Effect of the Outer Diameter of Flywheel on Reactor Coolant Pump Flywheel Integrity Evaluation

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1. Introduction

According to the US NRC standard review plan (SRP) 5.4.1.1 [1] and regulatory guide (RG) 1.14 [2], reactor coolant pump (RCP) flywheel integrity should be evaluated. The type of the RCP flywheel used at nuclear power plant in Korea is a shrink-fit such as shown in Fig.1. Shrink-fit and rotational stresses should be calculated to evaluate the integrity of RCP flywheel. If the stresses at the various speeds are not satisfied for the acceptance criteria, the geometry of the flywheel should be changed [3]. In this paper, the effects of outer diameter of flywheel on the RCP flywheel integrity are studied.

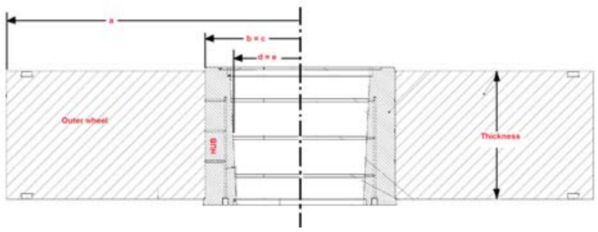

Fig. 1 RCP flywheel sketch

2. Maximum stress

Kim[3] described the method to calculate the stress for the RCP flywheel of APR1400 which was constructed by shrink fitting three parts which are the shaft, the hub and flywheel as shown in Fig. 1. The maximum stress is calculated by superposing the stresses due to the shrink fit and the rotation. The stress due to the shrink fit is proportional to the shrink fit and the stress due to the rotation is proportional to the square of an angular velocity.

The shrink fit should be larger than the radial displacement due to the joint release speed. In this paper, it is assumed that the shrink fit be determined by the joint release speed to minimize the stresses of the flywheel. It makes the minimum shrink fit. To evaluate the RCP flywheel integrity, the effect of the smoothing of interface on the stresses should be considered by adding it to the shrink fit.

2.1. Outer diameter of flywheel

One option to reduce the maximum stress of the flywheel is decrease of the outer diameter of flywheel. Fig. 2 shows the minimum shrink fit for the required joint release speed. Eq. (1) shows the shrink fit between outer wheel and hub for the required joint release speed. As the outer diameter of flywheel decrease, shrink fit for the required joint release speed will decrease.

$$\delta = \left(\frac{\rho\omega^2}{4gE}\right)\left[(3+\nu)\left(a^2 b - cd^2\right) + (1-\nu)\left(b^3 - c^3\right)\right] \quad (1)$$

Fig. 3 shows the maximum stresses with the outer diameter of flywheel for various conditions. As the outer diameter of flywheel decreases, the maximum stresses decrease. Eq. (2) shows the radial stress due to the rotation. As the outer diameter of flywheel decreases, the stress due to the rotation decreases and the stress due to the shrink fit decreases as well.

$$Sr = (1/8)(3+\nu)(\rho/g)\omega^2\left[a^2 + d^2 - a^2 d^2/r^2 - r^2\right] \quad (2)$$

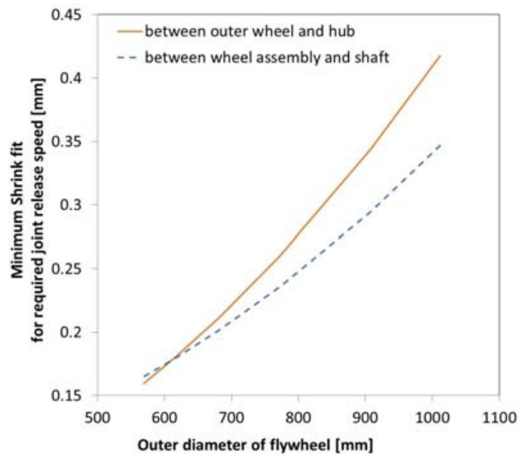

Fig. 2 Minimum shrink fit for the required joint release speed with outer diameter of flywheel

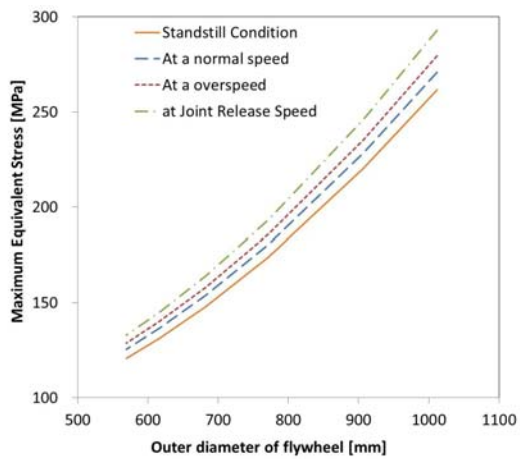

Fig. 3 Maximum equivalent stress with outer diameter of flywheel

2.2. Smoothing

RCP should operate after off-powered for coast-down operation during the required period. To operate RCP during the required period, the moment inertia of the flywheel should be the same as the outer diameter decreases. To maintain the moment inertia of the flywheel, the thickness of the flywheel might increase. As the thickness of the flywheel increases, the smoothing of interface will increase because of the manufacturing difficult. In this paper, it is assumed that the smoothing of interface is proportional to the thickness of the flywheel.

Fig. 4 shows the maximum stress with outer diameter considering the smoothing change. The critical outer diameter appears as it decreases. Fig. 5 shows the maximum stresses with the total smoothing of interface. The effects of the outer diameter and the smoothing of interface on the maximum equivalence stress are combined. As the smoothing of interface increases, the contact pressure and the maximum equivalent stress increase as shown in Fig. 5.

Fig. 6 shows the maximum joint release speed with the outer diameter. The maximum joint release speed is calculated by considering the smoothing of interface. The solid line shows the maximum joint release speed for no smoothing change. The dashed line shows that considering the smoothing change with the increase of the flywheel thickness. As the outer diameter decreases, the shrink fit and stress due to shrink fit decreases but the maximum joint release speed increases because of the lower stress due to the rotation. As the outer diameter decreases, the smoothing of interface increases and the maximum joint release speed increases.

3. Conclusion

In this paper, the effects of outer diameter of flywheel on the RCP flywheel integrity are studied. As the outer diameter decrease, the shrink fit decreases and the maximum stress decreases. The effects of the outer diameter and the smoothing of interface on the maximum equivalence stress are combined. The increase of smoothing change shows the increase of the radial displacement and the contact pressure and stresses at the standstill condition.

As the outer diameter decreases, the shrink fit and the maximum stress decrease but there is possibility to increase the smoothing. To reduce the stress of the flywheel the decrease of outer diameter can be one option, but the characteristics of RCP coast-down operation should be considered. The increase of RCP motor length due to the increase of flywheel thickness makes more vibration and bending stress of the RCP motor supports.

REFERENCES

[1] US Nuclear Regulatory Commission Standard Review Plan, NUREG-0800, Section 5.4.1.1, Rev. 3, "Pump Flywheel Integrity (PWR)," May 2010.

[2] US Nuclear Regulatory Commission Regulatory Guide 1.14, Rev. 1, "Reactor Coolant Pump Flywheel Integrity," August 1975.

[3] Kim, Dong-Hak, "Effect of the Shrink Fit and Mechanical Tolerance on Reactor Coolant Pump Flywheel Integrity Evaluation," Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 29-30, 2015.

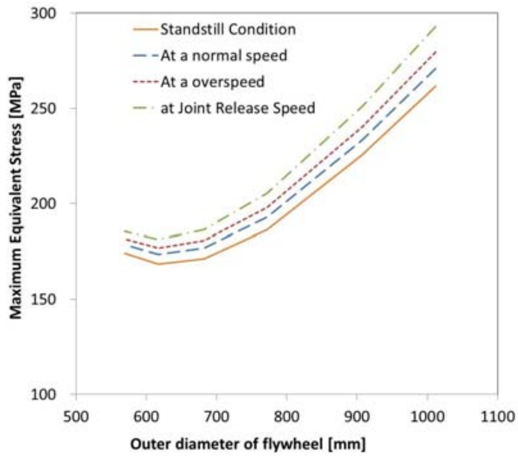

Fig. 4 Maximum equivalent stress with outer diameter considering the smoothing change

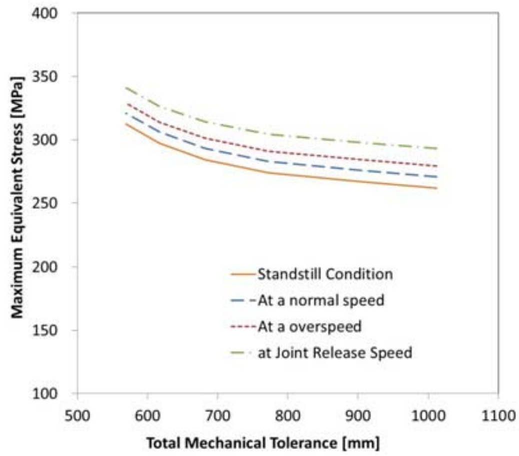

Fig. 5 Maximum equivalent stress with outer diameter considering just the smoothing change

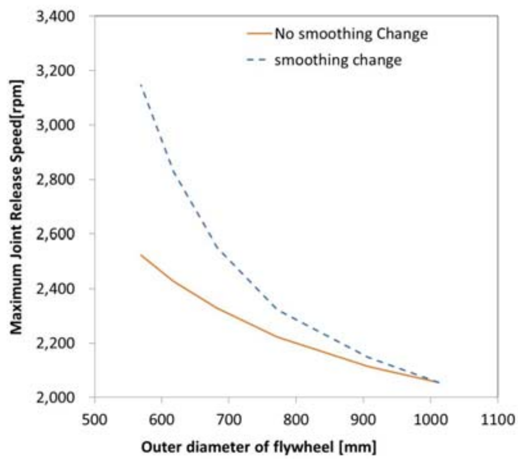

Fig. 6 Maximum joint release speed with outer diameter