THE MECHANICAL EFFECTS FROM THERMAL STRIPPING INDUCTION MOTOR STATORS

Howard W. Penrose, MsE
TK Design Technology, Inc.

Leo F. Dreisilker
Dreisilker Electric Motors, Inc.

Abstract: This paper describes the mechanical effects that result from the thermal stripping of induction motors. The study involved a variety of frame sizes and stator materials from a number of manufacturers.

Key words: Motor repair, Thermal stripping, air gap concentricity.

I. INTRODUCTION

Over the past decade an increasing amount of attention has been focused on electric motor repair and it's effect on efficiency and reliability. Most of the studies have dealt with efficiency and electrical effects with very little attention on the mechanical and continued reliability of the motor.

Several of the more detailed studies were performed by the Canadian Electrical Association starting with a 1991 Ontario Hydro repair study and ending with a 1994 Hydro-Quebec repair study. The 1991 Ontario Hydro study sent ten failed new 20 horsepower standard efficient motors out to several electric motor repair shops blind. An increase in losses was found in all the motors due to degradation of the motor core material. In 1993, B.C. Hydro published a similar study using nine 20 horsepower new energy efficient electric motors, failing them and sending them out blind.

The primary increase in losses was found to be caused by increased friction and windage losses due to incorrect bearing replacement. In 1994, a controlled study of electric motor repair was performed by Hydro Quebec in which several new 50 horsepower energy efficient motors were stripped, using thermal and mechanical methods, then tested. It was found that in the standard efficient motors older core steels were used which were more susceptable to heat above 410^{o}F while newer core steel can withstand higher temperatures.

At least two critical issues were overlooked in the above studies. One was the mechanical effects on the different materials used for stator housings. The second was the resulting reliability in those motors once returned to service. In addition, these effects were not viewed in motors taken from existing applications.

In this paper we shall review a study performed on twelve used electric motor stators at 650^{o}F and 800^{o}F of various stator materials, frame sizes, and manufacturers. The primary purpose was to estimate the resulting effect on reliability by modeling the changes using software. It is hoped that research will continue in this area.

II. THEORY

It is a known fact that many repaired motors do not last as long as new motors when repaired by traditional methods. The cause has not been fully reviewed nor studied.

The theory studied in this research project is that reliability is reduced through thermal effects on the stator frame. As a result, the air gap is uneven, soft foot occurs, and stator deformation and twisting occurs adding other electrical and mechanical stresses, reducing motor life. Motor stators will begin to deform naturally, resulting in changes to air gap, soft foot, and other stresses, which are accelerated when heat is applied. Stator core deformation may also occur as the stator core and frame are generally made of different materials with different coefficients of expansion. Many shops that use burnout stripping processes may cool down stators quickly prior to removing the windings. This may result in deformation as the different steels cool at different rates.

III. EXPERIMENTAL

Two sets of six used electric motor stators were selected randomly. The first set (A Group) consisted of two cast aluminum, two extruded aluminum, and two cast iron frames. The second set (B Group) consisted of five cast iron and one rolled steel frames. Frame sizes varied (Table I) randomly.

Group A was measured (Table II) and stripped using a temperature controlled burnout oven at 650^{0}F for ten hours then allowed to cool normally. The stators were then re-measured (Table III) and visually inspected (Table IV).

Group B was measured (Table V) stripped using a temperature controlled burnout oven at 800^{o}F for six hours then allowed to cool normally. The stators were then re-measured (Table VI) and visually inspected.

In both cases the same measuring instruments, procedures, and personnel were used as controls for the experiment. The core inner diameter was measured in three positions, front and back. The core position and stator dimensions were recorded. Core concentricity was measured in eight positions as were the rabbet fits. Foot flatness was measured on each foot using feeler guages and flat surfaces.

Table I
Frame Sizes

Motor	650°F	800°F
A	324T, Cast Aluminum	286T, Cast Iron
B		S324T, Rolled Steel
C		365T, Cast Iron
D	254TZ, Cast	284T, Cast Iron
E		326T, Cast Iron
F		254T, Cast Iron

A. 650°F Stripping Results

As it was observed, there were significant changes in the soft foot and rabbet fit concentricity with all of the motors. These changes were most prevalent in the aluminum stators versus the cast iron, as would be expected. In the cast aluminum stators, there was a very significant change to the soft foot condition of the motors, enough so that the stators could be noticably rocked back and forth on a smooth surface. The rabbet fit concentricity also changed significantly on all of the motors indicating warping of the ends of the stator frame. In all cases, the core remained in acceptable shape.

In addition, it was noticed that there was oxidation on the surfaces of the core steel of all of the stators and oxidation on the machined fits of the cast iron stators when they were left in a temperature controlled space for over one day. It is suspected that the cause of the oxidation is due to the raw metal being exposed and the vapor used in the temperature control of the burnout oven. Loose laminations were also observed in all of the samples tested.

B. 800°F Stripping Results

As there was a significant increase in soft foot and stator deformation in the aluminum stators at 650°F, the 800°F test was performed on cast iron and rolled steel stators only.

As it was observed, there were significant changes in soft foot, rabbet fit concentricity, and core steel position. Visually, the stators had some warping, and oxidation set in on all stators within two days. In addition, there were severe instances of loose laminations in all of the stators.

C. Modeling Results

The results were formed into three dimensional models using AutoCAD Version 14 and 3D Max. The purpose of modeling was to present an exagerated visual as well as a true dimension determination of the effects of rotor position within the stator.

Modeling the results created an understanding of what was truly happening to a motor in which even minor distortion was occuring. Those results were fairly dramatic and go a long way to help determine why some repairs do not seem to last as long as others.

D. Effect of Distortion on Reliability

The effects of frame distortion are more profound than was expected at the outset of this study. While other studies have shown an increased resistance to heat, by the core, this study has shown that even existing thermal stripping temperatures can affect the reliability of repaired electric motors.

One of the significant findings was an increase in soft foot. Soft foot, in this case, is a sign of frame twisting (as the motors were mounted vertically in the burnout oven). Once placed back into service, these motors may see an increase in frame stress, reduced air gap, or cracking of the frame or base if the soft foot is not properly compensated for.

Loose laminations indicate that the insulation between the laminations has been destroyed. This could cause increased core losses if the stator is improperly varnished. This situation may also cause additional noise in motors used in inverter applications. The stators in which the laminations had turned blue indicate low grade lamination materials. The bluing of the laminations indicate a change in the steel itself, indicating increased reliability; these effects are:

1 120 Hz (twice line frequency) mechanical vibration. This results in reduced bearing life and other vibration-related defects.

2 Shaft currents due to impressed currents onto the shaft. If these are severe enough, reduced bearing life will occur due to Electrical Discharge Machining, or bearing currents.

3 Rotor Rub, in severe instances may result. This occurs most often in motors which have tight air gaps or low grade steel or aluminum frames.

Bearing life is also reduced due to increased bearing stresses as the end shields are moved from the original position due to Rabbet fit and other frame dimension changes. The bearing may have the outer race slightly off center from the inner race, causing the balls to run out of center. In severe cases, this phenomenon will show on vibration analysis as a cocked bearing.

III. CONCLUSIONS AND SOLUTIONS

It can be found that there are definite mechanical effects due to thermal stripping of electric motors even at temperatures of 650^{o}F or better. This phenomenon is more severe in metals which have high rates of thermal expansion due to thermal distortion. Part of this is due to the original manufacture of the electric motor with "green metals," however, a great deal is due the the expansion, contraction, and distortion of the metals at high temperature. Also, as the higher temperatures often remove protective coatings from the core steel and frames, if they are not coated quickly they begin to oxidize. This may even be further aggravated by adding additional contaminants to the thermal stripping environment.

The result of the changes to a motor stator is reduced repair reliability. This reduction is due to stator stresses, bearing stresses, increases in soft foot, and air gap eccentricity. These causes can greatly reduce the life of repaired electric motors significantly (how to determine an approximate amount is the subject of a future paper). While further research is continuing in this area, the following should be observed in any motor repair in order to ensure reasonable reliability:

1 Use the lowest possible temperatures for as short a time as possible when stripping motors.

2 Remove the shells of aluminum frames when using temperatures of 600^{o}F, or more. (Note: Doing this may present a whole list of new potential challenges.)

3 Measure changes to the rabbet fits and foot flatness before and after stripping when using temperatures in excess of 600^{o}F.

4 Whenever possible, immediately coat the stator and laminations, after burning out, so that the parts will not oxidize.

Howard W. Penrose is the Vice President of TK Design Technology, Inc., a Training, Visualization, and Engineering support firm. He is the present Chair of the Chicago Section of IEEE, Vice Chair of the Fox Valley Subsection, and Chair of both the DEIS and PELS. Mr. Penrose has been involved in the electric motor distribution, repair, and engineering industry for over 12 years.

Leo F. Dreisilker is the President of Dreisilker Electric Motors, Inc. He has been involved in all aspects of the electric motor system aftermarket for over 25 years. Mr. Dreisilker has supported independent electric motor repair research for over the past five years.

APPENDIX

Table II
Before Thermal Stripping, 650°F Stators

Measurement	A	B	C	D	E
Core					
0	-0.0005	0	0	0	0
90	+.003	-0.005	-0.0035	0.003	0.0055
180	-0.0005	0.003	-0.003	0.005	0
270	-0.001	0	-0.004	0.005	-0.0035
Rabbet Fit					
0	0	0	0	-0.0005	0
45	-0.0005	-0.003	0.0015	0	0
90	0	-0.0035	0.0035	0.001	0.0015
135	0.0005	-0.0075	0.004	0	0.002
180	0	0	0	0	0
225	0.001	0	0.005	0.001	0
270	0	-0.003	0.0035	0.001	0.0015
305	-0.0035	0	0.003	-0.0005	0.0025
Foot Flatness					
1- F2, DE	0.001	0.005		0.001	0.001
2- F2, ODE	0.005	0.001		0.001	0.001
3- F1, DE	0.001	0.001		0.001	0.005
4- F1, ODE	0.005	0.001		0.001	0.005

Concentricity readings are taken from different points, depending on the motor. F1 is the left side of the stator facing the shaft end, F2 is the right side of the stator facing the shaft end. DE stands for Drive End, ODE stands for Opposite Drive End.

Table III
After Thermal Stripping, 650^{o}F Stators

Measurement	**A**	**B**	**C**	**D**	**E**
Core					
0	0	0.0025	0	0	0
90	-0.0035	0.005	-0.006	-0.009	0.0045
180	-0.024	0.01	-0.011	-0.0065	0.007
270	-0.018	0.0025	-0.004	0.004	0.009
Rabbet Fit					
0	-0.0005	0	0	0.002	0
45	0	0.002	-0.008	0	0
90	0.004	0.003	-0.011	-0.0005	-0.007
135	0.0105	-0.018	-0.011	0.002	-0.003
180	-0.0005	0	0.0005	0.0005	0
225	0.035	-0.006	-0.01	0	0
270	0.004	0.0025	-0.011	0.0015	-0.0065
305	-0.0005	0.003	-0.005	0.0065	-0.0055
Foot Flatness					
1- F2, DE	0.025	0.065		0.002	0.001
2- F2, ODE	0.015	0.001		0.002	0.001
3- F1, DE	0.01	0.001		0.001	0.005
4- F1, ODE	0.005	0.05		0.013	0.005

Concentricity readings are taken from different points, depending on the motor. F1 is the left side of the stator facing the shaft end, F2 is the right side of the stator facing the shaft end. DE stands for Drive End, ODE stands for Opposite Drive End.

Table IV
Visual Inspection and Notes for 650^{o}F
Post Thermal Stripping Stators

Stator	**Notes**
A	Laminations loose 1/4 inch on either side of the stator core. Over 50% of exposed surfaces had become oxidized after 2 days.
B	All laminations loose. All varnish on the core surfaces gone. Approximately 25% of the visible portions of the laminations, particularly around the teeth, discolored/blued. Approximately 25% of exposed surfaces oxidized after 2 days.
C	Laminations loose over 1/4 inch from either side. Less than 25% of exposed surfaces oxidized after 2 days.
D	Over 40% of exposed surfaces oxidized after 2 days. All laminations loose, with no varnish on exposed surfaces.
E	Laminations loose over 1/4 inch from either side. Less than 25% of exposed surfaces oxidized after 2 days.

Table V
Before Thermal Stripping, 800°F Stators

Measurement	A	B	C	D	E
Core					
0	0	0	0	0	0
90	-0.0025	-0.012	-0.004	-0.0045	-0.0075
180	-0.0015	-0.009	0.003	-0.011	-0.012
270	0	0.0025	0.0015	-0.008	0.0005
Rabbet Fit					
0	0	0	0	0	0
45	-0.001	0.0005	-0.0015	0.0005	0.002
90	-0.0005	0.003	0.006	0.004	0.006
135	0.001	0	-0.006	0.002	0.0055
180	0	0.0005	0	0	0
225	-0.0005	-0.004	-0.012	0	-0.002
270	-0.0005	0.0015	0.0055	0.005	0.006
305	-0.003	-0.001	-0.006	0.002	-0.0035
Foot Flatness					
1- F2, DE	0.0025	0.012	0	0	0.0015
2- F2, ODE	0.001	0.008	0.003	0	0.006
3- F1, DE	0.0085	0.008	0	0	0.003
4- F1, ODE	0	0	0	0	0.006

Concentricity readings are taken from different points, depending on the motor. F1 is the left side of the stator facing the shaft end, F2 is the right side of the stator facing the shaft end. DE stands for Drive End, ODE stands for Opposite Drive End.

Table VI
Before Thermal Stripping, 800°F Stators

Measurement	A	B	C	D	E
Core					
0	0	0	0	0	0
90	-0.009	-0.0135	-0.009	-0.009	0.005
180	-0.013	-0.006	0.006	-0.0135	-0.0025
270	-0.003	0.001	-0.0015	-0.0065	0.0045
Rabbet Fit					
0	0	0	0	0	0
45	-0.0015	-0.0025	-0.0015	0.0015	0.003
90	0.001	-0.002	-0.0095	-0.006	0.006
135	0.0005	0.0025	0.005	-0.0035	0.0035
180	0	0	0	0	0
225	-0.0005	0.002	0.006	0.0005	-0.005
270	0.001	-0.0015	-0.009	-0.006	0.006
305	-0.0035	-0.0025	0.0015	-0.003	-0.0025
Foot Flatness					
1- F2, DE	0.011	0.008	0.003	0.001	0.008
2- F2, ODE	0.014	0.004	0.009	0	0.011
3- F1, DE	0.013	0.025	0.002	0	0.003
4- F1, ODE	0.002	0.01	0.011	0	0.004

Concentricity readings are taken from different points, depending on the motor. F1 is the left side of the stator facing the shaft end, F2 is the right side of the stator facing the shaft end. DE stands for Drive End, ODE stands for Opposite Drive End.

Three Dimensional Motor Model