8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Pattern Formation in Wear Development of Rotating Disks

***Yoshiaki Terumichi[1] and Kiyoshi Sogabe[2]**

[1]Sophia University
7-1, Kioi, Chiyoda, Tokyo,
102-8554, Japan
y-terumi@sophia.ac.jp

[2]Sophia University
7-1, Kioi, Chiyoda, Tokyo,
102-8554, Japan
k-sogabe@sophia.ac.jp

Key Words: *Contact, Time-Delay System, Wear Development, Pattern Formation*

ABSTRACT

Wear development of a pair of rotating disks occurs when the rotation speed is high and the contact force is large. In some cases, a wavy pattern is formed that resembles corrugations; the amplitude of this wavy surface is enhanced by a time-delay mechanism[1]. In this paper, by considering wear development, we derive a model and numerical and analytical analysis for a system of two rotating disks for which there is contact rigidity between the disks. To explain the development mechanism of corrugations, the effects of rotation speed, support stiffness, and contact rigidity on pattern formation are investigated both analytically and numerically. It is well known that corrugations are produced on surfaces in rolling contact, for example, between two rolling disks, or between wheels and rails. In such systems, corrugations are produced by repeated contact at the same point with a time lag and with a fluctuation in the contact force. Numerical simulation is expected to be an effective technique for investigating the growth and development of corrugations with a view to finding methods for preventing them[2].

It is difficult to observe the development of corrugations in practical systems and in experimental set ups because they initially have very small amplitudes and they rotate at high speeds. In addition, since the time history of the system influences the development process, it is not possible to stop the machine or experimental setup in order to observe it. Therefore, numerical approaches are very effective for monitoring the development process. In our numerical approach, point contact on the surfaces of the disk circumferences is assumed. The profiles of these surfaces vary due to wear. Multibody dynamics can be used to obtain the constraint condition for the contact. The path of the contact point is constrained by the wavy surface of the circumference of the disk. The constraint condition is recalculated with each rotation by using the contact force, slip rate and wear rate. The contact force fluctuates due to the support stiffness and the contact rigidity. The amount of the wear z for each rotation of the disk is calculated using the wear rate, which is given by $W = s \times P$, where s is the slip rate and P is the contact force. Consequently, it can be expressed using the following relation, $z = c \times W$, where c is a material-dependent constant.

Figure 1 illustrates the analytical model used in this paper. The contact rigidity depends on the fluctuation of the contact force in accordance with the Hertz theory. In order to determine the mechanism of the corrugation development, the characteristics of

self-excited systems with a time-lag should be investigated. The eigenvalue problem is discussed in this paper. Figure 2 shows the polygon number for the natural frequency as a function of the rotation speed. Infinite and countable eigenvalues exist in such systems. The unstable eigenvalues are shown in Fig. 2. Based on this result, the magnitude of the real part of the eigenvalues is considered to be index of wear development. Figure 3 shows the corrugation development on the surface of the lower disk. Initially, both short and long-pitch corrugations are visible on the circumference of the disk. By contrast, only long-pitch corrugation remains after 30,000 revolutions. We demonstrate that corrugations develop with an increase in the depth and the area.

We summarize this study as follows. A model and an analytical analysis were proposed for pattern formation in wear development. Using the proposed method, a numerical simulation for the development of corrugations on the circumference of a pair of rotating disks was performed. The mechanism for corrugation development is discussed based on the numerical results and an eigenvalue analysis.

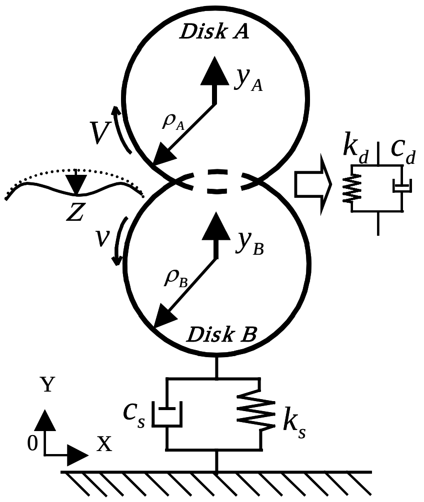

Figure 1 Analytical Model

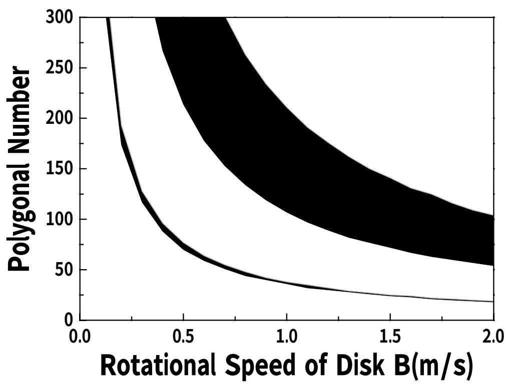

Figure 2 Unstable Plygonal Number

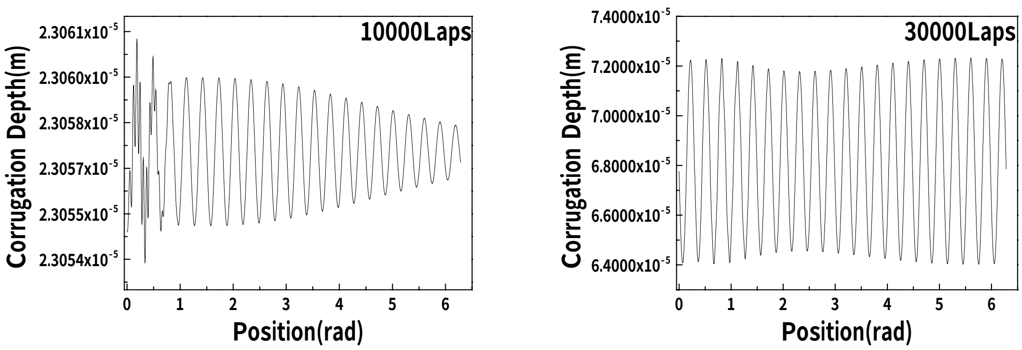

Figure 2 Corrugation Development on Circumference of Lower Disk

REFERENCES

[1] Y. Yoshitake, et. al, "Vibrations of a Forced Self-excited System with Time Lag", *Bull. of JSME*, **26-221**, pp.1943-1951 (1983).

[2] G. Osborne and B. Stone, "Chatter in Rolling Grinding", *ECCOMAS Thematic Conference, Multibody Dynamics 2007*, Conference Proceedings CD, (2007).