Curie Temperature and Vibrating String

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الملخص:
الهذف من هذه الدراسة هو محاولة إيجاد تفسيراً مقبولاً لأهتزاز سلك من مادة فيرومغناطيسية أثناء تغير في الطور من الفيرومغناطيسية إلى برامغناطيسية, وقياس درجة حرارة كوري. حيث تم وضع ثلاثة سيناريوات لتفسير هذه الظاهرة الفيزيائية. السيناريو الأول أن أهتزاز السلك ناتج عن أهتزاز في منظومة التجربة . السيناريو الثاني, ناتج عن تغير في الطور من الفيروماغنطيسية إلى البرامغناطيسية. في السناريو الثالث , نتيجة مرور التيار في السلك في وجود مغناطيس دائم . بعد فحص كل سناريو على حده وضمان عدم أهتزاز منظومة التجربة, استنتجنا الأتي, إن التغير في الطور من فيرومغناطيسي إلى برامغناطيسي يؤدي فقط إلى ابتعاد السلك عن المغناطيس الدائم. عند مرور تيار مستمر في السل(I= 2A, V=25V) سوف يؤدي إلى جذب السلك إلى المغناطيس والألتصاق به. بينما عند مرور تيار متردد في السلك تحذث عملية الأهتزاز والتغير في الطور عند (I=3.5A, V=25V), وعند درجة حرارة كوري 1195 كيلفن, وبذلك نعتبر السناريو الثالث الأكثر قبولاً لتفسير هذه الظاهرة.

ABSTRACT:
In this work, we would like to try to find an acceptable explanation to the vibrating ferromagnetic wire during phase change process from ferromagnetic to paramagnetic, and measuring Curie temperature . We suggested three scenarios to explain this phenomena , in the first one, is due to disturbance in the experimental set up. In the second scenario , is due to phase change from ferromagnetic to paramagnetic . In the third scenario , is due to passing a current in the wire in a presence of permanent magnet. After investigating these three scenarios , we concluded that , the phase change from ferromagnetic to paramagnetic led to movement of the wire away from the magnet only. When a direct current is set up in the wire at ($I=2\pm 0.01A$, and $v=25\pm 1V$), it will be attracted to the magnet and contacted with it . However, when an alternating current is passed in the wire, the vibration took place plus the change in phase at ($I=3.5\pm 0.01A$, and $V=50\pm 1V$) with Curie temperature equals to $1195\pm 7K$, so the third scenario is the more acceptable explanation for this phenomena.
moments ,rectifier

1.Introduction

At room temperature materials such as iron and nickel are ferromagnetic, and so they attract to permanent magnet. When these materials are heated above a certain characteristic temperature, they become paramagnetic and are no longer attracted to the magnet. This characteristic temperature is named the Curie temperature(T_c)in honor of the French physicist Pierre Curie who discovered it in 1892[1].

A simple way to demonstrate the existence of the Curie temperature is with the so-called Curie point pendulum[2-6]. Another simple demonstration uses a small magnet attached to a horizontal ferromagnetic wire[7]. The wire is heated by passing an electric current through it. When it reaches its Curie temperature the magnet drops from the wire, an equivalent demonstration, in which a vertical ferromagnetic wire is placed nearby a permanent magnet. Then the wire is heated by passing an electric current . When it reaches its Curie temperature the wire will move away from the magnet[8]. For more information about demonstrating and measuring the Curie temperature using several experiments, you can see reference[9] by the same authors of this article. In the experiment of vertical ferromagnetic wire , we noticed a very nice phenomena . When it reaches its Curie temperature the wire(straight, or spiral) started vibrating in addition to its displacement away from the magnet, to our knowledge this phenomena never been mentioned by previous authors[8]. For this reason we decided to study this phenomena in more details hopping to give acceptable explanation from physics point of view .

2. Basic Theory

In order to give acceptable explanation to this phenomena(vibrating wire), we will suggest several scenarios and test them individually, in addition of measuring Curie temperature for the wire (T_c).

Electrical energy W is delivered to the spiral wire at a constant rate P=VI, where V and I are, respectively, the potential difference across the wire and the current flowing through it. We may therefore write[8]:

$$T_c = \sqrt[4]{\frac{VI + e\sigma S T_0^4}{e\sigma S}} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where S and e are, respectively, the surface area and emissivity[9] of the ferromagnetic wire , σ =5.675x10^{-8}W/m^{2}K^4 is the Stefan-Boltzmann constant, and T_0 is the room temperature,

while the experimental uncertainty in T_c can be calculated using the fallowing formula [10].

$$\Delta T_c \approx T_c\left(\frac{\Delta I}{4I} + \frac{\Delta V}{4V}\right) \ldots\ldots\ldots\ldots(2)$$

- First scenario , since the wire is very fine any disturbance in the experimental set up will cause disturbance in the wire in the form of vibration .
- Second scenario, before Curie point the wire will be attracted toward the magnet, when temperature reaches Curie point the wire becomes paramagnetic , and will be displaced away from the magnet. Since the wire is very fine (0.42mm) in diameter it will cool very fast and becomes ferromagnetic , then it will be attracted again to the magnet. This process will repeat it self.
- Third scenario passing a current in the wire it will produce magnetic field which will interact with the permanent magnetic field causing these vibration.

2. Methodology

The experimental setup used in finding the Curie point is shown in figure below. It consists of a ferromagnetic heating wire(spiral, or straight), taken from a heater brand Evsan (of diameter 0.42mm, and 1500mm length), stretched vertically between insulating clamps mounted on the support stand. A permanent magnet is placed near the middle of the support stand in such way that attracts the wire. The wire is connected to the output of a Variac, voltmeter in parallel, and ammeter in series . In case of direct current we used in addition a rectifier.

Fig.(1) A photograph showing experimental setup

3. Result and Discussions

The following table gives typical data obtained for the ferromagnetic wire(spiral, or straight).

Alternating current	**Direct current**
Diameter (D)=0.42mm $\pm$ 0.01	Diameter (D)=0.42mm $\pm$ 0.01
Length (l) =1500mm $\pm$ 1mm	Length (l) =1500mm $\pm$ 1mm
Surface area (S) =1.98x10^{-3} $\pm$ 4 m^2	Surface area (S) =1.98x10^{-3} $\pm$ 4 m^2
Emissivity (e) =0.70	Emissivity (e) =0.70
Voltage at Curie temperature = 50 $\pm$ 1V	Voltage when wire attracted to the magnet =25 $\pm$ 1V
Current at Curie temperature =3.2 $\pm$ .01A	Current =2 $\pm$ 01.A
Curie Temperature(T_C) =1195 $\pm$ 7K	Attraction took place at 893 $\pm$ 10K

In order to explain the reason behind the vibrating ferromagnetic wire , we will go back to the different scenarios we proposed early to investigate them one by one :

- Even though the wire is very fine so that any disturbance , it will produce movement in the wire . In order to avoid this we isolated the set up completely from any disturbance.

- In the second scenario we suggested that the wire vibration is due to phase change from ferromagnetic to paramagnetic at Curie temperature , which means that the wire will be near the permanent magnet in the first case(it's temperature below T_c) , and away in the second case(it's temperature above T_c). This phenomena was demonstrated by very nice demonstration[11], but in our case the wire still connected to the power supply which means current still passing through the wire in other words it's temperature above Curie temperature. Thus the vibration of the wire is not due to phase change.

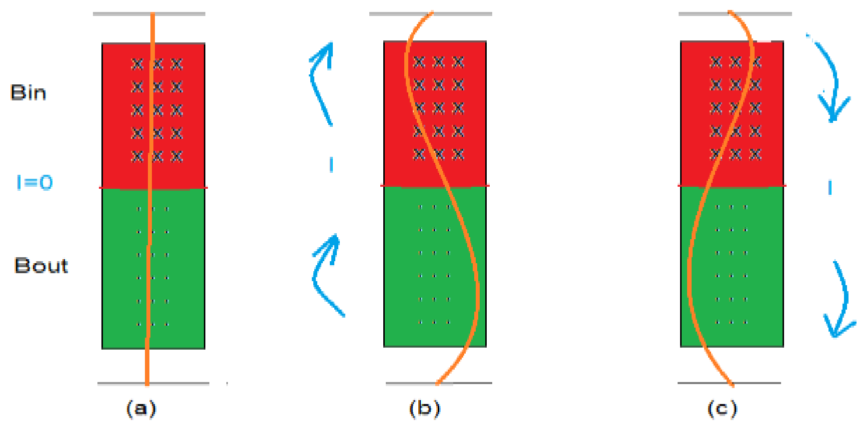

Fig.(2) A flexible vertical ferromagnetic wire is stretched in front of a permanent magnet with the field (as indicated). (a) When there is no current in the wire, it remains vertical. In case (b), and (c), it fallow the right hand rule.

- In the third scenario we suggested that the wire vibration is due to current passing through the wire. In this case we have to test two cases either direct current or varying current. In the case of direct current we noticed that at about 2 A, the wire will be attracted to the magnet , and not vibrating. In the case of alternating current, after reaching Curie temperature , the wire will be displaced away from the magnet and started vibrating. Thus we conclude that the wire vibration is due to an alternation current passing through the wire , this conclusion is supported by magnetic force on a current-carrying conductor[12] see fig.(2).

Fig.(3) Photograph shows the vibrating wire in front of a permanent magnet

Thus we conclude that in the case of alternating current two phenomena toke place, the first one the displacement of the ferromagnetic wire away from the magnet is due to the change in the phase from ferromagnetic to paramagnetic at Curie temperature, the second one is the vibration of the wire (spiral or straight) , see fig(3) is due to magnetic force on the current-carrying conductor. The Curie temperature measured in this study is comparable with [8], where T_c equals to 1073 $\pm$ 16K, if we take in consideration alloy of the substance .

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