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KSCIBHC BH Curve

Investigation of magnetic hysteresis property of different magnetic material. (determination of B-H curve for the given materials).

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1. Key concepts

- Magnetism
- Magnetic domains
- Hysteresis property

2. Introduction

The term ‘hysteresis’ is derived from a Greek word that roughly translates to the property of lagging behind. The term was first used by sir James Alfred to describe the behaviour of magnetic materials. In-fact, the property of hysteresis is observable in various branches of physics. Namely, elasticity, fluid dynamics, thermodynamics and magnetism etc.

3. Objectives

- To observe and study the magnetization behavior of the magnetic materials provided.

4. Theory

Materials that a spontaneous non zero value of magnetic moment even in a zero external magnetic field are called magnetic materials. Certain materials namely, Iron, nickel, cobalt and some of the rare earth elements exhibit a unique magnetic property called ferromagnetism. Ferromagnetic materials exhibit a long-range ordering phenomenon at the atomic level that cause the atomic magnetic moments to line up parallel with each other in a region called a domain. Within the domain, the magnetization is high, but in a bulk sample, the material will generally be non-magnetized, because, the domains will be randomly oriented with respect to one another, and the magnetic fields lines will get attenuated with in the neighboring domains. When an external magnetic field is applied to the sample, the magnetic domains to line up with along direction of the applied magnetic field, and the bulk sample will behave like a magnet.

- **4.1 Hysteresis Loop.**

Given in the figure 2 is a hysteresis curve for a ferromagnetic material. Along the X-axis is external magnetic Field (H), and Y-axis is the magnetization (M).

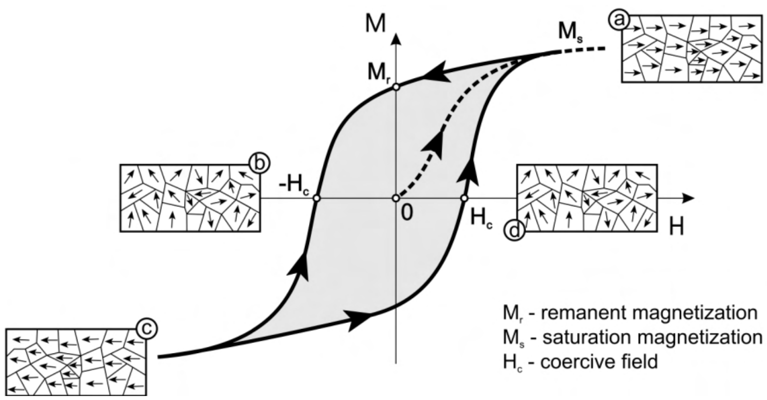


Figure 2: Hysteresis loop of a ferromagnetic material.

- A Ferromagnetic material, retains its magnetization even after the external magnetic field is removed. And the reversal or change in the direction of the applied external magnetic field results in a change in the magnetization of the ferromagnetic material. It is seen that the change in the magnetization lags behind the change in the applied external magnetic field. Thereby, a hysteresis behavior is exhibited.

- The hysteresis behavior can be explained by looking at the orientation of magnetic moments at the domain level.

1. When a ferromagnetic material is placed in a region of space that has a zero value of magnetic field, the magnetization in the sample will be zero, owing to the random orientation of the magnetic moments in each of the domains in the sample (Figure 3)

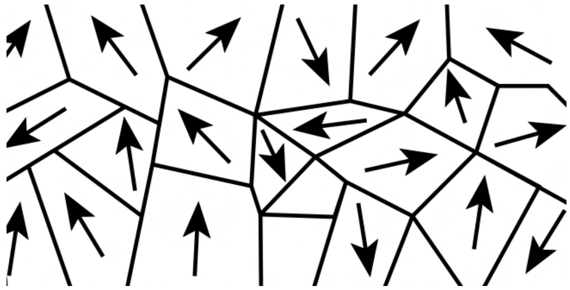


Figure 3: Random orientation of magnetic moments in an unmagnetized ferromagnetic sample.

2. As the applied external magnetic field starts increasing, there is a non-linear behavior in the magnetization curve (see the dashed line in figure 2) and then it reaches a saturation value. Any further increase in the value of the external magnetic field will not result in the increase in the magnetization of the sample. This is called saturation magnetization (M_S). The saturation level is reached when the magnetic moments of all the domains are aligned along the same direction. (See figure 4). Now, if the magnitude of the applied external magnetic field is reduced to zero. There will be a large degree of magnetization retained by the ferromagnetic sample, this is known as remanent magnetization (M_r). This is due to long range ordering of orientations of the domains in the sample.

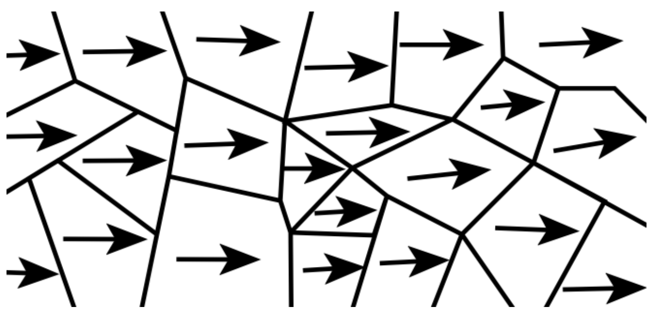


Figure 4: Orientation of the magnetic moments of the domains. Long range order can be seen.

On reversal of the direction of the applied external magnetic field, the intensity of the magnetization value of the sample starts decreasing, and crosses zero. The value of the

3. magnetic field at which the magnetization is zero is called coercive field (H_C). Coercive field is present one both sides of the X axis.

4. The reorientation of the magnetic moments to a direction that is diametrically opposite to the orientation at M_S, will occur when the external magnetic field is oriented in the direction opposite to when M_S is achieved.

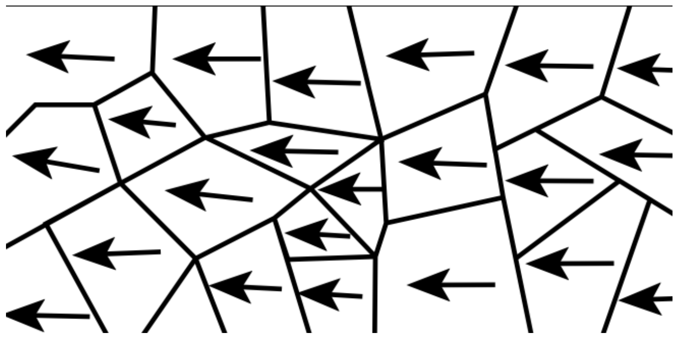


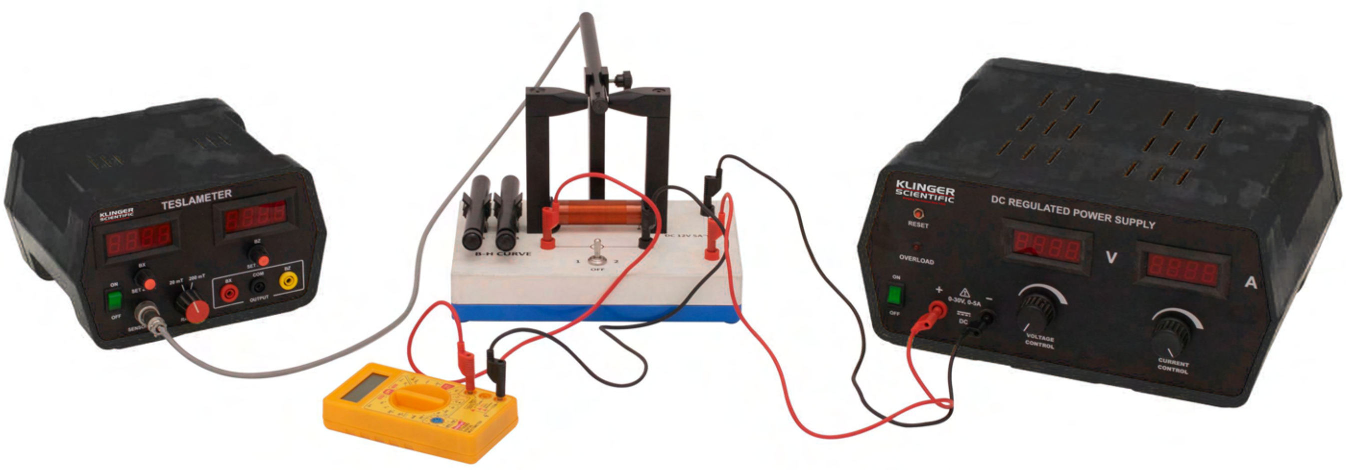
Figure 5: Orientation of the magnetic moments of the domains. Long range order can be seen. The field direction has been reversed,

5. Equipment

Sr. No.	Equipment	Code	Quantity
1	B- H Curve Measuring Instrument	KSCI-PH94014	1
2	Multimeter	KSCI-DMM	1
3	Advanced Power Supply	KSCI-61035D/5	1
4	Teslameter	KSCI-TMETER	1
5	MS Core		1
6	EN – 31 Core		1

6. Safety Instruction

- Components like the U core setup and power supply are heavy. Take adequate safety measures while handling them.
- Current applied to the electromagnet set up is



7. Experimental Setup

- Establish correct electrical connections to the U core setup, connect the multimeter in ammeter mode in series with the circuit
- Place the hall meter in the middle of the U core set up (bottom part)
- Place the given ferromagnetic sample in the sample holder
- Increase the current supplied to the U core set up in steps of 0.5 A till 5 A and record the value of the magnetic field (mT)
- Reverse the direction of current through the circuit. Now, vary the current in steps of 0.5 A

8. Tabulation

9. References

- Magnetic hysteresis, https://kobita1234.files.wordpress.com/2016/11/chp-8.pdf
- Magnetic materials, https://nptel.ac.in/content/storage2/courses/112108150/pdf/PPTs/MTS_16_m.pdf
- Hysteresis in ferromagnetic materials. https://ocw.mit.edu/courses/materials-science-and-engineering/3-024-electronic-optical-and-magnetic-properties-of-materials-spring-2013/lecture-notes/MIT3_024S13_2012lec25.pdf

10. Appendix

- **10.1 Sample readings**
- **1. Sample:** Mild steel (MS)

Current (A)	Magnetic field (mT)	Current (A)	Magnetic field (mT)
0	**1.** 0	**2.** -3.5	**3.** -9.28
0.5	**4.** 0.84	**5.** -4	**6.** -11.25
1	**7.** 1.67	**8.** -4.5	**9.** -13.22
1.5	**10.** 3.09	**11.** -5	**12.** -15.57

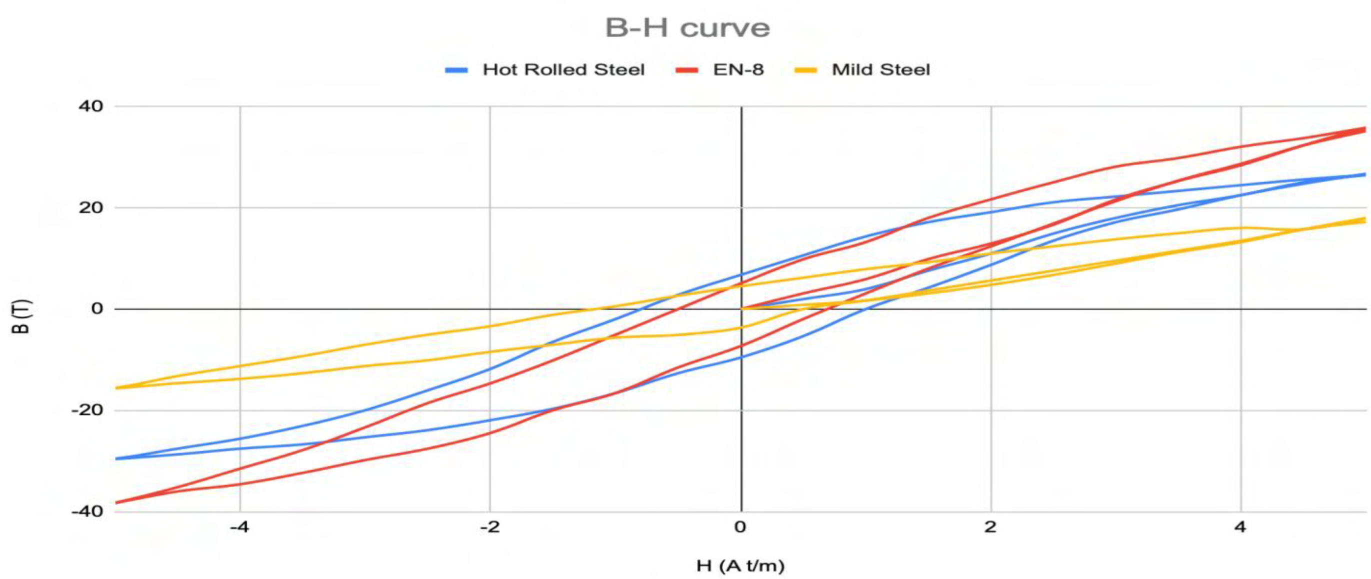
Current (A)	Magnetic field (mT)	Current (A)	Magnetic field (mT)
2	**13.** 4.78	**14.** -4.5	**15.** -14.63
2.5	**16.** 6.74	**17.** -4	**18.** -13.78
3	**19.** 9	**20.** -3.5	**21.** -12.66
3.5	**22.** 11.25	**23.** -3	**24.** -11.25
4	**25.** 13.22	**26.** -2.5	**27.** -10.11
4.5	**28.** 15.75	**29.** -2	**30.** -8.44
5	**31.** 18	**32.** -1.5	**33.** -7.03
4.5	**34.** 15.75	**35.** -1	**36.** -5.63
4	**37.** 16.03	**38.** -0.5	**39.** -5.1
3.5	**40.** 14.98	**41.** 0	**42.** -3.66
3	**43.** 13.78	**44.** 0.5	**45.** 0
2.5	**46.** 12.38	**47.** 1	**48.** 1.69
2	**49.** 10.97	**50.** 1.5	**51.** 3.66
1.5	**52.** 9.26	**53.** 2	**54.** 5.63
1	**55.** 7.88	**56.** 2.5	**57.** 7.59
0.5	**58.** 6.19	**59.** 3	**60.** 9.56
0	**61.** 4.5	**62.** 3.5	**63.** 11.53

Current (A)	Magnetic field (mT)	Current (A)	Magnetic field (mT)
-0.5	64. 2.63	65. 4	66. 13.5
-1	67. 0.56	68. 4.5	69. 15.75
-1.5	70. -1.13	71. 5	72. 17.22
-2	73. -3.38	74. -1	75. -5.63
-2.5	76. -5.06	77. -0.5	78. -5.1
-3	79. -7.03	80. 0	81. -3.66

- **2. Sample:** EN-8

Current (A)	Magnetic field (mT)	Current (A)	Magnetic field (mT)
0	82. 0	83. -3.5	84. -27.84
0.5	85. 3.09	86. -4	87. -31.5
1	88. 5.91	89. -4.5	90. -35.16
1.5	91. 9.87	92. -5	93. -38.25
2	94. 12.94	95. -4.5	96. -36
2.5	97. 16.66	98. -4	99. -34.59
3	100. 21.66	101. -3.5	102. -32.34
3.5	103. 25.31	104. -3	105. -29.81
4	106. 28.41	107. -2.5	108. -27.56
4.5	109. **32.34**	110. -2	111. -24.47
5	112. **35.72**	113. -1.5	114. -19.97
4.5	115. 33.75	116. -1	117. -16.59
4	118. 32.06	119. -0.5	120. -11.53

Current (A)	Magnetic field (mT)	Current (A)	Magnetic field (mT)
3.5	121. 29.82	122. 0	123. -7.31
3	124. 28.13	125. 0.5	126. -1.97
2.5	127. 25.03	128. 1	129. 3.09
2	130. 21.66	131. 1.5	132. 7.99
1.5	133. 18	134. 2	135. 12.38
1	136. 13.22	137. 2.5	138. 16.88
0.5	139. 9.84	140. 3	141. 21.32
0	142. 5.06	143. 3.5	144. 25.37
-0.5	145. 0	146. 4	147. 28.69
-1	148. -5.06	149. 4.5	150. 32.34
-1.5	151. -10.13	152. 5	153. 35.16
-2	154. -14.66	155. -1	156. -27.84
-2.5	157. -18.56	158. -0.5	159. -31.5
-3	160. -23.34	161. 0	162. -35.16


B-H curve
Hot Rolled Steel
EN-8
Mild Steel
40
20
0
-20
-40
B (T)
-4
-2
0
2
4
H (A t/m)