Rotational Characterization of the Main Shaft for Cone Crusher

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1. Introduction

A cone crusher is a compression type of machine which reduces the rocky material by squeezing or compressing the feed material between the concave and the mantle shown in Fig.1. In general, mine rock from quarry or building waste concrete can be used as a feed material. The working principle is basically impact generated by unbalanced force from eccentric rotation. Therefore, structural robustness and rotational behavior is very important to enhance the structural durability and the crushing performance.

Definitely, several studies can be found out but these efforts oriented to increase the crushing performance of the cone crusher. Johansson investigate the crushing efficiency by controlling the rotational speed [1]. Lee et al. and Atta et al. examine the effect of Closed Side Setting (CSS) [2, 3]. Despite these efforts, the rotational behavior of the main shaft which can directly affect the structural durability of cone crusher, has not been completely explained.

In this study, the rotational behavior of the main shaft is identified by motion defined by Euler angle and this behavior is compared with experimental behavior of the cone crusher. Consequently, this fundamental mechanism of the shaft rotation can be successfully used in optimal design of the cone crusher.

2. Fundamental Mechanism of the Main Shaft Rotation

2.1 Main parts and operational principle of the cone crusher

Cone crusher is mainly composed of the eccentric, main shaft, mantle, mantle core, concave and so on shown in Fig. 1. As the eccentric which can generate the appropriate gap for crushing the materials, rotates to cause the compression between the concave and mantle, the material gets smaller as it moves down through the wear liner as the opening in the cavity gets tighter. The crushed material is discharged at the bottom of the machine after they pass through the cavity.

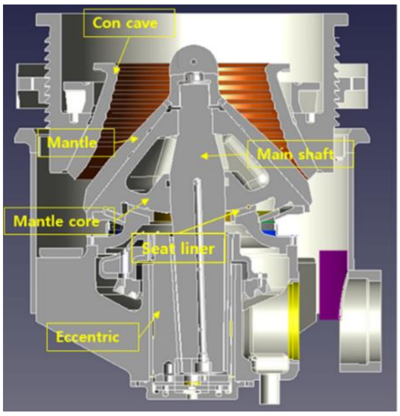

Fig. 1 Configuration of the Cone Crusher

The rotational force, generated by hydraulic motor, can be transmitted by several gear system and the eccentric begin the rotation eventually. The main shaft also start the eccentric motion simultaneously because this shaft is directly inserted to the eccentric. It is noted that the main shaft can rotate despite the assumption of frictionless between eccentric and shaft. Moreover, the rotational direction and angular velocity can be random. This behavior can be explained by the Euler's equations of motion.

2.2 Rotational characteristic of the main shaft

Euler's equations of motion can describe rotation of a rigid body, using a rotating reference coordinate with its axes fixed to the body and parallel to the principal axes of the body. In the case of this study, the main shaft can be considered as the rotating body of Euler's equations of motion. Fig. 2 show the rotating reference coordinate for this case.

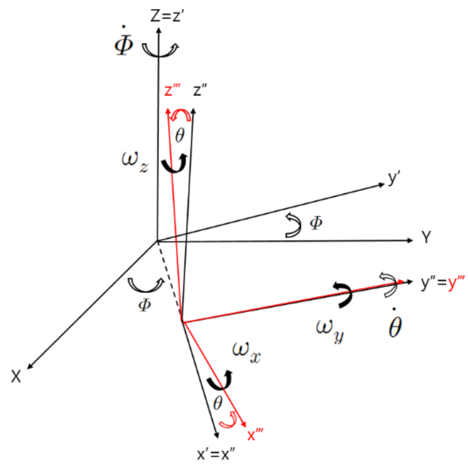

Fig. 2 Coordinate of Cone Crusher

Because the center of the main shaft is not located to the origin of general reference coordinate, the location of the main shaft must be shifted to the appropriate location. In this case, therefore, the angular velocity of the precession ($\dot{\phi}$) can be considered as rotational speed of eccentric, the nutation (θ) can be considered as the tilting angle of the main shaft generated by eccentric, and the spinning (ψ) can happens automatically. This spinning is considered as the rotation of the main shaft. Therefore, the rotational characteristic of the main shaft can be identified by this analysis

The following Eqs. (1), (2), (3) is the derived equations by above procedure and these equations can be expressed by Eq (4) because $\dot{\theta},\ \ddot{\phi}\ and\ \ddot{\psi}$ is zero in this modified coordinate system.

$$M_x = I_o(\ddot{\phi}\sin\theta + 2\dot{\phi}\dot{\theta}\cos\theta) - I(\dot{\phi}\dot{\theta}\cos\theta + \dot{\theta}\dot{\psi}) \quad (1)$$

$$M_y = I_o(\dot{\phi}^2\cos\theta\sin\theta - \ddot{\theta}) - I(\dot{\phi}^2\cos\theta\sin\theta + \dot{\phi}\dot{\psi}\sin\theta) \quad (2)$$

$$M_z = I(\ddot{\psi} + \ddot{\phi}\cos\theta - \dot{\phi}\dot{\theta}\sin\theta) \quad (3)$$

$$\dot{\psi} = \frac{(I_o - I)\dot{\phi}\cos\theta}{I} - \frac{Mgl}{I\phi} \quad (4)$$

Where,
$I_o = I_{zz} = I_{xx}$
$\mathrm{I} = I_{yy}$
M: Mass of ratating body [kg]
g: Gravitational acceleration $\left[\frac{\mathrm{m}}{s^2}\right]$
l: Distance between center of gravity of rotating body and revolution axis [m]

3. Correlation with experimental results

Fig 3. Experiment configurations

The actual experiments without the any load are carried out with three different eccentric RPM (250, 300, 350) and the rotational velocities of the main shaft are observed at steady-state and compared with the theoretical results. The following Table 1 shows the comparison between actual test results and estimated results from analysis based on the modified Euler's equations of motion. Although there is discrepancy of the value, it is noted that both results are some matched shown in Table 1.

Table 1 Comparison rotational speed

RPM [rev/min]	Experimental results	Analytical results
250	0.13[rev/s]=0.86[rad/s]	1.48[rad/s]
300	0.47[rev/s]=2.96[rad/s]	1.81[rad/s]
350	1.03[rev/s]=6.52[rad/s]	2.13[rad/s]

4. Conclusion

A new modified Euler's equations of motion for characterization of the main shaft is developed to enhance the structural robustness and optimal design for cone crusher. Although this platform is limitation for perfect match with real situation, this research can be useful if the fine tuning with various experimental data in the near future.

Acknowledgment

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