Study of Temperature dependence of magnets made of different materials

(Neodymium Vs Ferrite)

Science Fair Project Report

Level : *Middle Level*

Category : Physical Science

Submitted by

Syed Mohamed. A

(Grade 7)

ARRAHMAAN
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ABSTRACT

This science research project was conducted to study and compare the temperature dependence of neodymium and ferrite magnets and to find out which magnet has more temperature resistance at extreme temperatures. The tests were done using neodymium and ferrite magnets by treating the magnets under room temperature (33°*C*), freezer temperature (4°*C*), ice water bath (9°*C*) and boiling water bath (90°*C*). Magnetic strength was calculated using the amount of paperclips that the magnet was able to collect at each measured temperature.

Neodymium magnet attracted many paperclips than the ferrite magnet of same dimension at all the temperatures tested. It shows the magnetic strength of neodymium magnet is higher than the ferrite magnet. *The variation in loss of magnetic strength was high at boiling water test temperature than the freezer temperature.* When exposed to boiling water test, neodymium loss more magnetic strength than the ferrite magnet.

My investigation showed that even though the magnetic strength is higher in neodymium magnets than ferrite, it lost more magnetic strength when treated under extreme temperatures compared to ferrite magnet and so the ferrite magnet is more temperature resistance than neodymium magnet.

FERRITE MAGNETS

NEODYMIUM MAGNETS

INTRODUCTION

Magnetism and magnets have found many uses in products that we use daily. The once popular cassette and video tape were made using a reel of magnetic tape. Our ATM cards and credit cards have a magnetic strip which contains information. Magnetism is also used in transformers, motors, speakers, microphones and many more devices. Hospitals use Magnetic Resonance Imaging (MRI) to identify problems in patients, without having to perform surgery. .

Magnetism is an invisible force or field caused by the unique properties of certain materials. In most objects, electrons spin in different, random directions. This causes them to cancel each other out over time. However, magnets are different.

In magnets the molecules are uniquely arranged so that their electrons spin in the same direction. This arrangement of atoms creates two poles in a magnet, a North-seeking pole and a South-seeking pole. The magnetic force in a magnet flows from the North pole to the South pole. This creates magnetic field around a magnet.

When two unequal magnetic poles attract each other, the one magnet supports the parallel alignment of the molecular magnets in the other magnet. This renders both magnets a little stronger. When two equal magnetic poles repel each other, however, the one magnet disturbs the parallel alignment of the molecular magnets in the other magnet. This renders both magnets a little weaker.

The important part of the relationship between magnets and temperature is the fact that heating the magnet causes its molecules to become more disorderly. Magnets are dipoles, which means they have an opposite charge, or magnetic direction, at each end. This is a result of most of the magnetic molecules facing the same direction. When we heat our magnets, those polar molecules start moving around. The average direction of the entire magnet's polarity becomes a little bit messier because those magnetic molecules are no longer facing the same direction.

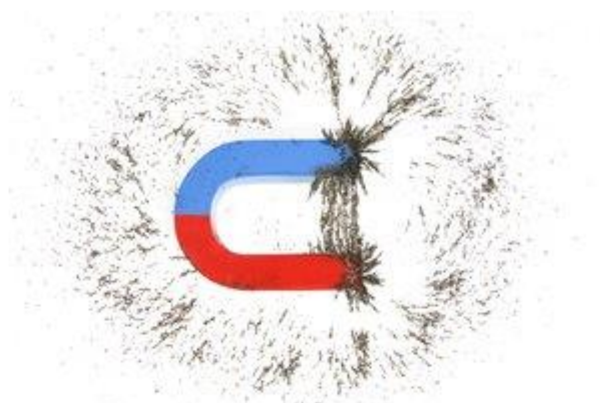
If magnets are heated to the Curie point, they lose their ability to be magnetic. The dipoles become so disordered that they can't return to their original state. Curie points are very hot, and would not be able to get your magnets to reach them without special lab equipment. For iron, the Curie Point is 1417°F.

As the boiled magnet cools from the boiling temperature of 100°C back to room temperature, it will return to its normal magnetic strength. Cooling the magnet even further to 0°C in ice water or -78°C in dry ice will cause the magnet to become stronger. Cooling causes the molecules in the magnet to have less kinetic energy. This means that there is less vibration in the magnet’s molecules, allowing the magnetic field they create to be more consistently concentrated in a given direction.

Neodymium magnets are really strong. The larger they get, the more careful you need to be to avoid being pinched or struck from the force of their attraction. A neodymium magnet (also known as NdFeB, NIB or Neo magnet), the most widely used type of rare-earth magnet, is a permanent magnet made from an alloy of neodymium, iron and boron to form the $Nd_2Fe_{14}B$ tetragonal crystalline structure. Developed in 1982 by General Motors and Sumitomo Special Metals, neodymium magnets are the strongest type of permanent magnet commercially available.

They have replaced other types of magnets in the many applications in modern products that require strong permanent magnets, such as motors in cordless tools, hard disk drives and magnetic fasteners. Even very small neodymium magnets should be handled with care.

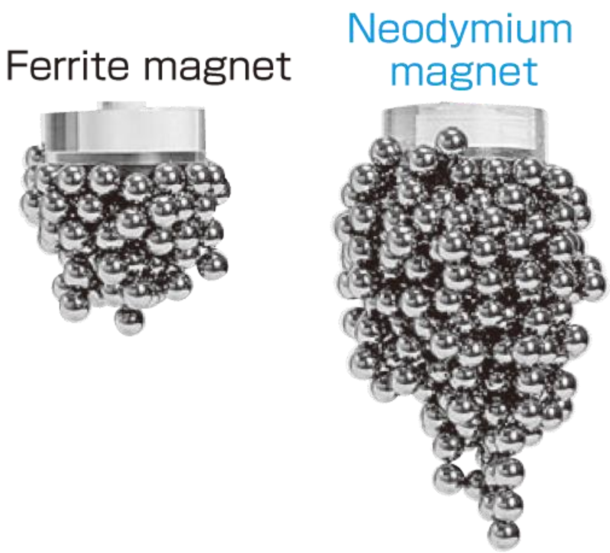
Ferrite magnets, also known as ceramic magnets are a type of permanent magnet and are made of the chemical compound ferrite, which consists of ceramic materials and iron oxide (Fe_2O_3), the chemical composition is SrO-6(Fe_2O_3). The raw materials used to produce ferrite magnets are strontium carbonate and iron oxide, each magnet consists of about 90% iron oxide and 10% strontium carbonate. Both materials are abundantly and economically available.



STATEMENT OF THE PROBLEM

Magnets are everywhere in our everyday lives. Hard drives that store data in our computer are coated with a magnetic material, the speakers in our headphones are powered by magnets, and our refrigerator uses magnets to hold its door shut. But the magnets can only operate within a certain temperature range.

We need magnets that function in extreme conditions, like in the cold emptiness of space. In our day-to-day life, magnets experience more-moderate extremes temperatures. It is important to note there are several types of magnets. I wish to find that neodymium and ferrite magnets are always permanent or they are exceptions at extreme temperatures. In my research, I plan to investigate, “Which magnet is more temperature resistance?”



HYPOTHESIS

Neodymium magnet is more temperature resistance than ferrite magnet.

DESIGN OF STUDY

INDEPENDENT VARIABLE:

- Type of Magnets (Neodymium and Ferrite)

DEPENDENT VARIALBE:

- Magnetic strength (this will be calculated using the amount of paperclips that the magnet is able to collect at each measured temperature)

CONTROLLED VARIABLES:

- Temperature
- Paperclips

MATERIALS:

- Neodymium and Ferrite magnets of equal dimensions
- Laboratory thermometer
- Plastic tongs for magnet
- Refrigerator
- Water
- Ice cubes
- Four strong bowls
- Small pot
- Induction stove for heating water
- Digital weighing machine
- Paper clips(1000)

PROCEDURE:

Important: Whenever the magnets are cool or heat to a desired temperature, it is very important to allow the magnet to equilibrate to the test temperature before measuring the magnet's strength at that temperature. Give the magnet at least 20 minutes to attain a uniform temperature when it is immersed in water and 30 minutes when it is in open air. This will ensure that not only the surface, but also the inner core of the metal, attains the desired temperature.

Measuring the Magnet Strength:

- Calculate using the amount of paperclips that the magnet is able to collect at each measured temperature.

A. Magnetic strength of Neodymium and ferrite magnets at room temperature.

1. Create a pile of paper clips in two separate bowls. The pile needs to be at least 1 inch wider than the magnet on each side of the magnet. Make sure the top of the pile of paper clips is flat.
2. Hold the Neodymium Magnet above the pile.
3. Lower the magnet down slowly until it rests in the middle of the pile of paper clips,
4. The magnet rests on a flat pile of paper clips that were originally placed as a flat pile. The number of paper clips it picks up when removed is a measure of the strength of the magnet.
5. Now, slowly remove the magnet from the pile. Should not add or remove any paperclips stuck on the magnet ideally with this movement. Try not to pick up extra paper clips that are not stuck to the magnet though.
6. Zero out weighing scale so it indicates 0 g when the container using to measure (measuring boat) is on the scale.
7. Remove all the paper clips picked up by the magnet from the magnet and gather them on measuring boat.
8. Record the mass picked up by the magnet in lab notebook for a total of 5 trials.
9. Repeat the steps 2-8 for ferrite magnet and for a total of 5 trials and record.

B. **Freezer Test**

1. Place one neodymium and one ferrite magnet in the freezer for about 30 minutes.
2. Place thermometer in the freezer.
3. Prepare pile of paper clips in two separate bowls.
4. Take both the magnets out, measure their strength (measure the weight of the paper clips attracted by the magnets separately) and put them instantly back where they got it from for this test so it is ready for next trial.
5. Leave the magnets for at least 10 minutes to equilibrate with the test temperature again.
6. Repeat steps 3–5 four more times for a total of five trials.
7. Take the thermometer out of the freezer and record the temperature of the freezer in the data table in lab notebook. Take the magnets out of the freezer.

C. Ice/Water Bath Test

8. In two plastic bowls, prepare equal bath of water and ice cubes.

9. Place the neodymium magnet in one of the bowl and ferrite magnet in another bowl. Make sure it is completely submerged.
10. Leave them in the ice/water bath for at least 20 minutes, evaluating intermittently if the bath needs extra ice. Note: Since the room is warmer than ice/water bath, heat will flow from the room to the bath, melting your ice. To keep the temperature of the bath at lower degree, replenish the ice.
11. Repeat steps 3–6. While do so, keep an eye on the ice/water bath, making sure it always contains some ice.
12. Use thermometer to measure the temperature of the ice/water bath and record the findings in data table. Take the magnets out of the water/ice bath.

D. **Boiling Water Test**

13. Put a pot with plenty of water on the stove and bring it to a soft boil.
14. Use tongs to put the magnet in the water. Also use the tongs to take the magnet out of the water. Leave the magnet in the water for at least 20 minutes to equilibrate.
15. Repeat steps 3–6. While do so, keep the water at a soft boil.
16. Use thermometer to measure the temperature of the boiling water and record the findings in data table in lab notebook. Take the magnet out of the water, let the water cool and safely dispose it.
17. Repeat 13-16 steps for ferrite magnet.

E. Analyzing Data

1. For each temperature, calculate the average mass the magnets picked up. Do this by adding the masses picked up by the magnet for Trial 1, Trial 2, Trial 3, Trial 4, and Trial 5 for a given Temperature (e.g. freezer temperature) and divide this total by the number of trials, here 5. Record the average in the last line of the data table.
2. Make a graph of magnetic strength, as measured by mass picked up (y-axis, the vertical axis), vs. temperature (x-axis, the horizontal axis) for both neodymium and ferrite magnet.
3. Look at data table and graph, and try to draw conclusions from the results.
   a. Does magnetic strength of neodymium and ferrite magnet increase, decrease, or stay the same over the temperature range tested?
   b. ***Which magnet has more strength at extreme temperatures? (Neodymium Vs Ferrite)***

COLLECTION OF DATA

PHOTOGRAPHS

Qualitative Data

TABLE 1: Room Temperature: 33°C

S. No	Trials	Weight of the paper clips attracted to the ***Neodymium Magnet (g)***	Weight of the paper clips attracted to the ***Ferrite Magnet (g)***
1.	Trail 1	50.21	27.36
2.	Trail 2	51.05	20.11
3.	Trail 3	50.40	22.18
4.	Trail 4	51.08	24.9
5.	Trail 5	50.43	25.7
6.	Average	50.63	24.05

TABLE 2: Freezer Test

Temperature: 4°C

S. No	Trials	Weight of the paper clips attracted to the ***Neodymium Magnet (g)***	Weight of the paper clips attracted to the ***Ferrite Magnet (g)***
1.	Trail 1	43.01	21.33
2.	Trail 2	48.38	20.99
3.	Trail 3	46.18	27.18
4.	Trail 4	44.56	22.73
5.	Trail 5	43.46	19.53
6.	Average	45.12	22.35

TABLE 3: Ice Water Bath Test

Temperature: 9°C

S. No	Trials	Weight of the paper clips attracted to the ***Neodymium Magnet (g)***	Weight of the paper clips attracted to the ***Ferrite Magnet (g)***
1.	Trail 1	48.51	24.4
2.	Trail 2	50.30	21.48
3.	Trail 3	38.76	19.88
4.	Trail 4	42.65	21.7
5.	Trail 5	44.23	22.9
6.	Average	44.89	22.07

TABLE 4: Boiling Water Test

Temperature: 90°C

S. No	Trials	Weight of the paper clips attracted to the ***Neodymium Magnet (g)***	Weight of the paper clips attracted to the ***Ferrite Magnet (g)***
1.	Trail 1	40.49	15.69
2.	Trail 2	33.39	15.99
3.	Trail 3	45.36	15.96
4.	Trail 4	41.32	15.32
5.	Trail 5	39.52	15.78
6.	Average	40.02	15.75

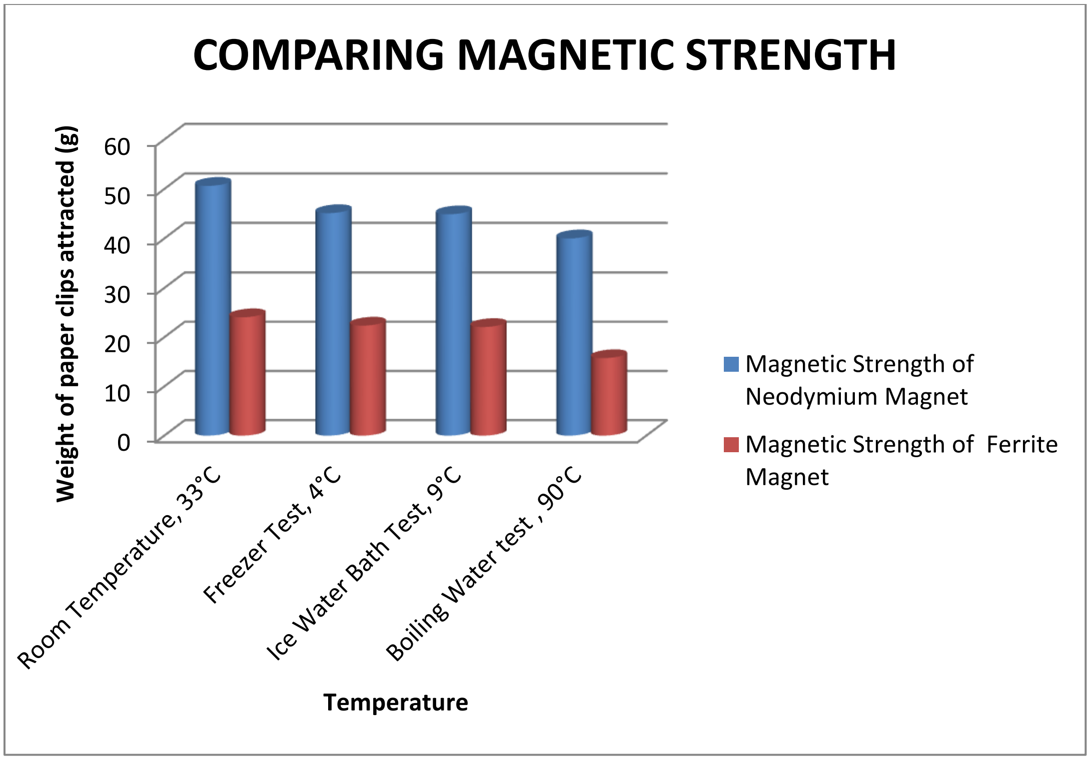
TABLE 5A: Comparision of Magnetic Strength at different temperatures

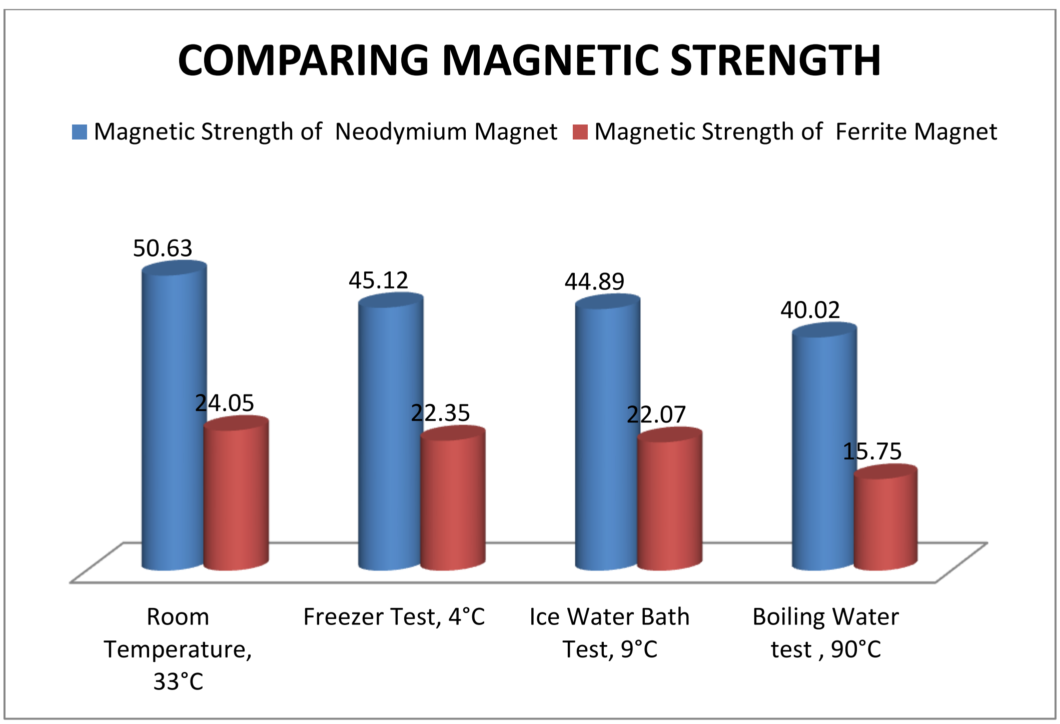
S. No	Temperature	Magnetic Strength of ***Neodymium Magnet***	Magnetic Strength of ***Ferrite Magnet***
1.	Room Temperature, 33°C	50.63	24.05
2.	Freezer Test, 4°C	45.12	22.35
3.	Ice Water Bath Test, 9°C	44.89	22.07
4.	Boiling Water test , 90°C	40.02	15.75

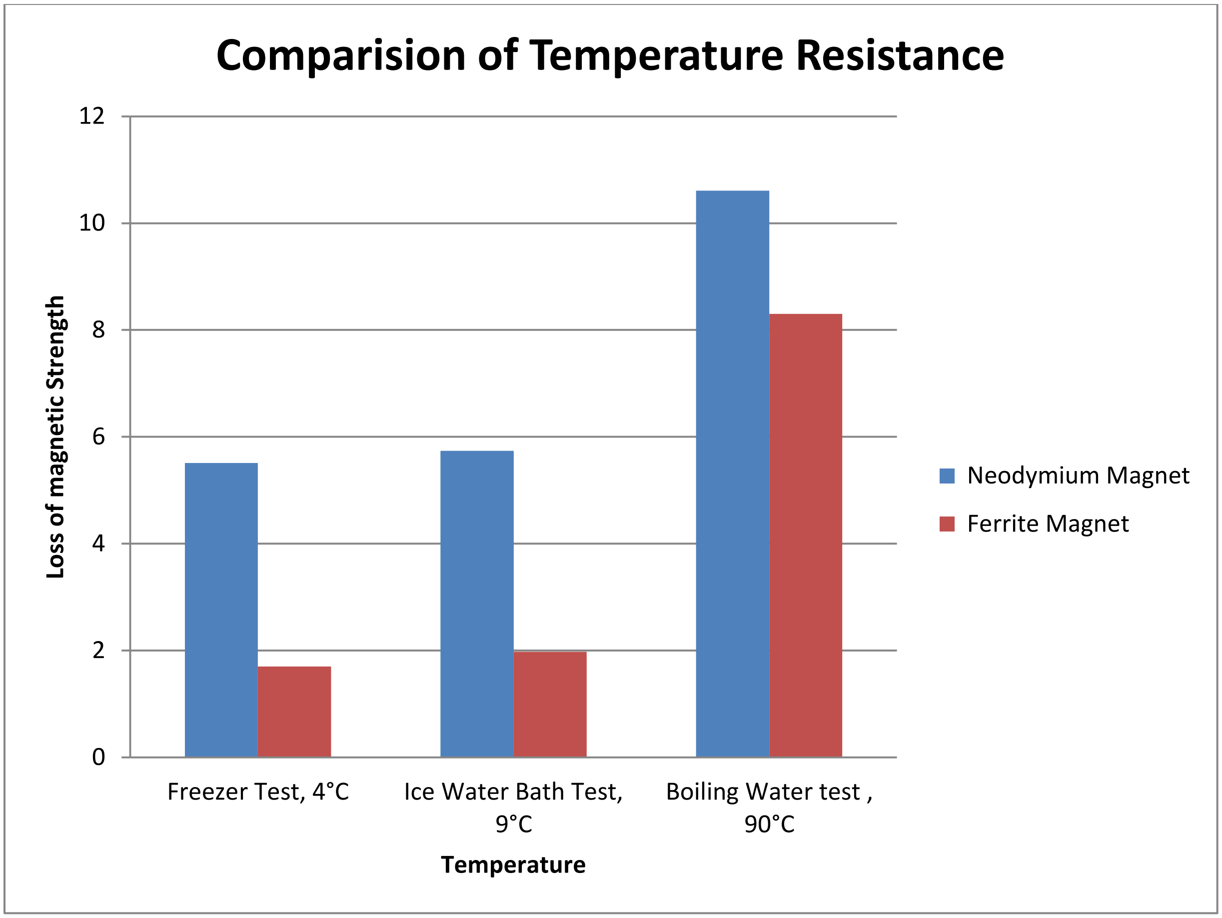
TABLE 5B: To check gain or loss of Magnetic Strength at different temperatures rather than at room temperature

S. No	***Temperature***	***Loss of Magnetic strength***	***Neodymium Magnet***	***Ferrite Magnet***
1.	Freezer Test, 4°C	Magnetic strength at Room Temperature- Magnetic strength at freezer temperature	5.51	1.7
2.	Ice Water Bath Test, 9°C	Magnetic strength at Room Temperature- Magnetic strength at Ice water bath temperature	5.74	1.98
3.	Boiling Water test , 90°C	Magnetic strength at Room Temperature- Magnetic strength at Boiling water temperature	10.61	8.3

GRAPHICAL REPRESENTATION







The above graph shows that even though the magnetic strength is higher in neodymium magnets, it lost more magnetic strength when treated under extreme temperatures compared to ferrite magnet.

RESULTS AND DISCUSSION

- Neodymium magnet attracts many paperclips than the ferrite magnet of same dimension at all the temperatures tested. It shows the magnetic strength of neodymium magnet is higher than the ferrite magnet.
- *In general, it is found that heating the magnet will cause the magnet to have a weaker magnetic field. Cooling the magnet will cause the magnet to have a stronger magnetic field.*
- *But when both the magnets are tested for freezer temperature, it shows loss in magnetic strength. I tried for more trials but it results the same. But the loss of magnetic strength is very less.*
- *The variation in loss of magnetic strength is high at boiling water test temperature than the freezer temperature.*
- Before my investigation, I thought that neodymium is more temperature resistance because of its higher magnetic strength than ferrite. But when exposed to boiling water test, neodymium loss more magnetic strength than the ferrite magnet. It shows that the ferrite magnet is more temperature resistance than neodymium magnet.

CONCLUSION

- My hypothesis, “Neodymium magnet is more temperature resistance than ferrite magnet.” has not been proved.
- When a magnets temperature rises it loses magnetic force so the higher the temperature of the magnet the less magnetic it is.
- Ferrite magnet is more temperature resistance than neodymium magnets.
- My investigation shows that even though the magnetic strength is higher in neodymium magnets, it lost more magnetic strength when treated under extreme temperatures compared to ferrite magnet.

APPLICATION

- Neodymium is a rare earth metal and a special material: Combined with iron and boron it creates the currently strongest permanent magnets in the world. They can be produced in various shapes (discs, blocks, cubes, rings, rods and spheres). Their nickel-copper-nickel coating lends them an appealing silver surface. Hence, these special magnets are great as gifts for arts and crafts fans and model makers.
- Compared to neodymium magnets, the adhesive force of ferrite magnets (ceramic permanent magnets) is much weaker. On the other hand, they are cheaper, suitable for outside use (rust-resistant) and can take heat up to 250 °C. If size and volume are less important than price, ferrite magnets can be a good alternative to neodymium magnets.
- Like all magnets, temperate affects their behaviour, but unlike rare-earth magnets, when ferrite magnets get hotter their resistance to demagnetisation increases because their intrinsic coercivity improves.
- This unique characteristic makes them extremely popular for applications that require high operating temperatures such as electric motors and generators, they are also widely used in loudspeaker systems. The intrinsic coercivity (The strength of the magnetic field that is necessary to make the magnetic polarization (strength of magnetization) to zero) of a ferrite magnet increases by approximately 0.4% for each degree Celsius increase (from ambient). On the downside, their output does reduce at the rate of approximately 0.2% for each degree Celsius increase. Both of these effects are reversible as the operating temperature returns to ambient, however, grades with low operating temperatures may suffer permanent demagnetisation at high temperatures.
- This means that Ferrite magnets can be used up to about 180℃ in some cases however, they are less effective in colder temperatures, particularly below 0℃. Typically they will display a reduced pull force, the extent of which depends on the size and shape of the magnet and the environment it is applied in. With careful design, a ferrite magnet can continue to be effective in temperatures as low as -40℃.

FUTURE ENHANCEMENT

Magnets are crucial to many more emerging technologies in future. I wish to research for new materials for magnets such that it has high magnetic strength, temperature and corrosion resistance, high producibility and efficiency.

ACKNOWLEDGEMENT

All Praise to ALLAH S.W.T the Almighty, for giving me the blessing, the strength, the chance and endurance to complete this project successfully.

The success and final outcome of this project required a lot of guidance and assistance from many people and I am extremely privileged to have got this all along the completion of my project. All that I have done is only due to such supervision and assistance and I would not forget to thank them.

I express my deepest sense of gratitude to Mrs.R.Sameem M,Sc, B.Ed, PGDCA, Principal for her guidance and valuable suggestions and for her keen interest in the investigation and in the presentation of this report.

I would like to express my deep thanks to Senior Principal Mrs.A.Parakath Nisha and Correspondent Mr.A.Sathakkathullah who gave me the golden opportunity to do this wonderful project.

I would not forget to remember Ms.A. Anis Parveen B. SC., B. Ed., and Mrs. M.Taj Nisha M,Sc, B.Ed, BA., for their encouragement and more over for their timely support and guidance till the completion of my project work.

I would also like to thank my parents and friends who helped and motivated me a lot in finalizing this project.

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