Waveform conditioning problems of nanocrystalline alloys under one/two-dimensional high-frequency magnetization

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ID:#19

Track ID: MT25-Thu-Af-Po4.10-09

Background

As a new kind of magnetic material, nanocrystalline alloys have high permeability and excellent loss characteristics, and measurement of high-frequency magnetic properties of nanocrystalline alloys have great significance on the development of high-frequency and high-power density transformer. In this paper, the problem of asymmetric distortion of the waveform in the nanocrystalline alloy high-frequency measuring is discussed and analyzed. A new rotational single sheet tester has been developed and vector magnetic properties of nanocrystalline alloys are measured. When the nanocrystalline alloy is near to saturated, the flux density waveform start distortion, a feedback control method is proposed to keep the flux density B sinusoidal which is very important to calculate the specific power losses during the magnetization.

Objectives

- Solving the problems of waveform distortion of magnetic field strength H and the magnetic flux densities in high frequencies.
- Measuring the magnetic properties of nanocrystalline samples in one/two-dimensional magnetization conditions at high frequency region.

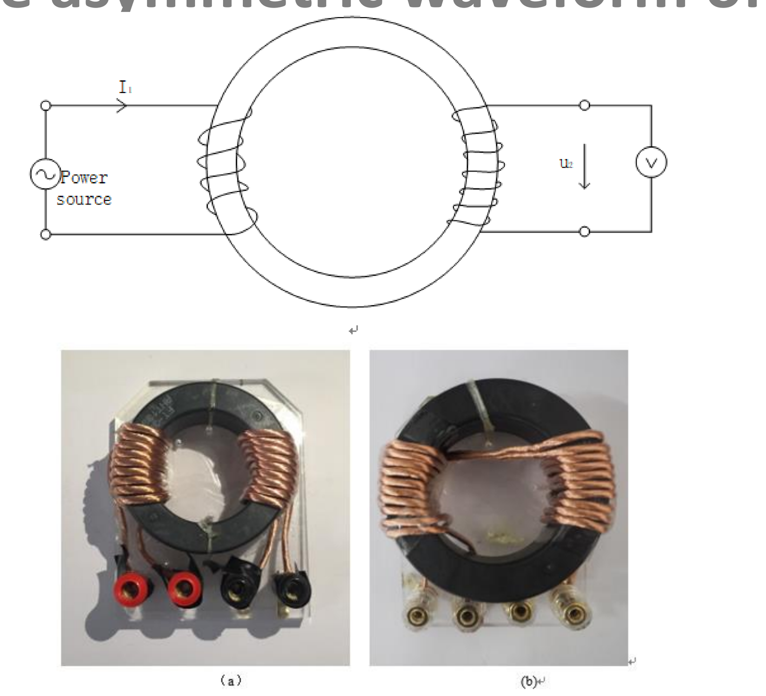
Conclusion

The waveform distortion problems in measuring the magnetic properties by the ring core method are first analyzed. To reduce the DC field influence, a square sample with small air gap rotational single sheet tester has been used. To improve the repeatability of the experiment, a model-free control algorithm has been developed and implemented in LabVIEW environment. The results show that the model-free method has good ability in process nonlinear problems. Finally, the vector magnetic properties of nanocrystalline alloys have been measured and discussed. The results show the nanocrystalline materials exist anisotropy and should be further studied as it is important for both fundamental research and industry application

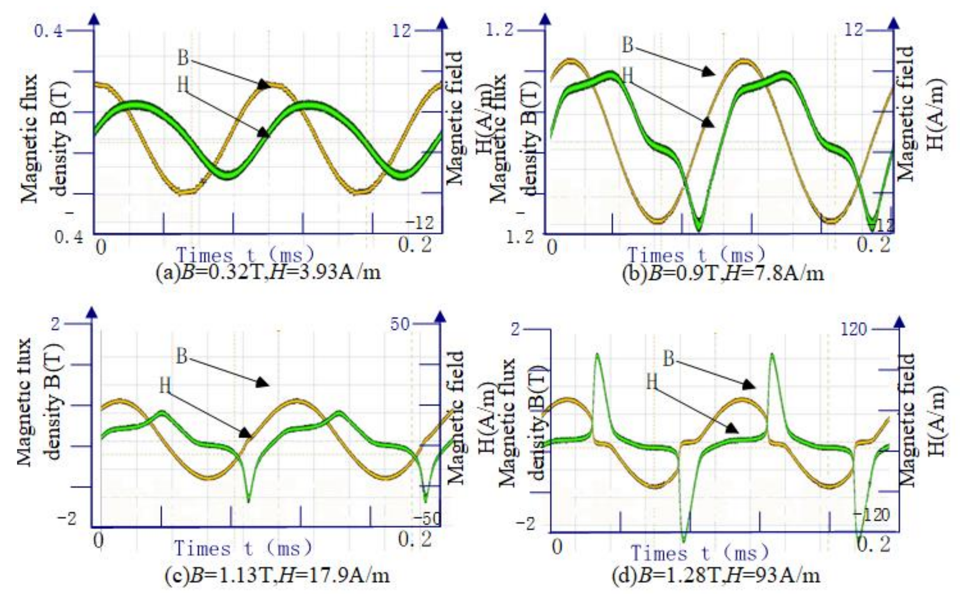
Methods

Phenomenon of the asymmetric waveform of magnetic field strength H

Some problem using the ring core method:
1, the effective path length is hard to determine;
2,these materials are very sensitive to DC disturbance as they have very high permeability. As shown in Fig.2, there exist a dc bias filed even the input voltage u1 is symmetric. When the magnetic field became stronger, the dc field has different values.
3, the magnetic strips are wounded in a ring core that will cause an asymmetric stress inside the material. The asymmetric stress would induce asymmetric magnetic properties such as different permeability in one magnetization cycle.

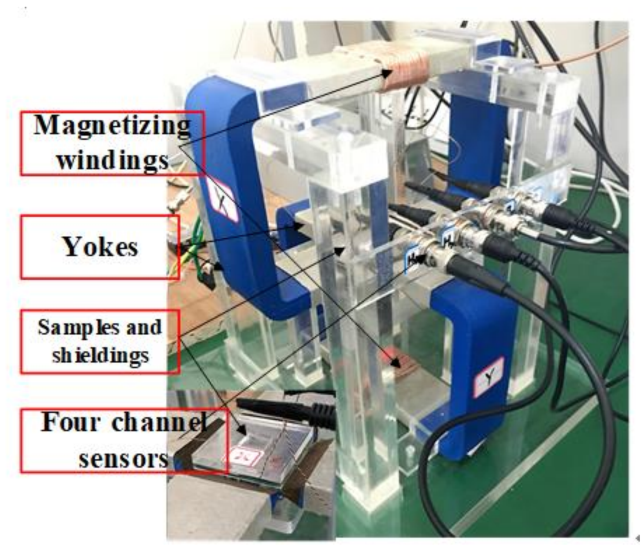


Principle of the one-dimensional magnetic property testing method

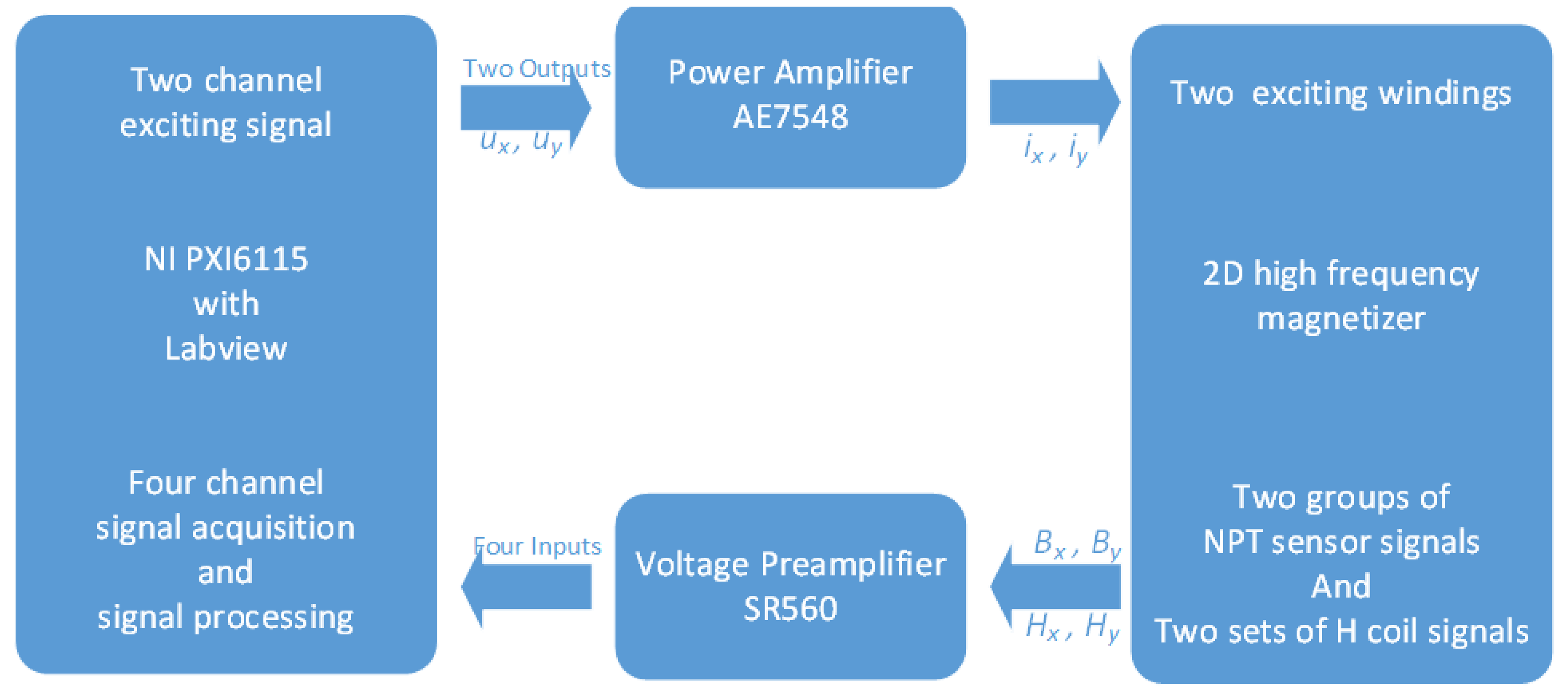


Control result of the flux density waveform

Samples

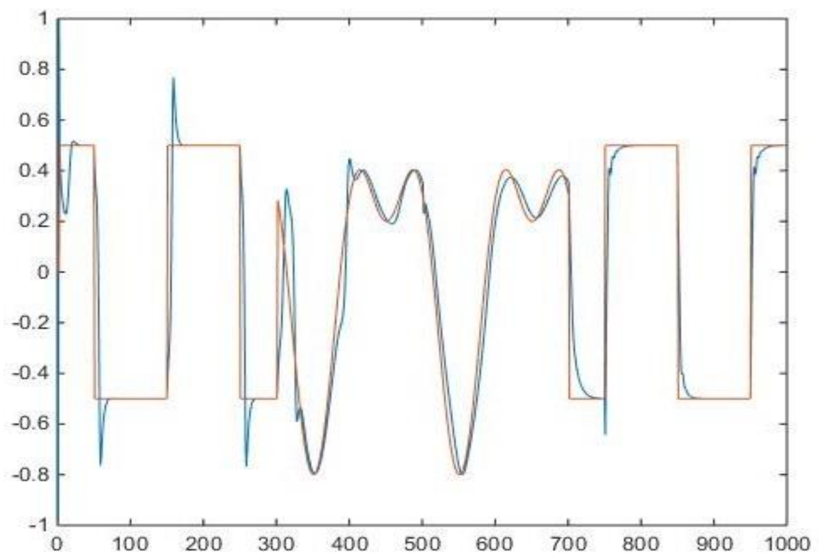


Vertical Square Rotational Single Sheet Tester(V-SRSST)

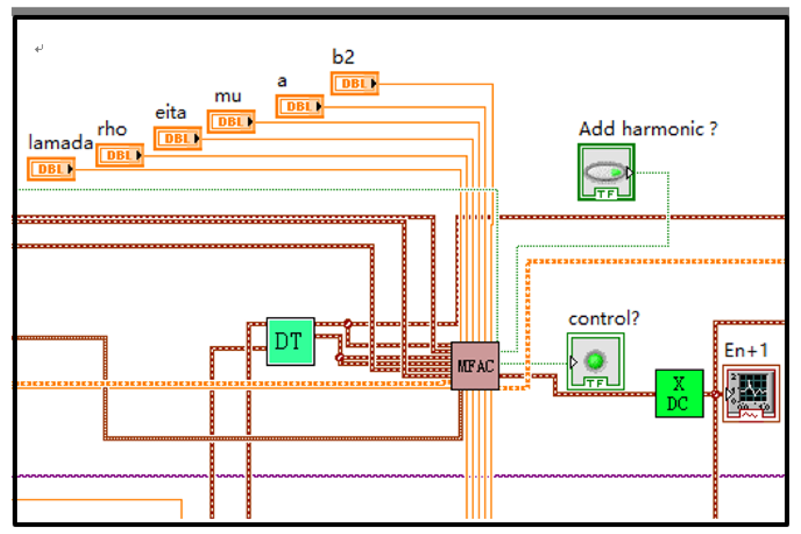


Schematic diagram of the nanocrystalline alloys testing system

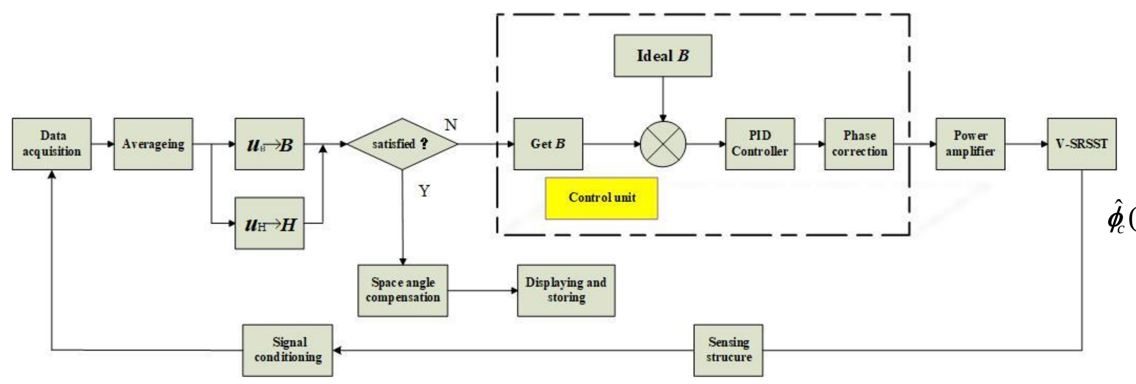
Results



Simulation of the performance of the controller



Realization of the control method in LabVIEW code

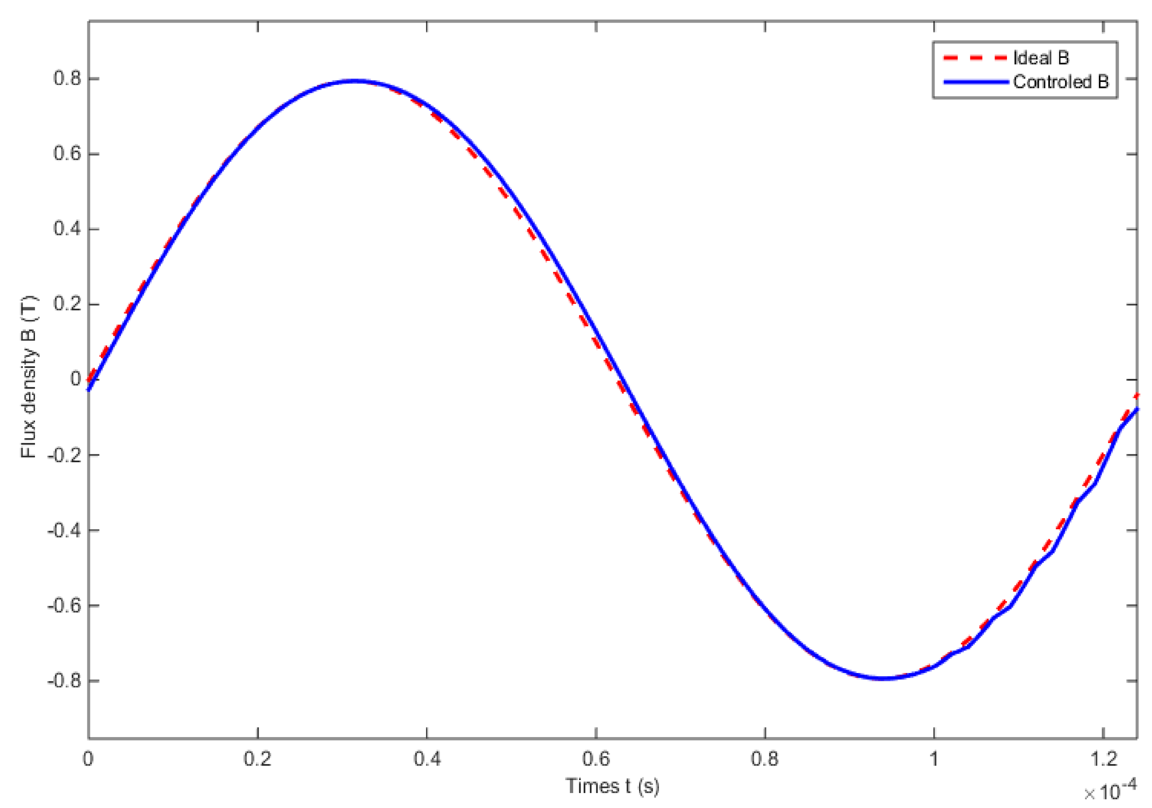


Control flow chart of the SMC testing system

A model-free control method is implemented in this experiment which is very powerful for solving the nonlinear problem:

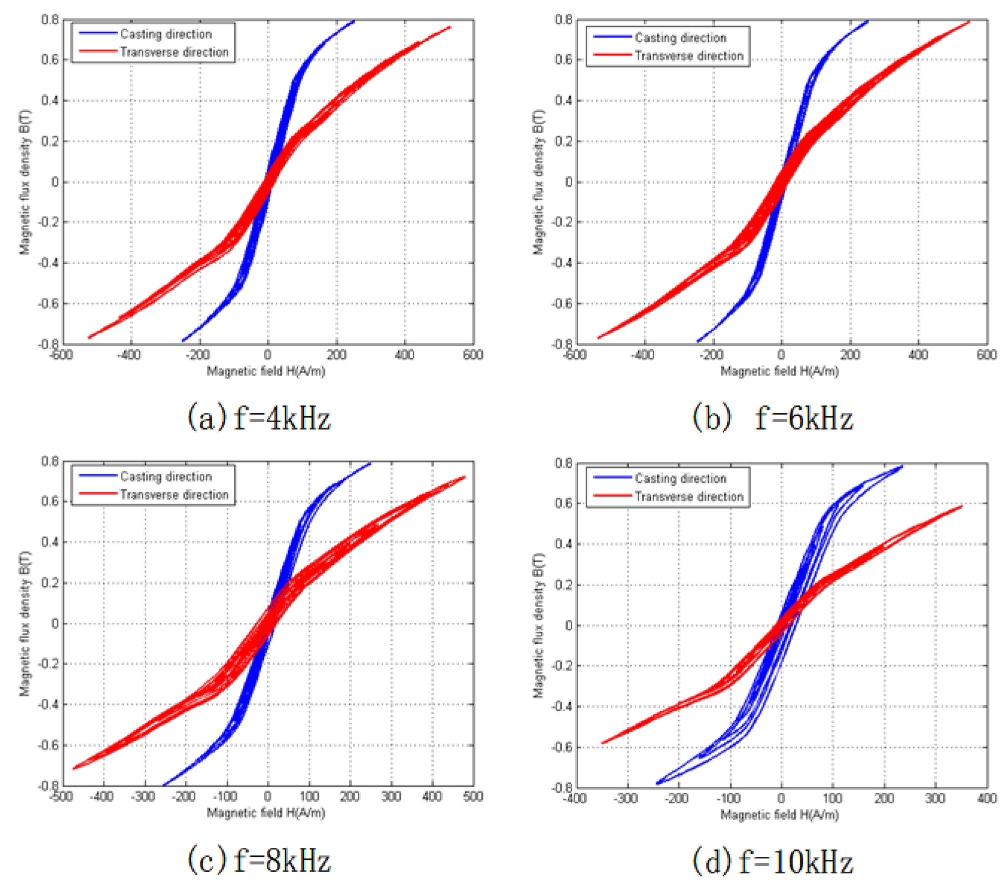
$$\hat{\boldsymbol{\phi}}_c(k)=\hat{\boldsymbol{\phi}}_c(k-1)+\frac{\eta(\Delta\boldsymbol{B}(k)-\hat{\boldsymbol{\phi}}_c(k-1)\Delta\boldsymbol{u}(k-1))\Delta\boldsymbol{u}^{\mathrm{T}}(k-1)}{\mu+\|\Delta\boldsymbol{u}(k-1)\|^2}$$

$$\boldsymbol{u}(k)=\boldsymbol{u}(k-1)+\frac{\rho\hat{\boldsymbol{\phi}}_c^{\mathrm{T}}(k)(\boldsymbol{B}^*(k+1)-\boldsymbol{B}(k))}{\lambda+\|\hat{\boldsymbol{\phi}}_c(k)\|^2}$$

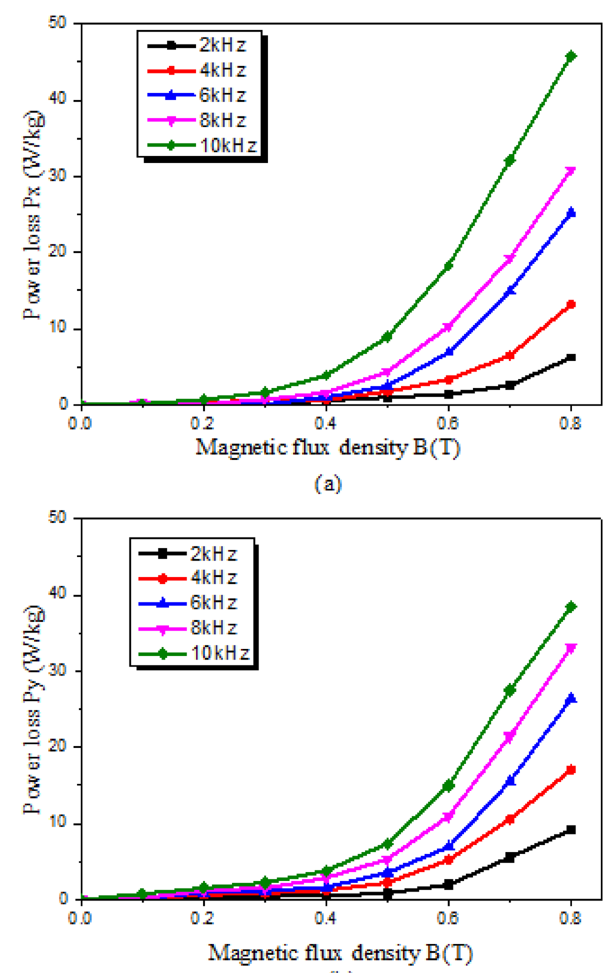


Control result of the flux density waveform

Testing results in two-dimensional magnetization



Hysteresis loops of the nanocrystalline alloys at different frequencies



Magnetic losses of the nanocrystalline alloys

By applying the Poynting theorem, the magnetic losses P can be calculated by:

$$P=\frac{1}{T\rho}\int_0^T(\boldsymbol{H}\cdot\frac{\mathrm{d}\boldsymbol{B}}{\mathrm{d}t})\mathrm{d}t$$

The nanocrystalline samples exit an anisotropy property and the permeability in the casting direction are much higher than that in the transverse direction. However, the area of the hysteresis loops is almost similar in the two directions.

Presented at the MT 25Conference , 2017 Aug. 27– Sep.1, Netherlands; Program I.D. number: 19