

Maintaining Efficiency During Electric Motor Repairs

Introduction

When a motor is repaired and/or rewound, it is crucial that the steps taken to maintain efficiency be coordinated. These steps must take into account the elements that make up motor losses. Core loss testing, and other specialized tests, require engineering interpretation to effect maximum efficiency as a total concept. This is in contrast to simply monitoring and controlling one of the parameters. For example, controlling the winding end turn length alone is no assurance that the repaired motor's efficiency will be maintained. Just addressing one element can even have a negative effect on some of the others. As an analogy, think of what happens to a balloon when it is squeezed in one place. It expands, i.e., becomes larger, in the other parts of itself. For the case of a rewound motor, an effort to reduce resistance by reducing the number of turns will result in an increase in core losses and copper losses due to increased current.

Results of Laboratory Tests on Rewound Motors

Since motors are not "the perfect machine," they can never achieve 100% efficiency. Likewise, electric motors have a finite life. Even under the best of operating conditions, bearings will wear out and windings will thermally age. When repairs are performed, the two prime concerns should be to maintain nameplate efficiency and retain reliability.

During the early 1990's, a series of independent laboratory tests on rewound motors were performed in the United States and Canada. The tests indicated a direct link between a repair service center's quality assurance program and the maintenance of a rewound motor's efficiency. Where quality controls were lacking, reductions in full-load efficiency of over 3% were measured. Based on the entire sample population, rewound motors lost 1/2 to 1 percentage point in full-load efficiency. A number of the laboratory tests documented that strict attention to design parameters and quality issues maintained, and in some cases improved, repaired motor efficiency.

Repair Methods That Affect Losses

Of the five categories of motor losses, there are three types that may be directly affected by repair methods. These are the stator copper (I^2R) losses, core iron losses, and bearing friction. The stator winding losses and core losses are the main source of increased losses, respectively, for rewound motors. Bearing friction losses have been found to be the primary cause of increased losses for motor repairs not involving a rewind. The two types of losses that would normally not be affected by repairs are rotor cage losses and "stray load" losses. The rotor cage, actually a winding consisting of bars and end rings, is rarely altered during rebuilding. Stray load losses is a term for those losses that cannot otherwise be accounted for.

Stator Winding Losses

The reason for higher stator copper losses is an increase in the resistance of the winding. The root causes for this increase can be the use of a smaller cross-sectional area of wire, increasing the number of turns in the coils, and/or increasing the distance that coils extend from the stator core. The proper way for a rebuilder to address stator winding losses is to put back into the motor the exact type and size of winding that was removed. Quality assurance programs should validate that this objective has been achieved.

It should be noted that sometimes a rewinder may reduce coil length and increase wire cross-section size so that a modest *reduction* in stator winding losses, and, hence, motor efficiency can be *improved* by rewinding. Further, applying the vacuum-pressure impregnation (VPI) process to a winding engineered for VPI will also reduce losses by improving the motor's ability to dissipate heat. That is, it will run cooler.

Stator Core Losses

Stator core losses may be changed due to the winding removal process. Most often the failed windings are “pyrolyzed” to facilitate removal, that is, heated to the point where insulation physically breaks down. This process breaks down the chemical bonds that act to glue the winding wires to each other and to the core. Breaking these bonds allows the coils to be removed without physically damaging or distorting the stator core iron. The core itself is made up of laminated steel disks that are insulated from each other by a very thin coating of what is termed “core plate”. The plating process enables the core to handle alternating current magnetization without overheating. Should the pyrolyzing process become too hot, it can damage the core plate insulation -- even destroy it. Therefore, damage to the core or its insulation results in increased losses.

There are quality controls that can prevent, or at least identify, core degradation. The pyrolyzing ovens should have tight temperature control, set at the minimum temperature needed to pyrolyze a winding. Core quality can be measured prior to and following winding removal by means of a core loss test. This test magnetizes the core to a specific value, then measurements are made of the core temperature and watts loss. Core quality and core loss are maintained if the temperature and wattage are the same before and after pyrolyzing. A high quality repair service center will pursue a reduction in core temperature and losses in the winding removal process. Such a process can result in a *reduction* in core loss for the rewound motor and, therefore, *improved* efficiency. Figure 1 illustrates results from before and after pyrolyzing process core tests. Note that core loss test result for this motor was reduced 20% (657 to 522 watts) by the tight control and high quality standards imposed during the winding removal process.

PASS				FAIL			
 LONGO INDUSTRIES Wharton, NJ				 LONGO INDUSTRIES Wharton, NJ			
Customer Data				Customer Data			
Customer:	BOMA	Horsepower:	150	Customer:	BOMA	Horsepower:	150
Work Order:	14330	Voltage:	460	Work Order:	14330	Voltage:	460
Manufacturer:	Marathon	Rated Amps:	170	Manufacturer:	Marathon	Rated Amps:	170
Ser. Number:	09-02192-10-1	RPM	1780	Ser. Number:	09-02192-10-1	RPM	1780
Date:	12/21/98	Frame:	445T	Date:	12/20/98	Frame:	445T
Stator Data				Stator Data			
Diameter:	12.125	Vent Width:	0	Diameter:	12.125	Vent Width:	0
Back Iron:	1.50	Number of Vents:	0	Back Iron:	1.50	Number of Vents:	0
Slot Depth:	2.00	Length of Core:	10.625	Slot Depth:	2.00	Length of Core:	10.625
Test Data				Test Data			
Pyrolyzed:	Yes	Power Factor:	0.31	Pyrolyzed:	No	Power Factor:	0.36
Voltage:	3.633	Kiloines/Sq.In.:	90.0	Voltage:	3.628	Kiloines/Sq.In.:	89.9
Kilowatts:	0.522	Watts/Pound:	2.25	Kilowatts:	0.657	Watts/Pound:	2.84
Amperage:	458	A.T./Inch:	8.27	Amperage:	504	A.T./Inch:	9.11
Hot Spot Data				Hot Spot Data			
Duration of Hot Spot Check 15 Minutes. Unit Ran at a Level of 458 Amps.				Duration of Hot Spot Check 15 Minutes. Unit Ran at a Level of 504 Amps.			
Temperatures:				Temperatures:			
(Celsius)				(Celsius)			
Ambient	17	Core Average	19	Ambient	21	Core Average	29
Hot Spot	21	Hot Spot	21	Hot Spot	34	Hot Spot	34
Temp Rise	4	Temp Rise	4	Temp Rise	13	Temp Rise	13
Judgements				Judgements			
Temperature rise is acceptable Watts per pound are acceptable. The unit has passed core tests.				Temperature rise is marginal. Watts per pound are marginal. Core repair is recommended.			
TESTED BY: D.A.		ENGINEER: R.C.		TESTED BY: P.R.		ENGINEER: R.C.	
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Figure 1: Core loss test results from an actual motor. The core as received was defective (FAIL), and was successfully repaired (PASS), during the winding removal process.

Bearing Friction Losses

Bearing selection and replacement can also affect repaired motor efficiency. The stator winding and core losses should not be affected by repair if a motor is not rewound. Therefore, for non-rewinds the prime concern is the potential increase in bearing friction losses. The key to preventing an increase in bearing loss is to retain exactly the same type of bearing. For example, if a bearing with contact seals is installed in place of a bearing without seals, a measurable increase in losses due to friction will result. Lubrication may also have an effect, particularly if too much lubricant is used. Excess grease will result in a churning effect that generates heat and mechanically degrades the bearing, especially the ball retaining cage. Here again, a

quality program will document and assure that the original bearing type and replacement bearings are exact duplicates, and that the proper amount of lubricant is applied.

Identifying and Correcting Previous Repair Mistakes

In addition to the measures previously mentioned, there are others that can also be applied. One is an awareness that the subject motor may have been degraded either by an in-service failure or the previous work of another rebuilder. A quality repair operation can measure the relative condition of an incoming motor by maintaining and subsequently referencing a database of winding designs and core loss test results.

Repair of Energy-Efficient versus Standard Motors

Are there different repair considerations for energy-efficient motors (EEMs) compared to standard efficiency motors? This is a fair and frequent question, and the sequel to this question is "Can an EEM be repaired without suffering a loss in efficiency?"

A qualified response to the first question would be that the repair considerations are identical whether the motor in question is energy-efficient or a standard efficiency motor. There are, however, subtle techniques, such as intentionally unequal coil turns in the stator winding, that may be used by the manufacturer to increase efficiency. Unless there is great diligence, some unique features may be overlooked -- and efficiency degraded.

The answer to the second question regarding the energy-efficient motor, which strikes to the heart of a rewind, is: motor efficiency can be maintained in the repair process. The required repair methods, and the need for quality assurance, have been previously outlined in this section. Motor users should compare their rebuilder's specifications to those mentioned herein. By so doing, they can make an objective judgment of repair quality level, repair reliability projections, and the maintenance or enhancement of the motor's nameplate efficiency.

Repair and Quality Standards

The Electrical Apparatus Service Association (EASA) is the international trade organization of electric motor rewinders and rebuilders. EASA has provided its member firms with formal standards and a quality assurance program to fit the world standard on quality, ISO-9002. These repair standards are supplemented by specific repair techniques, methods, and procedures to maintain motor nameplate efficiency. While EASA membership is not necessarily a guarantee, it is an indicator that a given rebuilder is abreast of the repair issues related to maintaining motor efficiency. The more quality-conscious a rebuilder is, the greater the probability that the efficiency of a repaired motor will be maintained and that reliability will be enhanced.

The ultimate quality system recognition is accreditation by an independent third party organization. This can be achieved by pursuing ISO 9000 quality system registration, which requires continual auditing by registrars, i.e., independent quality auditor firms, that are themselves accredited by a nationally recognized body. Such quality system registration is an objective way of indicating to customers that a repair facility is as good as it claims. In order to be registered, the facility must not only "talk the talk" (have documented procedures) and "walk the walk" (procedures implemented), but they must also "prove it" (third party accreditation). Although there are only a handful of motor rebuilders in the U.S. presently registered to ISO 9000, the number is sure to grow, as it has elsewhere worldwide. The goal of these quality systems is to effect Total Customer Satisfaction, not just performing an acceptable repair.