Online Resource 1

Compensating repair-induced core loss in rewound induction motors by constrained winding redesign: a loss-ratio criterion for repair shops

Mert Ekiz
mert.ekiz@std.yildiz.edu.tr

Reference numbers refer to the reference list of the paper.

S1 Leakage split and saturation at start

The separation step assumes equal stator and rotor leakage at 50 Hz. The FEA gives a direct check: at locked rotor, the magnetic energy stored in the stator slots (coils, separator and slot openings) is 33 % of the total slot energy at 50 Hz and 36 % at 2 Hz, for all three pitches; the rest is in the rotor bars. Repeating the separation and calibration with stator shares of 0.30–0.50 changes the rated efficiency by less than 0.03 points and the required copper area by at most 0.001 at the EASA limit and 0.006 at +50 %. The results are therefore insensitive to the split, and the equal split of the standards [16, 19] is kept rather than the FEA value.

At starting currents of 26–31 A the 2D locked-rotor reactance falls to 0.71–0.74 of its value at 4.6 A, while the resistance rises by about 2 %. The reduction is applied to the 2D leakage only; the 3D end-effect inductance is kept constant. With this saturated leakage the starting current of the original winding rises from 30.9 to 34.4 A, slightly beyond the evaluated range, where the reduction is held at its last value. The 7/9 designs of Table 4 of the paper then draw 5–7 % more starting current than the original winding. The best 8/9 design under the 10 % limit draws 9.3 % more; the 8/9 designs chosen under a 15 % limit draw 11–12 % more.

S2 Lumped thermal feedback

To test the fixed 75 °C, a lumped thermal feedback sets the winding temperature to 25 °C plus a rise proportional to a weighted loss sum (0.6 P_{Cu1} + 0.4 of the other losses), scaled so that the undamaged original reaches 75, 95 or 115 °C. With feedback, the required area at the EASA limit is 1.032, 1.028 and 1.024 for the three reference temperatures (D2: 1.086, 1.074 and 1.064): a rewind with more copper runs cooler, which lowers the need slightly. The fixed-temperature results are therefore conservative. The uncompensated damage, in contrast, grows with temperature for long end turns (D3: −0.98 to −1.23 points).

S3 Core damage with reduced permeability

Damage that also lowers permeability raises the magnetizing current, and thus the stator copper loss, and adds to the compensation need (Table S1). The reduced effective lamination fill is used here as a sensitivity case for this effect, not as a model of a specific damage mechanism: burn-off mainly degrades interlaminar insulation, which acts on eddy-current loss. At an effective fill of 0.80 the undamaged-core-loss case already needs 2.9 % more copper, and the EASA-limit case 6.7 %.

Table S1: Core damage with reduced permeability, original winding.

Effective fill	Core-loss increase	$\Delta\eta$ (pp)	Rated current (A)	Required $A_{\mathrm{Cu}}/A_{\mathrm{Cu},0}$
0.87 (calibrated)	+20 %	−0.33	7.70	1.034
0.84	+20 %	−0.44	7.75	1.045
0.80	0 %	−0.28	7.82	1.029
0.80	+20 %	−0.60	7.82	1.067
0.80	+50 %	−1.08	7.83	1.130

S4 Harmonic cage losses of the coil-pitch variants

Full pitch also loses the short-pitch reduction of the 5th and 7th belt harmonics. Under the 15 % limit its 16-turn design reaches +2.03 points at $k_{\mathrm{ins}} \leq 0.70$, with a 14.7 % higher starting current.

Harmonic cage losses were evaluated with additional magnetostatic FEA runs. The rotor was turned over one-sixth of an electrical period in 24 magnetostatic steps at rated load, with the rated stator currents and the fundamental bar currents of the equivalent circuit imposed. A 2D discrete Fourier transform of the bar-mean vector potential over time and bar index gives the open-circuit harmonic bar EMFs. Each cage mode then drives bar currents through its impedance: deep-bar resistance, end-ring term, and air-gap and slot leakage inductance, with a Carter factor of 1.1–1.4. The resulting harmonic cage loss is 0.0–0.2 W for 7/9, 0.1–0.3 W for 8/9 and 0.2–1.0 W for 9/9; the upper values evaluate the EMF in the skin layer at the top of the bar. The dominant component is the 300 Hz rotor-frame wave of the 5th and 7th belt harmonics. An analytic harmonic equivalent circuit [3] gives larger values with the same ranking: 0.2–1.4, 1.1–3.8 and 6–23 W, where the lower value includes skew and the upper is twice the unskewed estimate. The two estimates differ by an order of magnitude, mainly because the bar-mean potential underweights harmonic fields that decay into the bar and the analytic circuit neglects slotting; they agree only that the 5th- and 7th-harmonic cage loss is small, at most 0.08 points between 7/9 and 8/9. Rotor-surface and tooth pulsation losses and interbar currents, which also depend on pitch, are not modelled, so the pitch comparison holds only for the losses included.