suppression effect. (5) The method proposed by Li has a comparable or even slightly stronger THD suppression capability than our proposed method. However, it has the following drawbacks: First, the estimation of velocity based on the Kalman filter requires a high computational power of the controller. Second, the velocity estimation accuracy of the Kalman filter depends on accurate selection of the process noise covariance and measurement noise covariance, and the selection process can often be accomplished only by a trial-and-error method, which is a complex process. Third, the Kalman filter estimates the velocity with measured displacement as a known quantity and therefore is not a valid sensorless control method.

5 Conclusions

The sensorless velocity feedback control method is crucial to reduce the THD of low-frequency vibration waveforms and improve vibration calibration accuracy. This paper presents an improved sensorless velocity feedback control method for electromagnetic vibrators to improve the sensorless velocity extraction accuracy and interference suppression capability of the conventional method. The main conclusions are as follows:

(1) The use of AC resistors improves the accuracy of vibration velocity estimation. The harmonic interference introduced by the velocity estimation error, which is difficult to suppress with feedback control, is reduced.

(2) The ability of sensorless velocity feedback control to suppress interference declines as sampling resistance increases. Therefore, sampling resistors should not be used for obtaining the driving current.

(3) The proposed method reduces the THD of the vibration waveform by about 20% compared to the conventional sensorless velocity feedback control method.

(4) The proposed method has a THD suppression capability comparable to that of a recent advanced method. However, the proposed method has a simpler parameter adjustment process that does not use sensors and is more reliable, less costly, and easier to maintain.

The main contribution of this paper is the proposed improved method of sensorless velocity feedback control, which can be implemented with analog circuits. According to the results of experiments, the proposed method is simple and reliable, and has a low cost and high value in engineering applications for improving low-frequency vibration calibration accuracy. Subsequent work will focus on applying the sensorless velocity extraction method combined with other advanced control algorithms to further improve the performance of electromagnetic vibrators.

Contributors

Wei LI and Junning CUI designed the research. Wei LI and Xingyuan BIAN processed the data. Wei LI drafted the manuscript. Junning CUI and Limin ZOU helped organize the manuscript. Junning CUI revised and finalized the paper.

Compliance with ethics guidelines

Wei LI, Junning CUI, Xingyuan BIAN, and Limin ZOU declare that they have no conflict of interest.

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