

# Basic Verification of Hybrid-Excitation Memory Motor with Field Winding Connected Between Neutral Points of Dual Three-Phase Windings

-(Fourth Report) Effect of Efficiency Improvement under Load Operation -

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Variable-flux motors are promising for improving efficiency over a wide operating range because the optimum field flux depends on the operating condition. The authors have proposed a hybrid-excitation memory motor and drive system in which a field winding is connected between the neutral points of dual three-phase windings. In this system, two identical three-phase inverters generate zero-sequence voltage to apply field current through the field winding. Therefore, both torque production and variable-flux control can be achieved without an additional DC/DC converter dedicated to the field winding.

This paper summarizes load tests of a prototype machine using the proposed drive system. The prototype has symmetric dual three-phase armature windings, AlNiCo variable magnets, NdFeB fixed magnets, and a field winding led out through a hollow shaft. The maximum field current was set to 20.8 A, corresponding to the instantaneous maximum current of the inverter under rated armature-current operation.

The magnetization ratio was defined as the ratio of the no-load induced voltage to that obtained after applying a field current of 1 pu. Within a field-current range of  $\pm 1$  pu, the prototype achieved a flux variation range of 65%. Motor current, voltage, torque, efficiency, and loss components were measured at three representative operating points while the magnetization ratio was varied from 0.35 to 1.00.

The measured results indicate that the optimum magnetization ratio depends strongly on the operating condition. In low-speed high-load operation, a higher magnetization ratio improves efficiency because the increased field flux reduces the required armature current and copper loss. On the other hand, in high-speed light-load operation, a lower magnetization ratio improves efficiency because the reduced air-gap flux decreases iron loss. In high-speed medium-load operation, the highest efficiency was obtained at an intermediate magnetization ratio of approximately 0.7 pu. Compared with operation at the maximum magnetization ratio, the proposed variable-flux control improved efficiency by up to 8.4 percentage points under high-speed light-load conditions. These results experimentally demonstrate that adaptive magnetization-ratio control according to the operating condition is effective for improving motor efficiency over a wide operating range.

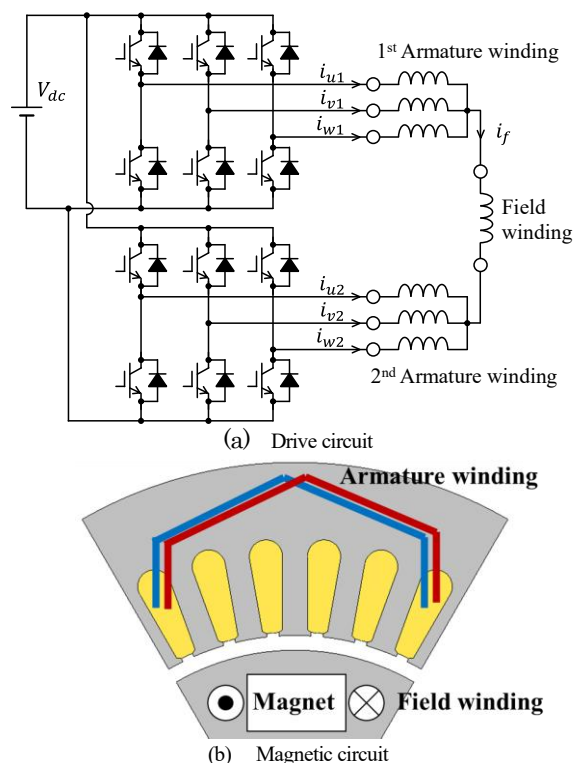


Fig.1 Proposed motor and drive system.

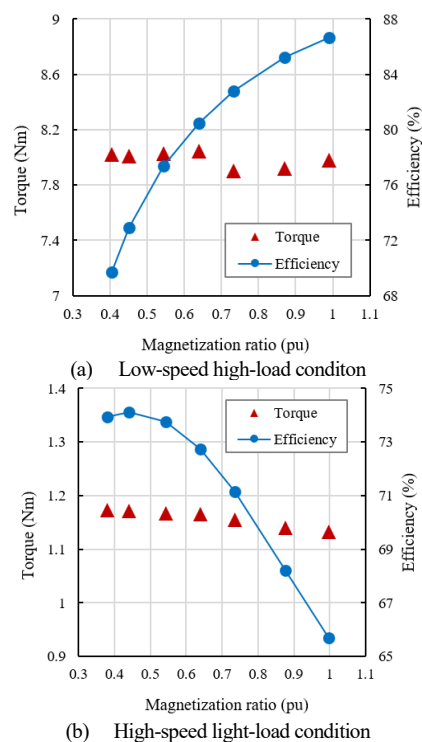


Fig.2 Measured efficiency and torque as a function of magnetization ratio