Paper ID: AM-279

Performance Analysis of a Fabricated Distinct Voice Coil Motor

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Abstract

Voice coil motor (*VCM*) *are direct drive, limited motion devices that use a permanent magnetic field and a coil winding (conductor) to produce a force proportional to the current applied to the coil. Voice coil motors are mostly used as linear actuators. This study focuses on designing and fabrication of a distinctive voice coil motor to be used in tactile sensing devices. The electromechanical conversion mechanism of a voice coil motor is governed by the Lorentz Force Principle. The fabricated VCM consists of two separate parts; the magnetic housing and the coil that is free to move axially in an air gap in magnetic housing. This paper investigates the performance of fabricated VCM by analyzing the response of load and linear displacement against current input to the VCM. The output characteristics of the developed VCM are explored against step and sinusoidal input as well.*

Keywords: VCM, Load, Programmable current, Sensor output voltage, Displacement.

1. Introduction

A voice coil (consisting of permanent magnet, collar and winding) is the coil of wire attached to the collar (moveable part) through apex between the permanent magnets. It provides the motive force to the collar by the reaction of a magnetic field to the current passing through it. The direction of the force is perpendicular to the magnetic flux as like of the rule of Fleming left-hand rule. VCM is a simplest type of electric motor that moves a mass along a line. These motors consist of two separate parts; the magnetic housing and the coil. Applying a voltage across the terminals of the motor causes the motor to move to one direction. Reversing the polarity of the applied voltage will move the motor to the opposite direction. The generated force is proportional to the current that flows through the motor coil [1]. This study focuses on designing and fabrication of a distinctive voice coil motor to be used in tactile sensing devices. Tactile sensing is the process of measuring information arising from physical interaction with it`s environment [2]. Tactual texture concerns the surface and material properties that our finger perceives by coming into contact with an object and /or sliding on the surface. The nature of surface contact is a key factor in the tactile identification of objects. To realize tactile sensing, a tactile sensing device will be constructed using stiffness control, which interacts with environment, gathering information by using sensor and generated required stiffness using VCM [3].

There are two types of voice coil motor; (i) moving coil voice coil motor and (ii) moving magnet voice coil motor. Several parameters describe a particular voice coil. These are mechanical parameters and electrical parameters. Mechanical parameters include size of housing (diameter and length or height and width and length), length of stroke, protruding length of shaft and so on [4]. Electrical parameter includes the force exerted per ampere of current, coil resistance, coil inductance, back EMF (volts per unit velocity). Electrical extremes and ratings of VCM are allowed peak current, allowed steady current, force at peak current [4-5]. Voice coil motors are several shapes such as- cylindrical frameless linear voice coil actuator (VCA), cylindrical semi-housed VCA, cylindrical housed linear VCA, cylindrical housed linear VCA with integrated sensor, rectangular linear VCA [6]. This paper focuses on design of rectangular linear VCM. The main advantages of rectangular linear voice coil motor are zero friction caused by moving parts, ideal for high acceleration applications, offers higher forces than cylindrical actuators than cylindrical actuators based on their size [7].

2. Principle of operation

The electromechanical conversion of a voice coil motor is governed by the Lorentz Force Principle. This law of physics states that if a current-carrying conductor is placed in a magnetic field, a force will act upon it.

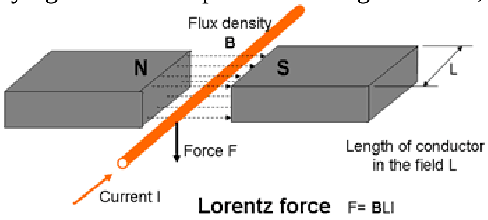

Fig.1: Lorentz Force Principle.

To design the controller for a specific set of poles, it is necessary to know the exact thrust co-efficient of the actuator [8]. Force generated by the VCM is determined by its thrust co-efficient which is the ratio of the generated force and supplied current to the VCM. Permanent magnets of the VCM cause the magnetic fluxes which run in the magnetic circuit, and magnetic fields can be generated by moving charges (current), alternating current fields and permanent magnets. Assuming that leakage and fringing effects are neglected, the magnetic flux, Φ is confined to the physical structure. For the computation of the magnetic flux density, B, it is assumed that flux, Φ runs entirely within the magnetic loop with constant coil winding section A , hence flux density could be measured as

$$\phi = BA, \Rightarrow B = \frac{\phi}{A} \tag{1}$$

The force generated by VCM can be known by knowing the supplied current [9]. The force generated by the VCM, orientation of magnetic flux, direction of force generation, current direction are can be determined by the Lorentz Force Principle .

$$F = BiL \tag{2}$$

(B: magnetic flux density, *i*: current, L: length of the coil in the magnetic field).

The values of B and L are constant is constant for a particular VCM. Therefore it is understood that force generated by VCM is proportional to i. But in the research we measured VCM coefficient by measuring the force magnitude for per unit of current supply.

Therefore in case of VCM, thrust generated can be determined by

$$F = BiL = k_i i \tag{3}$$

Nevertheless, due to some uncertainties like as binding of coil winding, position of the coil between magnet may cause some different in thrust coefficient of the VCM [10-11].

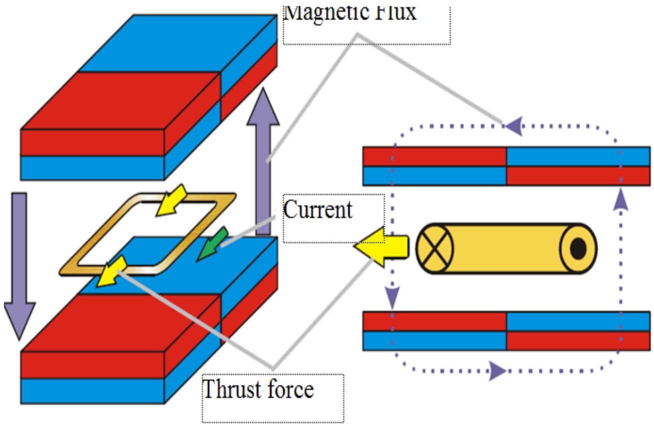

Fig.2. Working principle of VCM

3. Experimental setup

The developed voice coil motor consisting of a magnetic housing and this distinct VCM would be used to fabricate a tactile sensing device; the schematic diagram of the device is shown in Fig.3. A photograph of the developed device is shown in Fig. 4. The height, length, width of the developed device are 60 mm, 90 mm, 90 mm, respectively. The two permanent magnets providing bias forces are dimensioned by 40 × 20 × 2 mm^3, and they are made of Neodymium magnet. The coil used for winding is copper wire and the no. of turn in the winding is 280. The Eddy-current gap sensor is used to detect the displacements of the moving part of the VCM. The programmable current supply was supposed to the VCM by power amplifier circuit and the corresponding output force characteristic and displacement taken place was measured.

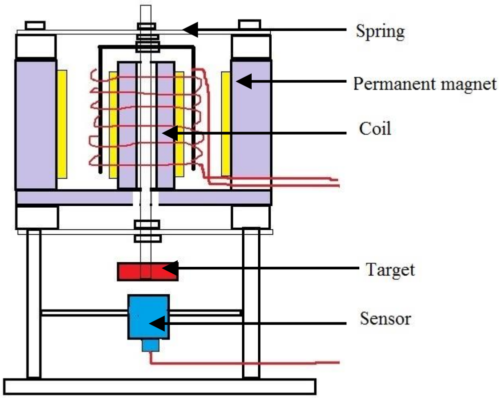

Fig. 3 Schematic diagram of experimental setup

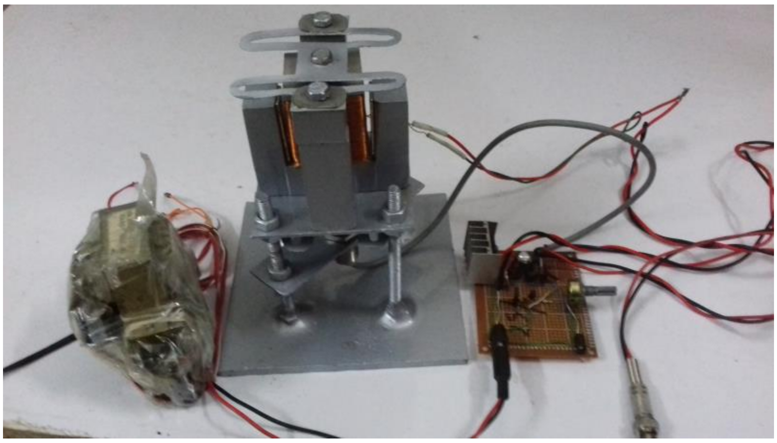

Fig. 4 Photograph of the Experimental setup.

4. Results

Table 1: Load *vs* sensor output

Load(N)	sensor output(mv)
0	806
1	805
2	803
3	802
4	801
5	800
6	798
7	797
8	796
9	795
10	793

Table 2: Current *vs* sensor output

Current(A)	sensor output(mv)
0	798
0.73	797
0.75	796
0.8	795
0.86	794
0.9	793
0.95	792

A certain current in the winding of the VCM generates a force in theory and this force causes the deformation of the spring (leaf) attached in the device. This deformation is measured in terms of the sensor output in voltage. Hence, the certain range of current supply in VCM and the corresponding sensor output voltage are observed and shown in table 2. This experiment is conducted to find spring deformations with respect the forces due to current in the VCM. This relation gives the magnitude of spring constant; and in this study, this spring constant is compared with the magnitude obtained in Table 1.

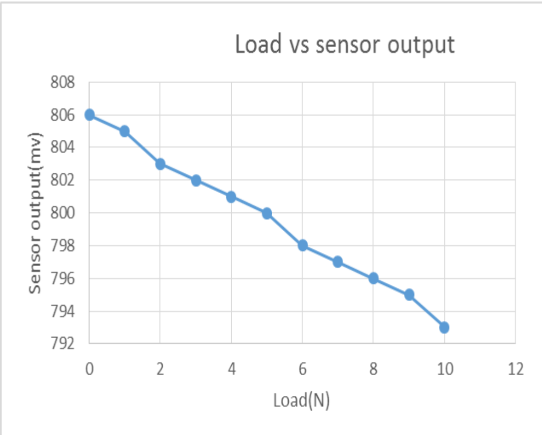

Fig. 5 Load *vs* sensor output

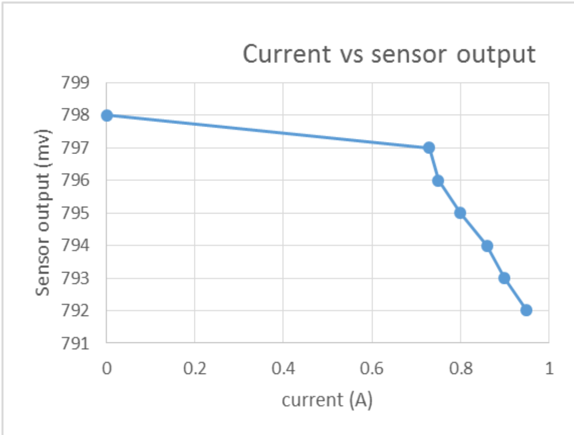

Fig. 6 Current *vs* sensor output

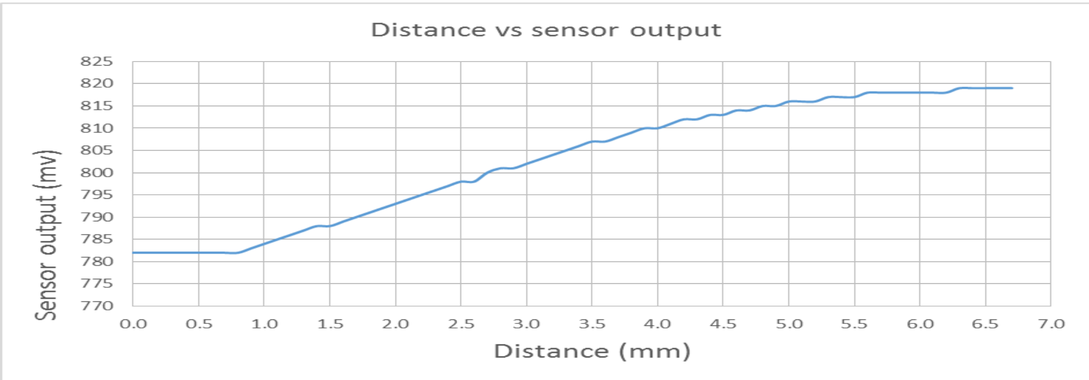

Fig. 7 Distance *vs* sensor output

Table 3 includes the data regarding to make a relation between data given in tables 1 and 2; in this table, the final data is representing the VCM coefficient with respect of realizing force by the VCM for a certain magnitude of current in the winding of VCM.

Figure 5 reveals that sensor output changes almost linear with respect to change of load, inherently the passive spring used in the device provide linear spring constant. On the other hand, Fig. 6 shows that the current supplied to the VCM coil *vs* sensor output is linear for input current range from 0.73 to .95 amp. It is seemed from this figure that force generated by VCM is linear with respect to the current for a certain range after certain magnitude of current; therefore a better actuating performance could be obtained by the developed VCM if a certain offset value regarding current is considered. Fig.7 shows that the displacement of the moving part of the VCM *vs* sensor output is almost linear. The Fig.7 specifies the sensor calibration, and this calibration is done to be used for achieving the optimal controller parameters.

Table 3: Current and corresponding force data.

Current (A)	Sensor output (mv)	Change in sensor output	Force per unit sensor output N/mV	Force (N)
0	798	0	0.7866	0
0.73	797	1	0.7866	0.7866
0.75	796	2	0.7866	1.5732
0.8	795	3	0.7866	2.3598
0.86	794	4	0.7866	3.1464
0.9	793	5	0.7866	3.933
0.95	792	6	0.7866	4.7196

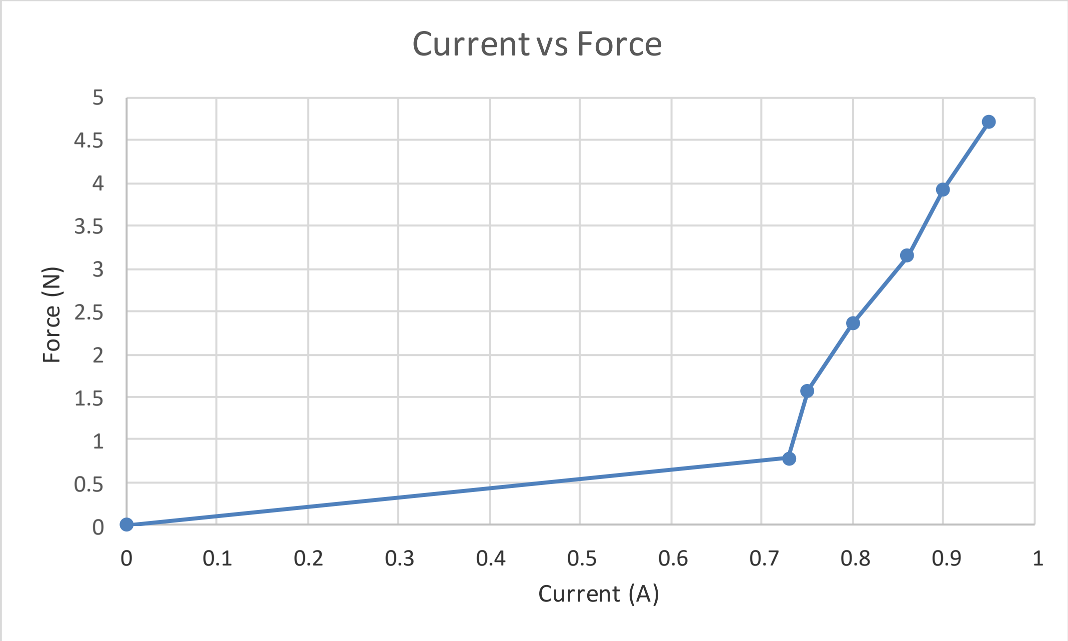

Fig. 8 Current *vs* Force

Fig. 8 reveals that Current *vs* Force is almost linear for input current range of 0.73 to 0.95 amp. It is apparent from this figure that force generated by VCM is linear with respect to the current for a certain range after certain magnitude of current supplied to the VCM coil.

5. Conclusion

The magnetic circuit and moving coil structure of the developed voice coil motor (VCM) that is supposed to be used in the tactile sensing device was designed and fabricated. The programmable current supply was supposed to the VCM and the corresponding output force and displacement character of the VCM was tested. Test result indicate that the designed VCM has linear output force and displacement character with respect to the current input at low frequency region with low noise and waviness. The voice coil motor is mostly used as linear actuator. It can be used where precision linear movement, precision force, oscillatory motion, dynamic movement require.

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