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Low-Cost Energy Production Using Fluttering Wind Belt

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ABSTRACT
This paper consists of details regarding the device called wind belt wind power generator in which author have discussed the working and construction of this device. The increasing demand for energy and decreasing fuel has led mankind to search for cheap and renewable energy. Also, many countries like India have to import a lot of fuel for generating energy. So, increasing the utilisation of renewable energy sources will reduce this problem. We have made a device which utilises wind energy to generate electricity utilising the flutter phenomenon, which is considered as the destructive phenomenon in suspension and aeronautics/aircraft. This flutter is attached with the magnet and coil arrangement. An electromagnetic resonator can also be made for magnet and coil arrangement. We can use any material with the characteristic of aeroelastic flutter. The magnet, attached with flutter, starts reciprocating due to flutter phenomenon. Whenever the wind blows, the flutter starts fluttering, resulting in the reciprocation of the magnet. This magnet has coils arranged on the either side of it. On reciprocation, it induces a current in the coils due to mutual induction according to Faraday's law of mutual induction. This device can utilise where even very small amount of wind is available.

Keywords Wind Belt, Wind Power, Energy, Aero-Elastic Flutter, Mutual Induction, Generator

1. INTRODUCTION

Wind Belt Wind Power Generator is a device which works on the principle of Aeroelastic flutter as well as on mutual induction process between the magnet and the coils. In this device, we have arranged the magnet on the ribbon, which on passing wind, starts fluttering on the basis of aeroelastic flutter. This fluttering causes this magnet also to reciprocate between the two coils arranged one above the other having little space for magnet between them. Due to this movement of magnet between the coils due to flutter, mutual induction takes place which leads to the induction of current as well as the voltage. As the wind speed increases, the voltage produced is increased. Also, due to the movable coil and magnet arrangement, the length for the flutter can be varied.

2. WORKING

The wind belt wind power generator works on the principle of mutual induction which includes flutter working on the principle of aeroelastic flutter. The following fig gives an idea regarding the working model of the device.

As is well known, "flutter" is a destructive aeroelastic phenomenon that must be avoided in aeronautical/industrial structures such as aircraft and suspension bridges. The present study, however, deals with a power generation system which extracts wind energy from flutter phenomenon by utilising it [1]. This device is kept in front of the wind which will receive from the table fan, ceiling fan, windy or hilly areas, etc. This wind when passes through the flutter i.e. ribbon, the ribbon starts fluttering at its position due to the effect of the aeroelastic flutter. Now, when this starts reciprocating at its position, the magnet attached to the ribbon will also start reciprocating at its position. Here, in our device, we have arranged coils above and below the magnets, having little space for the magnet to reciprocate. Now, due to this reciprocating of the magnet, the current will be induced in the coils according to the Faraday's law of mutual induction. An

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electromagnetic resonator [2] can also be made for magnet and coil arrangement. As we all know that reciprocating movement of magnet induces the alternating current in the coil, we have arranged the rectifier at the ends of the coil. The rectifier will convert the alternating current into the direct current, which we will collect in the capacitor to regulate the flow.

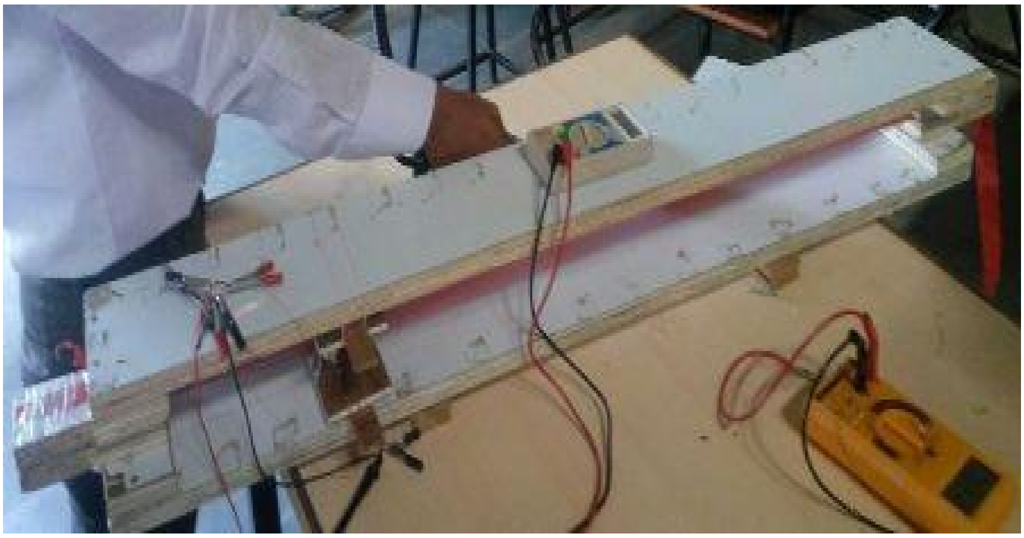

Fig 1: Working Model of the Device

3. DERIVED FORMULAE RELATED TO THE OUTPUT

Method 1 [3]:

The energy which wind produces must be taken into consideration and for simplicity the kinetic energy equation will be used to represent its nominal energy.

$$E_K = \frac{1}{2} \times m[k\ ] \times v^2 \left[\frac{m}{s}\right]^2 \tag{1}$$

The mass of air is written in terms of mass flow to make it easier to measure in practical scenarios and can be elaborated in the equation, where t is time and ρ is density.

$$\frac{m}{t}\left[\frac{k}{s}\right] = m\left[\frac{m}{s}\right] \times A[m^2] \times \rho \left[\frac{k}{m^3}\right] \tag{2}$$

The power (P) produced by the Wind belt can then be equated using

$$P[W] = \frac{1}{2} \times A[m^2] \times \left[\frac{k}{m^3}\right] \times v^3 \left[\frac{m}{s}\right]^3 \tag{3}$$

The density of air is not usually an ideal value to be measured through a wind turbine so instead, the ideal gas equation shown in equations 6 - 9 will be used to replace density with variables such as air temperature, T, and pressure, P, which are more effectively measured. Also, note V is volume, R is ideal gas constant, n is moles and M is molar mass. The density of air is not usually an ideal value to be measured through a wind turbine so instead, the ideal gas equation shown in above equations will be used to replace density with variables such as air temperature, T, and pressure, P, which are more effectively measured. Also, note V is volume, R is ideal gas constant, n is moles and M is molar mass.

$$. P\left[\frac{N}{m^2}\right] \times V[m^3] = n[m\ \ ] \times R\left[\frac{J}{K.m}\right] \times T[\mathrm{K}] \tag{4}$$

$$P\left[\frac{N}{m^2}\right] \times \left(\frac{m[k\ \ ]}{\rho\left[\frac{k}{m^3}\right]}\right) = n[m\ \ ] \times R\left[\frac{J}{K.m}\right] \times T[K] \qquad (5)$$

$$\rho\left[\frac{k}{m^3}\right] = \frac{M_A \left[\frac{k}{m}\right] \times P\left[\frac{N}{m^2}\right]}{R\left[\frac{J}{K.m}\right] \times T[K]} \qquad (6)$$

Where $M_A \ = 0.0287 \left[\frac{k}{m}\right], R = 8.314$

$$\rho\left[\frac{k}{m^3}\right] = 0.003484 \left[\frac{k\ .K}{J}\right] \times \frac{P\left[\frac{N}{m^2}\right]}{T[K]} \qquad (7)$$

The final equation derived from the above derivations is:-

$$P[W] = 0.001742 \left[\frac{k\ .K}{J}\right] \times A[m^2] \times \frac{P\left[\frac{N}{m^2}\right]}{T[K]} \times v^3 \left[\frac{m}{s}\right]^3 \qquad (8)$$

Method 2 [4]:-

The amount of EMF produced from the wind belt is given by:-

$$E = 2\pi \qquad (9)$$

Where $E = e$ generated (V)

N = Number of turns of coil

A = Area of ribbon (cm^2)

B = Magnetic field intensity (T) & $f = \frac{v}{d}$

Here, v = Velocity of wind (m/s)

d = Displacement by ribbon during flutter (m)

Dimensions which were used by us in these equations can be understood from the figure shown below.

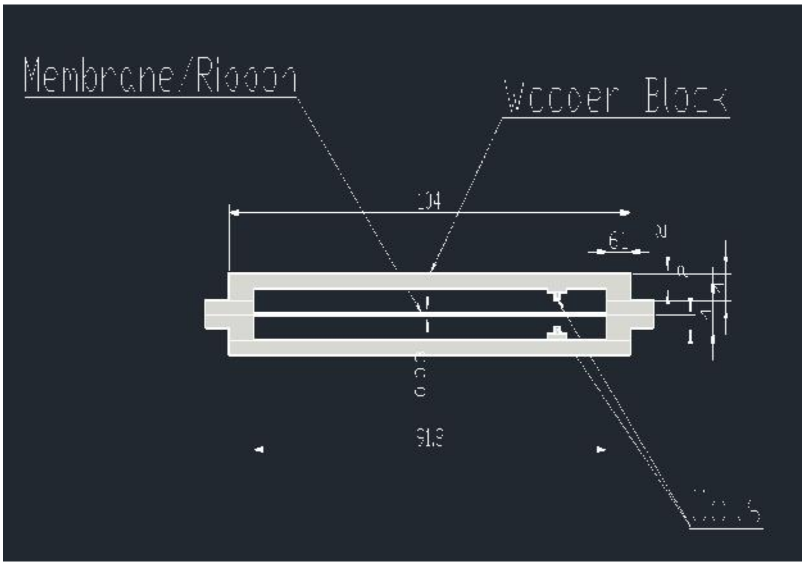

Fig 2: Dimensions in CAD model (all dimensions are in mm).

4. MAGNETIC PROPERTIES

The magnets used in this device are Nd-Fe-B (Neodymium-ferrite-Boron) magnets which are called as permanent magnets or rare earth magnets and have high magnetic field intensity compared to the ferrite magnet. The following picture will give an idea about the various magnetic materials present and their comparative strengths.

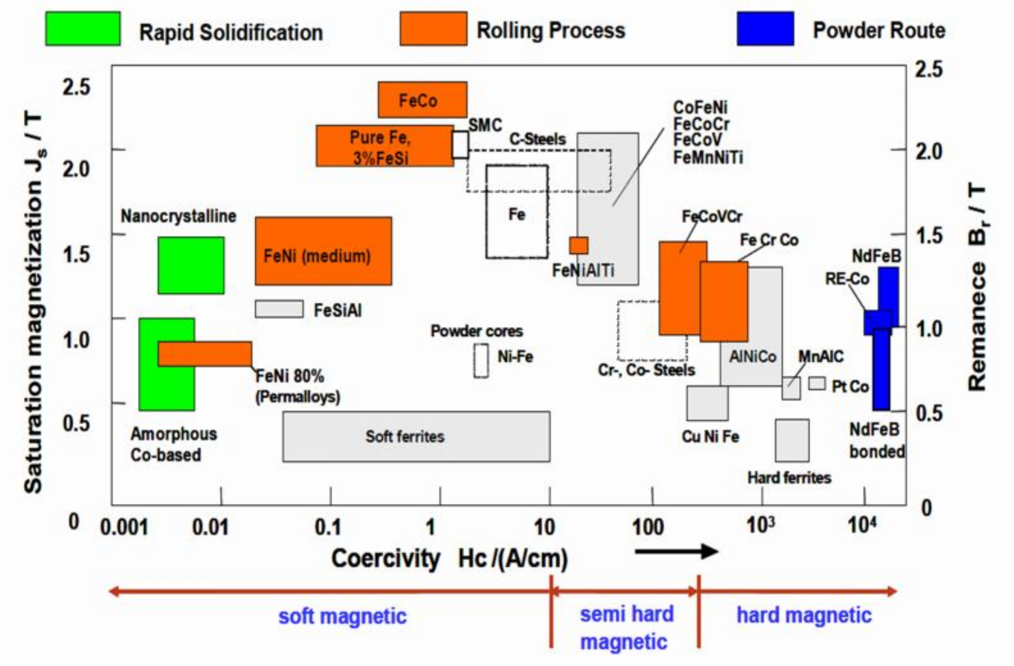

Fig 3: Overview of magnetic materials and alloys [5].

The benefit of using this magnet is that the magnetic field of these magnets never weakens and also they have high resistance towards the corrosion. Having the higher magnetic field intensity, these magnets give best results while used in the device as higher the field intensity, higher will be the flux produced which results in a higher induction in the coils. Nd-Fe-B magnets are differentiated in various types by providing grades. This number represents the maximum energy product in Mega-Gauss Oersteds (MGOe) where 1MGOe (cgs units) equals 7958kJ/m3 (SI units). The range available used to be N24 up to N52. The lower grades are no longer made and the range now starts at around N30 or N33. N50 is the highest readily available grade. N52 is possible but only in certain sizes. Although the maximum possible energy product is calculated in to be N64, it is unlikely such high strengths of Neodymium will be achievable in the near future. The current range of Nd-Fe-B magnets is as follows:-

N27, N30, N33, N35, N38, N40, N42, N45, N48, N50, N52, N30M, N33M, N35M, N38M, N40M, N42M, N45M, N48M, N50M, N30H, N33H, N35H, N38H, N40H, N42H, N45H, N48H, N30SH, N33SH, N35SH, N38SH, N40SH, N42SH, N45SH, N28UH, N30UH, N33UH, N35UH, N38UH, N40UH, N28EH, N30EH, N33EH, N35EH, N38EH, N33VH/AH.

The magnets we have used are N35 magnets.

5. COIL PROPERTIES

In common, the material used in the making of the coil is copper. Thus, the output or the current induced in the coil depends largely upon the grade of copper wire used. Copper wires are available in the market in two forms, commercial and non-commercial. The commercial copper wires are distinguished on the basis of its gauge. According to the SWG i.e. Standard Wire Gauge, as the number of gauge increases, the wire diameter decreases. We have used 28 SWG copper wires, to make a coil of 200 turns. As we have seen in the above formulae that the output depends upon the copper turns as well as the total width of the coil.

6. RESULT & DISCUSSION

The table shown below contains the values which are obtained under different wind velocities tabulated in Table 1.

Table 1. Output achieved at various wind speeds

Wind Speed (m/s)	Voltage (V)
1.5	0.01
2.5	0.02
3.3	0.035
3.7	0.043
4	0.05
5	0.069

$$E = 2\pi \qquad (10)$$

$$E = 2\pi \ \frac{v}{d} A \quad \left(\because f = \frac{v}{d}\right)$$

$$= 2\pi \ \frac{v}{d}\left(\frac{\pi}{4} \times {d_1}^2\right) B$$

Here, v=1.5, d=0.98, N=200, d_1=0.02 and B=1

$$\therefore \frac{\pi^2}{2} \times \frac{1.5}{0.98} \times 200 \times (0.02)^2 \times 1$$

$$\therefore E = 0.6043v$$

Here the theoretical value of the device's output is 0.6043 V. This value has been obtained constantly when we connect a capacitor in parallel with the rectifier is 0.64 V, i.e. we are getting the approx value to the theoretical one.

Table 2. Comparison of output with the other device

Sr. No	Average Wind Speed	Output obtained in the literature	Output of Proposed Device
1	3 m/s	0.01 volts	0.03 volts
2	4 m/s	0.04 volts	0.05 volts
3	5 m/s	0.09 volts	0.07 volts

Table 2 shows that our device has the better output than the other at initial speeds, which mean we have greater efficiency at a lower speed than theirs.

While assembling the device, we came to know about the limitation of different flutters, we tried various different types of flutters and finalised ribbon. The magnets were of diameter 1mm, which restricted the fluttering of ribbon, so to avoid that, we used the same magnet of smaller size. These magnets were light in weight, same magnetic strength, and gave better result and output voltage due to its low weight and area. The device's output is 0.64 V with a capacitor, which will need a step up diode or step up I.C. which will increase this output to 4-5 volts as per requirements. We did not use this circuit as it is hardly available anywhere in India. Overall this device is very cheap and gave better output compared to others of this range at low to medium wind velocity.

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