The Effect of Repair/Rewinding on Motor Efficiency

Introduction

Globally, electric motors account for two-thirds of the electrical energy used in industrial/commercial applications–at an annual cost of more than $100 billion (U.S.) in Europe and the USA alone. Although a motor's lifetime energy costs typically exceed its original purchase price many times, motor failure can cost even more–in lost production, missed shipping dates, and disappointed customers.

Industrial companies clearly need effective motor maintenance and management strategies that minimize motor acquisition and operating costs while avoiding unexpected motor failures.

Experienced users have long known that having motors repaired or rewound by a qualified service center reduces capital expenditures yet assures reliable operation. But rising energy costs have prompted questions about the energy efficiency of repaired/rewound motors.

To answer these questions, the Electrical Apparatus Service Association (EASA) and the Association of Electrical and Mechanical Trades (AEMT) studied the effects of repair/rewinding on motor efficiency, as briefly reported here. The full report (*The Effect of Repair/Rewinding on Motor Efficiency*), includes the "EASA/AEMT Rewind Study" and a "Good Practice Guide to Maintain Motor Efficiency." [1].

Background

Simple, robust and efficient, induction motors typically convert 90 - 95% of input electrical power into mechanical work. Still, given the huge amount of energy they use, even minor changes in efficiency could have a big effect on operating costs.

Rising energy costs and legislation have spurred significant improvements in motor efficiency in recent years. In the USA, the Energy Policy Act of 1992 (EPAct) mandated minimum efficiency levels for 1 to 200 hp general purpose motors. [Note: In 2007 the Energy Independence and Security Act (EISA) raised those minimums to NEMA Premium® levels while broadening the scope of motors affected.] Voluntary agreements among motor manufacturers and the European Commission (EC) are achieving similar results in Europe.

Meanwhile, claims that repair/rewinding inevitably decreases motor efficiency are commonplace. Based largely on a handful of old studies of mostly smaller motors (up to 30 hp/22.5 kW), they often assert that efficiency drops 1 - 5% when a motor is rewound–even more with repeated rewinds [2-6]. This misapprehension persists, despite evidence to the contrary provided by a more recent study by Advanced Energy [7].

In this context, decision makers may find it difficult to evaluate the reliability and efficiency of the motors they buy or have repaired.

Objectives of the study

The primary objective of the EASA/AEMT study was to determine the impact of rewinding/repair on the efficiency of induction motors through independent before-and-after testing, including the effects of these variables:

- Specific procedural controls
- Burnout temperatures
- Repeated rewinds
- Winding configurations and slot fills
- Physical (mechanical) damage to the stator core
- Low- versus medium-voltage designs
- Bearing lubrication practices

Another objective was to identify procedures that degrade, help maintain, or even improve the efficiency of rewound motors and then prepare a "Good Practice Guide to Maintain Motor Efficiency" [1].

A final objective was to attempt to correlate the results of running core loss tests and static core loss tests.

The results of tests carried out by Nottingham University (UK) for EASA and the AEMT show that good practice repair methods maintain efficiency to within the range of accuracy that it is possible to measure using standard industry test procedures (± 0.2%), and may sometimes improve it. The accompanying report also identifies the good practice repair processes and provides considerable supporting information.

Scope of products evaluated

The EASA/AEMT study focused on 22 new induction motors ranging in size from 50 - 300 hp (37.5 - 225 kW). These power ratings were chosen because they are more representative of motors that are typically rewound than the smaller motors in previous studies [2-6].

Other characteristics of the test motors included:

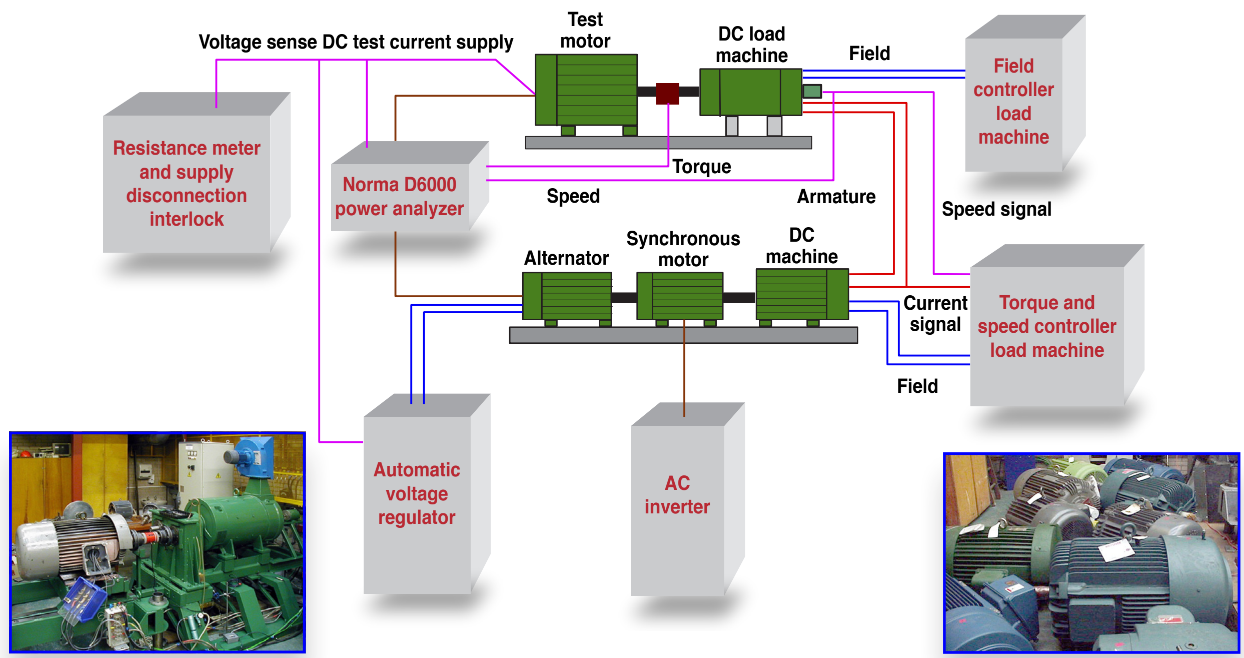
- Low- and medium-voltage ratings
- IEC and NEMA designs
- Open drip-proof (IP 23) and totally enclosed fan-cooled (IP 54) enclosures
- 2- and 4-poles

To check the results of earlier studies, two smaller motors (7.5 hp / 5.5 kW) were also efficiency tested before and after multiple burnout cycles.

Motor efficiency test procedures

Independent test facility and test protocol. The efficiency of each motor was independently tested at 50 and 60 Hz by Nottingham University (UK) before and after rewinding in accordance with IEEE Std. 112 B [8] using a dynamometer test rig (Figure 1) and instrumentation that exceeded the requirements of the standard. Each motor was tested, rewound and retested at least once; some motors were rewound and retested two or three times.

Figure 1. University of Nottingham test facility.



Validation of test procedures. To verify the accuracy of the test instruments and procedures that would be used, round-robin efficiency tests were performed on a new 30 kW (40 hp) IEC motor, first by Nottingham University and then by three other testing facilities: U.S. Electrical Motors (St. Louis, Missouri); Baldor Electric (Fort Smith, Arkansas); and Oregon State University (Corvallis, Washington).*

Each facility tested the motor at 50 and 60 Hz using the IEEE 112B test procedure and the loss-segregation method (at no load and full load). For comparison, efficiencies were also calculated in accordance with European standard BS EN 60034-2 [9].

Results comparable to those of round-robin tests previously conducted by members of the National Electrical Manufacturers Association (NEMA) also confirmed that the test protocol was in conformance with industry practice and not skewed by the evaluation method.

*Note: The round-robin tests showed that such factors as supply voltage, repeatability of test procedures, and instrumentation, taken together, can affect test results.

Results of efficiency tests on rewound motors

Test groupings. The 22 new motors studied were divided into groups based on test variables. As mentioned earlier, two 7.5 hp (5.5 kW) motors were also tested before and after multiple burnout cycles.

- **Group A.** These motors were rewound using a controlled burnout temperature of 660°F (350°C) but with no specific controls on stripping and rewind procedures.
- **Groups B, C and D.** These motors were rewound using controlled burnout temperatures of 680 - 700°F (360 - 370°C), as well as strictly controlled stripping/cleaning methods and rewind procedures (e.g., turns/coil, mean length of turn, and conductor cross-sectional area). Based on their beneficial effects (Figure 2), these controls form the basis of the "Good Practice Guide" in the full report. [1]

Table 1 shows the voltage ranges, power ratings, number of test/rewind cycles, and average efficiency change for the motors in each group.

Significance of test results

As Table 1 shows, the EASA/AEMT repair/rewind study found that the use of the good practice repair methods identified by the study maintain the original energy efficiency of rewound motors within the range of accuracy that it is possible to measure using the industry standard IEEE 112B test method (± 0.2%), and may sometimes improve it.

The test results for all groups also fell within the range of the deviation of initial round-robin tests, indicating that test procedures were in accordance with approved industry practice (see "Validation of test procedures" above).

For complete details about the test protocol, test data and results, the "Good Practice Guide to Maintain Motor Efficiency (Part 2)," core loss test methods, and a wealth of other supporting information, read *The Effect of Repair/Rewinding on Motor Efficiency* [1].

Table 1. EASA/AEMT Motor Repair/Rewind Efficiency Test Groupings and Results

Group	Number of motors	Voltage range	Power ratings	Controlled stripping and rewind procedures	Controlled Burnout temperature	Times processed	Times Rewound	Average efficiency change
A	6	Low	100 - 150 hp (75 - 112 kW)	No	660°F (350°C)	1	1	-0.4% (range -0.3 to -0.5%)*
B	10**	Low	60 - 200 hp (45 - 150 kW)	Yes	680 - 700°F (360 - 370°C)	1	1	-0.3% (range +0.2 to -0.2%)**
C1a	3	Low (random-wound)	100 - 200 hp (75 - 150 kW)	Yes	680 - 700°F (360 - 370°C)	3	3	-0.1% (range +0.7 to -0.6%)
C1b	2	Low (random-wound)	100 - 200 hp (75 - 150 kW)	Yes	680 - 700°F (360 - 370°C)	2	2	-0.1% (range +0.7 to -0.6%)
C2	2	Low (random-wound)	7.5 hp (5.5 kW)	Yes	680 - 700°F (360 - 370°C)	3	1	+0.5% (range +0.2 to +0.8%)
D	1	Medium (form-wound)	300 hp (225 kW)	Yes	680 - 700°F (360 - 370°C)	1	1	-0.2%

* Group A initially had an average efficiency change of -0.6% (range -0.3 to -1.0%) due to improper lubrication of two motors. This decreased to -0.4% (range -0.3 to -0.5%) when the problem was corrected.

** One motor was eliminated from the Group B results because its interlaminar insulation was faulty as supplied.

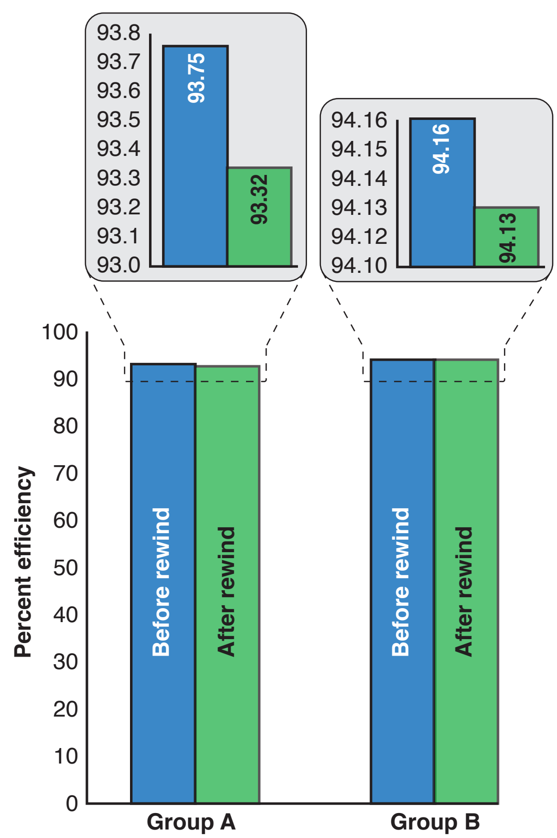


Figure 2. Average efficiency.

Conclusion

The results of the study clearly demonstrate that motor efficiency can be maintained provided repairers use the methods outlined in the "Good Practice Guide to Maintain Motor Efficiency (Part 2)."

Partial list of supporting information provided in the full report

- **EASA/AEMT Test Protocol & Results (Part 1).** Includes all test data and details; explains IEEE 112 Method B motor loss calculations; summarizes differences between IEC test standard BS EN 60034-2 and IEEE 112; and demonstrates the efficacy of common tests for determining if repair processes (especially winding burnout and removal) have affected motor efficiency.
- **Good Practice Guide to Maintain Motor Efficiency (Part 2).** Describes the repair methods and tips used to achieve the study's results; discusses losses that affect motor efficiency; and explains differences in how IEEE and IEC test standards treat stray load loss.
- **Appendix 4: Electrical Steels.** Describes the different types of electrical steel and interlaminar insulation used in stator and rotor cores and how good repair practices can prevent damage.
- **Appendix 5: Repair or Replace?** Provides comprehensive information and charts to help end users and repairers decide whether it's best to repair a motor or replace it with a new, higher efficiency model, based on such factors as annual hours of operation, availability of a suitable high efficiency replacement, downtime, and reliability.

References

[1] "Good Practice Guide to Maintain Motor Efficiency," *The Effect of Repair/Rewinding on Motor Efficiency*, St. Louis, MO, Electrical Apparatus Service Association, 2003.

[2] William U. McGovern, "High Efficiency Motors for Upgrading Plant Performance," Electric Forum 10, No. 2 (1984), pp. 14-18.

[3] Roy S. Colby and Denise L. Flora, *Measured Efficiency of High Efficiency and Standard Induction Motors*, North Carolina State University, Dept. of Electrical and Computer Engineering (IEL), 1990.

[4] D.H. Dederer, "Rewound Motor Efficiency," *Ontario Hydro Technology Profile*, Ontario Hydro, Nov. 1991.

[5] Markus Zeller, "Rewound High-Efficiency Motor Performance," *Guides to Energy Management*, BC Hydro, 1992.

[6] "Rewound Motor Efficiency," TP-91-125, Ontario Hydro, 1991.

[7] "The Effect of Rewinding on Induction Motor Losses and Efficiency," Advanced Energy, EEMODS 02, 2002.

[8] IEEE Std. 112-2004: *Standard Test Procedure for Polyphase Induction Motors and Generators*, New York, NY, Institute of Electrical and Electronics Engineers, 2004. (Note: 112-1996 was the current edition at the time of the study.)

[9] IEC Std. 60034-2-1: Rotating Machines–Part 2: Methods for Determining Losses and Efficiency for Rotating Electrical Machinery From Tests (Excluding Machines for Traction Vehicles), Geneva, Switzerland, International Electrotechnical Commission, 2007. (Note: The 1996 edition was current at the time of the study.)

Download the full report (including both the "EASA/AEMT Rewind Study" and "Good Practice Guide To Maintain Motor Efficiency") at *The Effect of Repair/Rewinding on Motor Efficiency*.

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