# Design and Experimental Verification of Limited Angle Rotary Torque PM Motor for Control Valve with Self-Alignment Characteristic

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N.E.E New electrical Energy Lab.

## I. Abstract & Introduction

✓ This paper deals with the design and characterization of permanent magnet torque motors with limited operating range. The de-sign method and the shape of the motor satisfying the range and torque value when applying the specific current value are presented and the characteristics of the motor designed through the finite element analysis are analyzed. The designed motor was fabricated and the experimental set was constructed to measure the torque value according to the current value and the rotation angle of the motor. Compared with the finite element analysis results, approximate values could be measured and the characteristics of the LART motor obtained through the analysis could be verified.

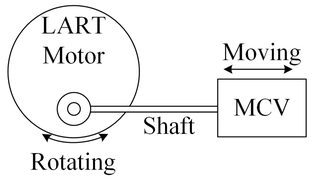



**Fig. 1. Operating concept of limited angle rotary torque motor with MCV (Main Control Valve)**

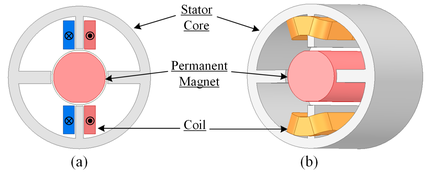



**Fig. 2. The Structure of LART PM Motor: (a) 2D FEM model, (b) 3D FEM model.**

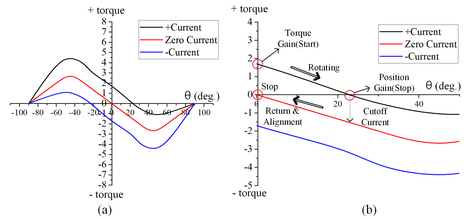



**Fig. 3. Torque characteristic graph of LART PM motor according to rotor position with self-alignment**

## II. Design Requirement Specification

**TABLE I. LART Motor Design Specification**

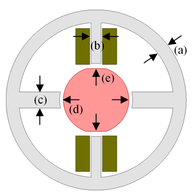
| Parameter | Value |
|---|---|
| *Max. Operating Angle* | ±35 deg. |
| *Position Gain* | 1.2 Adc |
| *Torque Gain* | 430 mNm @2Adc |
| *Redundancy* | 3 |
| *Max. Operating Current* | 4.5 Adc |

**TABLE II. Permanent Magnet Material Characteristics**

| Parameter | Ferrite | Nd-Fe-B | $Sm_2Co_{17}$ |
|---|---|---|---|
| *Br [kG]* | 3.5 ~ 4.5 | 11 ~ 14.5 | 9 ~ 11 |
| *Hcj [kOe]* | 3 ~ 5 | 10 ~ 30 | 10 ~ 30 |
| *Tc [°C]* | 450 | 315 | 825 |
| *Max. Operating Temperature [°C]* | 350 | 60 ~ 200 | 300 |

**TABLE III. Magnetic Torque According to Core Material**

| Parameter | Value |
|---|---|
| *ASTM A848(Carpenter)* | 294 mNm |
| *Hiper-Co Steel* | 286 mNm |
| *50PN470* | 286 mNm |
| *Steel-1008* | 279 mNm |




Design Parameter of LART Motor :
(a) : Yoke Thickness
(b) : Tooth Thickness
(c) : Align Pole Thickness
(d) : PM diameter(d-axis)
(e) : PM diameter(q-axis)

**Fig. 4. Design Parameter of LART PM motor**

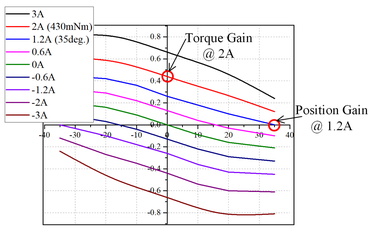



**Fig. 5. Torque characteristics analysis results of LART PM motor using FEM according to current value**

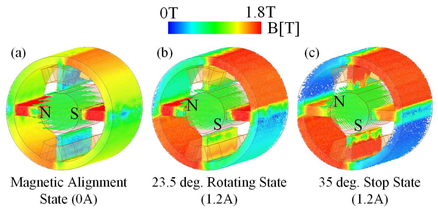
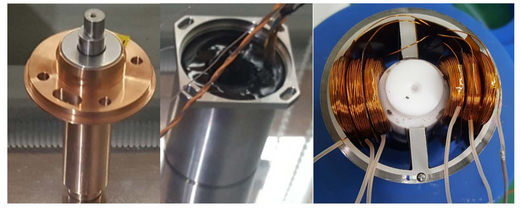



**Fig. 6. Torque characteristics analysis results of LART PM motor using FEM according to current value**

✓ Fig. 5 shows the result of the characteristic analysis of the designed motor. It can be confirmed that the rotation angle be-comes ±35 ° when the required condition of 1.2A is applied and the torque value generated at the origin when 2A is applied corresponds to the required torque value.

✓ It can also be seen that the rotor has the function of returning to its original position when the power is cut off. Fig. 6 shows the magnetic flux density distribution according to the rotational state of the LART motor.

## III. Experiment Set and Experiment Results



(a) Rotor Magnet (b) Stator Assembly (c) Stator winding

**Fig. 7. Manufactured model of LART motor**

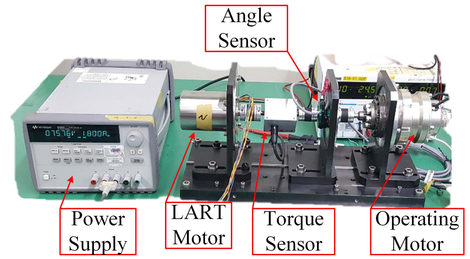



**Fig. 8. LART PM Motor Experiment set for evaluating motor performance.**

**TABLE IIII. Design Parameter of LART Motor**

| Parameter | Value |
|---|---|
| *Outer Diameter* | 63.2 |
| *Yoke Thickness* | 4.5 mm |
| *Tooth Thickness* | 3.4 mm |
| *Align Pole thickness* | 5.6 mm |
| *PM diameter* | 23 mm |
| *Stack length* | 45.2 mm |
| *Coil Turns (AWG 27)* | 800 |

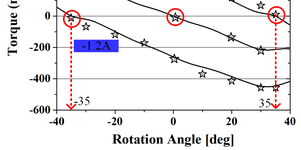



**Fig. 9. Position Gain Analysis Results and Experiment results**

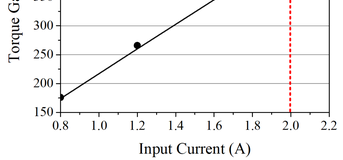



**Fig. 10. Torque Gain Analysis Results and Experiment Results**

✓ Fig. 8 shows the experimental set. The input current value of the motor was controlled through a DC power supply, and the angle of rotation of the motor and the torque value generated at this time were measured using an angle sensor and a torque sensor. The torque sensor is a rotary torque sensor that measures torque and outputs it as a voltage signal.

✓ Fig. 9 shows the comparison between the analysis results and the experimental results. When ± 1.2A was applied, the experimental results and the finite element analysis results were compared.

✓ Fig. 10 shows the result of measuring the torque generated at the rotor position at 0 degrees according to the input current. This means the torque gain value. The experimental results were found to be in good agreement with the results of the finite element analysis.

## Conclusion

✓ This paper deals with the design and characteristic analysis of the Limited Angle Rotary Torque motor with self-alignment characteristics. Through the proposed shape, it was confirmed that the position gain of rotating a specific range was satisfied.

✓ The designed motor was fabricated and the experimental set was constructed to measure the torque value according to the motor current and rotation angle. When compared with the finite element analysis results, an approximate value could be measured and the characteristics of the LART motor obtained through the analysis could be verified. The proposed shape can be easily applied when the design target of position gain and torque gain is changed.