A NON-SMOOTH MODEL OF GEAR VIBRATION

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Summary Gear transmission is extensively used in all kinds of mechanical system because of its high efficiency and reliability. In fact, the transmission produces noise and vibration. In this paper, marine gear rubber coupling was as the engineering background. The rubber sheet was put in the gear teeth on both sides of the experimental model with gear rattling vibration. Thus, the gear impact became elastic. Because of elasticity and damping in rubber, the energy of gear vibration was dissipated and the noise intensity was lowered. But because of the backlash and flexibility contact, the gear vibration appeared the non-smooth characteristic. It is necessary to establish the non-smooth mechanical model of gear vibration. Through the experimental and theoretical analysis, the complex dynamics behavior was revealed.

INTRODUCTION

In Gear transmission system, there exit two kinds of noise and vibration. The first one is Rattling, the second one is Hammering. Rattling has attracted high attention for it's one of the main sources of gearbox noise. Professor F.Pfeiffer[1] pointed out that Rattling vibration can be explained by the collision theory; Qi Feng and Jianming Wen [2,3]established a discrete stochastic model and stochastic amplitude modulation model gear Rattling vibration. About the experiment, F. Pfeiffer and K. Karagiannis [4] designed a single stage gear drive experiment device. On that basis, Wen and Sun improved the experiment device, realized the stochastic damping experiment, and analyzed the single stage stochastic damping model from experiment and numerical simulation aspects [5]. The studies mentioned above are on the base of classical impact theory, assuming the teeth of the gearwheels come into contact only for a very short time, describing step change of velocity and energy dissipation before and after the gear impact by a restitution coefficient. In this paper, the rubber sheet was put in the gear teeth on both sides of the experimental model with gear rattling vibration. Thus, the gear impact became elastic. Because of elasticity and damping in rubber, the energy of gear vibration was dissipated and the noise intensity was lowered. Because of the backlash and flexibility contact, the gear vibration appeared the non-smooth characteristic. It is necessary to establish the non-smooth mechanical model of gear vibration.

A NON-SMOOTH MODEL

The experimental model of gear vibration with rubber has shown Figure1. And the mechanical model of gear elastic impact has shown as Figure 2.

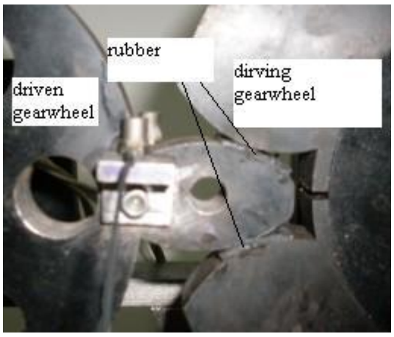


Fig1 experimental model

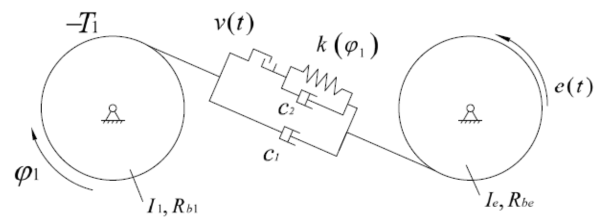


Fig2 mechanical model

The motion of the driven gearwheel can be divided into two parts in accordance with the backlashes: free flight phase and contact phase. In the free flight phase, the driven gearwheel can move freely between backlashes. While in the contact phase, the elastic impact will occur between the driving and driven gearwheel. And the motion equations are expressed by:

Free flight phase:

$$I_1\ddot{\varphi}_1 + d_1\dot{\varphi}_1 + T_1 = 0 \tag{1}$$

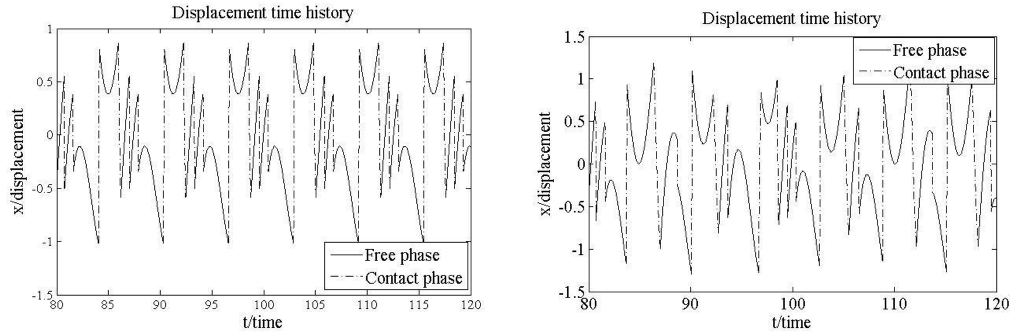
Contact phase:

$$I_1\ddot{\varphi}_1 + d_2\dot{\varphi}_1 + k_1(\varphi_1)\varphi_1 + k_3(\varphi_1)\varphi_1^3 + T_1 = 0 \tag{2}$$

In the above equations, I_1 is the moment of inertia for the driven gearwheel, φ_1 is the angle of vibration, d_1 is the damping ratio of free phase, d_2 denotes the damping ratio of contact phase, $k_1(\varphi_1)$ and $k_3(\varphi_1)$ indicate rigidity coefficient, $v(t)$ stands for time-varying backlash in figure 2.

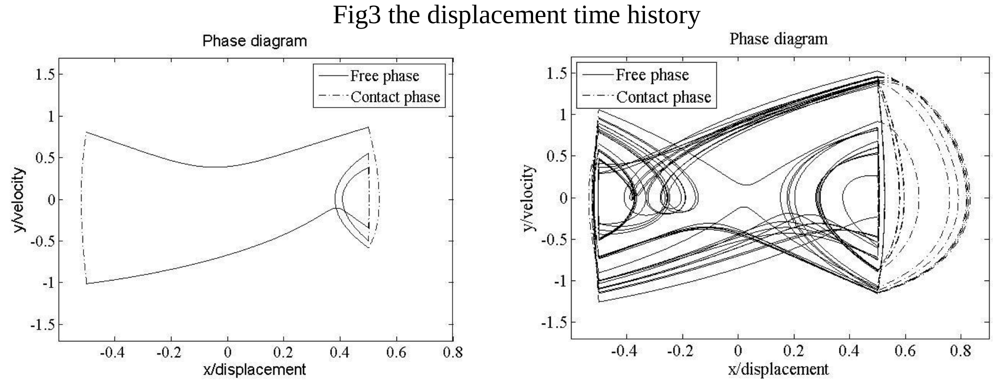
DYNAMICAL ANALYSES

If we put $T_1 = a\sin\omega t$, $\tau = \omega t$ and $\alpha = \dfrac{R_{be}a}{v_1}$, the dimensionless equations are obtained. Through MATLAB language programming, we can get the dynamic responses of the model. Figure 3 is the displacement time history, and (a) stands for $\alpha = 1.1$, while (b) stands for $\alpha = 1.4$. Figure 4 is the phase diagram, and (a) stands for $\alpha = 1.1$, while (b) stands for $\alpha = 1.4$. Figure 5 is the contact Poincare map, and (a) stands for $\alpha = 1.1$, while (b) stands for $\alpha = 1.4$.



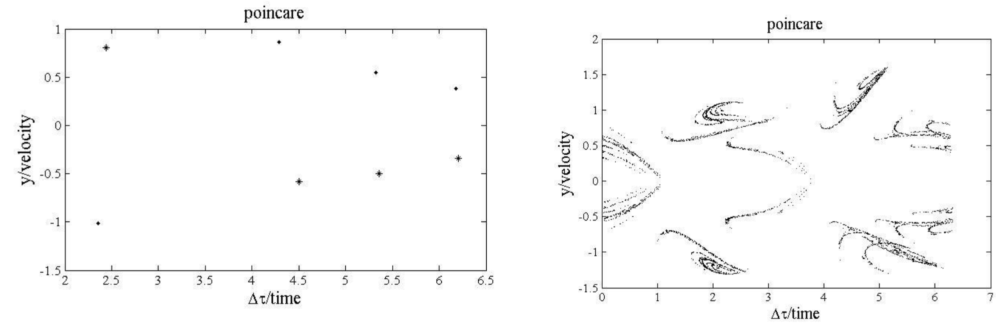
(a) $\alpha = 1.1$ (b) $\alpha = 1.4$

Fig3 the displacement time history



(a) $\alpha = 1.1$ (b) $\alpha = 1.4$

Fig4 the phase diagram



(a) $\alpha = 1.1$ (b) $\alpha = 1.4$

Fig5 the contact Poincare map

CONCLUSIONS

Gear transmission system is sensitive to excitation. It is to say that change of the amplitude of excitation may turn gear transmission system into chaos. It is found that the intensity noise of gear vibration is reduced by the elastic boundary.

References

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