A Study on Noise Reduction of PTO Gear-box for Driving Pump of Large Excavator

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ABSTRACT

A PTO gearbox ("gearbox") is designed to be mounted on a construction vehicle to convey power from the engine to multiple pumps. The gearbox uses oil bath lubrication, which often experiences a disruption in the supply of lubricant inside the gearbox. Poor lubrication in any gearing system is a major cause of a drop in its efficiency, which is often displayed in the form of heat or noise. This study describes a technology that can reduce noise by making splash lubricant inside the gearbox fall down along the wall like a curtain and measures its performance through comparison. Measurement of noise was made under no-load condition and load condition. For the former, measurement was made while the servo motor was used for driving to minimize noise from the equipment. For the load test, the noise from the equipment was unavoidable because an electrical dynamometer had to be used to control the load, but a comparison was made against the measured noise to determine where there had been any impact. If any impact was identified, a correction would be applied for the noise measured.

1. SPECIFICATIONS OF GEARBOX

The gearbox is installed between the engine of a super large excavator and its three hydraulic pumps and has three output axes. One of them transmits 20 percent of the input power while the other two transmit 40 percent, respectively. Power transmitted to each pump conveys hydro energy to the rotating section in the upper body of the excavator and the driving section and the hydraulic cylinder in the lower body to help enhance fuel efficiency.

Table 1. Specifications of gearbox

Item	Unit	Spec.
Gear type	-	Helical gear
Max. Torque/ speed	Nm/ r/min	3 000/ 1 800
Max. Power	kW	570
Input/ Output speed	r/min	1 800/ 1 838
Type of output	-	3 Axis (1*20%, 2*40%)
Gear ratio	-	0.979/1

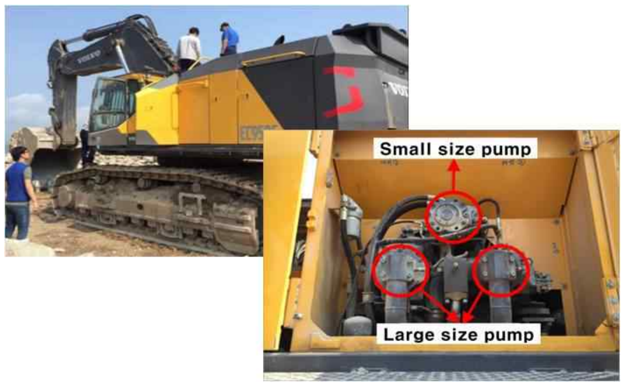

Figure 1. Application area of PTO Gearbox

2. INTRODUCING A NOISE REDUCTION TECHNOLOGY

The Ministry of Environment imposes restrictions on construction machines generating noise. Therefore, noise needs to be reduced to the level acceptable in the industry.

2.1. Introducing a technology to reduce noise from gearboxes

The existing noise reduction technology avoids resonance by changing the design of the gearbox or curtails vibration by increasing the strength of the part susceptible to deformation due to load. Specifically, resonance can be avoided by:

1. Changing the number of the teeth to achieve a different gear mesh frequency; or
2. Amending the shape of the teeth (for a different angle).

2.2. Introducing the new technology applied to the test product

Gearboxes usually use oil bath lubrication due to their poor cooling system. This method is not efficient in supplying lubricant throughout the gearbox and often reduces the gears' transmission of power. Loss caused by such inefficiency or reduction is displayed in the form of heat or noise. The key to the noise reduction technology described in this study is making splash lubricant for lubrication fall down along the wall. In addition, a lib in the form of an irregular grid is installed within the gearbox to help reduce structural noise.

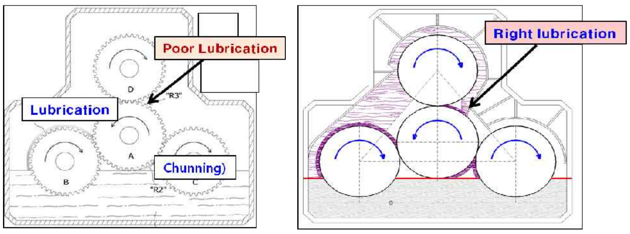

Figure 2. Noise reduction technology

3. METHODOLOGY FOR NOISE TESTING

In the noise test, a product embedding the noise reduction technology (test sample 1) and one without it are tested and compared to determine the effectiveness of the technology. Testing shall be carried out under no-load and load conditions.

3.1. Applicable theories

One factor that must be avoided during the noise testing is background noise that may affect the noise of the test product. Several characteristics associated with noise synthesis are applied to the noise test for the gearbox.

3.1.1. Noise synthesis (1)

The first noise synthesis is to isolate specific noise from a mix of noises from different sources. The correction table for background noise provided by ISO and KS specifications is based on such characteristics.

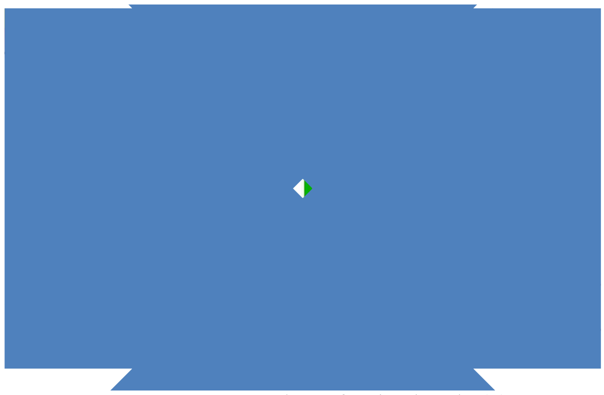

Figure 3. Subtraction of noise levels (1)

$$L_{S+N} + L_N = 10Log(10^{L_{S+N}/10} - 10^{L_S/10}) \quad (1)$$

If noise synthesis (L_{S+N}) and noise from source N (L_N) are known, noise (L_S) can be calculated from formula (1). No correction is required if there is no difference between calculated L_S and L_{S+N} as it means there is no impact of L_N.

3.1.2. Noise synthesis (2)

The second synthesis of noise is about synthesizing noise from n sources having the same noise level as shown in Figure 4.

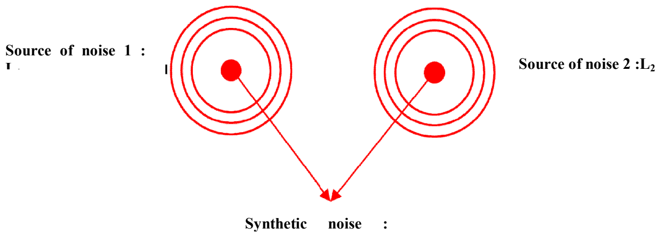

Figure 4. Subtraction of noise levels (2)

$$L_{total} = L_1 + L_2 + \ldots + L_N = L_1 + 10Log(n) \quad (2)$$

If there are two sources as in formula (2), the synthesized noise is only 3 dB higher than the noise from a single source.

3.2. Methodology for no-load noise testing

The no-load noise test uses a servo motor to minimize noise from the test equipment.

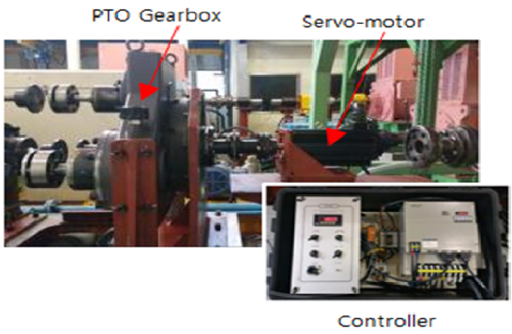

Figure 5. Test equipment of no-load test

The test method is as follow;

1) Measure the background noise prior to the test.

2) Measure the noise for 20 seconds during operation at 1800 rev/min.

3) If the difference between the background noise and the measured noise is no greater than 10 dB, apply correction according to Table 1. (Noise synthesis (1) shall apply.)

Table 1. Correction for background noise

[Unit : dB]

Difference	3	4	5	6	7	8	9
Correction	-3	-2		-1			

3.3 Methodology for load noise testing

For load testing, place two gearboxes across from each other and control input for one and output for the other using an electrical dynamometer.

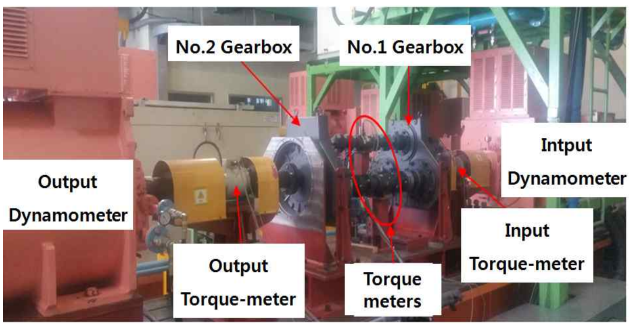

Figure 6. Test equipment of loading test

The test method is as follow;

1) Situate the microphone as shown in Figure 7.

2) Measure the background noise prior to the test.

3) Measure noise for 20 seconds under the condition set out in Table 2.

4) If the difference between the background noise (including noise from the test equipment) and the measured noise is no greater than 10 dB, apply correction according to Table 1.

5) Calculate the noise from one of the gearboxes based on the measured noise. (Noise synthesis (2) shall apply.)

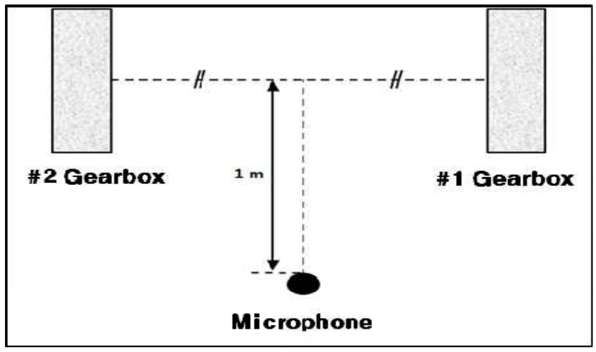

Figure 7. Microphone location

Table 2. Test conditions

Item	Test conditions [rev/min * Nm]
Loading conditions	1 100*3 000
	1 350*3 000
	1 500*3 000
	1 650*3 000
	1 750*3 000
	1 800*3 000

3.4 Test results

Table 3 shows results from the no-load noise testing.

The product embedding the noise reduction technology reported lower noise by approximately 3.8 dB(A).

Table 3. Test result of unloading condition

[unit : dB(A)]

Item	Test results	
	No.1 test sample	No.2 test sample
1 800 rev/min	71.4	67.6

Table 4 shows noise levels measured from the background and the test equipment during load noise testing.

Table 4. Noise of background & facilities

[unit : dB(A)]

Item	Test results
Background noise	47.3
Lubrication pump	66.9
Dynamometer	82.0

Table 5 shows results from load noise testing. No correction is required as the difference with noise from the background and test equipment is greater than 10 dB(A). The test results show that the product embedding the noise reduction technology reported lower noise by approximately 2.7 dB(A).

Table 5. Test results of loading conditions

[unit : dB(A)]

Item	Test results		
	No.1 test sample	No.2 test sample	Diff.
1 100*3 000	94.7	92.1	-2.6
1 350*3 000	96.4	94.4	-2.0
1 500*3 000	93.1	92.5	-0.6
1 650*3 000	96.8	92.6	-4.2
1 750*3 000	100	96.8	-32
1 800*3 000	99	95.5	-3.5

4. CONCLUSIONS

The results from the noise testing demonstrate that the noise reduction technology is effective, and the noise from the gearbox is not necessarily linked to the rate of revolutions. This is also confirmed by the references.

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