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STUDY OF FEASIBILITY OF PLASTIC GEAR TO REDUCE NOISE IN A GEAR PUMP

Metalsi Tani, F.* & Bourdim, A.*
* Université De Tlemcen, Faculté de Technologie, Laboratoire Eole, Département de Génie Mécanique, B.P. 230-13000 – Tlemcen – ALGERIE
E-mail: fethi_metalsi@yahoo.fr; bourdim@mail.univ-tlemcen.dz

Abstract:
Generally, gear pumps are classified as noise producing machines. With a view of reducing overall radiated noise level from gear pumps, without affecting the mechanical efficiency, an experimental investigation was carried out. In this study the possibility of utilizing a plastic gear instead of the conventional one was exanimate. On the rig built up for this purpose, two different kinds of tests were made.

The first part of the experiment was devoted to measurements related to mechanical performances and the radiated noise level from a conventional pump with a metal gear mesh, under different operating conditions. The second series of tests was carried out mainly to know the effect due to the replacement of the idler metal gear with the plastic one. This test also was performed under various operating conditions.

Serious difficulties were encountered with the plastic gear testing. On several occasions the plastic gear was destroyed. The debris from the plastic gear gave considerable trouble in some elements of the hydraulic circuit. In the plastic gear case, significant flow was observed. The results of the performance test on the plastic gear seem to be disappointing. Even though the plastic gear has good damping vibrations, there is no significant reduction in the overall radiated noise level from the gear pump. At low speeds, the plastic gear gave a lower performance rate compared to the conventional gear pump. However, at higher speeds, the performances were nearly the same. Further, the plastic gear seems to be unable to withstand a high level of loading. This can cause damages in the plastic gears and reduce the life period.

Key Words: Gear, Noise, Plastic Gear, Gear Pump

List of symbols:

η : global ratio of efficiency, [%]
N: speed [rpm]
L_p: Sound pressure level [dB]
P_{rms}: root mean square value of the pressure
T: reverberation time [s]
F_n: natural frequency
A_x, A_y and A_z: room sizes
V: volume of the room test
λ: Wavelength [m]
η_v: volumetric ratio η_m : mechanical ratio
P: output pressure [Bar]
P_0: reference value = 2.10^{-5} Pa
B: 10^3 [mbar]
To: 1s
n_x, n_y and n_z: entire values
S: surface [m^2]
Vo: reference volume: 1 m^3
c: sound celerity [m/s]

1. INTRODUCTION

Hydraulic equipment is widely used for applications on construction machines, plastic processing machines, industrial vehicles, etc. The fields of applications of hydraulic equipment are still increasing. Using hydraulic equipment is generally means increasing the sound level in machines and equipments.

However, noise pollution and deterioration of the working environment due to noise became an important problem to be solved. As many hydraulic machines, the gear pump have also some disadvantages, as noise, fixed cubic capacity, difficult control of internal loses, important loads on bearings because of the hydrostatic unbalance.

It's well known that gear noise is really a complex and difficult problem. Gear material, tooth profile, manufacturing errors, contact ratio are the main among the multitude factors which generate noise. Many researchers were interested in reducing it [1-3]. Just few of them studied to reduce gear pump noise [4] by reducing the intensity of the alternatives forces.

The purpose of this study is to replace a metal gear by a plastic one in a gear pump. An experimental study was carried out to reduce noise level without affecting the mechanical performance.

Two different configurations were considered. The first one is metal-metal gear, configuration 1; the second one is metal-plastic gear, configuration 2. According to the intrinsic properties of the thermoplastics as damping material, we expect noise reduction. But in this case, the gear pump has many factors which can affect noise. We then compare the mechanical characteristics of the two configurations.

As shown in figure 1 are simple and contain few parts. Their principal function is to transform mechanical power to hydraulic power which usually generates noise and vibrations. Those vibrations are transmitted by the fluid and the housing (structure). To determine noise level is generally a complicated operation because of other factors which may affect the measure, as the motor, the belts, etc…This pump consists of two meshed gears, suitably housed with a shaft to one of the gears. Close clearance are held between the housing and the gear sides to prevent excess leakage [5].

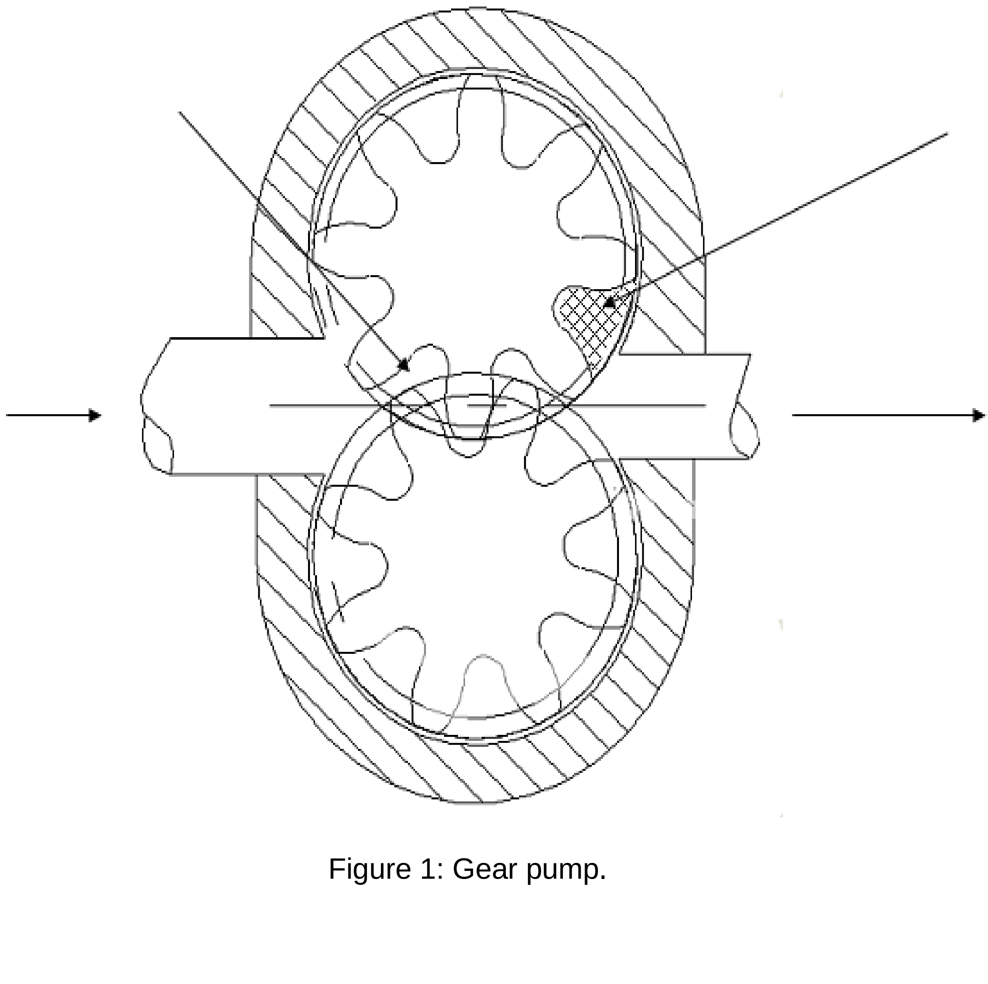

Figure 1: Gear pump.

2. EXPERIMENT STUDY

The rig built up for the experimental investigation concerns mainly two different domain, hydraulic and acoustic. The hydraulic system is illustrated in Figure 2.

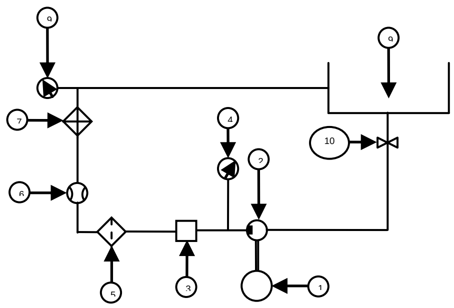

Figure 2: Hydraulic system.

This system permits to measure the flow under different operating conditions, speed and output pressure. While the oil temperature is kept constant it affects the flow. For the acoustic part, although the availability of the anechoic chamber, we have chosen preferred design and built a reverberant room for its convenience.

The room test was built according to standardization. We have made some measures on it. To avoid solid transmission, an elastic coupling, and damping material on the plate and elastic joints were placed in this system test. And then we have insulated the pump from other parts of the rig. The background noise, the transmission loss (about 30 dB close to the predominant frequencies), the reverberation time, the non-formation of the standing wave (some diffusers: 4, have been placed in the room) after analysing the sound diffusion, have been considered. (see figures in appendix). We have then determined the cut-off frequencies and design a special wall to eliminate the frequencies of coincidence.

To evaluate the efficiency of the pump, we should measure the power entering the pump. A special mechanical and electrical breakdown was designed and built for this purpose. The cubic capacity was determined by two experimental methods. The results obtained compare very well with the data given by the constructor of the pump.

3. RESULTS AND DISCUSSIONS

Figure 3, shows the global efficiency η versus the speed, for the two configurations.

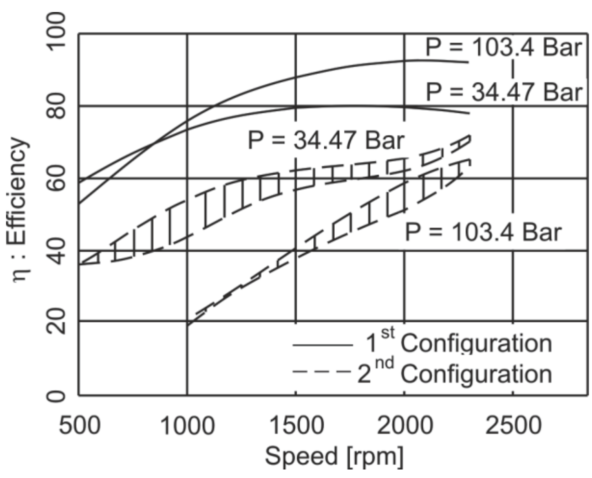

Figure 3: Global efficiency vs speed with P=34,47 bars and 103,4 bars.

Where the global ratio is given by: $\eta=\eta_v.\eta_m$, where η_v and η_m are respectively the volumetric and the mechanical ratio. We have found the same results as the manufacturer for the first configuration, metal-metal gear. But for the second one, to understand more we should analyse the volumetric ratio illustrated in Figure 4.

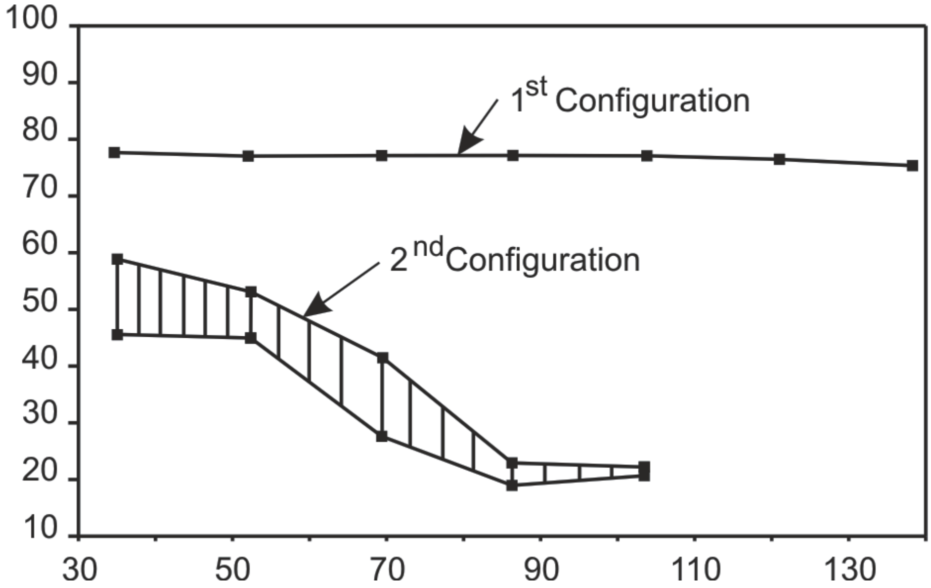

Figure 4: Volumetric ratio with N=1015 rpm.

The analyse of the volumetric ratio gives the real comparison between the two configurations At low speeds, around 515 rpm, there is a big decrease of flow. This occurs because of the deterioration of the plastic gear. So the loses are increasing under these conditions. But, at high speeds, and high pressure, we couldn't read a value for the flow but a range of values, (see Figure 4).

According to this figure and others which are not showed in this paper, we can say that the pump, second configuration is not as efficient as the first one.

4. SOUND PRESSURE LEVEL

The sound pressure level is given by:

$$L_p = 10 * Log_{10}\left({p_{rms}}/{p_0} \right)^2 \quad (1)$$

The measure of the sound pressure level, under different operating conditions, reveals that the frequency peak on diagrams are on gear mesh frequency or close to, because of gear eccentricity.

The sound pressure level spectrum has been done in 1/3rd octave band, because our purpose is to compare between the two cases.

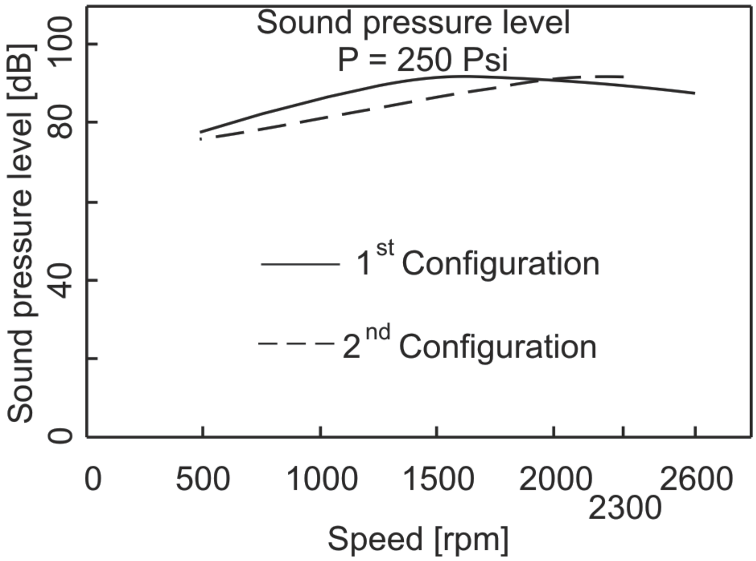

Figure 5: SPL vs speed with a fixed value of pressure.

We have varied pressure and speed to measure the sound pressure level to see the effect of each of them. The level of SPL mentioned on the above figures could be amplified because its frequencies could be so close to natural frequencies of the test room which are given by the following equation and then calculated.

$$F_n = \frac{c}{2}\left(\left(\frac{n_x}{A_x}\right)^2 + \left(\frac{n_y}{A_y}\right)^2 + \left(\frac{n_z}{A_z}\right)^2\right)^{1/2} \quad (2)$$

And we have noticed that, the more the output pressure is high, the sound level became steady for both configurations. Then, the level increases when increasing the speed. For the second configuration, we were limited to 2300 rpm because the tooth deterioration and the debris create some technical problems. We have illustrated many curves under these conditions to understand how it affects the sound pressure level.

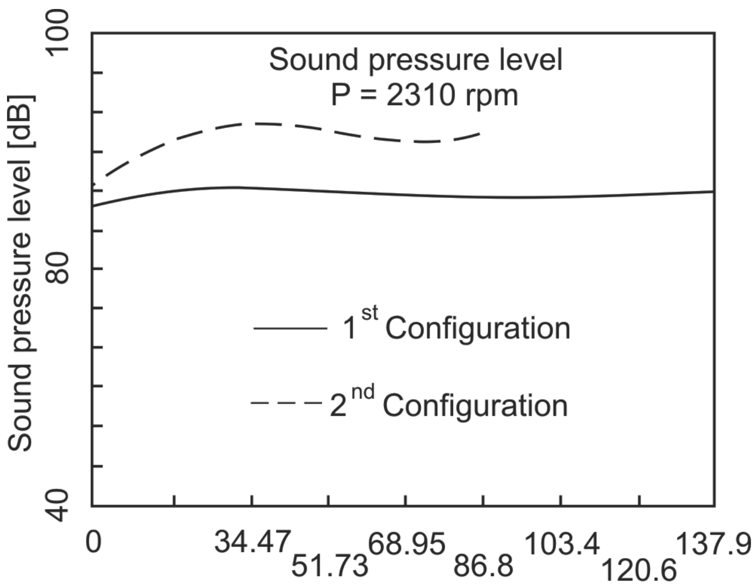

Figure 6: SPL vs pressure with a fixed value of speed.

The power acoustic level, [dB], is given by the following equation:

$$L_w = L_p - 10\,.\,Log_{10}\left(\frac{T}{T_0}\right) + 10.\,Log_{10}\left(\frac{V}{V_0}\right) + 10\,Log_{10}\left(1 + \frac{S.\lambda}{8.V}\right) - 10\,Log_{10}\left(\frac{B}{1000}\right) \quad (3)$$

And then the power level became:

$$L_w = L_p - 10\,Log_{10}\,T + 10\,Log_{10}(1 + 0.28.\lambda) - 1.17 \quad (4)$$

Figure 7, shows the power level for both configurations for a speed value of N=1010 rpm and an output pressure P= 34, 47 Bars. We notice that the power acoustic level is more important for the second configuration (metal – plastic) gear than the first one (metal- metal) gear. This, was calculated and illustrated for all different parameters.

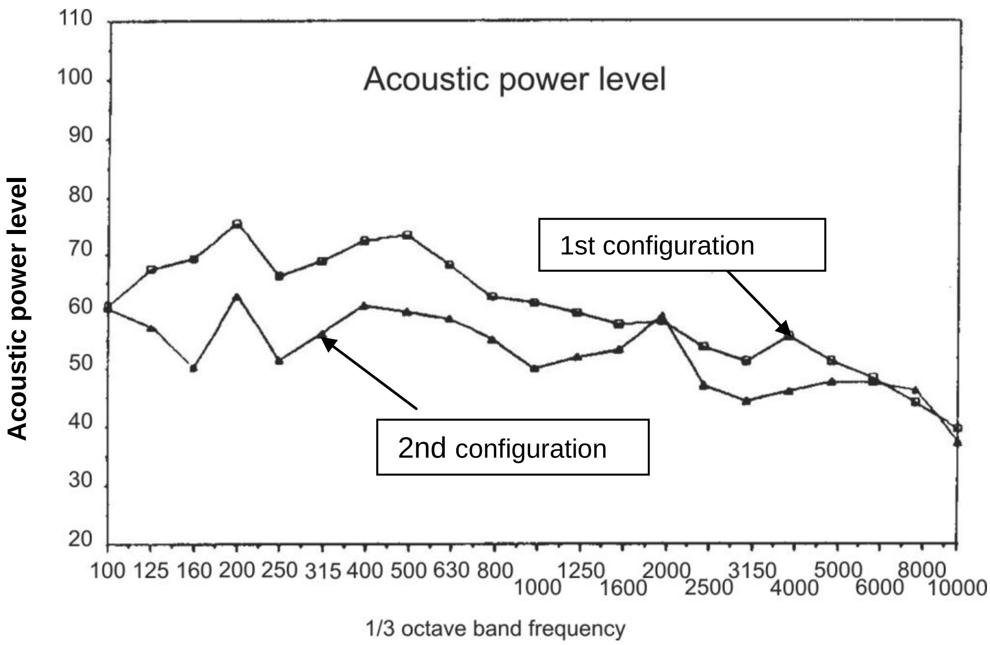

Figure 7: Acoustic power level.

4. CONCLUSION

The designed experimental rig is being used to determine a full of hydraulic parameters and to measure the sound pressure level.

A comparison study has been done between the two configurations. According to hydraulically and acoustical point of views, the pump with a plastic gear (second configuration) is not efficient while in the first configuration, tests were done without any particular problem. However, the second one was very difficult. We've got some problems to read the flow, because of the deterioration of the plastic gear. This tooth deformation causes the friction and eliminates the clearance between gears and the housing. So this was the main problem encountered and this also the fact which increases the noise generated.

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