Stress Analysis of Induction Motor Core Considering Anisotropic Magnetic and Magnetostrictive Properties

Ben Tong[1], Yang Qingxin[1,2], Yan Rongge[1*], Zhu Lihua[2], Liu Huaiwen[1], and Zhao Luna[1]

1. State Key Laboratory of Reliability and Intelligence of Electrical Equipment, Hebei University of Technology , *yanrg@hebut.edu.cn

2. Municipal Key Laboratory of Advanced Technology of Electrical Engineering and Energy, Tianjin Polytechnic University

ID: #660

Session: Thu-Af-Po4.05-24

IEEE MT 25

25th International Conference on Magnet Technology

IEEE | IEEE CSC Council on Superconductivity

Abstract—The non-oriented silicon steel in motor cores shows remarkably anisotropic magnetic and magnetostrictive properties under sinusoidal and harmonic excitations. Thus, in order to compute motor stress accurately, anisotropic magnetic and magnetostrictive properties must be considered. Firstly, this paper tests the anisotropic properties under sinusoidal and harmonic excitations to support the stress computation. Then, an electromagneto-mechanical coupled model for motors considering anisotropic magnetic and magnetostrictive properties is proposed and stress distribution of motor cores is calculated. Lastly, the frequency spectrum of the stress is analyzed to provide the theoretical basis of vibration and noise reduction for induction motors further research.

Measurements

The measurement device is shown in Fig. 1. In order to test and analyze the anisotropic properties under sinusoidal and harmonic excitations, the non-oriented silicon steel sheets are cut into different samples, shown in Fig. 2. The angle, marked in Fig. 2, are between the rolling direction (RD) of silicon steel and the length direction of the measured sample. Measurement results are shown in Fig. 3 and Fig. 4.

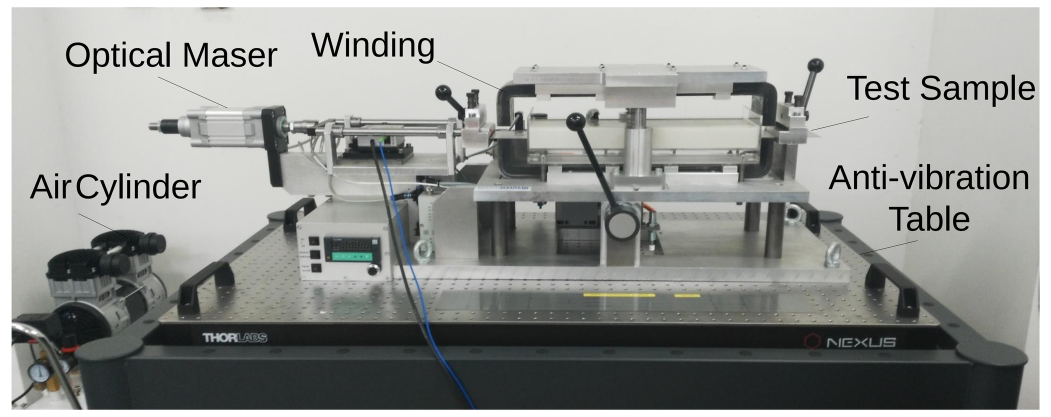

Fig. 1 Measurement device

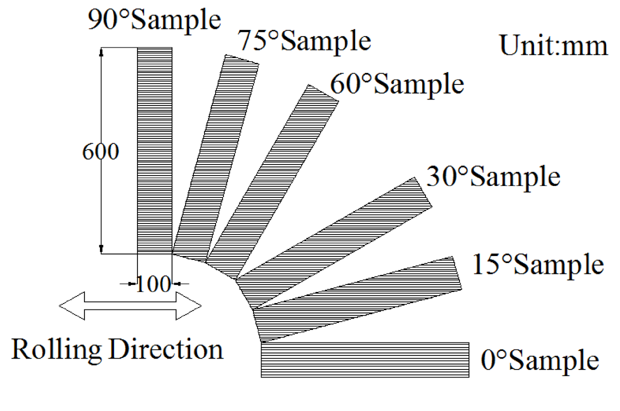

Fig. 2 Cutting method of silicon steel sheet samples.

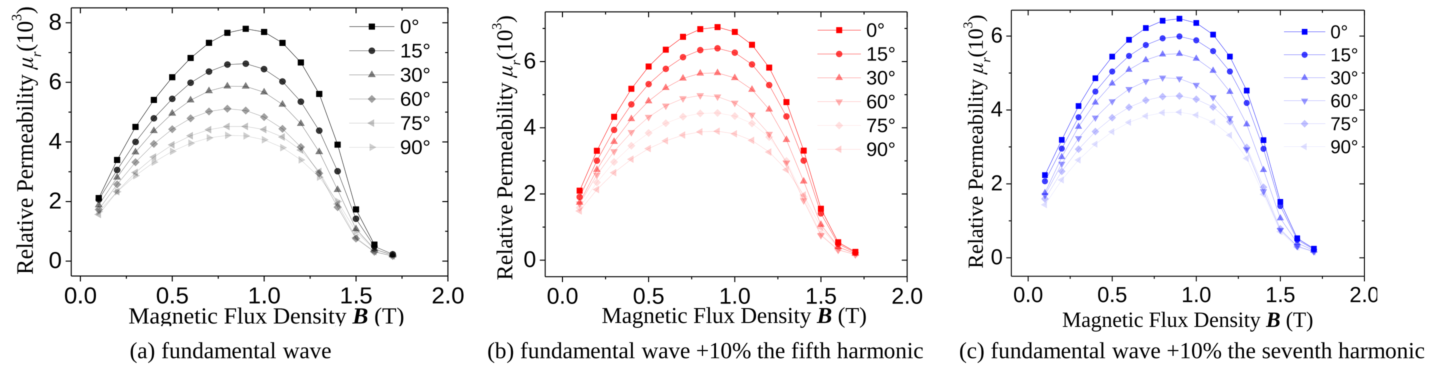

Fig. 3 The relative permeability of non-oriented silicon steel with different excitations.

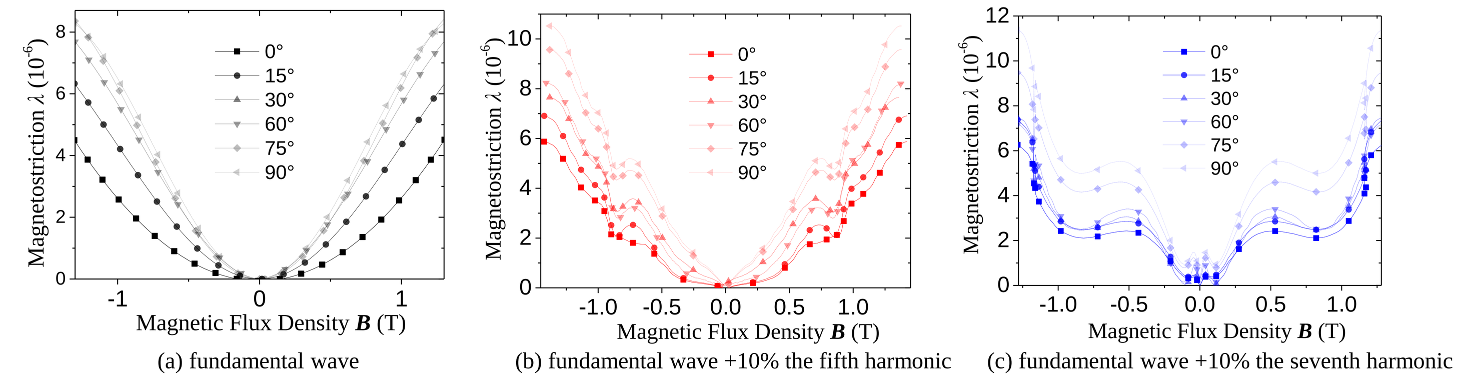

Fig. 4 The magnetostrictive curves of non-oriented silicon steel with different excitations.

Model

In order to analyze the stress in motor cores, the total energy functional of motors considering anisotropic magnetic and magnetostrictive properties can be expressed as follows:

$$I=\int_{\Omega_1}\left(\frac{1}{2}\cdot\boldsymbol{H}^T\cdot\mu^\theta\cdot\boldsymbol{H}\right)d\Omega_1-\int_{\Omega_1}\boldsymbol{J}\cdot\boldsymbol{A}d\Omega_1+\int_{\Omega_2}\frac{1}{2}\cdot\boldsymbol{\varepsilon}^T\cdot\boldsymbol{\sigma}d\Omega_2-\int_{\Gamma_2}\boldsymbol{f}^\Gamma\cdot\boldsymbol{u}d\Gamma_2-\int_{\Omega_2}\boldsymbol{f}^\Omega\cdot\boldsymbol{u}d\Omega_2+\int_{\Omega_2}\left(\boldsymbol{\sigma}\cdot d^\theta\cdot\boldsymbol{H}\right)d\Omega_2 \quad (1)$$

In order to consider anisotropic magnetic and magnetostrictive properties, μ^θ and d^θ can be expressed as the function of magnetic flux density module B' and angle θ.

$$d^\theta=g(B',\theta)\qquad \mu^\theta=f(B',\theta)\qquad B'=\sqrt{B_x^2+B_y^2}\qquad \theta=\tan^{-1}\left(\frac{B_y}{B_x}\right) \quad (2)$$

The exciting current with the harmonic injection in motors can be expressed as follows:

$$i_m=\sqrt{2}I\cos(\omega t+\varphi_m)+I_n\cos(n\omega t+\varphi_m) \quad (3)$$

Results

The analyzed model is a three-phase induction motor of 4-pole, 36 stator slots and 28 rotor slots. The finite element model is shown in Fig. 5.

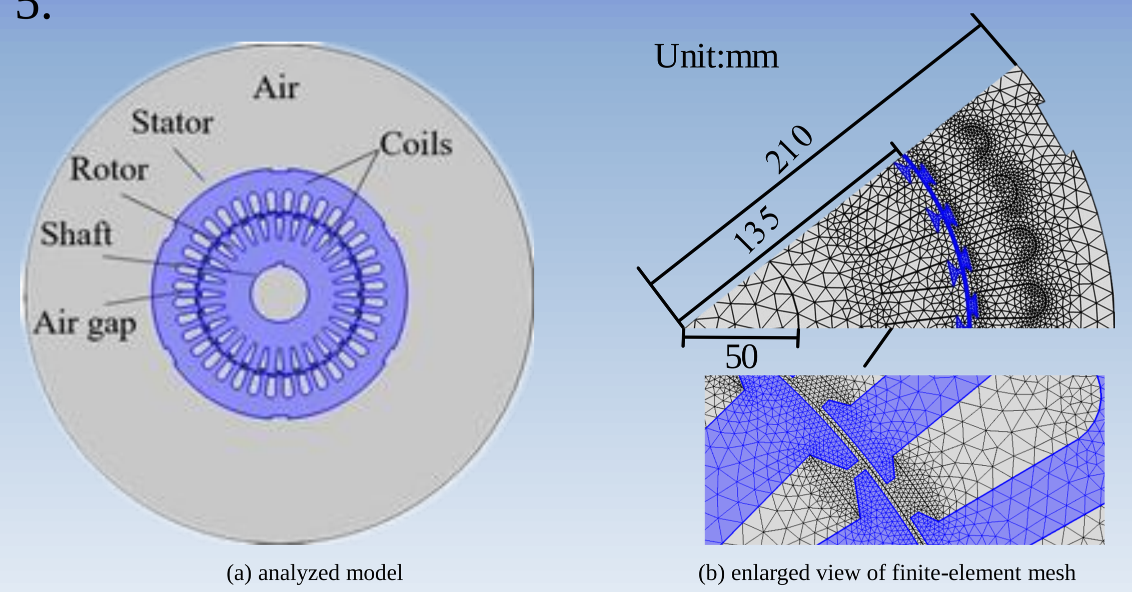

Fig. 5 Analyzed model of the induction motor and finite-element mesh.

The computed vibration characteristics of induction motor are shown in Fig. 6, Fig. 7, Fig. 8 and Fig. 9.

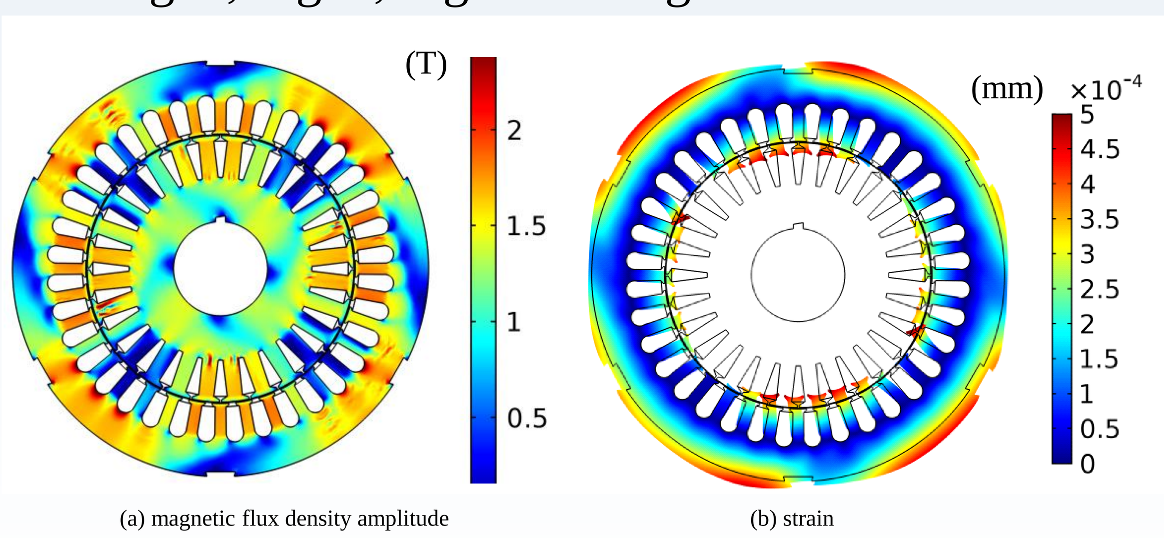

Fig. 6 The magnetic flux density amplitude and stator strain of induction motor cores at t=0.015s.

In order to analyze the source of motor vibration, the components of stator stress including circumferential stress and radial stress are calculated, shown in Fig. 7.

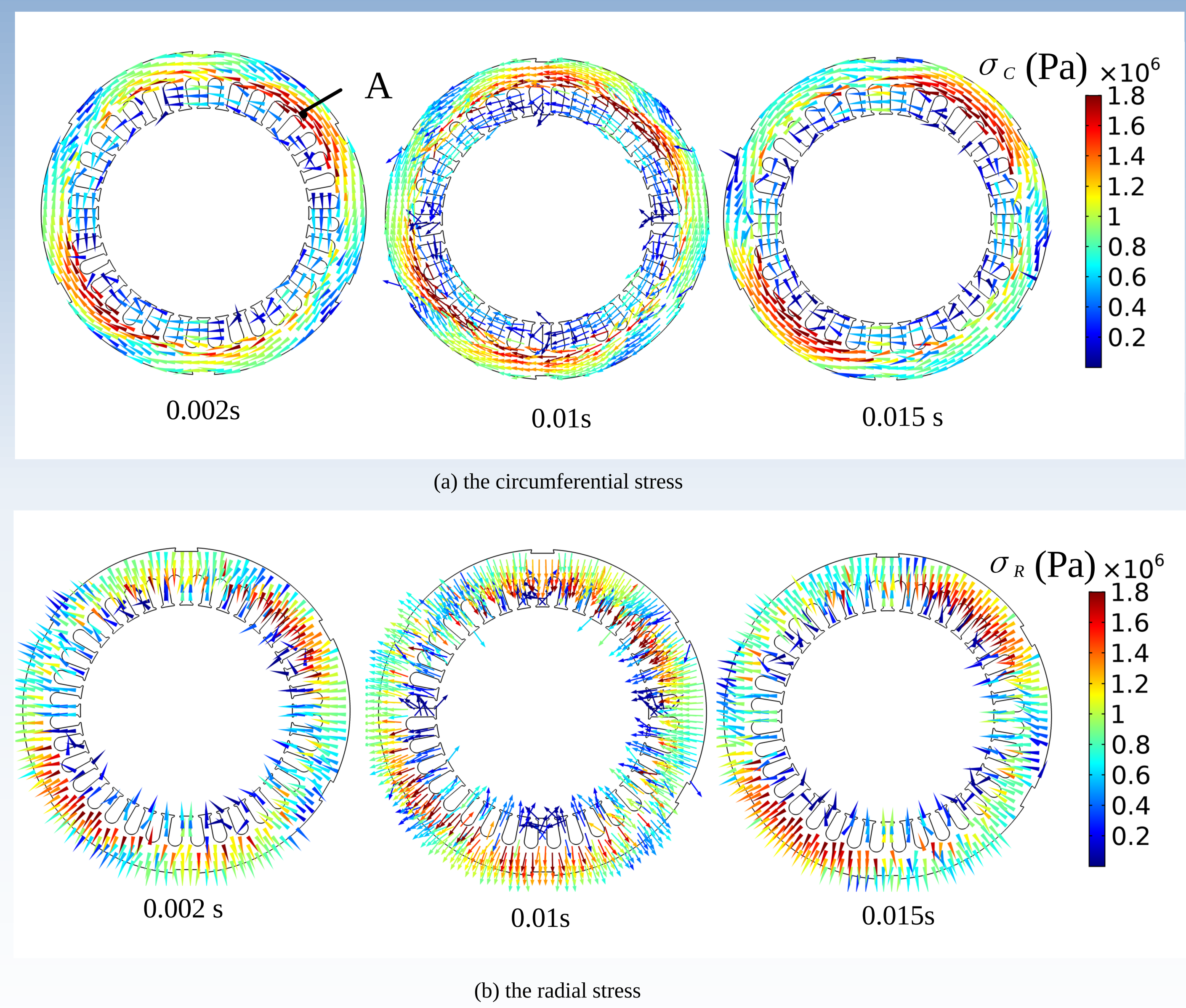

Fig. 7 The stress distribution of induction motor stator at different time.

In order to study the relationships between the stresses in different directions and time during the running of the induction motor, ponit A at the stress concentrated areas, shown in Fig. 6(a), are chosen to analyze stress characteristics. Stress curves under different applied exciting currents which is expressed in eq. (3) are shown in Fig. 8 and Fig. 9.

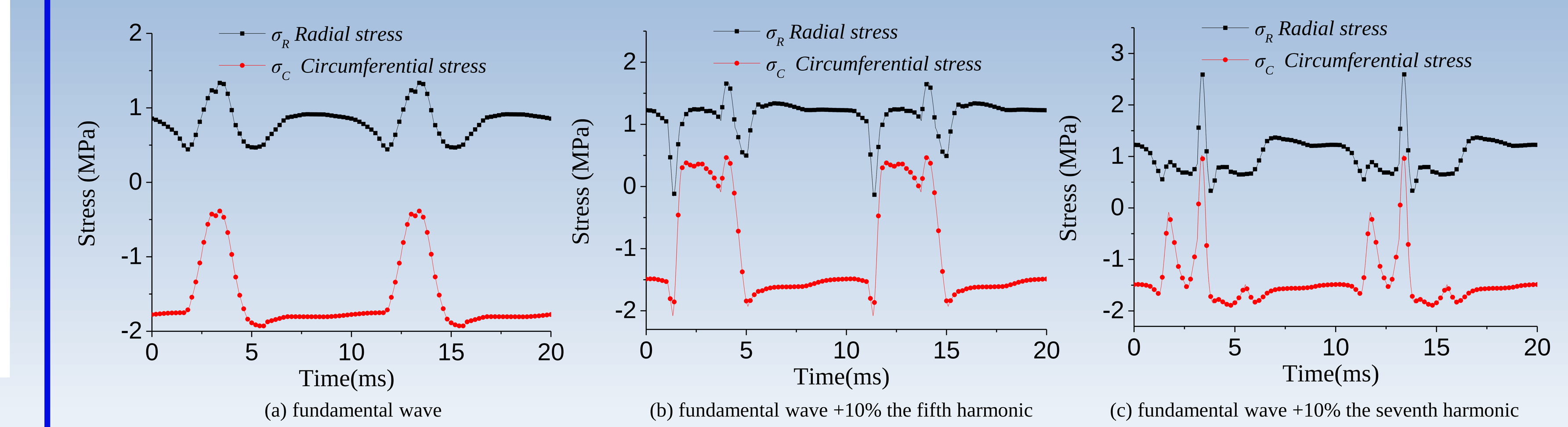

Fig. 8 The stress curves at point A under different exciting currents.

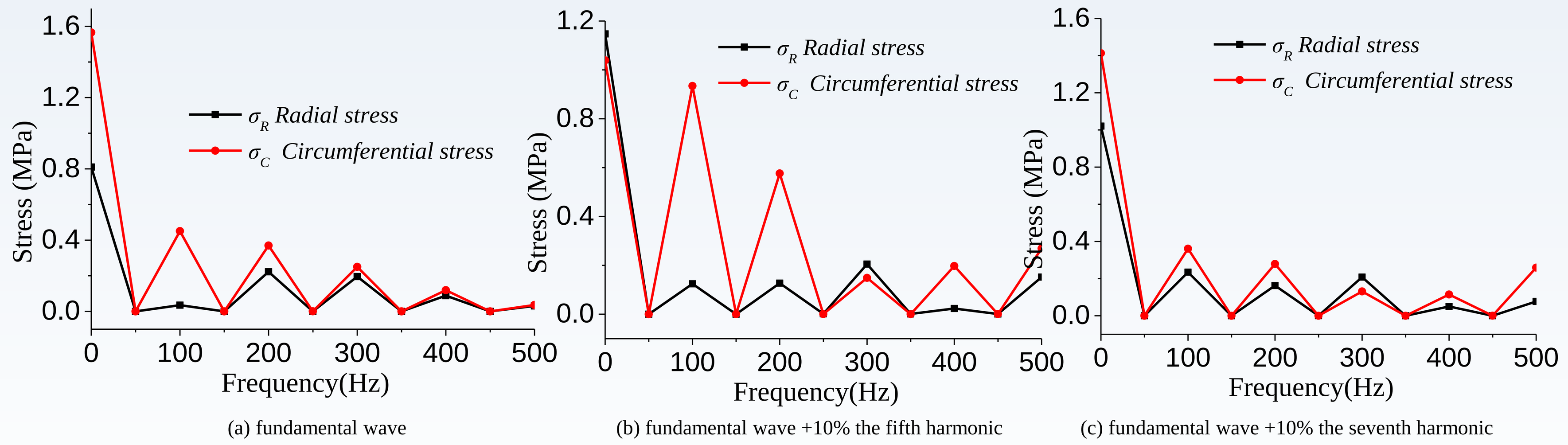

Fig. 9 The stress frequency spectrum at point A under different exciting currents.

CONCLUSION:

The radial stress and circumferential stress show different characteristics in different parts of motor cores. Meanwhile, the stress curves fluctuate greatly and the stress peak values increase relatively with the harmonic frequency.

Thus, different vibration damping materials are adopted at different locations, which will make the vibration reduction effectively.