"Role of Insulation Coating in Electrical Steels and their Final Applications"

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Abstract- Insulation coating is used in the electrical steels in order to reduce the losses occurred in the form of heat loss which is a part of overall core loss. These heating losses can be controlled by applying insulation coating by considering suitability and according to specific requirements. The guidelines for selection of appropriate coating are discussed in this paper.

Keywords: Electrical steel, coating, core loss

I. INTRODUCTION

The steel used in the steady and rotating electrical applications in daily life require high efficiency and lower losses. For this, manufacturers use particular type of steel i.e. Electrical Steel. The electrical steel industry mainly manufactures steel for the electrical appliances such as industrial and home appliances. These applications mainly include industrial motors, pump motor, traction motors, hybrid vehicle motors, compressor motors, alternator motors, large capacity generators etc. [1] Along with the rotating applications the stationary applications such as transformers also require electrical steels.

These steels are basically classified in two types

a. Cold Rolled Grain Oriented Electrical Steel (CRGO)
b. Cold Rolled Non Grain Oriented Electrical Steel (CRNGO)

For both the types of electrical steel the main requirement from the applications is
   a. Lower Hysteresis Loss
   b. High Insulation Resistance

This is the prime requirement of any electrical steel.

[3]The hysteresis losses are controlled with annealing and steel ingredients such as silicon (Si). The insulation resistance is achieved by applying insulation coating over the surface of electrical steel. This insulation coating is acting as insulator between the laminations and become cause for reducing losses like eddy current loss.

II. TYPES OF INSULATION COATINGS AS PER ASTM STANDARD

[1]As per ASTM Standard A976 the types of insulation coating for electrical steels are given in table no.1. This classification is mainly according to the chemistry, relative insulation resistance and its functional properties. The purpose of classification is to assist the manufacturers of electrical appliances for providing information related to insulative ability, punchability, temperature sustainability, weldability etc. for each coating type. The table no.1 provides the classification of insulation coating. The coatings are made of organic, inorganic or mixture of both organic and inorganic contents, proportion of which is decided as per required insulation resistivity values of end application requirements. Basically the semi processed steels are processed through bluing process which forms thin layer of oxidized film over the laminations of electrical steel which generally come under C0 type of coating. Other than C0 for cold rolled grain oriented and cold rolled non grain oriented electrical steel the application of coating is varied from C2 to C6 depending upon the insulation resistivity as mentioned earlier in this paper. Insulation coating classification as per ASTM standard A976 is shown in the following table.

Table No.1 [1]

Classification of Insulating Coating for Electrical Steel	
C0	An insulation consisting of the natural oxide film formed during mill processing. This thin coating will withstand normal annealing temperatures and oxides surface condition may be enhanced by annealing furnace atmosphere
C2	An inorganic insulation coating that consists of a glass-like film which forms during high temperature hydrogen anneal of grain oriented silicon steel as a result of the reaction of an applied coating of magnesium oxide and silicates in the surface of the steel. This coating is abrasive and can withstand normal stress relief annealing.
C3	An organic enamel or varnish coating that is applied over the steel's natural oxide surface. It provides very high levels of surface insulation resistance as well as protection against rusting. It also can increase die life by providing lubrication during the stamping process. While suitable at normal operating temperatures of electrical devices, it will not withstand the heat of stress relief annealing.
C4	An inorganic coating that is produced by a special chemical and thermal processing of the steel surface. It is best for punched laminations where only a moderate degree of surface insulation and increased die life are desired. This coating is not harmed by standard stress relief annealing temperatures, retaining adequate surface insulation characteristics.
C4AS	This anti-stick surface treatment provides protection against lamination sticking during the annealing process of semi-processed steels.
C5	This is a high-resistance insulation formed by a chemical treatment similar to that of C4 but with the addition of an inorganic filler to enhance its electrical resistance. It will withstand stress relief annealing if temperatures do not exceed 1500 degrees F (815 degrees C) and a neutral or slightly reduced atmosphere is used.
C5AS	A C5 type coating used primarily for preventing sticking of semi-processed non-oriented electrical steel and cold-rolled motor lamination steel during quality anneals. It also could facilitate welding of rotors/stators and minimize welding residue.
C6	This is an organic based coating with inorganic fillers added to improve insulation qualities. It is typically used for fully processed non-oriented steels. The coating improves the punchability of steel.

III. SELECTION OF INSULATION COATING TYPE

The selection of insulation coating will be depend on various factors such as size of motor lamination, end application of the motor, where it is used i.e. atmospheric conditions like temperature, humidity etc.

Mainly the final application user selects thinner coating for small laminated application. [2]This is because in smaller application the role of insulation coating in the core loss is very little and even if they use bare material then there should not be much difference in the losses compared with coated one. But in case of bigger size lamination it is necessary to have insulation coating over the electrical laminations. This requires mid-thick to thicker type of coatings.

Also depending on the applications it defers the selection of insulation coating type.

IV. PURPOSE OF INSULATION COATING

Following are some of purposes and their reasons explained for the application of insulation coating over electrical steel strip surfaces.

a. *Reducing eddy current loss-*

When electrical steel used as lamination core, [4] which is made of non-coated core material then the inter laminar electric current shorts and causes more power loss in the form of eddy current losses. In order to minimize eddy current losses, insulation coating is applied over the laminations which is used to reduce eddy current and losses due to it. Following Fig.1 shows the core loss distribution in the application.

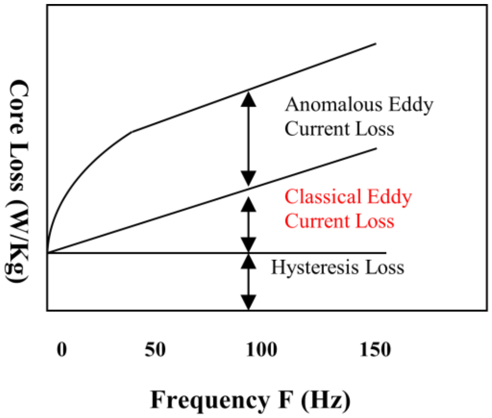

Fig.1. Core loss distribution

b. *Protecting steel from external environment-*
It protects from external environmental conditions like salts, oil, contaminations etc.

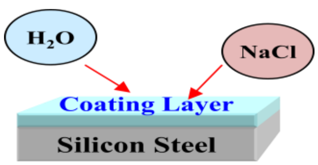

Fig.2. External environment factors

c. *Enhancing corrosion resistance and anti-weathering ability.*
The inorganic matter in the insulation coating behaves as anti corrosion resistant.

d. *Enhancing anti-oil , coolant*
   i. In motor core, insulation coating reduces the deterioration of steel from oil and external heating.
   ii. When motor is used under certain hot temperature (above 150°C) like turbo generator, coating layer should able to keep its insulation and adhesion properties.

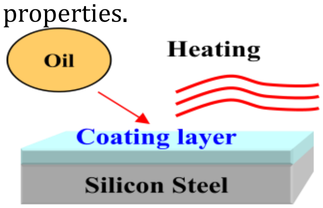

Fig.3. Heat and oil factors

e. *Enhancing the Punchability and Feeding ability*
   i. Punching ability –The organic ingredient in coating layer has cushion effect between die and punch, so the die life increases.
   ii. Strip feeding ability Increases.

f. *Protecting steel from the surface scratch caused by friction during punching process.*

V. SURFACE INSULATION COATING DEFECTS AND FACTORS CONTRIBUTING THE DEFECTS [2]

Many insulation defects occur in surface coating process through various reasons. These defects are mainly generated due to faulty process parameters of coater. Also there are some factors like damage of coater roll, nip pressure imbalance, bubble generation speed variation etc are some regular factors which contributes in the coating defect generation process. Following are some coating defects occur in process as;

a. Uncoated spots
b. Coating groove line
c. Coating peel off
d. Solution stain
e. Roll mark
f. Powder formation

The factors which contributes the above defects are as follows

a. Increase in solution temperature
b. Damage of roll threads
c. Solution density variation
d. Damage to coater roll
e. Nip (Roll) pressure imbalance
f. Drying and curing temperature fluctuation

Various factors individually and along with other factors combine together to produce different coating surface defects. Due to these surface defects, the final property of insulation resistance gets affected. As the insulation resistance decreases the power losses will increase and ultimately the overall efficiency decreases.

VI. EFFECT OF INSULATION COATING DEFECTS ON FINAL APPLICATION OF ELECTRICAL STEEL PRODUCTS.

The process of manufacturing motor laminations from a slitting of coil to assembly as shown in fig 4.

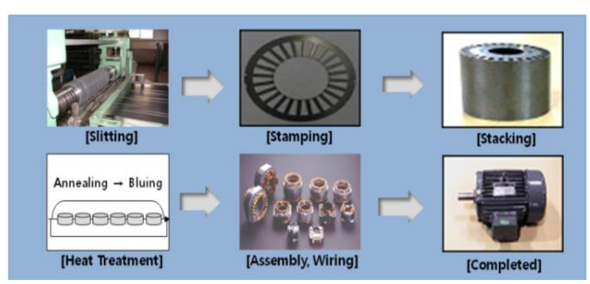

Fig.4. Process flow of end application product from electrical steel products

- Due to defects like uncoated spots, uncoated lines in products, there is chance of electric contact between two lamination surface of motor stack and get short.
- Due to this short eddy current is generated and heating losses are increased.
- These eddy current losses ultimately increase overall losses of motor and decrease motor efficiency.

VII. SUMMARY

In order to select appropriate insulation coating type this paper gives a brief idea for classification of insulating coatings for electrical steels according to their composition, relative insulating ability, and functionality. The main purpose of this classification is to simplify the selection of coating for the end users of insulating coatings. One should consider the coatings insulating ability, punchability, temperature sustainability, weldability, and fabricability before selection. Also the coating defects and their effects on end applications in the form of losses must be considered in order to improve the efficiency of end application.

VIII. REFERENCES

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