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Analysis of Magnetic Stiffness in a Balanced Armature Receiver Considering the Effects of Soft Magnetic Material Saturation

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The armature of a balanced armature receiver (BAR) is made by a soft magnetic material with a nonlinear B-H curve and a saturation value. Based on our previous research, the saturation of armature may affect the nonlinear magnetic characteristics, especial with a strong current or a big vibration displacement. As one of the nonlinear magnetic characteristics in electromagnetic field, the cogging force in the BAR is usually considered as magnetic stiffness, and acted as a negative mechanical stiffness in the mechanical field. To investigate how the negative mechanical stiffness affects the mechanical stiffness of the vibration system, and then influences the performance of the BAR, an analysis of the magnetic stiffness considering the saturation in the armature is proposed. Two analysis methods are proposed in this paper: one is lumped parameter method (LPM) to equivalent the BAR into a simplified magnetic circuit; the other is a mass of simulations with 3D finite element method (FEM). The magnetic stiffness (cogging force) can be obtained in the analyses with varying displacement and without current. Two types of permanent magnets (PMs) are applied in both analysis methods: one is strong PMs which generate saturation at a middle range of displacement; the other is weak PMs which do not get the saturation even with maximum displacement. Comparison of two cases with both the LPM and FEM will be performed in this paper. To verify the effects of magnetic stiffness, the resonance frequency of the armature vibration displacement should be measured. To eliminate the stiffness effect produced by the sealed air in the back volume and front volume in the BAR, samples with holes punched on both of the upper and lower cover are manufactured. The modeling of 3D FEM simulation and the simulated resonance frequency are followed the measurement, and verified experimentally.

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