EXPERIMENTAL TEST OF HYDRAULIC EXTERNAL GEAR PUMPS

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Abstract

In this study hydraulic spur gear pump tests are studied before mass production. The gear pump test set up is developed for verification and validation. The design criterias of equipments of gear pump test setup are determined as handling constituent parts particularly. Experimental application is performed for hydraulic gear pump sample and results are discussed in detail.

Keywords: External Gear Pumps, Gear Pump Performance Criteria, Gear Pump Test Setup, Volumetric Effeciency of Gear Pumps.

INTRODUCTION

The use of hydraulic systems and hydraulic pumps dates back to the very beginning. Gear type pumps is developed at the years of Second World War. Basic principles and parameters of gear pumps are based at that times works. Recently hydraulic pumps are preferred according to hydraulic systems requirements. Especially hydraulically powered positive displacement pumps are very popular nowadays.

External gear pumps (EGPs) have gained popularity among applications in many fields like fluid power transmissions and systems, automotive, aerospace thanks to their advantage of simplicity, robustness and low cost. Several studies were performed to analyze and innovate the gear profiles of EGPs to achieve better performance, in terms of flow smoothness power to weight ratio [1]. Flow non-uniformity at the outlet port is considered as one of the most important detrimental features for all positive displacement pump designs. As a matter of fact, low level of outlet flow fluctuation leads to low levels of noise emissions and reduced chances of mechanical vibration in the downstream systems [1,2,3]

In literature studies, it has been seen that researchers are mainly working on the analysis of hydraulic pumps using the finite element method.

Refs. [4] contain a good description of the hydraulic systems using gear pump as a power source and taking countermeasures for noise and vibration reduction. Mucchi et al. in [4] have developed a model which has been assessed using experiments: the experimental accelerations and acoustic pressure measured in operational conditions have been compared with the simulated data coming from the combined model. The combined model can be considered a very useful tool for design optimization.

Refs. [4] include useful explanations about spur gears "The simulation of the dynamic behavior of a speed-increasing gearbox was also carried out using finite element (FE) methods in [5], where a 3D-contact FE model is used to model the time variable meshing stiffness of the gears, while the gearbox housing is modelled using tetrahedral solid elements. The combined analyses of gears and oil bearings have been developed in the literature using several oil bearing formulations. In particular, in Ref. [6] the dynamics of a spur gear pair supported by journal bearings was studied using the theory proposed in [7]. Gearbox vibrations have been widely studied in the literature by using several methods; in [8] by using a torsional vibration model, in [9, 5] by using an FE model, in [10,11] by using a multibody model.

Moreover, the noise and vibration behaviour of a gearbox has been modelled by using FE methods in [9]. The emitted noise of gear pump has also received attention in [12-14].”

Rana in [15] presented work with the help of external helical gear type gear pump test rig to generate experimental data with the contaminated burnt oil as fluid medium. Setup was run at a different rpm with the speed of motor through vari-o-state, which measured the help of the tachometer. At a different rpm of the gear rotor was checked the performance of the external gear pump. This data were validated with the theoretical estimation.

Egbe in [16] presented an experimental study on testing the external gear pump. The components of the external gear pump were assembled and the pump was coupled to an electric motor (0.64kw, 1400rpm). The suction port was connected to the oil tank of a laboratory hydraulic rig and the discharge to the inlet of test rig. The oil discharge (in litres/minute) of the pump was measured at different pressure heads.

Unlike previous studies, the performance of the five produced gear pumps were examined for flow rate variations, volumetric efficiency and pressures by means of a test setup and the results were presented graphically.

MATERIAL AND METHOTS

In this section gear pump test setup equipments are presented. The setup is capable of newly designed hydraulic gear pumps verification and validation.

Hydraulic Gear Pump Test Setup Equipments

Setup Chassis

The Chassis is designed for mounting equipments of hydraulic gear pump test set up seen in figure 1.

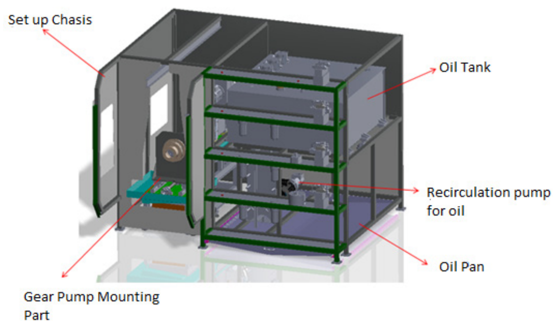

Fig. 1. *Gear pump test setup chassis*

Here the Chassis is designed from structural steel it is designed for standart spur gear pump test.

Excessive oil is collected at Oil pan at the base part of chasis. Recirculation pump is used for circulation of excessive oil to Oil tank. Suction and delivery hoses (2-2.5m) are handled for transfering oil from oil tank to gear pump [17].

The Driving Unit

The driving Unit is mounted at the back of Gear Pump Mounting section seen in figure 2. Driving units are used for hydraulic gear pump test samples. Security cages are used for the security of rotating parts. Servo Motor is prefered at driving unite it must work both clockwise and counterclockwise. Maximum torque values at ultimate rotating speed must be reached at the electric motors. Torque meter is handled between gear pump samples and motors. Guideway is preferred for demontage of system equipments (Gear Pump Samples, Torque Meter).

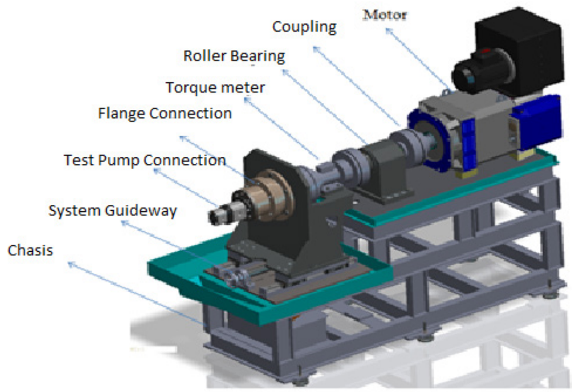

Fig. 2. *The driving unit*

Tests at Gear Pump Samples

Gear Pump Performance

Gear pump samples are evaluated according to pump effciency values. Possitive displacement gear pumps flow characteristics are directly proportional with pump shaft rotating speed. The amount of displaced hydraulic fluid is equal to pump geometric volume at these gear pumps. Volumetric performance values are decreasing from theoretical performance beceause of the leakages occured at spaces and seals. Gear Pumps volumetric performance is about % 85–96. Volumetric and total efficiency may be defined as following formullas.

$$\eta_v \ (Volumetric\ Efficiency) = \frac{Real\ Flow\ Rate}{Theoritical\ Flow\ Rate} \quad (1)$$

$$\eta_0 \ (Total\ Eff.) = \frac{Output\ Power}{Input\ Power} \quad (2)$$

Gear Pump input power is defined as follow

$$Input\ Power\ (W) = \frac{Fluid\ Pressure * Real\ Flow\ rate * 100}{Total\ Eff.} \quad (3)$$

Gear Pump Performance Curves

Gear pumps are evaluated according to definition curves. Definition curves are indicated flow rate variation versus hydraulic pressure. In figure 3 definition curves of new and worn gear pump is presented.

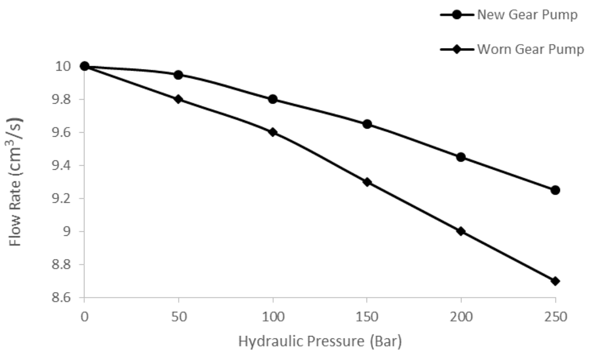

Fig. 3. *Flow rate variation with increasing hydraulic pressure for new and worn gear pumps*

It is seen from figure the hydraulic fluid leakeage flow rate is about %7 for new gear pumps where %13 for worn gear pumps.

Gear Pump Performance Test Criterias

Performance Tests are used for the validation of gear pumps under different pressure and speed values for high temperature conditions .Pump efficiency values are evaluated according to international standart SAE J745 and customer demands. Volumetric efficiency values are compared. These test is validated the gear pumps according to flow rate variation with increasing hydraulic pressure. The real flow rate values are collected from tests compared with theoritical flow rate values. These procedure applied to spur gear pumps for increasing rpm values (750rpm-3000rpm) seen in figure 4. Hydralic fluid temperature is 50 ℃ at these analysis.

It is seen that life test, hydraulic pressure and rpm values are important parameters effective on volumetric efficiency of gear pumps.

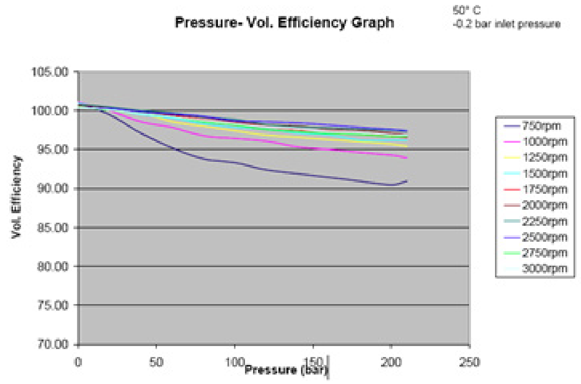

Fig. 4. *Volume efficiency of gear pumps with pressure for different rpm values*

Gear Pump Tests

Gear pumps are mounted to test set up with bolted connections seen in figure 5. Five Gear Pump samples are tested according to conditions below according to customer demands.

Fig. 5. *Connection of gear pumps to test setup*

The Aim of test: The measurement of volumetric efficiency values of for different pressure and speed values.

Test Conditions: Gear Pumps are tested for 0-200Bar test pressure,1000-3000 rpm test speeds. ISO Vg68 Hydraulic fluid is used at tests. Fluid temperature is 50 °C in our tests.

Acceptence Criteria: Minumum 39.5 lt/min flow rate under 200Bar pressure, 1500rpm for 50°C fluid temperature is aimed.

Tested Hydraulic Gear Pump Caracteristics

Hydraulic gear pumps (figure 6) are designed as externally geared, work at 6-25 cm3 / cycle , 250 bar operating pressure, 3000 cycle/min operating speed. Pump external body material is aluminium, gear material is 20CrMoV5 alloy. Five same type gear pump samples are used at tests for design verification and validation.

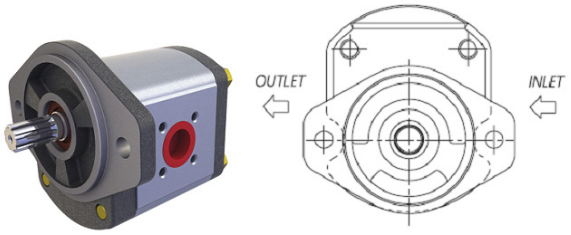

Fig. 6. Hydraulic external gear pumps at tests

RESULTS AND DISCUSSION

In the study five same type spur type gear pumps are tested according the test conditions presented at previous section.

First Gear pump Test Results

Gear Pump performance test results for first gear pump is given at figure 7-8.

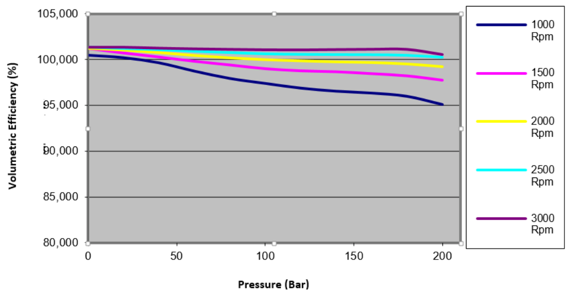

Fig. 7. Volumetric efficiency variation with pressure for increasing speed (First gear pump)

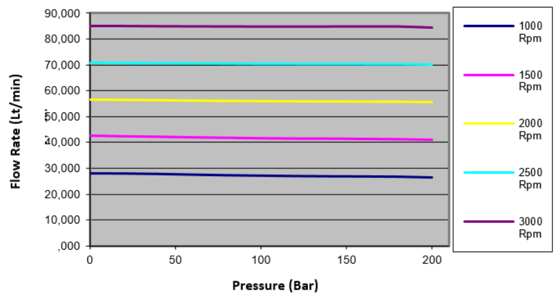

Fig. 8. Flow rate variation with pressure for increasing speed (First gear pump)

The graphics show that the first gear pump reach 41.7lt/min flow rate with %97.79 vol.eff. under 200 bar pressure and 1500 rpm speed. This gear pump is pass the test according to acceptance criteria above.

Second Gear pump Test Results

Gear Pump performance test results for second gear pump is given at figure 9-10.

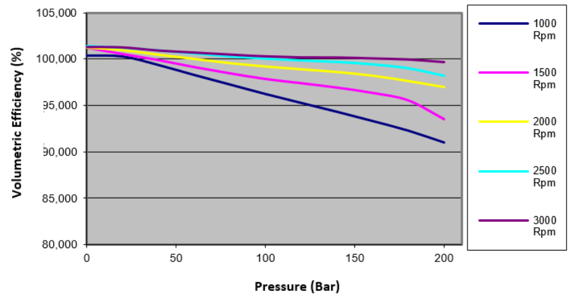

Fig. 9. Volumetric efficiency variation with pressure for increasing speed (Second gear pump)

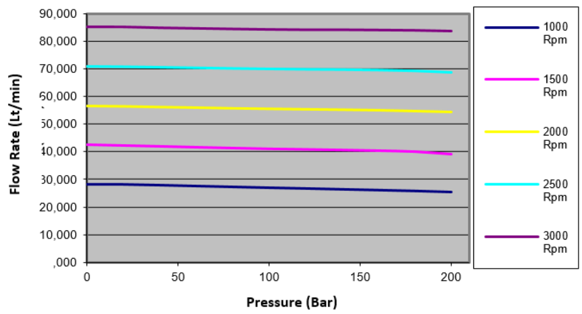

Fig. 10 Flow rate variation with pressure for increasing speed (Second gear pump)

The graphics show that the second gear pump reach 39.28 lt/min flow rate with %93.52 vol.eff. under 200 bar pressure and 1500 rpm speed. This gear pump isn't pass the test according to acceptence criteria above.

Third Gear pump Test Results

Gear Pump performance test results for third gear pump is given at figure 11-12.

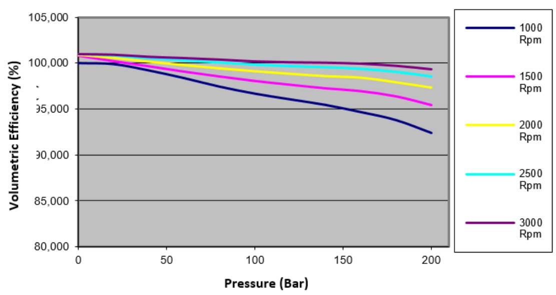

Fig. 11 Volumetric efficiency variation with pressure for increasing speed (Third gear pump)

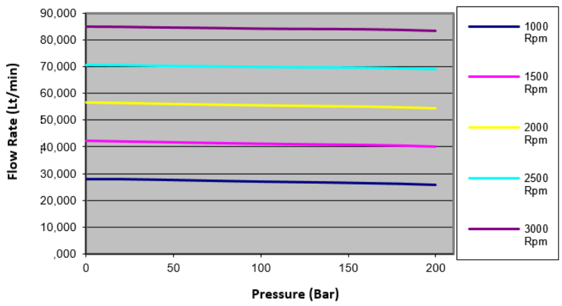

Fig. 12 Flow rate variation with pressure for increasing speed (Third gear pump)

The graphics show that the third gear pump reach 40.07 lt/min flow rate with %95.40 vol.eff. under 200 bar pressure and 1500 rpm speed. This gear pump is pass the test according to acceptence criteria above.

Fourth Gear pump Test Results

Gear Pump performance test results for fourth gear pump is given at figure 13-14.

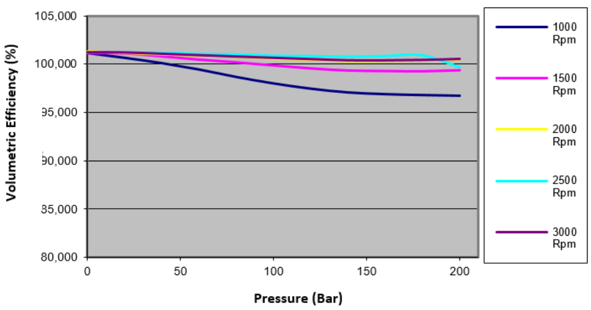

Fig. 13 Volumetric efficiency variation with pressure for increasing speed (Fourth gear pump)

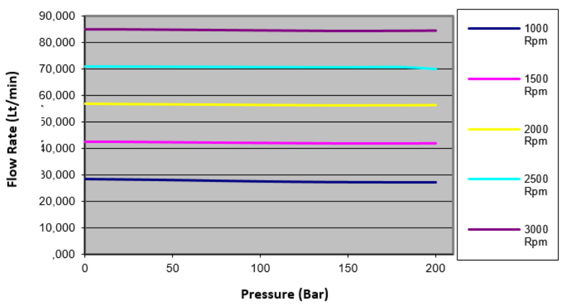

Fig. 14 Flow rate variation with pressure for increasing speed (Fourth gear pump)

The graphics show that the fourth gear pump reach 39.4 lt/min flow rate with %93.81 vol.eff. under 200 bar pressure and 1500 rpm speed. This gear pump isn't pass the test according to acceptence criteria above.

Fifth Gear pump Test Results

Gear Pump performance test results for fifth gear pump is given at figure 15-16.

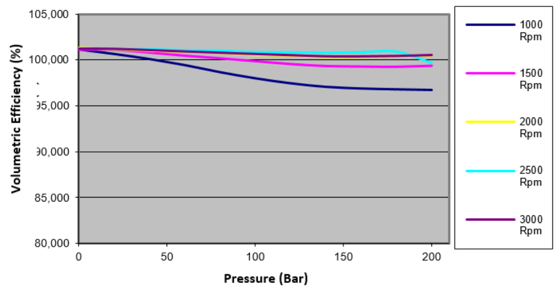

Fig. 15 Volumetric efficiency variation with pressure for increasing speed (Fifth gear pump)

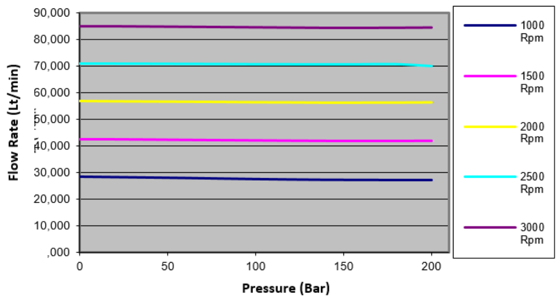

Fig. 16 Flow rate variation with pressure for increasing speed (Fifth gear pump)

The graphics show that the fifth gear pump reach 41.74 lt/min flow rate with %99.37 vol.eff. under 200 bar pressure and 1500 rpm speed. This gear pump is pass the test according to acceptence criteria above.

CONCLUSIONS

In this study hydraulic spur gear pump tests are performed with designed gear pump test setup. Five same type gear pump test results are evaluated according to acceptence criterias. Test results show that tested newly designed spur gear is found suitable for mass production. Higher volumetric efficiency values may be obtained with controlling the hydraulic fluid leakeage at gears. The teeth form a visible trace on the body at first tests at gear pumps. The tolerance between the body and gears must be suitable to provide seal at the gear pumps. For this reason the gear pumps not passed the test must be dismounted and investigated.The tolerance values must be redetermine for new productions.

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