SUMMARY OF Ph.D. DISSERTATION

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Title

Self-Excited Vibration of a Cleaning Blade in a Laser Printer
—Influence of Mode Coupling due to Friction Force—

Abstract

A squeaking noise may occur from a cleaning blade in a laser printer or a copy machine via electro photography. This phenomenon has been well known as one of typical problem occurring while developing of products for many years. However, there is a dearth of information about a mechanism except that friction force between a photoreceptor and a blade causes the self-excited vibration. In a development phase, the solution of this problem is found spending a great amount of time by trial and error. The concern for recurrence of the problem keeps remaining without theoretical clarification of the mechanism. Thus, it is expected to clarify the mechanism of the self-excited oscillation and to find out the fundamental solution to prevent the squeaking noise. The self-excited vibration discussed in this paper has features different from conventional researches: the source of the vibration is not a photoreceptor but a cleaning blade, it occurs at enough high rotating speed of a photoreceptor that the inclination of the frictional force to a relative speed has positive value. Moreover, steady-state amplitude of the self-excited vibration cannot be mentioned in conventional researches, because the self-excited vibration had been treated as a divergence of a linear system. In this study, we clarify the mechanism of the self-excited vibration including nonlinear analysis of steady-state amplitude.

Chapter1 summarizes the background and previous studies.

In chapter2, by observation in an actual machine, we clarify the features of this squeaking noise quantitatively. Then, we reveal that the frequency of the squeaking noise is corresponding to a natural frequency of the cleaning blade.

In chapter3, we present a coupled-mode flutter model using Finite Element Model of the cleaning blade, provided that the normal force at the contact point can be represented in a linear combination of mode displacement according to the modal analysis theory. Then, by a numerical simulation based on the presented model, we reveal that a natural frequency when a system becomes unstable is corresponding to a frequency of the noise. From this result, we also clarify that the self-excited vibration is caused by coupling between a bending mode and a shrinking mode.

In chapter4, we discuss a nonlinear analysis of the steady-state amplitude. Here, for a problem that orthogonality between eigenvectors of the system is not guaranteed because of the nonsymmetrical stiffness matrix, we extracted only unstable modes from the system by using adjoint vector. Then, we consider a nonlinear term from the condition to avoid an appearance of a secular term and formulate a nonlinear equation about unstable mode displacement. Then, solution of unstable mode displacement obtained by the method of multiple scales is reconstructed in 2-DOF. Based on the above-mentioned result, we express a displacement of the cleaning blade as a linear combination between eigenfunction of non-coupled system and unstable mode displacement and reveal the theoretical equation of steady-state amplitude. Then, the coefficient of nonlinear term is determined by substituting a measurement value of steady-state amplitude for the theoretical equation.

In chapter5, by using the theoretical equation formulated in the previous chapter, estimation of the steady-state amplitude about some blades modified thickness and free length is carried out. Then, we reveal a validity of our study by a comparison between calculation and measurement and utility to industrial application

Chapter6 summarizes the results of this study.