Stepper motor:

Mechatronics Project Report

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Group 3

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The document consists of all the work step by step done by the group in making stepper motor, starting from selecting the project, specifications, calculations, assembly, programming up to its working and application.

The following document is report on project of mechatronics subject taught by Sir Harshal Oza and assisted by Ms. Jaina Mehta.

Content:

1. Initial Specifications:

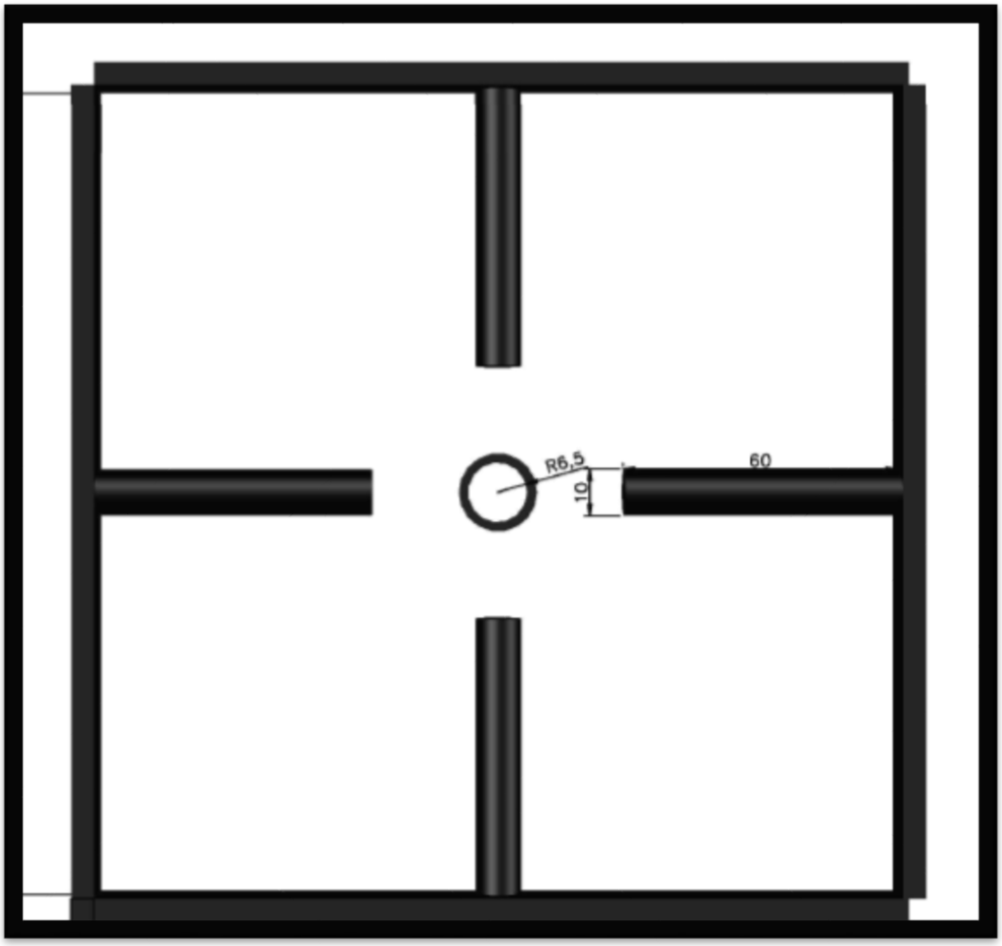
The first process was to decide the type of motor we wanted to make which would be feasible too.

- So we went through Nema stepper motors specifications.[1]
- We also cleared the type of stepper motor we wanted to make.
- The specifications we had were to approach towards calculations:
  1) Drive system:- unipolar
  2) Phases -2(4 coils)
  3) Rotor:- Permanent magnet rotor. *(Cheap, can take the specified angle/step)*
  4) Steps:- 12/revolution
  5) Type of permanent magnet : Neodymium bar magnet.
  6) Type of bearing : roller bearing
  7) Object used for windings : big nails.
  8) Wire to be used: Teflon insulated or copper wire of approximately 25 gauge.
  9) Arduino : ATMEGA 328
  10) Drive circuit : L298n

Reasoning for assuming above characteristics:

- Rotor consisted of permanent magnets and that too neodymium because neodymium is available in shops. Also we dropped the idea of variable reluctance stepper motors as we found this one to be more feasible.[2]
- We decided to have bar magnets instead of ring magnets of thin cylindrical magnets later because…

  If we used one ring magnet we will have to connect gears on its north south poles with proper teeth. That will bring the question of giving tooth to coils which is not easily made. Also we didn't use cylindrical magnets because in calculation of its magnetic field according to dimensions (available) and remanence (from sources) [3] **,**the value was very low in comparison to that of a bar magnet. The calculation is shown in later part.



2. Design:

- This was the initial sketch we had as a prototype.
- In final parts we had some small changes according to the calculations we had will be mentioned later.
- Here in above diagram the acrylic supports to the coils.
- And there is also a sheet below the bearing shown at centre in diagram which is supported by a acrylic pipe fitted below in the sheet.

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3. Calculation:

Magnetic flux density calculation:

- Magnetic flux of magnet changes according to dimensions and formulas.
- Formula for bar magnet:

$$B = \frac{B_r}{2}\left[\tan^{-1}\left(\frac{LW}{2z\sqrt{4z^2+L^2+W^2}}\right) - \tan^{-1}\left(\frac{LW}{2(z+D)\sqrt{4(D+z)^2+L^2+W^2}}\right)\right]$$ [4]

Where, B_r = Remenance = $1.32\, Tesla$ [5]

L = length of the magnet = $20mm$

z = air gap = $5mm$

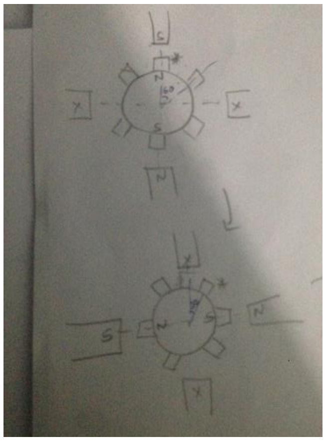
W = width of bar magnet = $25mm$

D = thickness of bar magnet = $6mm$

So putting values in above equation,

$$B = \frac{1.32}{2}\left[\tan^{-1}\left(\frac{20 * 25}{2 * 5\sqrt{4 * 25 + 400 + 625}}\right) - \tan^{-1}\left(\frac{20925}{2(6+5)\sqrt{4 * 121 + 400 + 625}}\right)\right]$$

$$= 0.66(56.1 - 30.33)$$



$B = 17.0082\, Tesla$

Deciding diameter of rotor/bearing:

- Circumference = arrangement of magnets around it

$$\therefore 2\pi r = (20 + 5) * 6 = 25 * 6$$
$$= 150$$

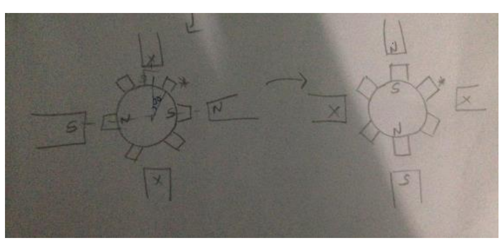
$$\therefore r = \frac{150}{2\pi} = 23.8mm$$

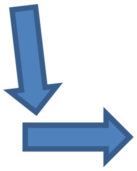
- Nearly available and convenient bearing dimensions: $40mm\ od, thickness = 6mm$

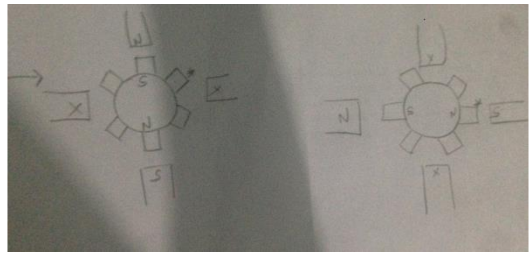
Note: In above calculation 20mm is length of magnet grounded on bearing and 5mm is the assumed space between 2 magnets.

Note: Why number of magnets taken as 6?

Diagram:







Current calculation:

$$T = J\alpha = Ni(A \times B) = NiAB\sin\theta$$

Moment of inertia of rotor:

$m = 100gm$ (measured by weighing machine)

$r_o = 2cm = 0.02m$

$r_i = 0.75cm = 0.0075m$

$$J = \frac{1}{2}m\left(r_o^2 - r_i^2\right) = \frac{1}{2}100(0.02^2 - 0.0075^2)$$
$$= 1.7$$
$$\approx 2\ kg\ m^2$$

Angular acceleration calculation:

$$\Delta\theta = \frac{\pi}{6} = 0.52$$

$t = 1\, sec$(Assumed, can change according to code)

$\alpha = \frac{\Delta\theta}{(\Delta t)^2} = \frac{\pi}{6*1*1} = 0.52\, rps^2$

$T = I\alpha = 2 * 0.52$ (1)

Torque due to coil windings:

Assumed:

- ✓ $N = 500$
- ✓ Length is taken $65cm$ approximately in each of the coil.
- ✓ θ As shown in diagram is taken $\pi/6$.
- ✓ So per winding in uni-direction = 50 turns.
- ✓ The nail used was of $19mm$ diameter.
- ✓ But the coil becomes of $2.5cm$ diameter.
- ✓ Area of coil's cross-section,

$$A = \pi\left(\frac{2.5}{100 * 4}\right)^2 = 1.277 * 10^{-4} \quad m^2$$

$$\therefore T = 500i * 1.277 * 10^{-4} * 17.0082 * \sin 30$$

By equation (1),

$$\therefore 2 * 0.52 = 500i * 1.27710^{-4} * 17.0082 * \sin 30$$

$$\therefore i = 1.9 \cong 2\, ampere$$

Properties calculations:

1)$\mu(core) = \frac{B}{H} = 0.00001254$

2)Inductance in per coil $= 0.07\ H$[7]

3)Voltage= $8.3V$[8]

4)Resistance $= 4\ ohm$[8]

5)Resistance through multimeter $= 4.1\ ohm(1.9 + 2.3)ohm$

6)Magnetic field intensity of per coil = $\frac{\mu_0 NI}{l} =$

$$1.257 * 10^{-6} * 500 * 2 * \frac{1}{0.064} = 0.196\ Tesla$$

7) $\emptyset\ =$

$$= \frac{N_1 i_1 + N_2 i_2}{\frac{\mu_c}{l_c A_c} + \frac{\mu_0}{l_g A_g}}$$

$$= \frac{500*2*2}{\left(\frac{0.0001254}{0.124*0.0001227)}\right) + \left(\frac{0.000001257}{0.005*0.02*0.025}\right)}$$

$$= \frac{2000}{0.872} = 2333.8\ weber$$

4.Characteristic selection of different parts:

Mechanical parts:

Body part:

Acrylic sheet

- Base
- Support to coil
- PVC Pipe
- Roller bearing
- 25 gauge insulated copper wires$(25 * 4)m$
- 4 nails

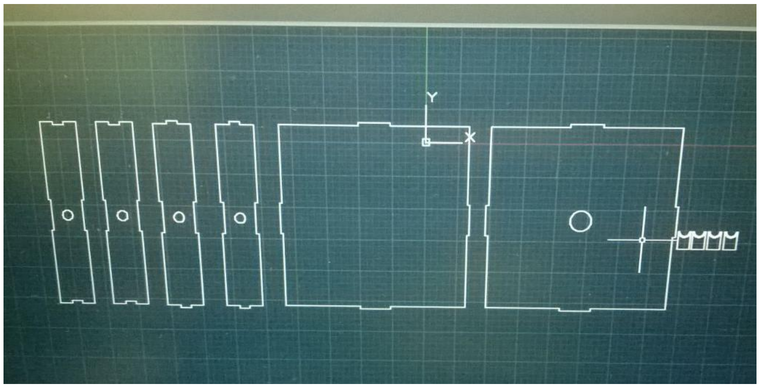
Electrical parts:

- Arduino genuino(ATMEGA 32)
- 2-Electric drives(amplifying to 2 ampere)
- Microprocessor used - L298n[6]

5. ASSEMBLY:

Manufacturing body

The body part was designed in laser cad as following:



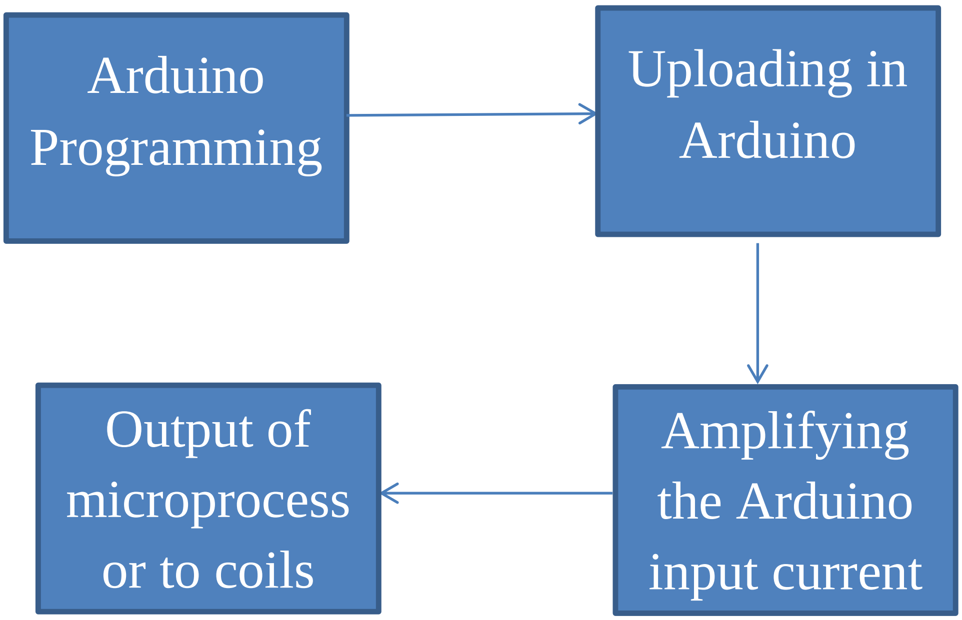
Assembly was done as shown below:

Points to be noted in assembly:

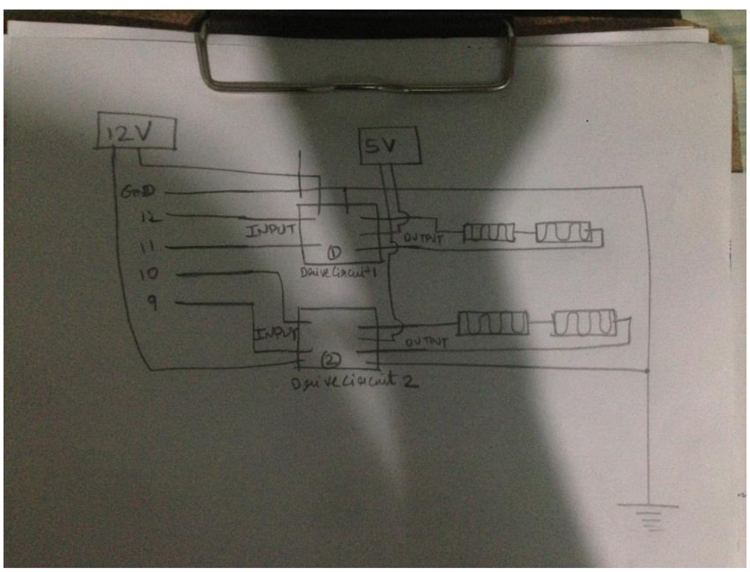
1. The length was decides as: length of coil(64 mm) + air gap($5\ mm$) + Bearing outer diameter($20\ mm$).
2. PVC Pipe was grooved in the base with an hole cutter.
3. Neodymium magnets were cut to requires dimension with a hand grinding machine.

Making electrical parts:

Drive circuits were all soldered in General board. The circuit has to follow the path as shown below:



Circuit diagram and interference with coils is as below:



Programing:

```
// Stepper motor code
void setup()
{
//arduino input values
  pinMode(12, OUTPUT);
  pinMode(11, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(9, OUTPUT);
}
//on-off of coils
void loop()
{
 // 11,12 coils activated
 //10,9 off state
  digitalWrite(11, HIGH);
  digitalWrite(12, LOW);
  digitalWrite(10, LOW);
```

```
  digitalWrite(9, LOW);
  delay(2000);
//10,9 coils activated
//11,12 off state
  digitalWrite(9, HIGH);
  digitalWrite(10, LOW);
  digitalWrite(11, LOW);
  digitalWrite(12, LOW);
  delay(2000);
 //11,12 reversely coils activated
//10,9 off state
  digitalWrite(12, HIGH);
  digitalWrite(11, LOW);
  digitalWrite(10, LOW);
  digitalWrite(9, LOW);
  delay(2000);
//10,9 reversely coils activated
//11,12 off state
```

```
digitalWrite(10, HIGH);
digitalWrite(9, LOW);
digitalWrite(11, LOW);
digitalWrite(12, LOW);
delay(2000);
}
```

Implementation:

- Used in making of gear clocks.
- Used in floppy disk drives.
- Camera lenses.
- Used for control of speed and rotation.
- Sorting machines.

Future scope:

- Accuracy in holding the magnets on bearing.
- To mount gears on the rotor through shaft to use it as a motor.

10. References:

1) http://www.pbclinear.com/Download/DataSheet/Stepper-Motor-Support-Document.pdf
2) http://dkc1.digikey.com/fi/en/tod/Microchip/TypesofStepperMotors_NoAudio/TypesofStepperMotors_NoAudio.html
3) https://en.wikipedia.org/wiki/Neodymium_magnet

4) https://en.wikipedia.org/wiki/Neodymium_magnet
5) http://www.datasheetspdf.com/PDF/L298N/69648/
6) http://www.calctool.org/CALC/phys/electromagnetism/solenoid

7) file:///D:/users/notes/mechatronics/Project/Coil%20Physical%20Properties%20Calculator.html

11. Acknowledgement:

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