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Safety Analysis of a Spiral Lift on an Aerial Work Platform

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***Abstract*— This study developed a resonance model for safety analysis of the spiral lift on autonomous driving platform. Because of difficulties in modeling a spiral shape, an unlocking model was applied to design the spiral lift. The unlocking model was based on the shear force and was useful in predicting the response of the spiral spring. The safety usage of the spiral lift was investigated in consideration of vibration from passengers.**

I. Introduction

An industrial lift, a type of aerial work platform (AWP), transports workers to an elevated area in a factory, a construction site and theater [1]. The spiral lift achieves a linear elevation using a screw mechanism that generates a large thrust force in comparison with a smaller torque [2]. The spiral lift has an interlocking mechanism that combines a tooth and a wind-up spring in previous study [3]. The safety of the spiral lift must be guaranteed to prevent collapse caused from activities of a passenger. The safety of the spiral lift is critical to the resonance of the spiral spring. Thus, a shear force model was developed to calculate the natural frequency of the spiral spring using the unlocking model.

II. Methods

A photo in Fig. 1 shows the mechanism in the aerial work platform using a spiral lift. When a lift motor rotates a tooth spring in the spiral lift, the teeth meets grooves on the top and bottom of a wind-up spring. The wind-up spring is guided upward, forming a spiral shape that resembles a cylinder. The heavy weight on the load space presses against the circumference of the cylinder. The axial load acts on the shear direction of the thin cross-section. The natural frequency of this unlocking model is obtained from shear displacement using the spring constant and load mass in following equation.

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k_u}{m}} \qquad (1)$$

The natural frequency of the spiral spring can be calculated using the spiral stroke and the mass; therefore, the stroke can inversely be obtained using the natural frequency. Thus, an impact test was performed to investigate the natural frequency of the spiral spring using a laser displacement sensor. Vibration was analyzed using an FFT of the sensor responses.

III. Results

Dual peaks were also observed after the FFT in the experiment. This is caused by local bending of the spring owing to the larger length-area ratio between the spiral stroke and the cross-sectional area. The peak frequencies ranged from 8 to 30 Hz according to the stroke extension. A converted length of an ideal resonance was obtained using the sum of the first and second peaks. The converted length from the FFT was directly proportional to the spiral stroke and was used to predict ideal resonance frequency under various conditions.

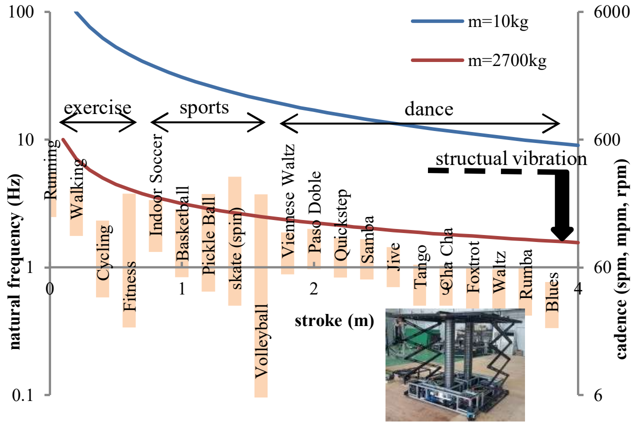

Figure 1. Vibration effects of various activities on the spiral lift

IV. Discussion & Conclusion

The curves of the natural frequencies in Fig. 1 are obtained from the converted length. The frequencies of activities on the AWP were determined from previous studies on cadence measurement. Considering natural frequencies, most of the activities affect structural vibration rather than spring resonance. Violent activities, such as exercise and sports, can cause resonance at high loads and long spiral strokes. In addition, drilling using a hydraulic breaker must be avoided because of its high power and blow frequency (6 – 20 Hz). The proposed unlocking model revealed that it was suitable for machine design. The vibration concept was derived from the shear force, which is different from the conventional studies. The unlocking model was also available to check safety usage in a factory, a theater and a construction site. This paper discussed axial modes only; thus, it is necessary to discuss torsion and tilt modes in the future.

References

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