (kW)} \]

### Table 2. Data from total Reynolds and Head calculations

| Aperture (o) | Reynolds Numbers | Head Total (m) |
|--------------|------------------|----------------|
|              | Series           | Parallel       | Series | Parallel |
| 10           | 12120,07         | 2908,82        | 42,11  | 32,35    |
| 20           | 21331,37         | 21331,37       | 25,33  | 24,30    |
| 30           | 27342,98         | 35633,06       | 12,36  | 17,47    |
| 40           | 30251,80         | 44359,52       | 9,37   | 13,73    |
| 50           | 31027,46         | 49643,86       | 6,65   | 11,89    |
| 60           | 31512,25         | 51146,73       | 5,17   | 11,73    |
| 70           | 31512,25         | 51873,94       | 4,97   | 11,46    |
| 80           | 31512,25         | 52601,14       | 4,92   | 11,41    |
| 90           | 31512,25         | 53570,77       | 4,87   | 11,41    |

### Table 3. Data from calculation of hydraulic power, shaft power and pump efficiency

| Aperture (o) | Hydraulic Power (Watt) | Shaft Power (Watt) | Pump Efficiency (%) |
|--------------|------------------------|-------------------|---------------------|
|              | Series                 | Parallel          | Series              | Parallel  |
| 10           | 85,73                  | 15,80             | 515,38              | 649,8     | 16,63 | 2,43  |
| 20           | 90,77                  | 87,07             | 429,48              | 530,1     | 21,14 | 16,43 |
| 30           | 56,77                  | 104,57            | 395,12              | 444,6     | 14,37 | 23,52 |
| 40           | 47,61                  | 102,29            | 360,76              | 410,4     | 13,20 | 24,92 |
| 50           | 34,65                  | 99,15             | 360,76              | 393,3     | 9,61  | 25,21 |
| 60           | 27,39                  | 100,74            | 360,76              | 393,3     | 7,59  | 25,62 |
| 70           | 26,31                  | 99,89             | 360,76              | 376,2     | 7,29  | 26,55 |
| 80           | 26,04                  | 100,80            | 360,76              | 376,2     | 7,22  | 26,79 |
| 90           | 25,76                  | 102,63            | 360,76              | 376,2     | 7,14  | 27,28 |

3.2. Discussions

3.2.1. Series head connection and parallel to valve openings. The graph in Figure 3 above can explain that the head produced on the valve opening of 10° to 20° in the series stacking circuit produces a larger head than the parallel stacking head. Meanwhile, at the valve openings of 20° to 90°, the head produced by the series of series arrangement is inversely proportional to the head of the valve opening conditions below 20°. Thus, the head in the parallel stacking circuit will be greater than the head in the series stacking circuit when the valve opening is opened at 20° to 90°.
3.2.2. Correlation of series flow discharge and parallel to valve openings. The graph in Figure 4 above can explain that the flow discharge generated at valve openings of 10° to 20° in series stacking circuits results in a larger flow rate compared to the flow discharge in parallel stacking circuits. Meanwhile, at the valve openings of 20° to 90°, the flow discharge generated by the series stacking circuit is inversely proportional to the flow discharge at the valve opening conditions below 20°. Thus, the flow discharge in the parallel stacking circuit will be greater than the flow rate in the series stacking circuit when the valve opening is opened at 20° to 90°. The flow rate of the parallel stacking circuit at the opening valve 90° is 55.25 litters / minute, while the flow rate of the series stacking circuit at 90° opening valve is 32.50 litters / minute.

3.2.3. The relationship of the series head and the parallel to the flow discharge. From the head graph of the flow discharge (Figure 5) below it can be seen that the series of pump head is larger than the pump head parallel circuit of the flow rate of 2.08 x 10^{-4} m^3 / sec or 12.50 l / men up with 3.66667 x 10^{-4} or 22 l / men can reach the maximum pump head which is 40 m, while the parallel pump flow capacity is greater than the pump capacity of the series circuit, the series pump circuit can only reach 5.42 x 10^{-4} m^3 / sec or 32.50 l / men, parallel circuit produces pump capacity up to the maximum pump capacity of 56 l / min.
The culmination point between the series and parallel pump circuits occurs at the 24 m pump head and the pump flow rate is 22 l/min in this case the pump work line of the series circuit intersects the work line of the parallel circuit pump at that point. When the flow discharge is reduced or raised from this point the pump head gradient series circuit increases and decreases significantly but the pump head gradient parallel circuit increases and decreases very little. Finally, in Figure 5, it can be seen that the series of series pumps has a higher head range than the parallel circuit pump head run, but the parallel flow pump discharge range is much greater than the series flow rate. This statement is also strengthened by what is shown in Figures 3 and 4.

3.2.4. The connection efficiency of the series and parallel to the valve opening. From the efficiency graph of the valve opening (Figure 6) above, it can be recognized that for the parallel circuit pump the biggest efficiency occurs at 90° opening, which is 27.28% and the smallest at 10° opening is 2.43%, while for the pump the series efficiency is the largest at the opening of 20° is 21.14% and the smallest one at opening 90° is 7.14%. Pump efficiency in parallel circuits increases with the increase of valve openings or the efficiency increases with increasing flow, rising significantly from openings 100 to 300 or from flow discharge 3 l/min up to 36.75 l/min. The efficiency of the pump in the series circuit rises up to the opening of 200 or the flow discharge is 22 l/min, but then decreases with the increase in valve opening or flow rate.
larger flow rate than the series circuit pump, but to obtain the maximum head, the series pump efficiency is smaller than the efficiency of the parallel circuit pump.

From the results of the research results above, it shows that the flow management method with variations of the valves as has been done by previous researchers (Senen 2004) does not give a picture that the pump optimum work has been achieved because the head culmination point and flow discharge occur in high flow resistance which means that the pump's working efficiency is at a low point. The method of rotation variation at the pump (Mastur & Warso 2015) needs to be done in future research.

4. Conclusions and Suggestions

4.1. Conclusions

1. The head of the pump range of the series circuit is greater than the parallel pump head range so that the pump in the series circuit can be reached by the maximum pump head from 4.87 m to 42.11 m but at the lowest parallel pump 11.41 m to the highest only 32.35 m.

2. On the other hand the pump flow rate range of the parallel circuit is much greater than the pump flow rate range of the series circuit so that in parallel pump pumps the maximum flow of the pump is obtained, from 31 / men to 55.25 l / men and at the pump the series of the lowest flow rate is 12.50 l / men and the highest is only 32.50 l / men.

3. Based on the purpose of this study in terms of pump performance, to meet the needs of high head, the pump installation is arranged in series and vice versa if what is needed in the pump installation system is high flow rate, the pump is ordered in parallel.

4. Considering the efficiency of energy use, it can be concluded that the parallel pump efficiency range is large to get a larger flow rate than the series circuit pump, but to get the maximum head, the series pump efficiency is smaller than the efficiency of the parallel circuit pump.

5. Flow regulation method with variations of the valve does not give a description that the pump optimum work has been achieved because the head culmination point and flow discharge occur at high flow resistance which means that the pump's working efficiency is at a low point compared to the maximum efficiency that can be achieved.

4.2. Suggestion

1. The use of a rotameter measuring instrument is very helpful to get accuracy in measuring the flow rate, but it needs to be added with the same capacity to obtain a more flexible measurement range, in future research.

2. In addition, the pressure gauge used in the measurement range needs to be enlarged from 4 bars to 6 bars so that the flow pressure measurement does not reduce the pressure gauge performance.

3. In the next research, it is necessary to do research with variations in rotation above and below the maximum rotation of the pump so that the optimum work of the pump can be achieved.

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