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A Study on Brushless DC Motor for Air Fan Module of Fuel Cell Power Pack

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Abstract. This paper presents design of brushless DC (BLDC) motor which is applied in air fan module for fuel cell power pack. Developed motor is outer rotor type BLDC motor, high efficiency and low cost are main targets to achieve in design process. Manufactured motor is combined with blade fan, and air flow and pressure with respect to the various load conditions are measured. From the simulated and measured results, we verify the application possibility as air fan module for power pack.

Key words

Fuel cell power pack, Air fan module, Brushless DC motor

1. Introduction

Increase of high power portable devices attracts abundant attention to high-capacity movable power supply. Various attempts are continuing to increase the energy density of secondary battery, however, satisfactory results are not presented till now. Fuel cell system is one of the alternative technologies and the application fields are extensive, for instance, transportations, power plants, and portable military devices [1-2]. The main parts of the fuel cell systems are stack and balance of plant (BOP). BOP increases the operating performance and durability of the stack by controlling pressure, temperature, and humidity of fuel or air. BOP consists of fuel and air supply device, power converter and controller, heat exchanger, sensors, reformer. This paper presents BLDC motor of air fan module for cooling and air supply. Considering driving and installation conditions, the specifications of motor are determined and manufactured motor are assembled to fan module to estimate performance characteristics.

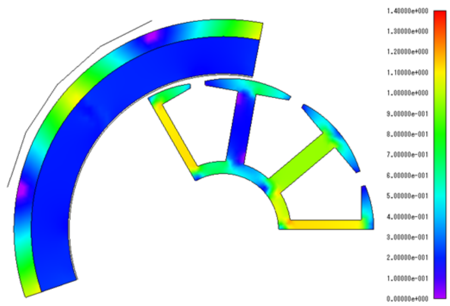
2. Design and simulation

The proposed motor is 3 phase BLDC type with 6 pole and 9 slots. Conventional single or 2 phase motors for fan module have relatively great speed changes according to the load variations, they are unfavourable in BOP systems requiring wide load ranges. In addition, 3 phase motors have low noise and vibration characteristics due to low torque ripple, and high efficiency is expected. Ring type rubber magnet is applied and sensorless driving scheme is chosen. The specific design parameters of the proposed motor are shown in Table 1.

Fig. 1 shows magnetic flux density of rotor and stator core at rated driving condition. The maximum flux density of the teeth and yoke are 1.21 and 1.26 T, respectively. The cogging torque and back EMF are 1.1mNm0-pk and 0.74V0-pk @1,000rpm, respectively. The cogging torque is about 10% of rated torque and no load speed and torque constant can be estimated using the calculated EMF value. Fig. 1(d) shows rated torque wave when input voltage of 12V is applied. In rotational speed of 6,500rpm, rated torque of 13.8mNm is induced.

Table I. Specific parameters of designed motor

parameters	value	unit
pole/slot	6/9	
rotor diameter	35	mm
stator diameter	24.5	mm
active length	13	mm
air gap	0.5	mm
permanent magnet	rubber	
coil diameter	0.35	mm
turn number per phase	90	



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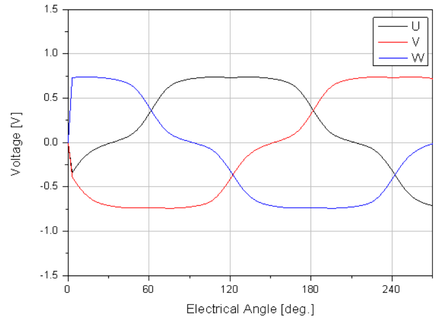

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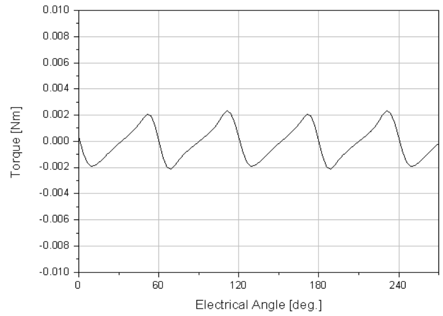

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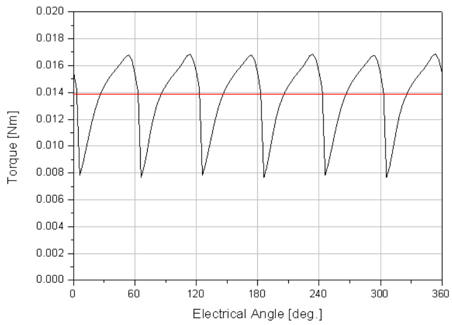


(d)

Fig. 1. Simulated results of the proposed motor. Magnetic flux density(a), back EMF(b), cogging torque(C), rated torque(d).

3. Manufacturing and test

Fig. 2 shows manufactured motor based on above design parameters. PCB board for connection of phase coils is located between stator core and lower base yoke, and ring type magnet is boned inside the rotor core. The measured EMF wave of the manufactured motor is shown in Fig. 3. A reasonable agreement is seen to be achieved in value and shape comparing with the simulated result in Fig. 1. Through the results we can confirm that the applied material characteristics of permanent magnet and core, and winding specification are reflected well in manufacturing process.

Fig. 2. Manufacture motor

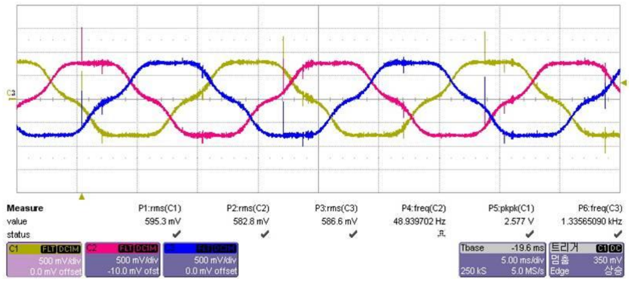


Fig. 3. Measured EMF@1,000rpm

Fig. 4 shows input and output characteristics of the proposed motor with respect to the load variations. The measurement equipment consists of a DC power supply, dynamometer, powermeter, and a laptop computer for display and load control. When rated input voltage of 12V is applied, the maximum efficiency of 79.1% and the rotational speed of 6,500rpm are estimated within the rated load range from 10 to 12mNm. Fig. 5 shows phase current wave of motor when load torque of 12mNm is applied in which we confirm favourable switching of inverter is developed. The input current value is 808mA and stable driving can be expected considering current density. Fig. 6 shows the designed fan blade and the completed blower module. The fan blade is assembled to the rotor core of the motor and the stator of the motor is united to module case. Fig. 7 shows test bench for air flow and pressure. The maximum air flow is about 2CMM and the maximum efficiency of 21.5% is estimated at the air flow of 1.6CMM as shown in Fig. 8.

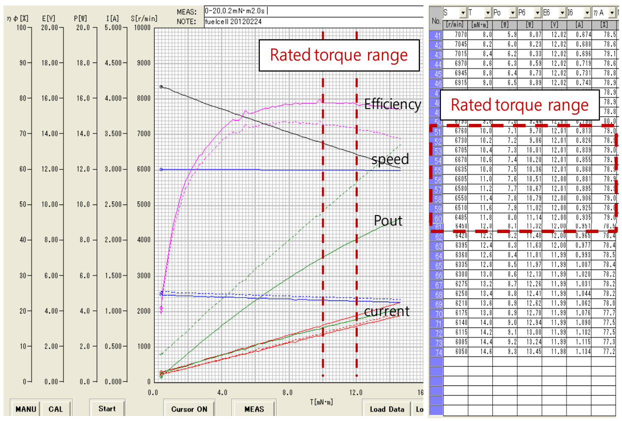


Fig. 4. Input and output characteristics with respect to load variations

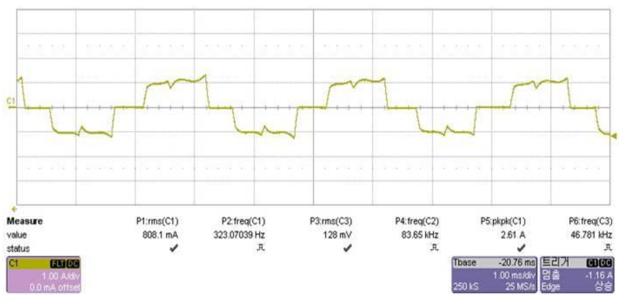


Fig. 5. Input current at rated load torque

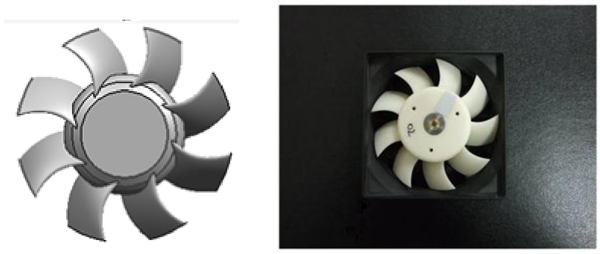


Fig. 6. Designed blade and assembled air fan module

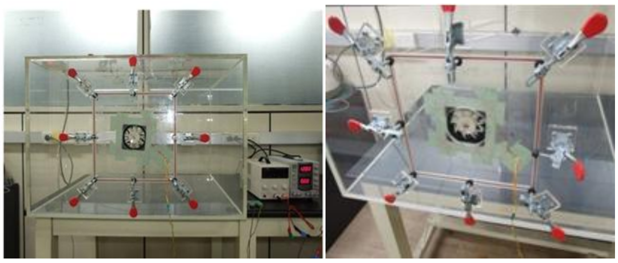
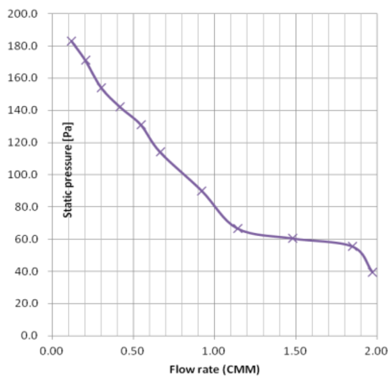
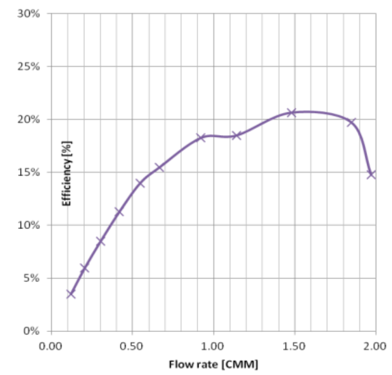


Fig. 7. Test bench for air flow and pressure



(a)



(b)

Fig. 8. Static pressure (a) and efficiency (b) with respect to the air flow variations

4. Conclusion

This paper presents design of brushless DC motor of the air fan module for fuel cell power pack of 150W. Developed motor has outer rotor with rubber magnet for low cost. The rated power is 8W and the maximum efficiency is gained within rated driving range. The manufactured motor is combined with fan blade and tested for air flow, pressure, and efficiency. In extensive paper, we will present more specific design methods and discussion supporting above results

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