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Application of a bending type segment permanent magnet actuator

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ABSTRACT

A bending type design and application presented for the construction of segments permanent magnet (PM) actuator made up of thin plastic strip with segment PM, rectangular PM and support. The strip consists of one layer good bending functional plastic sheet and PM segments under the action of magnetic force, thus obtain a maximum center deflection of bending plastic strip. The N45H (sintered neodymium-iron-boron) material is used for the segment PM and rectangular PM. The purpose of this paper is to investigate the center deflection of thin plastic strip with segments of PM under bending. The center deflection performs as the stroke length in the segment PM actuator. The important of this paper might be contributed to the innovation of mechanical part designs. The segment PM actuator can produce stroke length with its own magnetic energy.

KEYWORDS

Bending type;
Segment;
Permanent magnet;
PM;
Actuator;
Deflection.

INTRODUCTION

There are some major actuating methods used and applied in the conventional actuators. It is often already to find the application fields in electric, hydraulic and air pressure. In the field of permanent magnet (PM) actuator, the actuating method is still under going investigated and designed. In 2013, Tiegna et al.[1] reviewed the state of the art of analytical models in the pre-design stages for the PM machines. In 2012, Hsieh[2] presented the magnetization reversal application of micro cantilever, ferromagnetic, multilayer thin films in the PM actuator under the action of external magnetic field. In 2012, Chen et al.[3] designed a PM spherical actuator by using a rotor with 8 neodymium-iron-boron (NdFeB) PM poles and a stator with 24 coils. In 2010, Arunanidhi and Singaperumal[4] used Terfenol-D ($Tb_{0.3}D_{0.7}Fe_{1.9}$, made in USA) rod with high dynamic servo valve to design the magnetostrictive actuator (MA). In 2009, Jia et al.[5] used the giant magnetostrictive materials (GMM, $Tb_xD_{1-x}Fe_y$, $x = 0.27 \sim 0.35$, $y = 1.9 \sim 1.95$, made in China) slender rod to design and improve the proportional plus integral plus derivative (PID) feedback control of the position in the giant magnetostrictive actuator (GMA). In 2009, Watson et al.[6] introduced the rotational, bending and torsion types of actuating matters in the ultrasonic actuator. In 2008, Ishiyama and Yokota[7] presented the cantilevered MA constructed by 1×5 mm amorphous Fe–Si–B magnetostrictive material with 1.1 μ m Cu substrate layer in the 10 kA/m magnetic fields and produced 153 μ m displacements. In 2008, Oh and Ahn[8] introduced some applications and concepts of micro systems used in magnet actuator e.g. micro valves, micro pumps, micro mixers, micro mirrors and micro switches. In 2008, Grunwald and Olabi[9] designed the MA with Terfenol-D slender shaft of 8mm diameter and 79mm length, and found the elongation of shaft is proportional to the magnetic field intensity. In 2007, Ghodsi et al.[10] used the high temperature superconductor (HTS) and the bimetal strips composited of 40mm length, 8.5mm width, 1mm thickness Galfenol (Fe–Ga) and stainless steel to apply and control a positioning actuator. In 2004, Ackermann et al.[11] used a spherical PM actuator to simply construct the high-fidelity force-feedback joystick. In 2003, Jiles and Lo[12] presented some improved magnetic properties e.g. magneto-resistance, magneto-optics, magneto-electronics and magneto-elasticity in the applications of magnetic sensors and actuators. In 2002, Coey[13] introduced one of the PM actuator applications in the uniform magnetic field. In 2002, Kruusing[14] presented the optimal magnetic force calculation and measurement in the cylindrical PM and coaxial planar coils. In 2001, Janocha[15] surveyed the actuating types of magnetic field driven actuators e.g. electromagnetic, electro-dynamic, magnetostrictive or magneto-rheological (MR). In 2000, Howe[16] showed the application fields of magnetic actuators in aerospace, automotive, industrial, healthcare and computer. There are some particular motions e.g. rotary, linear, continuous and limited in the magnetic actuators. In 1999, Carotenuto et al.[17] demonstrated the piezoelectric actuator with a disk stator of 32 mm diameter, 0.2 mm thickness, with the cylindrical PM rotors of 6 mm diameter, 5 mm length and with prismatic beam as the linear output for 1.21 m/s velocity, 0.51 N forces in the 18V voltages. In 1997, Claeyssen et al.[18] used the GMM rod of 20mm diameter, 100mm length to design and investigate the linear MA. In 1996, Fastenau and Loenen[19] introduced the sintered NdFeB PM material used in the applications of CD-lens actuator, personal computer (PC) card hard disk drives (HDD) spindle motors, voice coil motor (VCM), loudspeaker, magnetic resonance imaging (MRI) and automotive.

The author has some experiences in the fields of generalized differential quadrature (GDQ) computation and application of MA. In 2013, Hong[20] introduced an application of a bending type MA. The center deflection of the two-layer laminated strip with Terfenol-D and plastic material under bending performs like as the stroke length in the MA. In 2012, Hong[21] presented the computational center displacement GDQ solutions of magnetostrictive functionally graded material (FGM) plate (Terfenol-D, Si_3N_4 and SUS304) with four sides simply supported under rapid heating. In the similar application, it is interesting to investigate the center deflection of the strip with segment PM and plastic material under bending in the segment PM actuator. The segment PM actuator is made up of thin strip, magnet and support. The thin strip consists of PM segments on the top surface of plastic material sheet. The purpose of this paper is to present an available stroke length feature for the center deflection of thin strip under bending in the segment PM actuator.

METHODS OF APPLICATION

Design and construction

A bending type of the segment PM actuator is constructed as shown in Figure 1. The PM actuator composed of actuation shaft, thin plastic strip, segment PM, rectangular PM and support. The actuation shaft performs the direct output motion of actuator. The plastic sheet of dimensions 63 mm $\times$ 12 mm $\times$ 1 mm used as the thin plastic strip. The magnet material N45H (sintered NdFeB magnets) is used in the application. The magnet of dimensions 10.5 mm 5 mm 3mm N45H used as the segment PM. The magnet of dimensions 10.5 mm $\times$ 5 mm $\times$ 3mm N45H used as the segment PM. The magnet of dimensions 75 mm $\times$ 14 mm $\times$ 5mm N45H used as the rectangular PM. The rectangular block of dimensions 93 mm $\times$ 63 mm $\times$ 16 mm aluminum used and cut off inside as the support. The rectangular N45H PM is fixed in the support. The thin plastic strip is simply supported and parallels 17 mm apart from rectangular N45H PM in the support.

Declaration of the test methods

The usually international standard test methods used ASTM standards and ISO standards that define the performed way and the precision result in 2011 by Liu et al.[22]. In this paper did not use the method of inter-

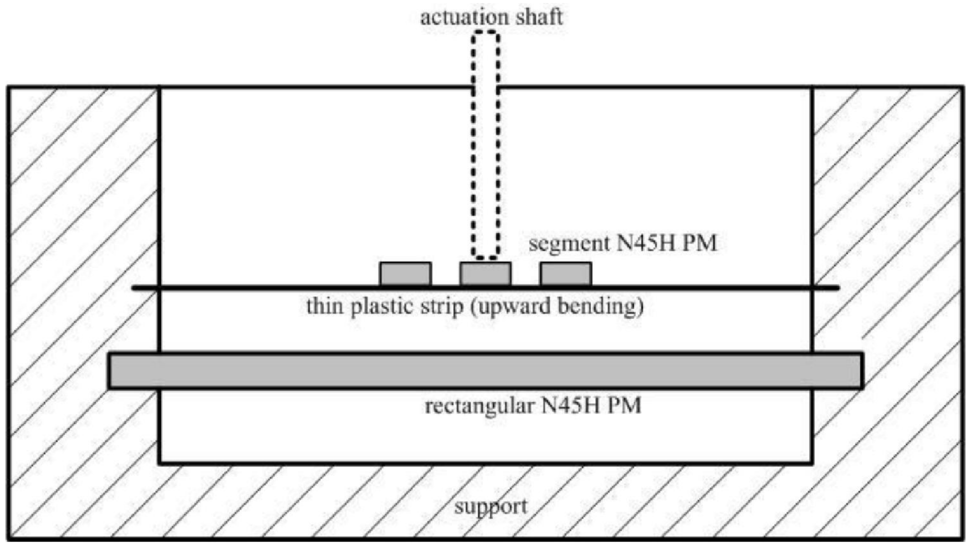

Figure 1 : The construction of bending type segment PM actuator

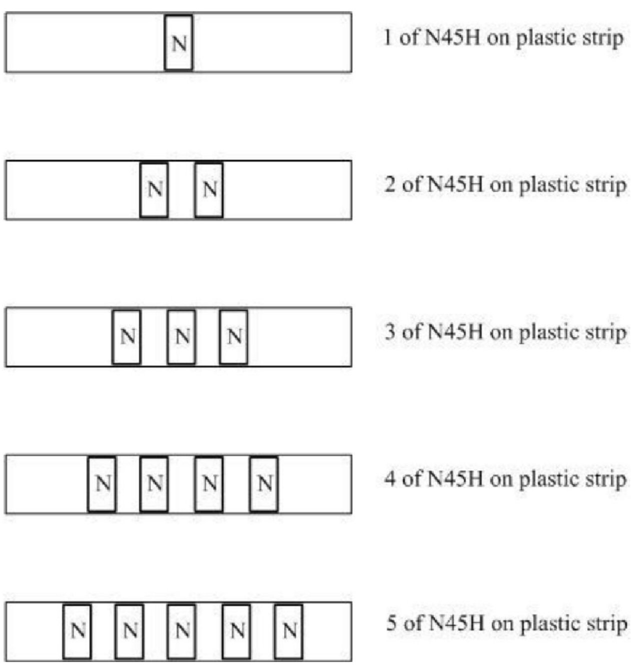

Figure 2 : The 1-5 numbers of segment PM fixed on the top surface of plastic strip

national standard tests, used only personal investigation view to find the preliminary and simple results.

Segment PM and plastic strip bending test

The segment N45H PM fixed on the top surface of thin plastic strip. The 1-5 numbers of segment N45H PM located at the symmetric position with respect to the center of plastic strip as shown in Figure 2. The same distance 4 mm between each segment N45H PM used for the 2-5 numbers of segments. All of the magnetic pole N of segment N45H PM is upward to the

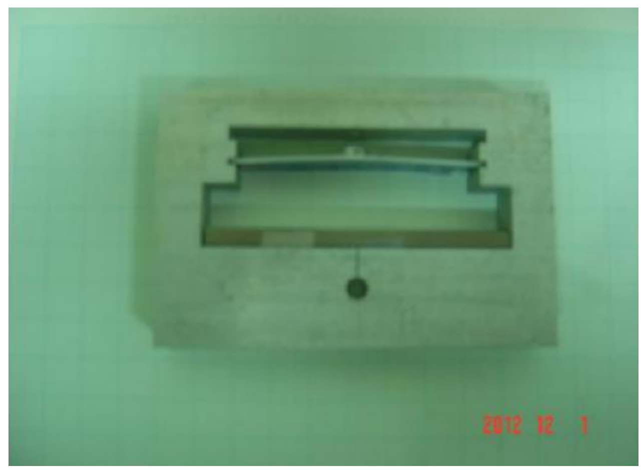

Figure 3 : Bending test of one segment N45H PM on the thin plastic strip

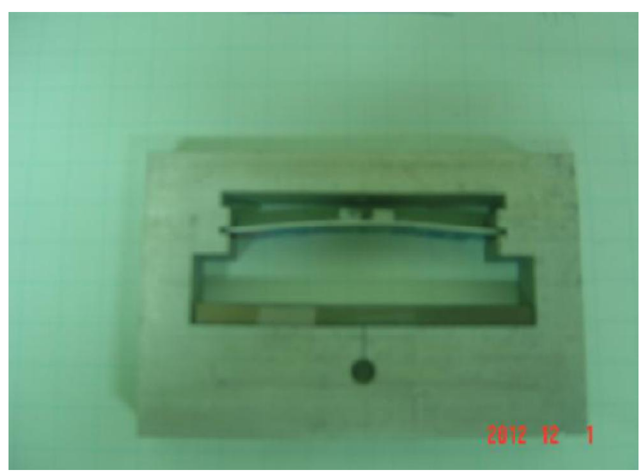

Figure 4 : Bending test of two segments N45H PM on the thin plastic strip

plastic strip. The segment N45H PM and plastic strip bending upward when the repulsive magnet force comes from the rectangular N45H PM. The center deflection

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Figure 5 : Bending test of three segments N45H PM on the thin plastic strip

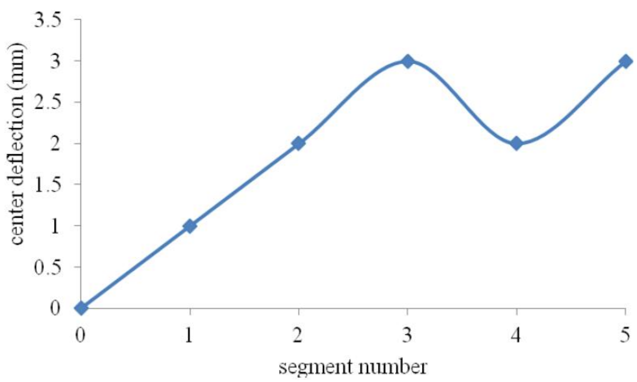

Figure 6 : The center deflections of the plastic strip vs. numbers of segments

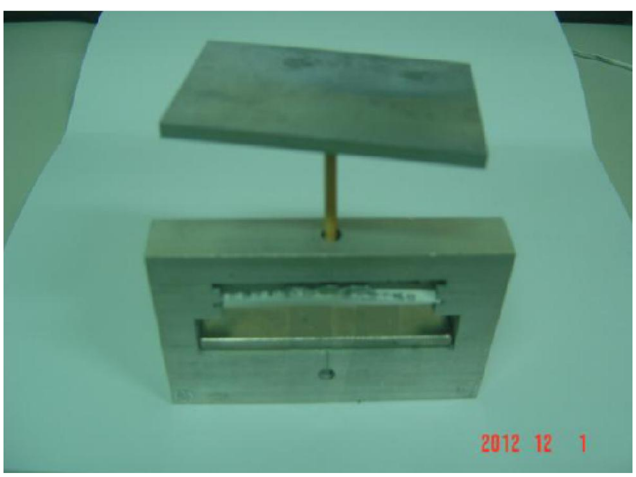

Figure 7 : Provide the stroke length and lift the load for 3 segments PM actuator

of the plastic strip provides the available stroke length in the segment PM actuator. The bending tests of one, two and three segments N45H PM fixed on the top surface of thin plastic strip are shown in Figures 3-5, respectively.

RESULTS AND DISCUSSIONS

The center deflection values of the plastic strip for the 1-5 numbers of segments N45H PM are shown in Figure 6. The center deflection values for the 1-5 numbers of segments are 1mm, 2mm, 3mm, 2mm and 3mm, respectively. It is good for 3 numbers of segments PM actuator to provide the maximum center deflection value (3mm) as the stroke length and lift the load as shown in Figure 7. The direct output center deflection can be amplified to an enough available value (greater than 3mm) by using the lever arm device. The similar experimental result can be compared with the center deflection of self-deformed composite material presented by Trakakis and Galiotis in 2010 by heating an epoxy strip (270mm $\times$ 20mm $\times$ 1.8mm) embedded with carbon and glass fiber[23], the steady center deflection value 3.5mm can be found at 400s and 110°C. In conventional mechanical actuator device that converts external energy (created by air, electricity or liquid) into motion and force. In the segment PM actuator, bending type design can provide another actuation motion by using its own magnetic energy. The important in the future of green energy, this application might be contributed to the innovation of mechanical part designs.

CONCLUSIONS

A simple bending type design and application of segments PM actuator presented and constructed by thin plastic strip with segment N45H PM, rectangular N45H PM and support. The 3 numbers of segments PM actuator can provide the maximum center deflection value 3mm as the stroke length and lift the load. The bending type design can perform an actuation motion by using its own magnetic energy in the segment PM actuator.

REFERENCES

[1] H.Tiegna, Y.Amara, G.Barakat; Overview of analytical models of permanent magnet electrical machines for analysis and design purposes, Mathematics and Computers in Simulation, **90**, 162–177 **(2013)**.

[2] Y.P.Hsieh; Magnetization reversal observed by the deflection of magnetic actuator, Journal of Magnetism and Magnetic Materials, 324 **(2012)**.

[3] W.Chen, L.Zhang, L.Yan, J.Liu; Design and control of a three degree-of-freedom permanent magnet spherical actuator, Sensors and Actuators A: Physical, 180 **(2012)**.

[4] S.Arunanidhi, M.Singaperumal; Design, analysis and simulation of magnetostrictive actuator and its application to high dynamic servo valve, Sensors and Actuators A: Physical, 157 **(2010)**.

[5] Z.Jia, H.Liu, F.Wang; Researches on the computer digital control system of giant magnetostrictive actuator, Mechatronics, 19 **(2009)**.

[6] B.Watson, J.Friend, L.Yeo; Piezoelectric ultrasonic micro/milli-scale actuators, Sensors and Actuators A: Physical, 152 **(2009).**

[7] K.Ishiyama, C.Yokota; Cantilevered actuator using magnetostrictive thin film, Journal of Magnetism and Magnetic Materials, 320 **(2008)**.

[8] K.W.Oh, C.H.Ahn; Magnetic actuation, Comprehensive Microsystems, **2**, 39–68 **(2008)**.

[9] A.Grunwald, A.G.Olabi; Design of a magnetostrictive (MS) actuator, Sensors and Actuators A: Physical, 144 **(2008)**.

[10] M.Ghodsi, T.Ueno, H.Teshima, H.Hirano, T.Higuchi, E.Summers; "Zero-power" positioning actuator for cryogenic environments by combining magnetostrictive bimetal and HTS, Sensors and Actuators A: Physical, 135 **(2007)**.

[11] B.Ackermann, H.Steinbusch, T.Vollmer, J.Wang, G.W.Jewell, D.Howe; A spherical permanent magnet actuator for a high-fidelity force-feedback joystick, Mechatronics, 14 **(2004)**.

[12] D.C.Jiles, C.C.H.Lo; The role of new materials in the development of magnetic sensors and actuators, Sensors and Actuators A: Physical, 106 **(2003)**.

[13] J.M.D.Coey; Permanent magnet applications, Journal of Magnetism and Magnetic Materials, 248 **(2002)**.

[14] A.Kruusing; Actuators with permanent magnets having variable in space orientation of magnetization, Sensors and Actuators A: Physical, 101 **(2002)**.

[15] H.Janocha; Application potential of magnetic field driven new actuators, Sensors and Actuators A: Physical, 91 **(2001)**.

[16] D.Howe; Magnetic actuators, Sensors and Actuators A: Physical, 81 **(2000)**.

[17] R.Carotenuto, N.Lamberti, A.Iula, M.Pappalardo; A new linear piezoelectric actuator for low voltage and large displacement applications, Sensors and Actuators, 72 **(1999)**.

[18] F.Claeyssen, N.Lhermet, R.L.Letty, P.Bouchilloux; Actuators, transducers and motors based on giant magnetostrictive materials, Journal of Alloys and Compounds, 258 **(1997)**.

[19] R.H.J.Fastenau, E.J.van Loenen; Applications of rare earth permanent magnets, Journal of Magnetism and Magnetic Materials, 157/158 **(1996)**.

[20] C.C.Hong; Application of a magnetostrictive actuator, Materials & Design, 46 **(2013)**.

[21] C.C.Hong; Rapid heating induced vibration of magnetostrictive functionally graded material plates, Transactions of the ASME, Journal of Vibration and Acoustics, **134**, 021019 **(2012)**.

[22] P.Liu, R.L.Browning, H.J.Sue, J.Li, S.Jones; Quantitative scratch visibility assessment of polymers based on Erichsen and ASTM/ISO scratch testing methodologies, Polymer Test, 30 **(2011)**.

[23] G.Trakakis, C.Galiotis; Development and testing of a self-deformed composite material, Composite Structures, 92 **(2010)**.