Vibration / Self-Excitation	Polygonal deformation of Roll of Papermaking Machine	Rotating Machinery

Object Machine

Rubber-wound bottom roll (controlled crown roll, CCR) opposed to a top roll (made of stone) at the paper machine pressed part (part for dewatering by nip pressurization), refer to Fig.1

Observed Phenomena

When the paper machine was operating at an increased nip pressure (line pressure) of 110kgf/cm during the maximum paper making speed (1082m/min) operation, vibrations gradually increased, and about several ten minutes later, such excessive vibrations (exceeding 20mm/s at the bearing pedestal, refer to Fig.2) occurred that further operation was made impossible. Frequencies were widely distributed in the range of 80 to 90Hz, where 88Hz component was dominant, which corresponds to 13.8 times the bottom roll rotational speed of 6.378Hz. Moreover, the bottom roll and the top roll vibrated with the reverse phase in the vertical direction (Fig.3).

Cause Estimation

Assumed causes for the vibrations of a frequency about 14 times a component of the number of revolutions are (1) Ball passing vibrations of a self-alignment ball bearing, and (2) Polygonal deformation by pattern formation of a rubber-wound bottom roll. The ball passing vibrations were slightly different for the 13th and 14th orders, so that a roll tetra decagon pattern formation was assumed as the cause. Generated frequencies a little lower than the 14th order of roll speed also match.

Analysis and Data Processing

The eigenmode under a nip-pressurized condition during standstill was checked (Fig.4). As a result, it was determined that the natural frequency was near 90Hz, and that the problem was an instable phenomenon of a time-delay system due to a pattern formation of the 14th frequency of rotational speed. The time history waveforms in Fig.3 indicate that repetitive vibrations occurred with a period of about 1.25sec (0.8Hz). This is the rotating frequency of a felt (blanket) that travels under pressure for dewatering of paper, and 88Hz corresponds to the 110th order of this frequency. Thus, this may be called a complex phenomenon where pattern formation of both the rubber-wound roll and the felt belt is involved.
Fig.6 shows an example of trial calculations made on the basis of a pattern formation model (Fig.5) presented in the reference literatures (1) and (2). Illustrated here are the natural frequencies of two rolls vibrating in the reverse phase (non-rotating, 2nd natural frequency), where an instability occurs, together with generation of a Polygonal deformation phenomenon according to the order of rotation.

Countermeasures and Results

Since avoiding operation near the critical speed of 90Hz mitigates the problem, a countermeasure of avoiding the use of maximum speed operation. General effective countermeasures include (1) change in the operation speed (as in this case), (2) addition of a damping element effective for relative vibrations in the nip direction (vertical direction) of both rolls, and (3) attachment on the bearing part of a dynamic vibration absorber that is tuned to the natural frequency to cause instability (reference literatures (3)).

Lesson

There are many phenomena related to Polygonal deformation of long-distance truck tires and workpieces of machine tools.

References

(1) Sueoka et al. (seven persons), "Polygonal deformation of roll-covering rubber", (in Japanese), Transaction of JSME, Vol.59. No.563, (1993-7), pp.2078-2085
(2) Yamaguchi et al. (five persons), "Rubber damping and deformation recovery characteristics", (in Japanese), Transaction of JSME, Vol.59, No.566, (1993-10), pp.2932-2937
(3) Kondo et al. (three persons), "Optimum design of dynamic absorber for pattern formation phenomena generated in contact rotation systems", (1st report, in case of single degree of freedom system), (in Japanese), Transaction of JSME, Vol.71, No.704, (2005-4), pp.1131-1138

Keywords

Contact rotating system, pattern formation, chatter mark, corrugation, rubber roll, press part, felt belt, joint, belt period, papermaking machine, calendar, viscoelastic characteristics, three-element Voigt model, delayed elastic index

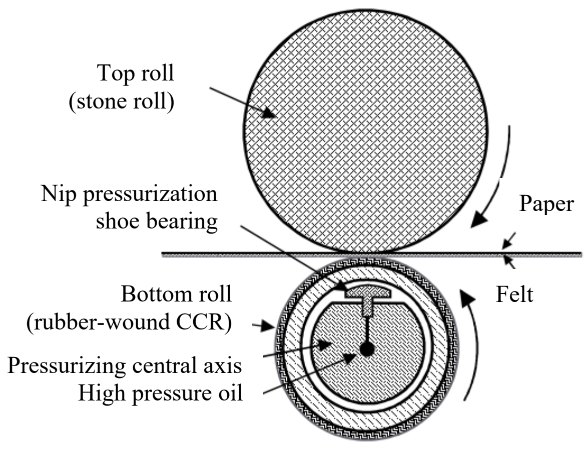


Fig.1 Top roll and bottom roll

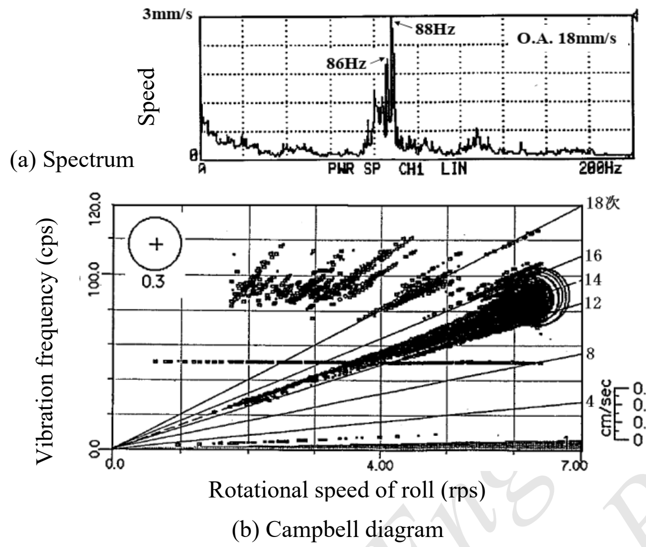


Fig.2 Vibration of bottom roll bearing (spectrum and Campbell diagram)

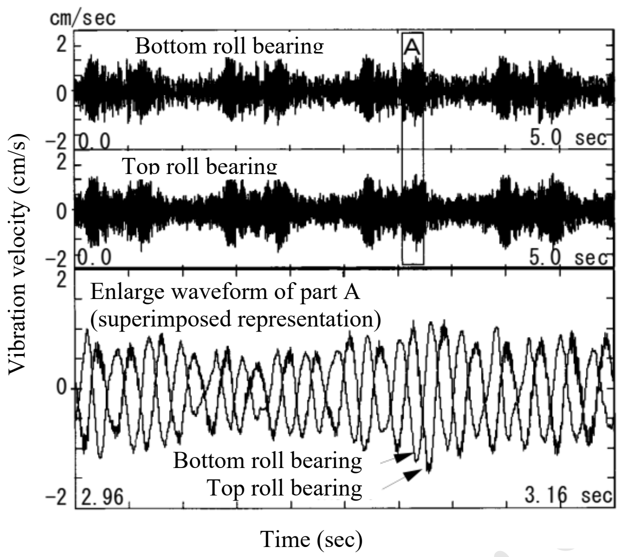


Fig.3 Vibration of top roll and bottom roll bearings

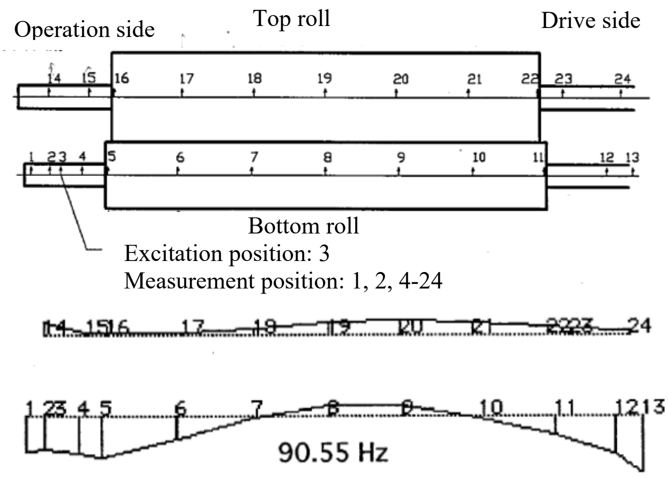
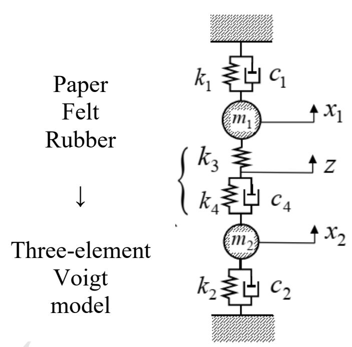


Fig.4 Natural frequency mode for nip-pressurized & non-rotation



$m_1=m_2$=1400kg, $k_1=k_2$=4.3E+7 N/m,

$c_1=c_2$=0 Ns/m, k_3=3.4E+7 N/m,

k_4=1.9E+8 N/m, c_4=3.7E+5Ns/m,

α=2.0 1/s (delayed elastic index)

Fig.5 Two-mass model and parameter

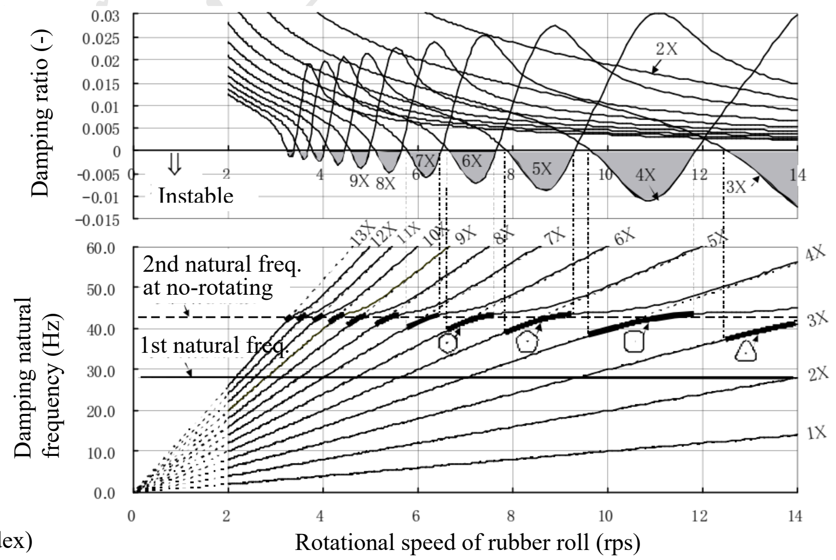


Fig.6 Instable vibration for two-mass model (instable for bold solid lines)