Study on Correlation Between Rotor Vibration and Mechan-ical Stress in Ultra-High-Speed Permanent Magnet Synchronous Motor.

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I. MOTIVATION FOR RESEARCH Recently, the use of high-speed permanent magnet synchronous motors (PMSMs) has become prominent owing to their high efficiency, simple structure, high power density, and small size [1–2]. However, in the case of ultra-high-speed PMSMs, rotational mechanical vibration due to the high speed of the rotor may cause serious damage to the integral system. Thus, vibrations in the PMSM have become a critical issue [3–4]. Although numerous sources of vibration exist in a motor, the mechanical vibration generated by the rotor is of particular importance. The rotor contains a permanent magnet (PM) with a protective retaining sleeve, and centrifugal and compressive forces are generated on the surface of the PM-with-sleeve when the rotor rotates at high speeds. This mechanical stress is affected by the PM diameter, sleeve thickness, and shrink fit (radial interference fit). Moreover, the rotor vibration could increase if the PM or sleeve is broken during operation. Therefore, for reduction of rotor vibration and stable driving, sleeve thickness and shrink fit should be considered in the design stage. This study investigates the correlation between rotor vibration and mechanical stress in an ultra-high-speed PMSM. Two PM rotors that have the same performance characteristics but different shrink fits were studied, and the vibration of these two PM rotors were analyzed. In order to evaluate the correlation between the mechanical stress and vibration, the rotor design parameters, such as sleeve thickness and shrink fit, were varied. II. DESIGN OF PMSM BASED ON ROTOR MECHANICAL STRUCTURE In this paper, the design and analysis of an ultra-high-speed PM rotor for a 500 W 400,000-rpm-class compressor are discussed. The paper is divided into three main parts: design of the sleeve thickness and shrink fit depending on the PM diameter, validation of the initial designs by finite element method (FEM), and validation of the initial designs by experiments using a manufactured model. In a future study, a more-specific comparison of the initial designs from an accurate design method that takes into consideration the mechanical structure and dynamic characteristics of the PMSM will be thoroughly investigated, for its contribution to related researches and industrial applications.

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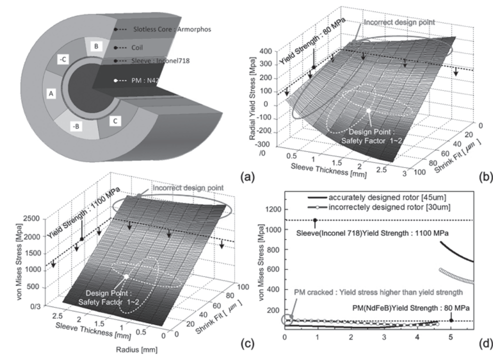

Figure 1. (a) Analytical model, (b) changes in radial yield stress of the PM according to the sleeve thickness with the shrink fit, (c) changes in von Mises stress on the sleeve according to the sleeve thickness with the shrink fit, and (d) comparison of the von Mises stress according to shrink fit.

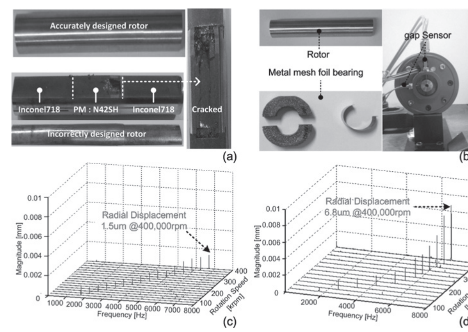

Figure 2. (a) Comparison of designed rotor, (b) experimental setup with a rotor (sleeve material: Inconel 718), (c) vibration of the accurately designed rotor, and (d) vibration of the incorrectly designed rotor.