**Highlights**

* This paper revealed the vibration reduction mechanism of the ring squeeze film damper.
* The law of oil film pressure, bearing capacity, and deflection angle with eccentricity and the width-to-diameter ratio is analyzed.
* The oil film whirl mechanism of the ring squeeze film damper is revealed according to the analysis of the transient characteristics.
* The fluid-structure coupling method is used to analyze the influence of oil filling on the dynamic characteristics of the elastic ring.