Comparison of Gear and Peripheral pumps performance, evaluation of their reliability at operation region

M. E. Qazizada¹, E. Pivarčiová¹, E. Pivarčiová² & W. Bialy²

¹Technical University in Zvolen, Faculty of Environmental and Manufacturing Technology, Department of Machinery Control and Automation Technology, Masarykova 24, 960 53 Zvolen, Slovakia
²Silesian University of Technology, Faculty of Organization and Management, Institute of Production Engineering, 41-800 Zabrze, ul. Roosevelta, Poland

Abstract

This paper concentrates on comparison of Gear pump and Peripheral pump types, and their reliability evaluation at operating region. The paper focusing on volumetric flow rate, head, power, efficiency, torque, net positive suction head available and required, and basic principles for reciprocating pumps discussed. The results from the the experimental work are compared, reliability evaluation at operation region, and the use of reliability based criteria in the determination by characteristics of Gear and Peripheral pumps. Furthermore the determination of efficiency and reliability–based limits for the recommendable operating region of a variable speed driven, is discussed, to operate both pumps at or near its best efficiency point (BEP).

Keywords: Reliability evaluation; Gear and Peripheral pumps; Operation region

1. Introduction

Peripheral and Gear pumps operate on completely different principals. With Peripheral pumps, flow results from a pressure differential created by the pump. For a Gear pump, pressure differential results from flow created by the pump (John, 2012). The basic difference between Gear and Peripheral pumps is evident in the pump's response to a system's head-flow curve. Several pump applications are presented to illustrate the selection process needed to insure pump reliability. The performance overlap region, where both pump types should be considered (David, 1994). This work firstly studies the use of reliability based criteria in the determination by characteristics of Gear and Peripheral pumps, such as to measure the basic representative functional curves of a given type of pump, to evaluate the behavior of reliability, the head, and flow of fluid transported by a given type of pump at different frequencies of rotation. An addition the determination of energy efficiency– and reliability–based limits for the recommendable operating region of a variable speed–driven is discussed. Ideally a pump is operated at or near its best efficiency point (BEP), in order to optimize the pump energy consumption based on its efficiency. Additionally, the risk of cavitation and the amount of hydraulic excitation forces caused by the pressure distribution on the impeller are typically minimized near the BEP, meaning maximized pump reliability in this operating region (Barringer, 2003; Bloch, 2010; Güllich, 2008; Nelik, 2005). The range around the pump BEP is often called the recommendable or preferred operating region (ANSI/HI, 1997; PSM, 2008). If the pump is driven outside this operating region, the pump efficiency decreases, and it may be susceptible to harmful phenomena. Gamez-Montero investigated on characterize contact stress of a trochoidal-gear set when it works as part of the hydraulic machine (Gamez Monteroa, et al 2006). Colbourne simplified the problem by neglecting friction at the contact points and, in this way, obtained analytical solutions, which can be used to modify the gear parameters and reduce contact stress (Colbourne, 1994). Frith and Scott studied comparison of an external Gear pump wear model with test data. This research was about measuring the actual material lost due to wear is impossible
in a practical sense (Frith and Scott, 1996). David B. Parker worked on the operating principles of positive displacement Gear pumps differ from centrifugal pumps. The investigation was about the basic difference evident, in the pump’s response to a system’s head and flow curve (David, 1994).

2. Material and devices

Following experiments will be proceeded in Edibon equipment. Equipment have a four pumps. This equipment designed to determine the operating physical appearance of several types of pumps, such as centrifugal pump, axial flow pump, Gear pump and Peripheral pump. The scheme of four pumps is illustrated in Figure 1 (Edibon, 2014). Gear or positive displacement and Peripheral pumps sometimes seem to inhabit different worlds. Users are generally much more familiar with one type than the other. (John, 2012).

3. Theoretical overview and applied formulas for calculation of pumps specifications

The same equations applied to calculate Gear and Peripheral pumps characteristics. Net head $H$ is the height of the fluid column in the open pipe after the pump (Blišťan 2011). The pumps characteristic indicates the delivery head, which is necessary for delivering the fluid against the existing resistances in the piping for any flow rates (Benra, 2013).

$$H = \frac{p_2 - p_1}{\rho g}$$  \hspace{1cm} (1)

Where $P_1, P_2$ shows the pressure drop of the pump system. Or specific work $\epsilon_w$ done by the pump is:

$$\epsilon_w = Hg = \frac{p_2 - p_1}{\rho}$$  \hspace{1cm} (2)

The power given to the fluid $P_w$ is denominated hydraulic power or output power and calculated (Chalghoum, 2016):

$$P_w = \rho g Q H$$  \hspace{1cm} (3)

The mechanical power $P_f$ given to the pump by the activator motor is denominated control power or input power and can be calculated as (Larralde, 2010):

$$P_f = \omega T = \frac{2\pi}{60} n T$$  \hspace{1cm} (4)

$$P_f = \frac{2\pi}{60} n T$$  \hspace{1cm} (5)
The $\omega$ is the angular axis speed in $[\text{rad sec}^{-1}]$, $n$ frequency of rotation in (rpm. revolutions per minute) and $T$ the torque in the axis in $[\text{Nm}]$, to obtain the power in $[\text{W}]$ (Haidary, 2013).

Pump efficiency $\eta$ is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump (Blišťan, 2011).

$$\eta = \frac{P_f}{P} = \frac{\rho g Q H}{\frac{2\pi n}{60} \omega T}$$ \hfill (6)

NPSH has two parts: NPSH required ($\text{NPSH}_R$) and NPSH available ($\text{NPSH}_A$). ($\text{NPSH}_R$) is a function of the pump and it is defined as:

$$\text{NPSH}_R = \left( \frac{P}{\rho g} + \frac{\omega^2 r^2}{2g} - \frac{P^*}{\rho g} \right)$$ \hfill (7)

Where $P_i$ and $w_i$ are the pressure and velocity at the inlet of the pump and $P^*$ is the transported liquid’s steam pressure (Sentyakov, 2013). Velocity is calculated as:

$$w = \frac{Q}{A}$$ \hfill (8)

Where $A \ [\text{m}^2]$ is the circular surface area of the impeller which is calculated as:

$$A = \frac{\pi D^2}{4}$$ \hfill (9)

Where $D \ [\text{m}]$ is impeller diameter (Wang, 2016).

4. Calculation of gear and peripheral pumps characteristics

Experiments recorded values with different frequency for Peripheral pump set in Table 1. The pump was driven at ten different relative flow rates and at a rotational speed ranging 2600 rpm. To calculate the experimentation data at the begging of measuring new data we found $t_{av}$, for obtaining of average temperature, we measured water temperature $t_1 = 21 \ [\degree \text{C}]$ at the beginning and $t_2 = 23 \ [\degree \text{C}]$ at the end of the experiment, then $t_{av} = 22 \ [\degree \text{C}]$. According to average temperature acceleration of gravity and density of water are chosen from physical properties’ table of water 9.81 $[\text{m s}^{-1}]$ 997.9 $[\text{kg m}^{-3}]$ respectively.

<table>
<thead>
<tr>
<th>Data</th>
<th>$Q$ (l min$^{-1}$)</th>
<th>$T$ (Nm)</th>
<th>$H$ (m)</th>
<th>$P_{ui}$ (W)</th>
<th>$P_i$ (W)</th>
<th>$\mu$ (%)</th>
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<td>284.37</td>
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</table>

Intersection curves of efficiency with pump curve Figure 2, the efficiency is always below 100% since the supplied power is always larger than the hydraulic power due to losses in controller, motor, and pump components. (Grundfos, 2009).
Laboratory measurements were carried out for a Gear laboratory pump too, the pump was driven at ten different relative flow rates and at a rotational speed ranging 450 rpm by adjusting its operation with the frequency converter and control valves. The measurement data was stored which has shown in Table 2.

<table>
<thead>
<tr>
<th>Data</th>
<th>Q (l min⁻¹)</th>
<th>T (Nm)</th>
<th>H (m)</th>
<th>P_W (W)</th>
<th>P_f (W)</th>
<th>µ (%)</th>
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<tr>
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<td>33.43</td>
<td>28.75</td>
<td>552.37</td>
<td>7.20</td>
</tr>
</tbody>
</table>

System curve with pump curve see Figure 3 which indicate the intersection point of pump curve and system curve of pump, at constant speed 450 rpm revolutions are plotted. The intersection of pump curve with system curve shows our operating point (Larralde, 2010).
5. Results

The experimental data from comparison of Peripheral and Gear pumps showed that these pumps can operate at different rotational speeds, various heads and flow rates without any mechanical problem. Pumping system equipped with measurement sensors that are used for control and monitoring purposes. The results are shown in (Table 1) and (Table 2) the flow rate, Head, Powers, efficiency and torque are measured in different speeds of rotation from (2600, 450 rpm) for Peripheral and Gear pump respectively, and the result are calculated in from equations (1-3-5 and 6). The \( H \), \( P_w \), \( P_t \) and \( \eta \) for Peripheral pump at 2600 rpm are calculated in ten steps of different flow rate see (Table 1). According to these data the Figure 2 is plotted that shows the pump runs reliable at its operation region, the figure shows the pump curve at 2600 rpm represented that in the value of \( H \) is 12,94 [m] the flow rate \( Q \) is 4,66 [l/min], decreasing of \( H \) to 2,79 [m] cased to increase the flow rate to 18,56 [l/min]. For Gear pump the head, hydraulic power, mechanical power, efficiency, and net position suction head at 450 rpm are measures too in ten different flow rate see (Table 2). Based on these data the Figure 3 is shows that the Gear pump runs reliable at its operation region too, the figure shows the pump curve at 450 rpm represented that in the value of \( H \) is 33,43 [m] the flow rate \( Q \) is 5,26 [l/min], decreasing of \( H \) to 1,67 [m] cased to increase the flow rate to 12,67 [l/min]. The NPSH\(_a\), velocity, and surface area by using equation (7, 8 and 9) are calculated 10,99 [m], 0, 47 [m/s\(^2\)] and 0,0007 [m\(^2\)] respectively. The comparison between Gear and Peripheral pumps indicated that often Gear pump is used for producing high pressure then Peripheral pump.

6. Conclusion

Gear pumps are capable of moving a wide range of fluids. Entrained gasses, solids, low viscosity to high viscosity, and low net positive inlet pressure available can all be designed. The high mechanical efficiency offers energy savings. Peripheral pump can be used for pressure increasing, fluid transfer and distribution. They are suitable for flooded suction applications. In (Table 2) from characteristic calculation of Gear pump achieved that in 450 rpm in the low flow rate 5,26 [l/min] can produced a high head 33,43 [m]. However from characteristics calculation point view in (Table 1) the Peripheral pump which is run in 2600 rpm, in low flow rate 4,66 [l/min], produced the head of 12,94 [m]. Furthermore in (Table 1) and (Table 2) the consumption of hydraulic power and mechanical power in Gear or positive displacement pump is from low flow rate to high gradually increasing too much, but in Peripheral pump from low flow rate to high flow rate the consumption of hydraulic power and mechanical power gradually increasing is not reached to higher values of consumption as Gear pump.

7. Summary

Gear and Peripheral pumps sometimes seem to inhabit different worlds. The multi pump testing bench, provided by Edibon Spain, allows measuring the operation characteristics of four pumps (centrifugal pump, axial pump, Gear pump and Peripheral pump). An important advantage of these types of pumps are that they do not need valves either in the aspiration nor in the drive, that is to say, they are able to pump air, gas or liquid without any negative effect, also they do not require a feed. High pressures are possible, although the flow speeds are limited. The main disadvantage of Gear pump is that very close interstices between the end of rotors and the carcases are needed which is affected on its reliability. Any waste or corrosion in this region caused by the material pumped reduces the efficiency of the pump and have negative effects on pump’s reliability, and The main disadvantage of Peripheral pump is especially whenever the pump driven near to 1400 rpm or slow revolutions per minute. Experiments showed that a Gear and Peripheral pumps can appropriately operate in various rotational speeds, heads, and flow rates.

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References


