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NORMAL FLUX DISTRIBUTION IN 45° T-JOINT OF THREE PHASE TRANSFORMER CORE WITH STAGGERED YOKE AND LIMB10MM

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ABSTRACT
This paper describes the result of measurement of normal flux distribution 3-phase 100kVA transformer core assembled with 45^0T-joint. The investigation involves the variation of normal flux distribution in the core lamination. The normal flux distribution has been measured using no load test by arrays of search coil. The highest normal flux distribution occurs at the corner edge of the centre limb that is 0.160T and lowest at upper edge of yoke that is 0.121T. The average value of normal flux distribution is high at flux transfer region of the lamination. The flux transfer mechanism shows that two separate path flowing horizontally in the yoke before leaving the lamination to vertically adjacent layer and combine with the flux in that layer. Then, it will transfer back to origin region and extend through the centre limb.

KEY WORDS
Grain oriented silicon iron, transformer core, normal flux distribution, fundamental flux.

1. Introduction

Power transformers are usually employed in electric power stations, high voltage transmission lines and large utilities. On the other hand, distribution transformers can be found in small and midsize industries, hotels, hospitals, schools, entertainment centers, residential areas and etc [1].

Transformers are ubiquitous in all part of the power system, between all voltage levels, and exist in many different sizes, types and connections [2]. Grain-oriented 3% silicon-iron is used for transformer cores where high efficiency and low weight are often paramount [3]. The efficient operations of power transformer cores depend on a large extend on the design of the joints between their limbs and yokes. The most complex joint in three limb cores are the T-joints at the intersection of the centre limb and yokes. Under ideal conditions the total flux in the limbs of a transformer core has a sinusoidal waveform, but in the corners of the core the flux is far from sinusoidal. The additional loss caused by the flux distortion can lead to localized heating within the joints [4]. Previous research work had been carried out on interlaminar flux density distribution (normal flux) at T-joints and corners of transformer cores built with grain-oriented Si-Fe laminations in various configurations [4]. The interlaminar flux change has already been used to estimate additional localized loss of transformer cores and also to help achieve optimum joint configuration of a transformer core.

The objective of this research is to measure normal flux distribution on the lamination of transformer core that built from the electrical steel (M5 grade material) 3% silicon-iron assembled with 45^o T-joint mitred lap corner joint with staggered yoke and limb by using arrays of search coils.

2. Experiment Apparatus and Measuring Techniques

Three phase 100kVA distribution transformers are assembled with 45° T-joint, mitred overlap corner joints length of 10mm as indicated in figure 1. Each core is 550 mm x 580 mm with the limbs and yokes 100 mm wide as indicated in figure 2. The main apparatus consisted of three phase cores, two yoke cores and three limbed cores and the cores are assembled from 0.3 mm thick laminations of M5 grain oriented silicon iron (CRGO) [7]. Each core comprises of 15 layers. The system for measuring normal flux density is shown in Figure 3.

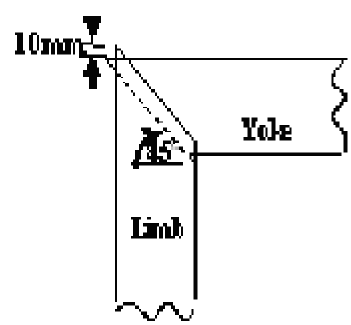

Fig. 1: Corner-joint transformer core type with staggered yoke and Limb 10mm

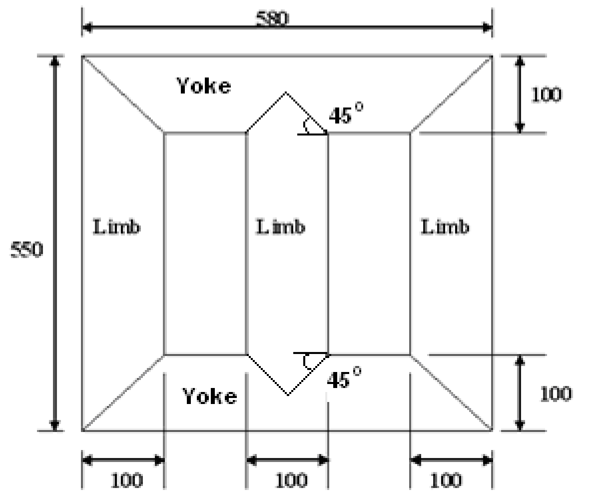

Fig. 2: Dimension (mm) of 45̊ T-joint 100kVA transformer model

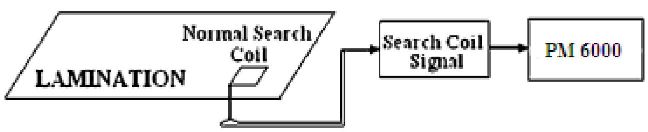

Fig. 3: Associated system for measuring normal flux density.

In order to study the normal flux density variation, normal search coil arrays are used to measure normal flux density variation along and across the lamination. The squares of 10mm x 10mm normal search coils of 0.15mm diameter copper wire stuck on test laminations in the T-joint of the transformer core using polyurethane varnish. The solderable enamel copper wire is to thin enough for winding the single turn search coils, without affecting the flux distribution to any degree. Each pair of search coil leads is twisted together tightly to avoid stray voltage. The locations chosen must cover the areas where the flux is more likely to vary direction so as to find the mechanism distribution of the flux behavior. The location of the investigation for the transformer core is shown in figure 4.

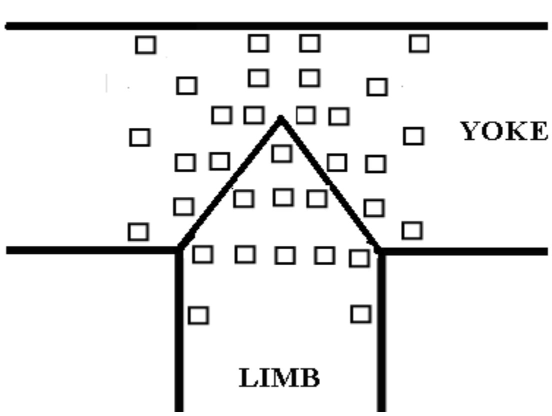

Fig. 4: The normal search coils position in the T-joint of transformer core

3. Results and Discussion

Fundamental normal flux density at T-joint flowing in a direction normal to the plane of the lamination in the staggered yoke 10mm 1.5T, 50Hz is shown in figure 5.

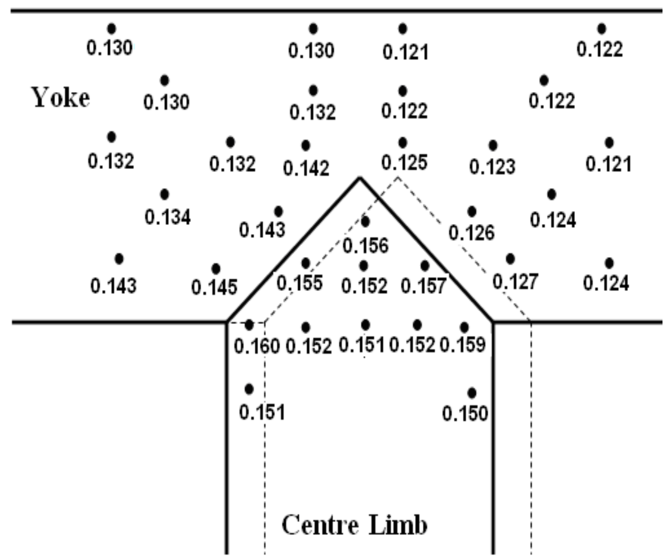

Fig. 5: Distribution of the normal direction of fundamental flux density at T-joint with overlap length of 10mm during 1.5 at 50Hz.

The magnitude of the normal flux density is high at and close to an intersection between two adjacent laminations. The highest normal flux occurs at the corner edges of centre limb that is 0.160T at flux density 1.5T, 50Hz. The average magnitude of normal flux density is largest at the overlap region and smallest at the upper edge of the right yoke. The fundamental normal flux density increases as it approaches the T-joint and gradually decrease as it travels further away from the joint. The magnitude of fundamental normal flux density traveling between joints reaches minimum at the mid point of centre limb. This alteration in the fundamental normal flux density is due to increase and decrease of flux density that has been energized.

The instantaneous magnitude and direction of flux at this instant is shown in figure 6 at this instant the total flux in the centre limb reaches its maximum and both right and left yoke carry half their maximum flux.

Since the yokes carry only half the maximum value of the total flux, the majority of the flux from the outer of right and left yoke is carried through the inner half of butt-joint of centre limb and the largest flux concentration is found in the upper edges of centre limb.

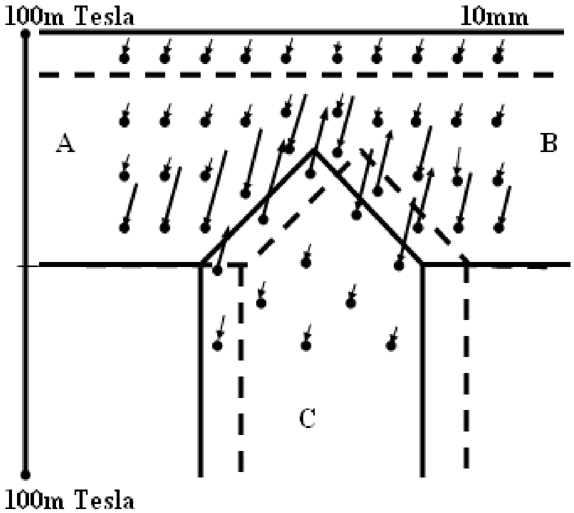

Fig. 6: Distribution of the fundamental component of localised normal flux density in the 45 ^{o} T-joint of three phase core built at different instant in time when $\omega t=60^{o}$.

Flux path and flux transfer mechanism between laminations at the T-joint has been illustrated as figure 7 for staggered yoke arrangement. The diagram shows that the flux transfer mechanism between yoke and limb in the T-joint may occur simultaneously at the same instant in time. This can be seen for example at the A and B region where two separate path flowing horizontally before leaving the lamination to vertically adjacent layer of D and F respectively and combines with the flux in that layer. Consequently, the core material in this region approaches saturation. At the same time, this existing flux will transfer back to the C region and extend to the whole length of the middle limb. It has been noticed that the magnitude of normal flux density high at the butt-joint and decrease as the distance away from the joint.

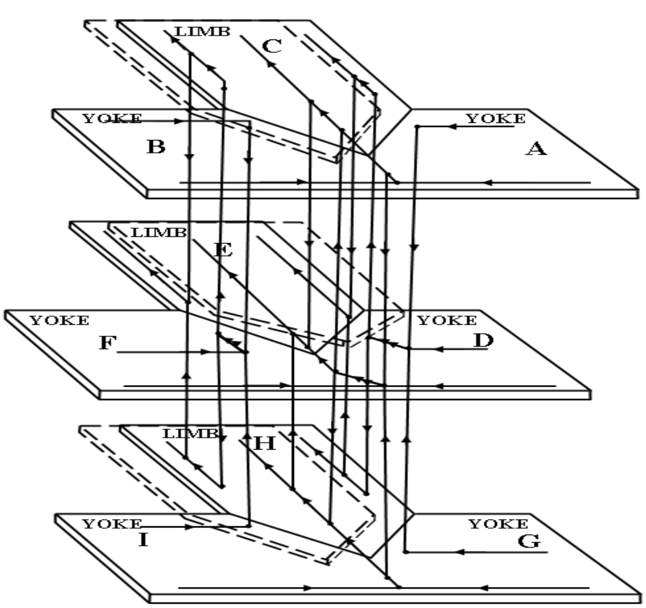

Fig. 7: Flux transfer between laminations of staggered yoke limb arrangement at the T-joint.

4. Conclusion

From the result of this investigation, the normal flux distribution in the cores assembled with 45^{o}T-joint was found varies along overlap area of the staggered at the T-joint. High normal flux distributions occur in the corner edge of the centre limb that is 0.160T and gradually decrease as it travels far away from the joint area.

The flux transfer mechanism between yoke and limb in the T-joint may occur simultaneously at the same instant in time. The flux transfer mechanism most occur at T-joint of the transformer core compared to other places. The magnitude of normal flux density is high at the butt-joint and decrease as the distance away from the joint.

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