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Accurate Equivalent Modeling and Thermal Analtsis of Stator Slot of Flat Wire Motor

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Abstract
This paper presents a new method for the layered equivalent modeling of slot winding in the stator of a flat wire motor to accurately study the thermal performance under steady-state conditions. The conventional equivalent model for flat wire winding involves treating the slot winding as a single copper rod for temperature analysis. This method is not applicable to flat wire motors under high-power density operating conditions. As the power density of the motor increases, the flat wire winding is more affected by skin effect and proximity effect, resulting in a sharp increase in AC loss and uneven distribution of losses in the slot winding. The conductor losses are highest near the slot opening, a characteristic that conventional model is unable to reflect. The proposed layered modeling method fully takes into account the characteristics of flat wire winding. This method involves adding interlayer insulation to divide the overall modeled conductor into layers and fully considers the thermal parameters, heat transfer characteristics, and distribution of materials within the slot to establish a new equivalent model for flat wire winding. Finally, the comparison of the results with the actual model and experimental tests demonstrates that this method effectively improves the calculation accuracy by 2.2% of the flat wire winding equivalent model.

Keywords Flat wire motor · Accurate modeling · Stator slot · High power density · AC loss · Layered flat wire winding model · Thermal analysis

List of Symbols

k_h	Hysteresis loss coefficient
k_c	Eddy current loss coefficient
B_m	Magnetic field amplitude
$B(t)$	Magnetic field waveform
H_x	Magnetic field strength in the x direction (A/m)
J_z	Conductor current density (A/m^2)
μ	Conductor permeability (H/m)
σ	Conductivity of conductor (S/m)
ω	Electric angular velocity (rad/s)
H_1	Modulus of magnetic field strength (A/m)
$H2$	Modulus of magnetic field strength $H2$ (A/m)
φ_1	Phase of the magnetic field strength H_1 (rad)
φ_2	Phase of the magnetic field strength $H2$ (rad)
P_{cu}	Total copper losses of winding (W)
P_{AC}	AC loss (W)
P_{DC}	DC loss (W)
L_a	Effective length of the conductor (m)
B	Flux density of sinusoidal external magnetic field (T)
σ	Electrical conductivity (S/m)
ω	Angular frequency (rad/s)
h	Conductor height (m)
w_r	Conductor width (m)
λ_i	Thermal conductivity of each insulating material (W/(m·K))
δ_i	Equivalent thickness (m)
A_{in}	Area of the insulating paint (m^2)
H_w	Conductor height (m)
B_w	Conductor width (m)
H_c	Height of the flat copper wire (m)
B_c	Width of the flat copper wire (m)
N	The number of conductors per slot
Aim	Area of impregnated paint (m^2)
Δm	Quality difference between unimpregnated and impregnated motors (kg)
Z	The number of stator slots
Lah	Average length of the half-turn coil (m)

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