The 10th JFPS International Symposium on Fluid Power FUKUOKA 2017 Oct. 24-27, 2017 The Japan Fluid Power System Society

DESIGN METHOD FOR HYDRO-MECHANICAL TRANSMISSION FOR VEHICLE (Prediction of Noise Based on 1D and 3D Simulation)

Takeshi OUCHIDA*, Yasukazu SATO**

*Robotics Group, Fundamental Technology Research Division, Research & Development Center, YANMAR Co., Ltd.
2481 Umegahara, Maibara, Shiga, 521-8511 Japan
(E-mail: Takeshi_ouchida@yanmar.com)
** Faculty of Engineering Division of Systems Research
Yokohama National University
79-5 Tokiwadai, Hodogaya-ku, Yokohama, Kanagawa 240-8501 JAPAN

Abstract. For agricultural tractor, these two performance has been very important; high efficiency and maneuverability because the operator has increasingly required the fewer fuel consumption and easier and more precise control of the tractor. Therefore, new hydraulic mechanical transmission has been developed especially to fit their demand. Generally speaking, HMT is well known for the high efficiency level thanks to their splitting power flow between mechanical and hydraulic path. Moreover, its step-less variable speed feature is suitable for the operator demand such as quick and smooth speed change. However, HMT is hydraulic powered system then hydraulic noise may more often occur than the pure mechanical transmission; such as power-shift transmission or dual clutch system. Purpose of this paper is to show how to design tractor transmission with HMT concerning with hydraulic noise.

Keywords: Hydraulic Mechanical Transmission, Noise, Simulation

DEVELOPPED HMT

Structure Overview

Conventional tractors transmission technology mainly consists of "mechanical" or "Hydraulic" types. FIGURE 1 shows appearance of newly developed HMT (Hydraulic Mechanical Transmission), which was developed with the concept that it brings both high transmission efficiency of mechanical type and high maneuverability of hydraulic type. The main features of this HMT are as following;

- Only one plunger block into which plungers of pump and motor are inserted.
- Spool mechanism which switch hydraulic oil path while the expansion and compression process.
- Continuous variable speed control with the electromagnetic proportional valves

FIGURE 1. Newly developed HMT

PROCEDURE OF SOUND PRESSURE LEVEL PREDICTION

Procedure

In order to predict the hydraulic noise level, calculation procedure has been developed as shown in FIGURE 2.

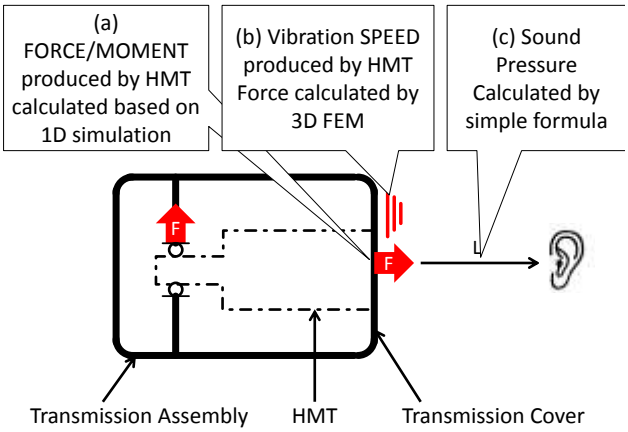

FIGURE 2. Procedure of Sound Pressure Level Prediction

Each steps of the procedure are as following;
(a) Hydraulic pressure simulation on HMT
For the purpose of reducing the hydraulic noise, one-dimensional numerical model has been developed (FIGURE 3). This 1D model provides all forces and moments produced by the pressure in each plunger chambers, high and low pressure ports. Hydraulic Oil flow from Plunger chamber is switched from low (high) pressure port to high (low) pressure port. It is well known that V-shaped notch on the valve plate is effective to reduce the high frequency noise of axial piston pumps [1]. This HMT has same functional part, which is named timing spool as shown in FIGURE 4. The spool geometry determines how quickly opens or closes the fluid path.

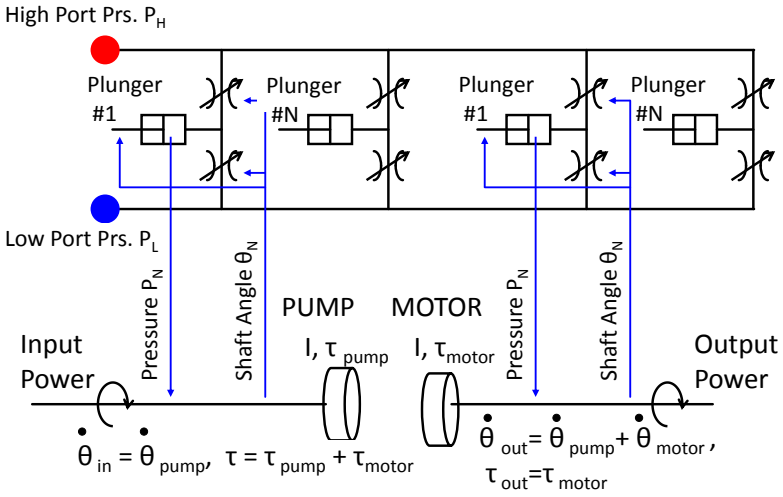

FIGURE 3. 1D Simulation Model

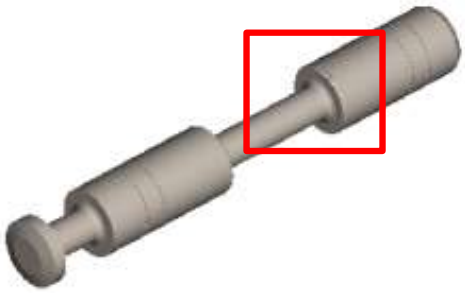

FIGURE 4. Timing Spool

(b) Transmission vibration simulation
By using the calculated forces and moments, vibration speed of transmission assembly has been calculated with FE frequency response analysis (FIGURE 4).

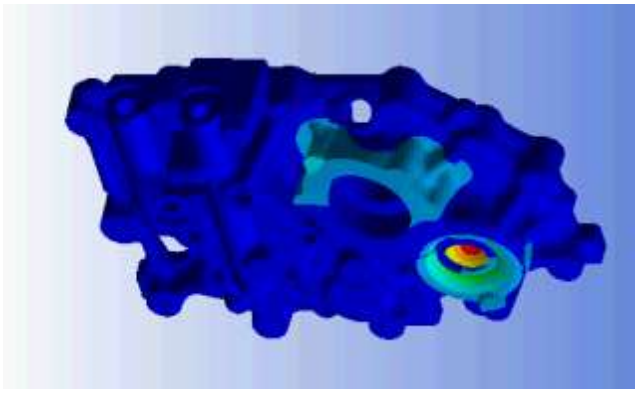

FIGURE 4. FE Frequency Response Analysis
(Transmission Cover)

(c) Sound pressure calculation
Sound pressure level has been calculated by using the vibration speed of the transmission parts surface and formula (1).

$$P = j\omega\rho \frac{V_0 e - j\omega r / c}{2\pi r} \cdot 4ab \quad (1)$$

where, ρ, c, Vo, ω, r, 2a, 2b are air density [kg/m3], sound speed [m/s], vibration velocity on the surface of the cover [m/s], vibration rotational speed of the sound source [rad/s], distance from the sound source [m], height and width of sound source [m].

RESULTS OF SIMULATION

Hydraulic Pressure simulation

1D model which calculates the each plunger chamber and ports pressure brought all forces and moments affecting to the cover where HMT is mounted. TABLE 1 shows the condition of the simulation. This condition represents the tractor operating mode in which tractor runs at quite slow speed; 0.35km/h with no traction load.

TABLE 1. Condition of Simulation

Transmission Input Speed = HMT Pump Speed	min^{-1}	2,800
Transmission Output Speed = HMT Pump Speed - Motor Speed	min^{-1}	210
Transmission Reduction Ratio	-	13.3
Transmission Output Load	-	No load

FIGURE 5 is a one example of the result which shows the pressure frequency spectrum in high pressure port. In this case, the plunger block rotates 2,800min-1; thus the pump's 1st harmonic order is 327Hz and the motor's 1st harmonic order is 302Hz because motor rotational speed is the difference between input and output speed. This results shows that the higher the harmonic order is, the lower the pressure spectrum peak becomes.
Also Fig.6 shows the axial direction of the force produced by all plunger chamber pressure. Frequency of 1st harmonic order of the pump is simulated as 327Hz and motor as 302Hz. Then the higher order of force is calculated up to 4,000Hz.

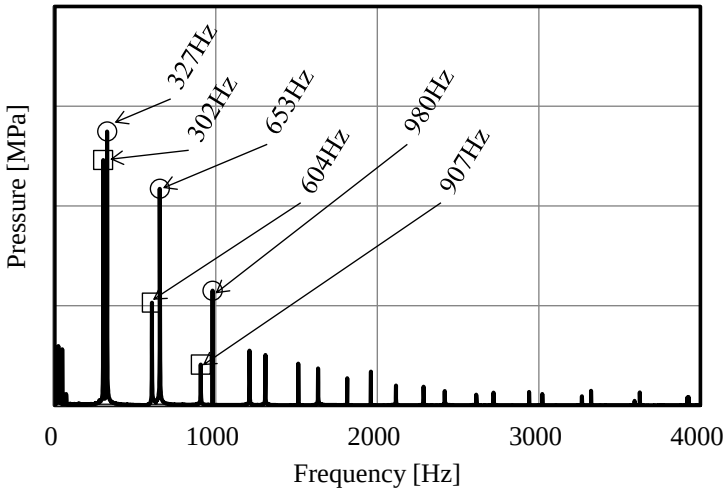

FIGURE 5. Simulation Result of the Pressure in High Pressure Port

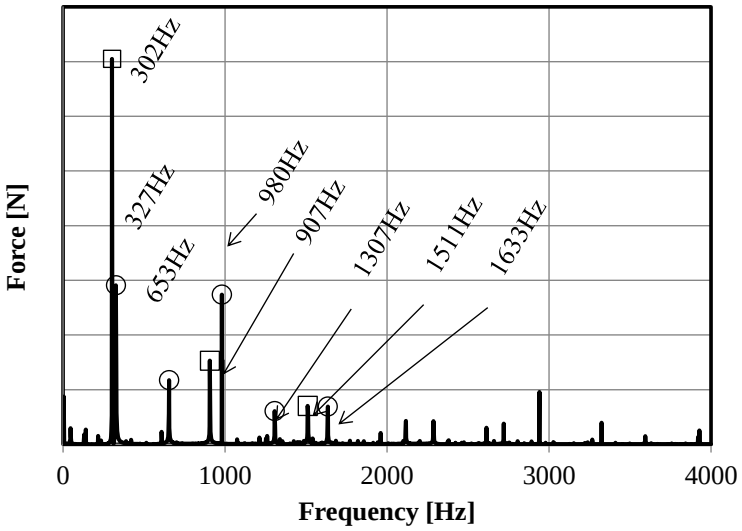

FIGURE 6. Simulation Result of the Force Affecting to Transmission Cover

Transmission Cover Vibration

Forces calculated by 1D model was used to predict the transmission cover vibration. The axial forces have been applied to the cover surface where HMT is fastened and the whole edge of the cover has been treated as the fixed end (FIGURE 7).

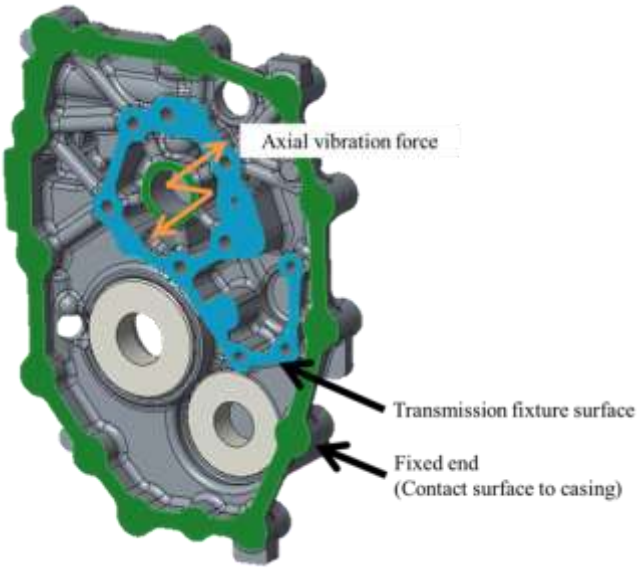

FIGURE 7. Constraint and Vibration Force Input of the Transmission Cover

FIGURE 8 shows the vibration acceleration on the transmission cover surface. The frequency spectrum has great peaks around 3kHz.

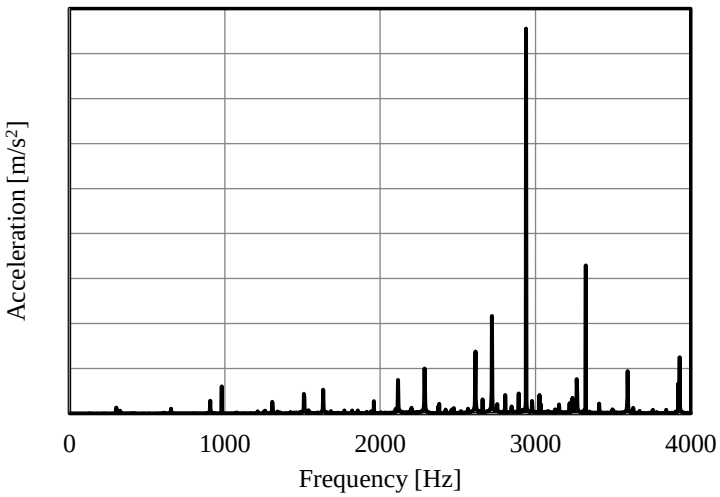

FIGURE 8. Simulation Result of the Vibration Accelerate on the Cover Surface

CONCLUSION

This paper shows the method that predicts the transmission noise produced by the hydraulic pressure in HMT. Then the results of the force simulated by 1D model were shown. Moreover, the vibration acceleration on the cover surface was predicted. In next step, the simulation of the sound pressure will be done and the experimental data will be measured to be verified this method.

ACKNOWLEDGMENTS

The authors are thankful to Mr. Jin MIYAZAWA, a former graduate student of Yokohama National University, for his cooperation in various simulations.

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1. T. Grahl: 8 AFK , 1988, pp187-204.

