PREDICTION OF NOISE & VIBRATION EFFECT OF AGRICULTURAL TRACTOR TRANSMISSION AT DESIGN STAGE

JungHun Kim and YoungSun Kang
Mechanical Design Department,
TongYang Moolsan Co., Ltd., Korea

ABSTRACT

At design stage of the TRX1 agricultural tractor transmission(New product of TongYang Moolsan Co., Ltd), the noise and vibration of the transmission were analyzed theoretically for the optimal design of the transmission. For this analysis, the finite element model was developed using a commercial computer software, ANSYS. The noise and vibration of the TRX1 transmission housing were predicted by the modal analysis. Natural frequency of the TRX1 transmission housing was ranged from 12.53Hz(1st mode) to 30.05Hz(5th mode). The fifth mode took place at the bearing metal in the area of rear transmission housing and was very close to the gear mesh frequency(30.5 Hz) of low range gear at the low creep shifting. Based on the results, the bearing metal of the range shift housing was re-enforced with the rib at design stage.

Key Word : Agricultural Tractor, transmission housing, Modal Analysis, FEM

INTRODUCTION

Current trend of tractor design is to focus on the driver's comfort. In order to provide better driving environments, the analysis of the noise and vibration reduction are inevitable.

In the tractor transmission, there are several noise and vibration sources such as gear mesh, shaft misalignment, bearing, etc. To analyze the noise and vibration of the tractor transmission systematically, it is necessary to understand the relationship between a tractor transmission housing and the noise and vibration sources. For this purpose, the overall vibration characteristic of the tractor transmission housing are essential. Vibration characteristic can be obtained by a modal analysis. Modal analysis of the transmission housing can be performed by numerical method using a finite element model.

In the previous research[2], the critical velocity of the transmission shaft was found at the higher frequency than 55Hz. This frequency was away from the

shaft operating rpm. For this reason, transmission gear mesh frequencies in the range shift gears which run at a relatively lower frequency were focused on in the research.

TRX1 transmission gear mesh frequency was calculated at 3 different speeds. Natural frequency of the TRX1 transmission housing was obtained by the finite element model analysis. Comparison was done between the transmission gear mesh frequency and the transmission housing natural frequency.

The objective of the study is

1. To obtain the natural frequencies of the TRX1 tractor transmission housing, using a finite element model
2. To modify the TRX1 transmission housing at design stage on the basis of the comparison of the transmission housing natural frequency to the transmission gear mesh frequency

MATERIALS AND METHODS

The transmission of TRX1 tractor designed in 1995 by TongYang Moolsan Co., Ltd.(TYM) was used for the analysis to improve the tractor quality from a view of the noise and vibration at design stage. The transmission was modeled using a finite element software, ANSYS(Ver 5.1). Although TRX1 tractor transmission housing consisted of 3 parts of front, mid, and rear housing, 3 parts were considered as one whole transmission housing for a simple analysis. 4-node shell elements were used to develop the transmission housing(Figure 1). Natural frequencies and mode shapes were obtained using modal analysis(subspace method) provided by ANSYS.

RESULTS AND DISCUSSION

Gear mesh frequencies of gears in the area of range gear shifting were calculated at 3 different engine speed(1500, 2400, and 2600 rpm). TRX1 engine was assumed to run at between 1500 rpm and 2400 rpm in the field. Maximum engine speed was 2600 rpm. Gear mesh frequencies of range shift gears were shown in the table 1. Shaft critical speed was less interested. Because the previous study showed that critical speed of the shaft was higher than 3300rpm, lower frequencies generated by the gear mesh was paid more attention.

Natural frequency was found from the finite element analysis and summarized in the Table 2. The first mode took place at 12.5 Hz as a bending mode. The second one was a mixed mode of bending and torsion at 20.5 Hz. The third mode was a torsional mode at 24.5 Hz. The fourth mode was another bending mode at

26.9 Hz. These four modes represented the natural frequencies of the whole transmission housing. The fifth one(30.05 Hz) represented the bearing metal motion in the rear transmission housing(Figure. 2).

When the creeper was engaged with the range speed on, gear mesh frequency of low range gear was from 19.1 rpm to 30.5 rpm. Comparing the natural frequency with the gear mesh frequency, resonance could be expected during the tractor operation due to the overlap of natural and gear mesh frequencies. This resonance could not be avoided because the gear reduction ratio was fixed and the large change of the natural frequency of the transmission housing was very difficult practically from the point of manufacturing cost and assembly.

However, at least one resonance mode could be avoided because gear mesh frequency on the creeper shift with the low range on matched the fifth mode frequency of the rear transmission housing. To avoid the resonance phenomena in the creeper low range tractor operation is to decrease the deflection of the transmission housing by increase the system stiffness. For this purpose, a rib was added to provide more strength with the bearing metal. Modal analysis was performed again with the modified finite element model. A re-enforced rib was modeled with beam elements.

The analysis result showed that the natural frequency of the bearing metal was increased up to approximately 10% (33 Hz). This change could be acceptable because the gear mesh frequency of 33.1 Hz took place at the maximum engine speed. In the field, operating engine rpm is generally 10 % below the rated engine rpm which generated a gear mesh frequency of 30 Hz.

CONCLUSIONS

The objective of this paper was to reduce the effect of the noise and vibration of TRX1 tractor transmission using a finite element model at design stage. The following conclusions were drawn:

1. Gear mesh frequencies of range shift gears of TRX1 tractor were overlapped with natural frequencies of transmission housing.
2. Resonance mode on a bearing metal in the rear transmission housing of TRX1 was avoided by adding a re-enforced rib.

Table 1. The gear mesh frequency range (unit : Hz)

ENGINE rpm / Name of Gear	1500	2400	2600
The second cleeper Gear	44.9	71.9	77.9
The Low range Gear	19.1	30.5	33.1
The High range Gear	40.9	65.4	70.8

Table 2. The natural frequency of transmission case

No. of mode	Natural Frequency (Hz)
1	12.53
2	20.51
3	24.45
4	26.88
5	30.05

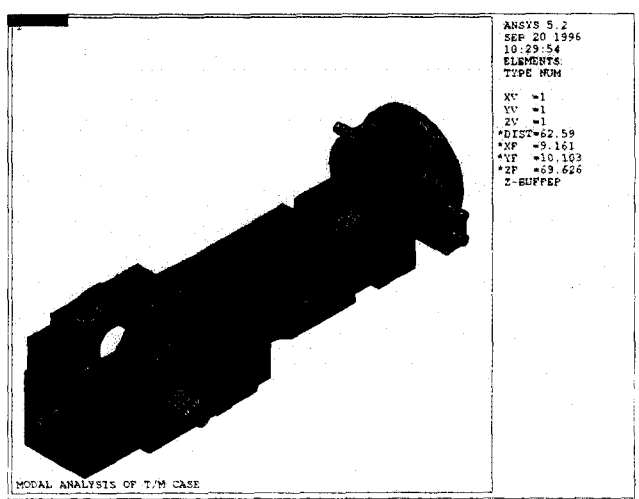

Figure 1. The FEM model of transmission

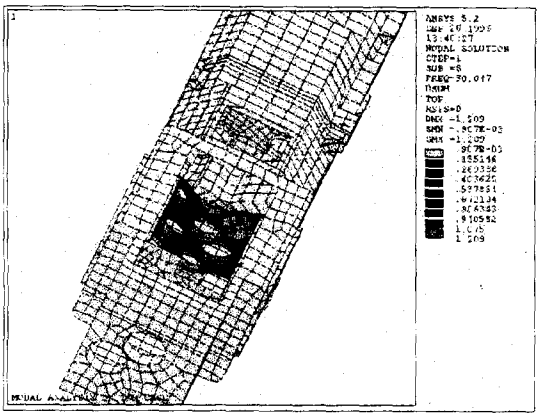

Figure 2. Local bending mode on bearing support plate (original model)

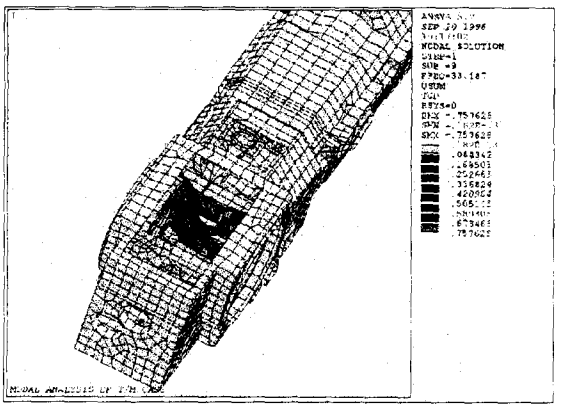

Figure 3. Local bending mode on bearing support plate (after increasing stiffness)

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