Application of Rotating Arms Type Permanent Magnet Motor

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Abstract

The present application related to a rotating arm type permanent magnet motor, in particular to a permanent magnet motor that was actuated by the action of the magnetic forces of a permanent magnet stator of a stator module and two thin ring permanent magnets of a rotor module. The purpose of present permanent magnet motor was to provide the torque produced by a magnetic force of the magnetic energy of a stator to drive the rotation of the rotor. The rotating arm type permanent magnet motor comprised an external support frame base, a stator module and a rotor module. The external support frame base included an upper frame, a lower frame and two side frames. The stator module included an elastic metal plate cantilever arm and a permanent magnet stator. The rotor module included a rotating shaft, a double arc shaped rotating arms type support frame, and two thin ring permanent magnets. Magnet material N45H (sintered Nd–Fe–B) was used for the permanent magnets of stator and rotor. The values of magnetic forces (attraction force and exclusion force) were inverse proportional to the position distances of poles (N pole and S pole) above the top level of thin ring permanent magnets, e.g. c= 12mm. The greater value of magnetic forces got the faster rotation speed. The values of magnetic forces could produce the good enough torque for the thin ring permanent magnets to rotate the shaft when position b= 8mm better than that when position b= 17mm. In the future, with the help of using an external swing motion of electrical controlled swing-type device to produce complete rotation, the present permanent magnet motor might save electricity and power sources. Some preliminary rotation speed data of rotating shaft in a permanent magnet motor were obtained and presented with manually controlled.

Keywords: rotating arms type, permanent magnet motor, stator, rotor

1. Introduction

Some kinds of power sources including electric power, water power, wind energy and solar power are used and applied in many fields. The electric power is generated in power plant that usually operated and supplied by fossil fuel. Electricity is used as a power in the electromagnetic motor to transfer electrical energy into mechanical energy and drive the movement of mechanism into the forms of rotation, vibration and linear motions. In 2018, Woodford [1] presented the movement rule, rotational work and motor type for the electromagnetic motor. In 2018, Liu et al. [2] presented the motor's efficiency and working capacity of electromagnetic-fluid-thermal simulations for the permanent magnet linear motor (PMLM). Water power is used to generate electricity in water storage reservoir, water usually used and operated through the dam were built in the valley and water flows all year round in the rivers. Wind energy and solar power are usually used in the fields of renewable energy sources (RES) for better friendly life of the natural environment. In 2016, Boie et al. [3] presented an integration analysis for the developments of RES and electricity market in North African (NA). Also, improving electric motor efficiency

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is more interested in a permanent magnet motor to save energy and reduce energy consumption. In 2015, Sun and Zhang [4] introduced a novel bi-directional energy conversion system to provide high efficiency of voltage on permanent magnet direct current (DC) motor by using a super-capacitor rather than a battery. There are some control applications in the type of permanent magnet synchronous motor (PMSM), permanent magnet brushless direct current (PMBLDC) motor, linear motor, stepper motor and alternating current motor. In 2013, Ramírez-Leyva et al. [5] used a Power Electronics Texas Instruments experimental system to validate the passivity strategy of a PMSM speed control. Higher performance of the controller can be reached by using the PMSM. In 2012, Demirtas and Karaoglan [6] used the response surface methodology (RSM) to obtain the proportional integral controller coefficients in a PMBLDC motor. Some optimal parameter values are found by using the RSM tuning. In 2009, Hassanpour Isfahani and Vaez-Zadeh [7] presented the high efficiency, high power factor and high power density of line start permanent magnet electric synchronous motors to reduce the energy consumption. For the fans, compressors and pump applications which move a fluid, the load torque is proportional to the square of the rotational speed. In 2008, Ganssle et al. [8] described the rotor with alternating north and south poles in permanent magnet stepper motor. As the coils are energized by electric, the rotor is pulled around. In 2007, Bolund et al. [9] gave an overview of flywheel technology and application, and studied the flywheel rotor stored the kinetic energy in high voltage motor/generators for renewable energy generation. In 2006, Matsuura [10] reviewed the Nd–Fe–B (neodymium-iron-boron) sintered magnets for the applications of industrial motor, automobile and electric appliances. Some improvements of permanent magnet properties still undergoing invented. In 2004, Compter [11] presented the six degrees of freedom of movement control for the electro-dynamic planar motor with moving coils to generate two directional movements. In 2002, Coey [12] reviewed the permanent magnet applications of the magnetic force effects in three types of magnetic fields, for actuators, motors, generators and sensors in uniform magnetic field, for controlling beams, bearings and mineral separations in non-uniform magnetic field, and for magnetometers, switchable clamps and metal separation in time-varying magnetic field.

In 2013, Chowdhury [13] introduced the kinetics and multidisciplinary enterprise future in molecular motor. It would be a challenge intended to drive a motor without using external electric power or gas power for the better living environment in the future. The author presented and published the US patent for the manuscripts. In 2016, Hong [14] presented the rotating arm type permanent magnet motor in the patent US 2016/0094095 A1. The author also presented some papers about the investigations of permanent magnet and magnetostrictive materials. In 2014, Hong [15] completed the simple design and application of a bending type segment permanent magnet actuator with N45H (sintered Nd–Fe–B) material. In 2013, Hong [16] used the Terfenol-D material to design and construct the application of a magnetostrictive actuator. In 2013, Hong [17] studied the transient response of magnetostrictive functionally graded material (FGM) square plates under rapid heating with the generalized differential quadrature (GDQ) method. In 2012, Hong [18] used the GDQ method to investigate the rapid heating induced vibration of magnetostrictive FGM plates. It is interesting to investigate and develop a new rotating arm type permanent magnet motor that comprising an external support frame base, a stator module and a rotor module. The purpose of this paper is to investigate the possible rotational motion of permanent magnet motor. In the future, with the help of using an external swing motion of electrical controlled swing-type device to produce complete rotation, the present permanent magnet motor might save electricity and power sources.

2. Design and Construction

New design and application of permanent magnet motors were developed and constructed as shown in Fig. 1. The rotating arm type permanent magnet motor comprising an external support frame base, a stator module and a rotor module. The external support frame base included an upper frame, a lower frame and two side frames. Each of the upper and lower frames had a through hole formed at a position near a center position, and the bearing was installed in the center position. The rectangular block made in aluminum material with outer dimensions 220 mm × 100 mm × 20 mm was used as the frame base, and used the copper wire cutoff manufacturing machine to cut off the rectangular inner block with dimensions 180 mm × 80 mm × 20 mm. Drilled the through holes $\phi 8$ mm in the central position for rolling bearings and rotating shaft to be installed into the positions. The rolling bearings with outer diameter $\phi 8$ mm, inner diameter $\phi 5$ mm and length 2mm were used to fix rotated shaft. The rotating shaft made in aluminum material with diameter $\phi 5$ mm, length 150mm was used to perform the rotational motion. The rotor module included a rotating shaft, a double arc shaped rotating arms type support frame, and two thin ring permanent magnets, wherein a left and right bracket was installed onto the left and right side of the double arc shaped rotating arms type support frame, respectively, and a center hole was formed at the center of the double arc shaped rotating arms type support frame, and the thin ring permanent magnet was an N45H permanent magnet. In each side of the double arc shaped rotating arms type support frame with outer diameter $\phi 76$ mm, inner diameter $\phi 66$ mm, arc angle 240°, made in aluminum material was shown in Fig. 2. Two thin (2mm thickness) ring permanent magnets were fixed onto each side surface of the double arc shaped rotating arms type support frame, respectively. The stator module included an elastic metal plate cantilever arm and a permanent magnet stator, wherein the elastic metal plate cantilever arm was a SUS304 stainless steel plate, and the permanent magnet stator was also an N45H permanent magnet. Permanent magnet N45H also called "Neo" or "Nd-Fe-B" magnets were used for the magnet material. The thin ring permanent magnet N45H with outer diameter $\phi 76$ mm, inner diameter 72mm, height 10mm as shown in Fig. 3 was provided by MAG CITY CO., LTD. Company located in Taiwan. The permanent magnet stator with 11mm arc length, 10mm height and 2 mm thickness thin permanent magnet was shown in Fig. 4 and placed in the proper position away from the top of the rotating shaft. Currently to interpret the matter of designs, the permanent magnet stator was placed simply at the tip of rectangular 63 mm × 12 mm × 1 mm stainless steel SUS304 strip that was fixed simply together with the cantilever two-layer strip bounded by rectangular 320 mm × 23 mm × 1 mm stainless steel SUS304 was shown in Fig. 5.

Fig. 1 Simple construction of rotating arms type permanent magnet motor

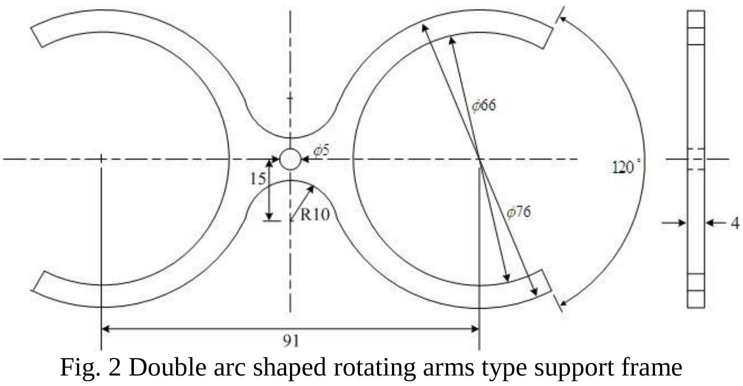

Fig. 2 Double arc shaped rotating arms type support frame

Fig. 3 Thin ring permanent magnet N45H

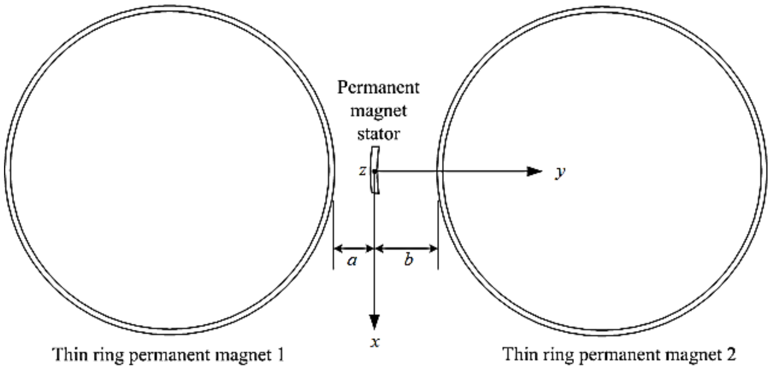

Fig. 4 Top view of two thin ring permanent magnets and permanent magnet stator

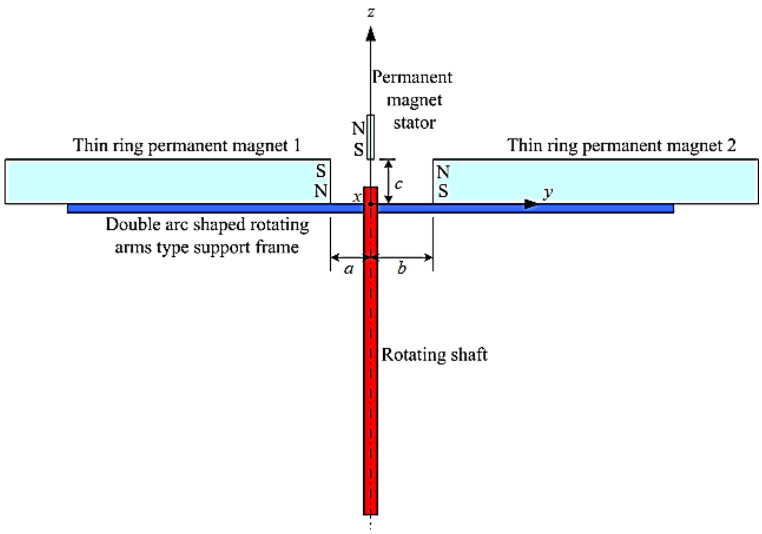

Fig. 5 Front view of two thin ring permanent magnets and permanent magnet stator

Declaration of the test methods was stated as follows; some of international standard test methods were usually used such as ASTM and ISO standards that define the precision way by Liu et al. [19] in 2011. In this paper did not use any international standard tests for the convenient, only personal investigation view of DOE method was used to find the preliminary and fundamental results. Locations of permanent magnets in rotor and stator modules were stated as follows, generally, the permanent magnet material N45H was very brittle and working in the general temperature 25℃ of environment. For the installation of rotor module, two thin ring permanent magnets were simply fixed at left and right surfaces respectively onto the double arc shaped rotating arms type support frame with the locations that were defined in the Fig. 5 (wherein a was the distance between an edge of the left thin ring permanent magnet and rotating shaft center, b was the distance between an edge of the right thin ring permanent magnet and rotating shaft center, and c was the distance between the permanent magnet stator and the upper surface of the double arc shaped rotating arms type support frame). The local Cartesian coordinate z-axis was in the direction of rotating shaft, x -axis and y-axis were perpendicular to the rotating shaft. Usually, thin ring permanent magnet 1 of rotor module was horizontally located at a position from its right side of ring to the left side of x -axis. Thin ring permanent magnet 2 of rotor module was horizontally located at b position from its left side of ring to the right side of x-axis. The center of each one thin ring permanent magnets was located in the y-axis. The permanent magnet stator was placed vertically above the rotating shaft and located at c position to the top surface of the double arc shaped rotating arms type support frame. The magnetic force direction of thin ring permanent magnets of rotor module was in the z -axis, e.g. the upper half of thin ring permanent magnet was S pole, thus the lower half of thin ring permanent magnet was N pole. The placements of two thin ring permanent magnets were installed with an opposite polarity with respect to each other, e.g. the S pole of thin ring permanent magnet 1 was directed upward, thus the N pole of thin ring permanent magnet 2 was directed upward. The magnetic force direction of permanent magnet stator was also in the z -axis, e.g. the upper half of permanent magnet stator was N pole, thus the lower half of permanent magnet stator was S pole.

3. Results and Discussion

Permanent magnet rotating test was stated as follows, when the permanent magnet stator properly approached to above of the rotating shaft and located at c position, the exclusion force came from the S pole of permanent magnet stator and the S pole of thin ring permanent magnet 1, in the same time in the opposite side of the double arc shaped rotating arms type support frame, the attraction force came from the S pole of permanent magnet stator and the N pole of thin ring permanent magnet 2, the torque produced from the exclusion force, attraction force and ring positions a, b with respect to z -axis, thus the shaft began to rotate. The magnetic forces came from the thickness sides of permanent magnet stator (2mm) could be neglected by properly using the storage energy effect of fly wheel devices for thin ring permanent magnets. After half rotation of shaft, the attraction force came from the S pole of permanent magnet stator and the N pole of thin ring permanent magnet 2, in the same time in the opposite side of the double arc shaped rotating arms type support frame, the exclusion force came from the S pole of permanent magnet stator and the S pole of thin ring permanent magnet 1, the torque produced again from the attraction force, exclusion force and thin ring permanent magnets positions a, b with respect to z -axis, thus the shaft continued to rotate and completed a whole rotation. The two thin ring permanent magnets rotated as a flywheel to store its energy. With the help of flywheel energy storage, magnetic torque came from the magnetic energy and flexible function came from the stainless steel SUS304 strips, the shaft continued easily and possibly to complete the next rotation.

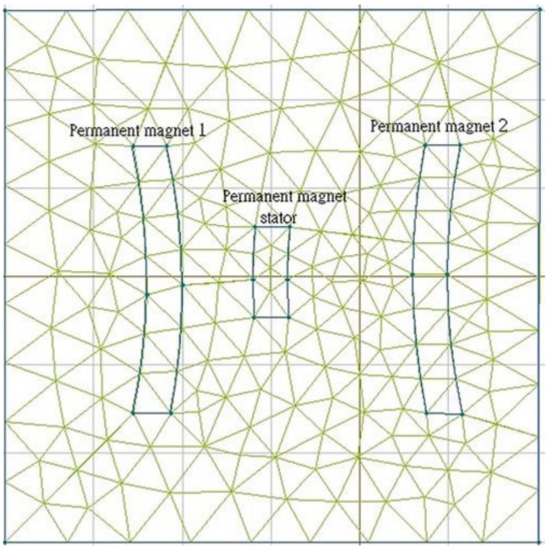

Fig. 6 Simply geometry of Nd-Fe-B magnets with meshes in the QuickField software

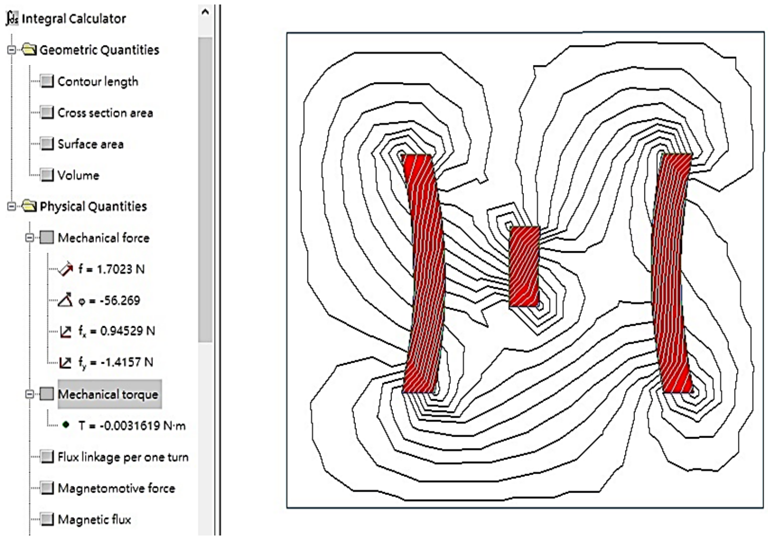

Fig. 7 Torque and magnet field of Nd-Fe-B magnets in the QuickField software

It would be better to have simulation data to validate the experimental results, the simulation of magnetic forces for the permanent magnet would be found in the commercial programs, e.g. QuickField, COMSOL, Maya and ANSYS. It was available to use the QuickField student edition 6.3 SP1 software for the magnetostatics study to simulate the torque in the dominated-simply geometry of Nd-Fe-B magnets with meshes as shown in Fig. 6. The torque and magnet field of Nd-Fe-B magnets in the QuickField software were shown in Fig. 7, the mechanical torque T= -0.0031619 Nm was found for the Nd-Fe-B magnets with coercive force H_c= 653000A/m.

The permanent magnet motor rotation test successively rotated with manually controlled the permanent magnet stator to provide the forward and backward of swings and had the following preliminary data. To investigate the effect of positions of permanent magnet stator on the rotation speed of rotating shaft, considering the positions a= 8mm, b= 13mm, c= 12-50mm, the variation of rotating shaft rotation speed (rpm) vs. c (mm) was shown in Fig. 8 with manually controlled. The rotation speed values of rotating shaft were increasing with c values decreasing. Because the values of magnetic forces (attraction force and exclusion force) were inverse proportional to the position distances of poles (N pole and S pole) above the top level of thin ring permanent magnets, e.g. c= 12mm. The greater value of magnetic forces got the faster rotation speed. The rotation speed values of rotating shaft would be zero when c= 0mm, because the values of magnetic forces could not produce enough torque for the thin ring permanent magnets to rotate the shaft.

When the permanent magnet stator was in the position c=12mm, the rotation speed value of rotating shaft was 24 rpm. To investigate the effect of positions of two thin ring permanent magnets on the rotation speed of rotating shaft, considering the positions a= 8mm, b= 8-17mm, c= 12mm, the variation of rotating shaft rotation speed (rpm) vs. b(mm) was shown in Fig. 9 with manually controlled. The rotation speed values of rotating shaft were also increased from 10 rpm to 36 rpm with b values decreasing from 17mm to 8 mm. When the thin ring permanent magnet 2 was in the position b=8mm, the rotation speed value of rotating shaft was 36 rpm. The positions in equal distance of two thin ring permanent magnets a=b=8mm with respect to z-axis were in good position to provide the rotating shaft more easily to rotate. Because the values of magnetic forces could produce the good enough torque for the thin ring permanent magnets to rotate the shaft when position b= 8mm better than that when position b= 17mm.

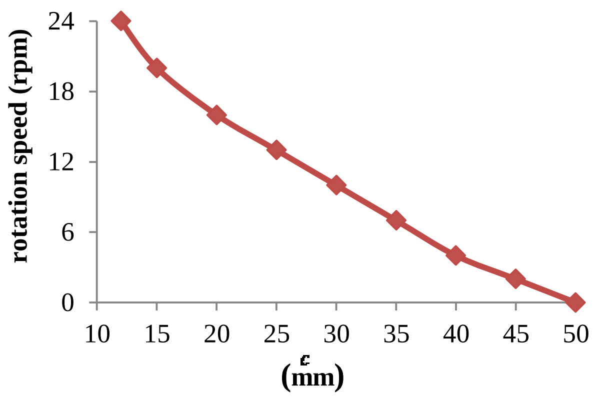

Fig. 8 Rotating shaft rotation speed (rpm) vs. c (mm) with manually controlled

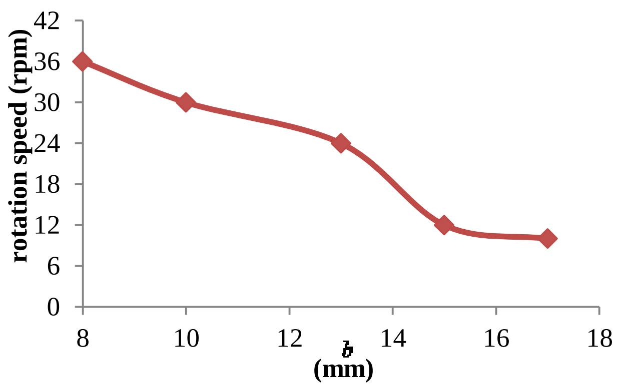

Fig. 9 Rotating shaft rotation speed (rpm) vs. b (mm) with manually controlled

In conventional, a motor was a mechanical device that converts energy (created by air, electricity or liquid) into motion and torque. The simple rotating arm type permanent magnet motor was a new, different design of the conventional motor. The present permanent magnet motor provided the torque produced by a magnetic force of the magnetic energy of a stator to drive the rotation of the rotor. This rotating arm type design and construction of the permanent magnet motor would be used as a basic method to form some usual rotating arm type permanent magnet engine in the future. The rotating arm type permanent magnet motor might be developed to produce a suitable shaft rotation speed and also had the load torque capability at the forthcoming time.

4. Conclusions

A new successful and simple rotating arms type design and application is introduced for the permanent magnet motor that is constructed by the action of the magnetic forces of a permanent magnet stator of a stator module and two thin ring permanent magnets of a rotor module. The permanent magnet motor rotation test successively rotated with manually controlled the permanent magnet stator to provide the forward and backward of swings and had the preliminary data. When the two thin ring permanent magnets locate in the equal distance with respect to rotate shaft axis, it is in good position to provide the rotating shaft more easily to rotate. The importance of this application might be contributed to the pollution reduction of mechanical part innovation designs in the green energy. The rotating arm type permanent magnet motor can produce complete rotation with a suitable motion controller in the future. For example, electrical controlled swing-type device would be applied as the kinetic energy input system to produce completely rotation with its own magnetic energy for the permanent magnet driving motor. Also the swing-type device would be used and applied to the input force forms of natural wave produced from ocean, lake and river. The electrical controlled swing-type device would be used to provide the forward and backward of swings for the permanent magnet stator. The main contributions of this paper might be presented an approach method of advanced designs in the energy saving for permanent magnet motor.

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