Core Loss and Core Hot Spot Testing: An Overview

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Abstract: What is the importance and differences between core loss testing and hot spot testing in electric machines through the repair process? How are they performed and what results do they provide? In this short article we will discuss the basics of core and hot spot testing and their impact on electric machine reliability. This white paper is limited to stator cores only with other core loss types being presented in future white papers.

I. Introduction

The electric motor repair and rewind process is a crucial aspect of maintaining and extending the life of electric motor assets and investment when less than the cost of replacement. This process involves replacing damaged or aged components, such as the windings, bearings, and insulation system in a way to restore the motor's performance and efficiency. One of the critical steps in ensuring a reliable and efficient motor rewind process is conducting core loss and hot spot testing to evaluate potential damage during the rewind process or as a result of original equipment failures or deficiencies.

Traditionally and during standards development there is often disagreement in the energy used to evaluate the core and what constitutes a pass or fail. The field strength designed into and applied to the core will generate a measured combined watts loss of hysteresis and eddy current losses of the core laminations. These losses are defined as:

1. Hysteresis loss (watts): energy loss caused by the continuous reversal of magnetic domains in the core material as it follows the alternating magnetic field. This value can only be changed in newer energy and premium efficient core steels with extreme heat beyond what is expected through industry standard temperature-controlled burnout oven practices as identified by EASA (Electrical Apparatus Service Association and the US Department of Energy).
2. Eddy current loss (watts): energy loss due to the circulation of induced currents within the core material. The separation of laminations with insulating material is used to keep this value low. Small shorts from smearing, breakdown of insulating material, small burrs across laminations, and other defects.
3. To some extent warped laminations will also cause deficiencies in core loss and hot spot tests due to a fringing effect.

The following IEEE and EASA standards and tech notes cover the use of core loss testing:

1. IEEE Std 117-1992, "IEEE Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electric Machinery," which was superseded by IEEE Std. 56-2016.
2. IEEE Std 56-2016, "IEEE Guide for Insulation Maintenance of Electric Machines," which combined random wound and form wound machine insulation systems into a single standard including the decision to select 0.85 to 1 Tesla core saturation.
3. IEEE Std 62.2, "IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus – Electrical Machinery."

4. IEEE Std 1068-2015, “IEEE Standard for the Repair and Rewinding of AC Electric Motors in the Petroleum, Chemical, and Process Industries,” which is an industry consensus standard for repair.
5. EASA Std AR100-2020, “Recommended Practice for the Repair of Rotating Electrical Apparatus,” which is the motor repair industry recommendations for repair practices.
6. EASA Technical Manual.
7. EASA Tech Note No. 17, “Stator Core Testing,” which provides details on manual evaluation of stator core losses and hot spots.
8. NAVSEA S6260-BJ-GTP-010, “Electrical Machinery Repair; Volume 1, Electric Motor, Shop Procedures Manual.”
9. NAVSEA S9086-KC-STM-010, “Naval Ships’ Technical Manual Chapter 300 Electric Plant – General.”

II. Purpose of Core Loss and Hot Spot Testing

Both core loss and hot spot testing plays an essential role in the motor rewind process in order to:

1. Diagnose inefficiencies: the losses in the core represent an average of 15% of the total electric motor losses. Through measuring core losses before and after removing copper and core repairs the repair shop can identify any additional core losses and will pinpoint areas that may require repair or replacement.
2. Identifying damaged core sections: used to identify damaged or deteriorated sections of the core that may contribute to increased energy losses and decreased reliability. Increased temperatures around damaged core sections will accelerate degradation of insulation materials in the winding reducing the motor’s ability to survive operating conditions over time.
3. Location of weak points or failure-prone sections: hot spot testing can identify areas that will operate with higher than expected temperatures and related thermal stress, which can be addressed through the repair process.

III. When is Core Loss and Hot Spot Testing Performed

Both tests are normally performed in electric motors during normal repair when visible damage has occurred to the core such as rotor rubbing or material passing through the core. Other instances are when previous rewinds have occurred without checks and visible damage or missing laminations are found.

In the rewind process core loss and hot spot testing is performed before and after removing the copper from the core. This is to provide testing and evidence that no damage occurs during the process. Standards such as IEEE 1068 identify that core losses should not change more than 20% and all standards identify that hot spots shall not exceed 10C over the ambient of the core. Multiple technical papers and standards discuss an average limit of 6 watts per pound for smaller and medium machines (EASA Tech Note 17). This value will tend to be lower in higher efficiency electric machines and higher in large machines such as power generators.

IEEE 1068 provides the following limits based upon the Tesla value of the core. When using a core loss tester or IEEE Std 62.2 in which hot spot testing is performed for 30 minutes and should not have any hot spots greater than 10C. Core loss of high efficient motors at a calculated 1.4 Tesla should be no more than 6.6 W/kg (3 W/lb) or standard efficient motors at 11 W/kg (5 W/lb). Losses should not increase more than 20% between the before and after core loss test.

It is important to ensure that the proper dimensions of the core and air ducts are observed as well as the peak core flux in Webbers, which can be calculated as per formula C.2 in IEEE Std 56. One of the challenges with IEEE Std 56, however, is that Annex C outlines values of 0.85 to 1 Tesla when testing the core, which changes the effective watts loss findings to lower values than those found in IEEE 1068 and EASA standards. The selection of the pass/fail values were heavily debated in the development of IEEE Std. 56 with manufacturers pressing for lower values of saturation.

IV. The Use of Infrared in Core Loss Testing

While most standards mention the use of fixed thermal sensors; a common approach to detection of hot spots when high energy is applied to the core is infrared. Selecting a good infrared camera that is not affected by the magnetic fields and an experienced technician who can discern results of surface temperatures versus reflection. Other considerations are warped core laminations with dirt or contamination in between that can arc and cause false high temperatures.

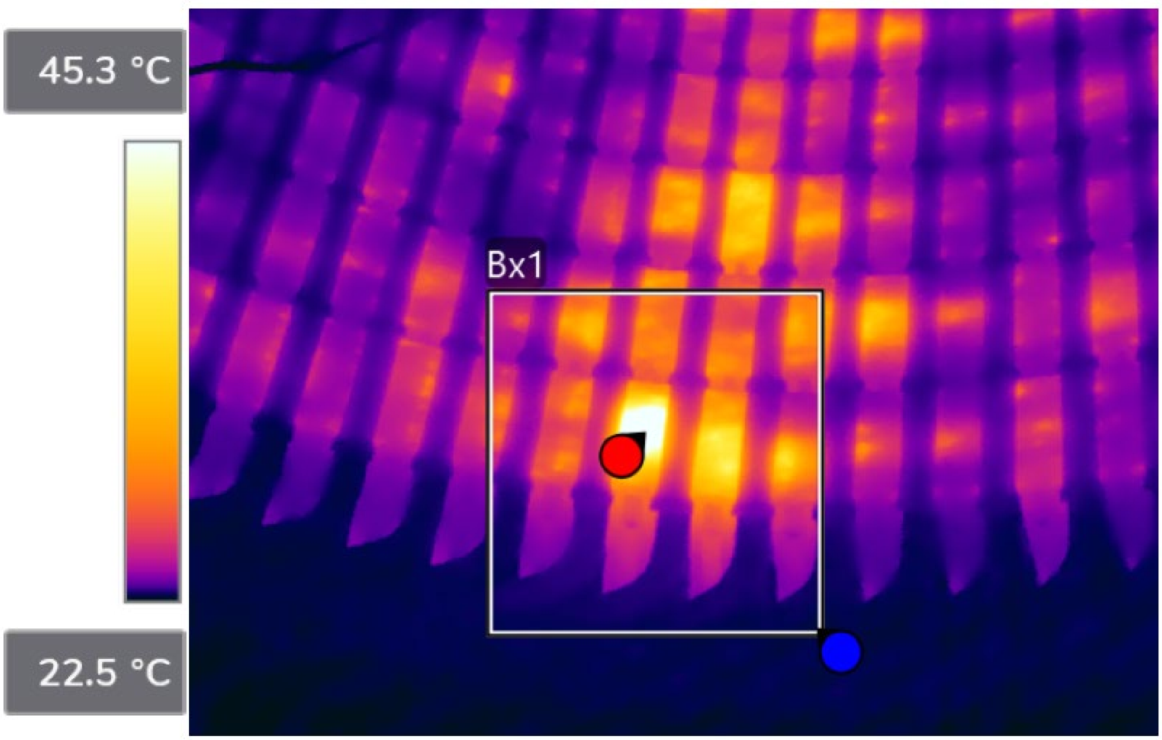

Figure 1: Infrared of hot spot in a core with a 54.2C hot spot versus 26.3C average.

Differences in core color, lighter color laminations and lighting can cause false positives. The infrared should be taken as close to perpendicular to the stator core as possible. However, in cases such as shown in Figure 1 the ~28C hot spot appears to be relatively obvious.

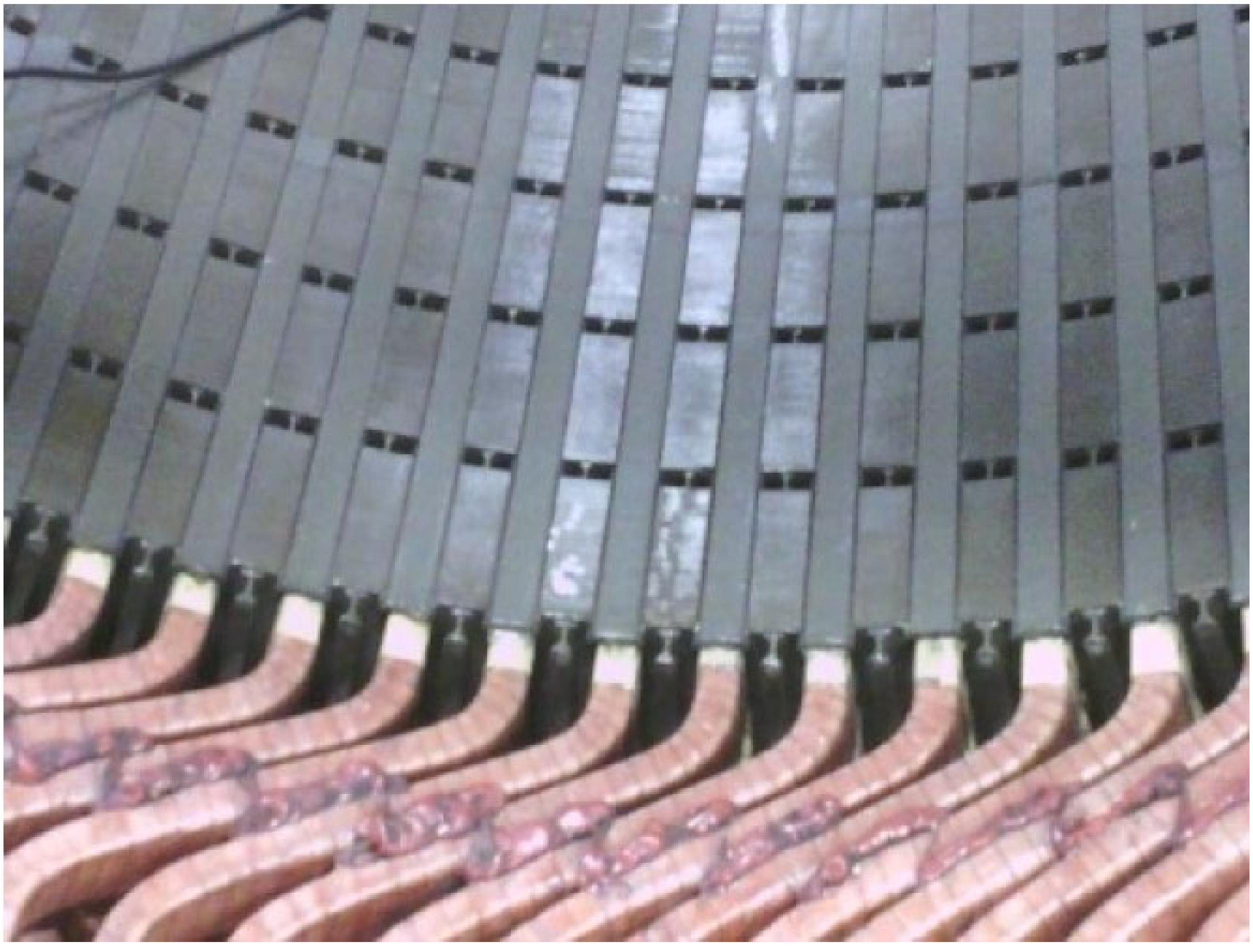

Figure 2: stator with white dots marking where hot spots were located.

As shown in Figure 2, hot spot related damage is not always visible.

V. Conclusion

In this basic overview of core loss and hot spot testing we've discussed the basic reasons for this test, the standards and references, and the average target values. The impact of core loss and hot spot testing is in relation to both excess losses during operation and degraded insulation resulting in reduced reliability with the expectation of ground faults. In some cases, it is cost effective to reinsulate and restack the core, replace laminations, or other repairs without removing the laminations. In others it could result in a temporary repair while a replacement is found. Finally, outright replacement of the motor would be warranted in the case of the findings of Figures 1 and 2.