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Electromagnetic Design of Induction Motors for Electric Vehicles using Self-organizing Methods

Taketsune Nakamura [1)]　Yushi Kido [1)]

1) Kyoto University, Graduate School of Engineering
Kyotodaigaku-katsura, Nishikyo-ku, Kyoto, 615-8510, Japan (E-mail: nakamura.taketsune.2a@kyoto-u.ac.jp)

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In this study, we conducts basic study on optimal design of a 24 kW class squirrel-cage induction motor for EV application[1,2]. First, for the stator, we create a winding arrangement with an ideal spatial rotating magnetic field distribution by assuming the winding as a line current and applying pulse width modulation (PWM) concept to the spatial domain. In the case of rotor bars of the rotor, a cross-sectional minimization model is also created for the rotor bars and its performance is evaluated. By using the idealized model, the influence of the shapes of the stator slots and the rotor bars can be neglected and the electro-mechanical energy conversion can be discussed in detail.

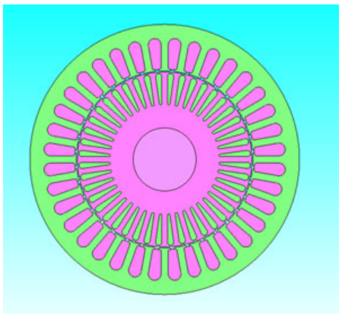
After that, we generate a realistic model by enlarging the conductor cross section while maintaining the performance of the line current model under appropriate conditions. During this process, the concept of self-organization is referenced and incorporated into the program so that the structure can be uniquely determined regardless of the designer. Using the previously reported maximum output 24 kW class machine as a benchmark[3], the design is carried out under the same volume and magnetomotive force conditions.

Fig. 1(a) shows the benchmark model[3] and Fig. 1(b) the designed model with self-organizing method. Fig. 2 shows the analysis results of the torque characteristics (rotating speed: 5400 rpm, slip: 0.045). As shown in the figure, when the number of rotor bars is 42, the torque reaches 25.21 Nm. It should be noted that the above result is slightly different from the directly obtained one by the self-organizing design method (number of rotor bars: 36), and further study of the design method is required in the future. In any case, since the torque value of the benchmark machine was 24.71 Nm, that obtained based on the self-organizing design method (25.21 Nm) exceeds this value, and there is already great possibility.

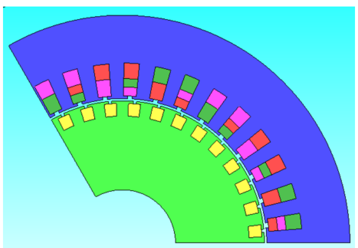
(1) Taketsune Nakamura, and Yushi Kido, Japanese patent application, 2021-158009 (2021)

(2) Taketsune Nakamura, and Yushi Kido：in preparation (2022)

(3) Miwa Tobita, Ken-ichi Ikeda, Shingo Itoh, Taketsune Nakamura, and Gyoo Ma：Characterization of 24 kW Class Squirrel-cage Induction Motor for Electric Vehicles, Proceedings of 23rd International Conference on Electrical Machines (ICEM'2018), pp. 97-103 (2018)

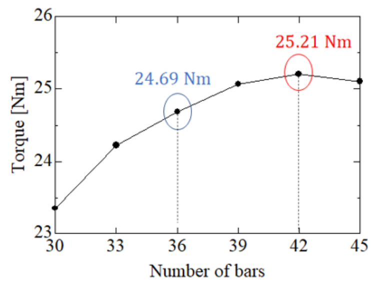


(a) Benchmark model[3]

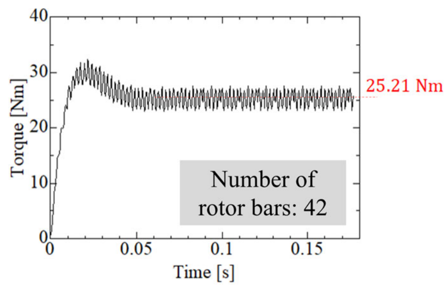


(b) Self-organizing model

Fig. 1 Design results of a squirrel-cage induction machine with a maximum output of 24 kW



(a) Torque vs. number of rotor bars



(b) Torque characteristic when the number of rotor bars is 42

Fig. 2 Torque characteristic analysis result of maximum output 24 kW class machine using self-organization method (Rotating speed: 5400 rpm, slip: 0.045)