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Research Article

The Analysis of Single Coil Circuit Model of Food Grade Knitted Fabric

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Abstract: In this study, we study the single coil circuit model of food grade knitted fabric. The eddy current loss is related to the electrical conductivity, the closure of the coil and the frequency of electromagnetic wave based on the Faraday electromagnetic induction theory. Thus, it can construct a sensor circuit model of fabric coil and analyze the influence of resistance value of coil to the shielding effectiveness.

Keywords: Conductivity, contact resistance, sensor circuit model, the resistance of knitted coil

INTRODUCTION

Yarns form food grade knitted fabric through the regular mechanical movement of knitting needle and between the coil and the coil with each other. So, the fabric coil is the minimum unit of food grade knitted fabric and it is an important sign to recognize the food grade knitted fabrics. The fundamental reason why the food grade knitted fabric with electromagnetic shielding is conductive metal fiber's participation, which makes the coil to generate eddy current loss of the electromagnetic waves (Cizhang, 1986). Based on the Faraday electromagnetic induction theory, the eddy current loss is related to the electrical conductivity, the closure of the coil and the frequency of electromagnetic wave. Thus, it can construct a circuit model of fabric coil and analyze the influence of resistance value of coil to the shielding effectiveness (Xianchong, 1986).

In this study, we study the single coil circuit model of food grade knitted fabric. The eddy current loss is related to the electrical conductivity, the closure of the coil and the frequency of electromagnetic wave based on the Faraday electromagnetic induction theory. Thus, it can construct a sensor circuit model of fabric coil and analyze the influence of resistance value of coil to the shielding effectiveness.

THE CIRCUIT MODEL OF FOOD GRADE KNITTED FABRIC COIL

Food grade knitted fabric strings into a circle, between the two transverse coil connected by the sinker loop and the two longitudinal coil through extension line, needle loop and leg connected, The conductivity of yarn will affect the conductivity at the contact point of interleaving place. Based on the analysis, if assume that the yarn is uniform wires, uniform resistance distribution, the circuit model of fabric coil can be constructed (Fig. 1).

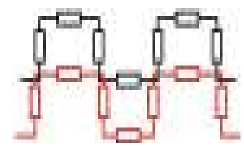

Fig. 1: The circuit model of food grade knitted fabric coil

As an independent unit by the coil in the food grade knitted fabric, on each closed coil, two needle loops (up, down) and two legs (left, right) form the closed loop (Changzheng *et al*., 2005).

The first arranged transversely coil is formed by the black line and the second arranged transversely coil is formed by the red line; The apart of intersection between the black line and the red line is the intersecting point between the first arranged transversely coil and the second arranged transversely coil. Black coils (non closed) is composed of a needle loop and two leg components, assuming that three parts of resistance value are all R, which is the broken loop's resistance and the rest is no resistance wire. So that it can simplify the complex structure of knitted coil into pure resistance circuit.

An independent coil's resistance model (Fig. 2) is simplified to the equivalent circuit model for analyzing the resistance of knitted coil (Fig. 2) (Zhu *et al*., 2012).

The closed knitted loop: In the cases that the crossing point is no contact resistance and the electrical conductivity of yarn under a good condition, If the knitting coil are connected with each other and the leg and the needle loop completely contact, there are no contact resistance in the interleaving point the whole coil is the same as the effect of circuit with four equivalent resistance (Fig. 3).

Because the coil is composed of four equivalent resistance, so the transverse and Longitudinal resistance is the equivalent resistance. This is a very ideal state. At the time, the coil can form an effective

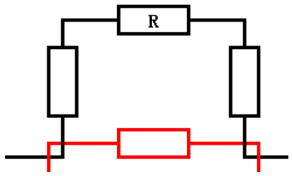

Fig. 2: The circuit model of single food grade knitted fabric coil

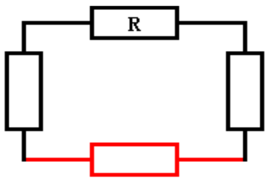

Fig. 3: The closed Knitted loop

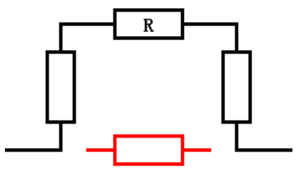

Fig. 4: The Knitted loop not closed

closed loop, which can produce a great deal of eddy current loss and it can produce the shielding of electromagnetic wave and this is one of the basic mechanism of food grade knitted fabric anti-radiation.

The knitted loop not closed: Due to the poor yarn structure and the contact point has space, if the Knitted coil string into a circle, Leg (black) contact with the interleaving point of needle loop (red), the circuit is completely nonconducting and the whole coil can not form an effective closed loop (Fig. 4).

In the state, the coil in the transverse circuit is connected and the coil has transverse resistance $R_t = 3R$ and Longitudinal circuit is circuit broken $R_w = \infty$ (R_w represents all resistance); therefore, the coil can not form an effective closed state. According to Lenz's law, only closed circuit can produce eddy current effect on the electromagnetic wave and to reduce the electromagnetic energy. Obviously coil can't effectively shield electromagnetic.

TRANSVERSE AND LONGITUDINAL CIRCUIT MODEL OF FOOD GRADE KNITTED FABRIC

If the electrical conductivity of the fiber yarn materials is fine and the contact resistance of the contact points is zero. Circuit model related to the transverse food grade knitted fabric (Fig. 5).

From Fig. 5, it can see that transverse single row of food grade knitted fabric like the complex compound circuits that are made of multiple equivalent resistance when measured the lateral resistance.

By the same token, the food grade knitted fabric longitudinal apart circuit model shows in Fig. 6.

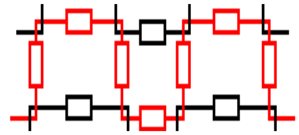

Fig. 5: Transverse knitted circuit model

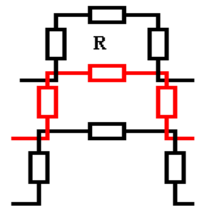

Fig. 6: Knitted longitudinal circuit model

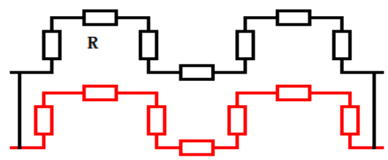

Fig. 7: Knitted transverse circuit model

It is not hard to see that transverse and longitudinal equivalent circuit in the condition of perfectly conducting is the same, so their resistance is equal. and $R_T = R_L$ ("T" is equal to transverse; "L" is equal to longitudinal) At this moment each coil forms a effective closed loop, which can cause the biggest eddy current loss to electromagnetic waves and under the condition of other parameters equal, food grade knitted fabric shielding effectiveness is best.

When there is something that winding interlacing point contact surface has a gap and the contact point is unable to connect due to the structure of yarn, it can conclude the electric model as shown in Fig. 7.

At this time two row yarns each other at contact is not conducting, now it can conclude the result which is $RT = 7R^2/(7R+7R) = 1/2R$. It is clearly that the resistance is greatly reduced and form the effective closed loop which can produce eddy current loss; but the fabric of the shielding effectiveness is low because of the unable connectivity of the longitudinal knitted coil which can only form the limited closed loop, so it cause the small eddy current loss.

By the analysis to the Fig. 7, it is clearly that the longitudinal coil can't form a closed loop when the crossing points between the red and black wires are not conduction. In theory, the longitudinal resistance is unlimited ($R_L = \infty$). At this time the entire fabric of interlacing point is broken and the coil will not be able to form effective closed loop between each other. Therefore, the electromagnetic shielding performance of food grade knitted fabric is poor.

The states mentioned above are extreme. Under normal circumstances, although the point of connection between columns of coil (black) and needle arc (red) is not very close and often change when food grade knitted fabric is weaved by the metal conductive fiber, there are always some interwoven points are connected and can form effective closed loop on the food grade knitted fabric because of the existence of many crossing point on food grade knitted fabric. There are many factors can affect the coil's connectivity such as food grade knitted fabric tightness, the type of yarn slip and so on. From external tensile, connectivity of a circuit formed by knitting coil is severely affected, alternately conduction and disconnect some contact. Even in the static measurement of knitting fabric. The longitudinal circuit resistance maybe changed greatly due to the yarn connection contact point instability. But lateral resistance almost no change, so there is:

$$R_T \le R_L \le \infty$$

KNITTED COIL INTERWOVEN POINT CONTACT RESISTANCE MODEL

Food grade knitted fabric's good electromagnetic shielding performance not only depends on the size of the lateral resistance value, but is related to the effective closed loop how much fabric can form. In order to better describe under normal the knitted coil's guide connectivity problem in the interwoven point, we will ignore resistance of conductive fiber or yarn itself to form a model.

Connections of knitted coil between each other depend on the yarn string sets, It can be seen from the Fig. 8: regardless of the yarn resistance, the food grade knitted fabric is circuit connected by numerous contact resistance; In the whole circuit, each contact resistance's (R_j) change will directly affect the single coil circuit effectively closed state and connectivity and affect the entire fabric of circuit connectivity. And the size of the contact resistance will also affect the electromagnetic eddy current loss. Regardless of other factors, the greater the contact resistance of a single coil is, the worse closing coil guide connectivity is and the eddy current loss will be reduced, the shielding effectiveness of the fabric is more small and vice versa.

The two states mentioned above are extreme. Under normal circumstances, although the point of connection between the leg of coil (black) and needle loop (red) is not very close and often change. There is a contact resistance $R_j = \rho l/s$, R_j is the contact resistance of the contact points; ρ is the resistivity of material; L is the length of the conductor; S is the cross-sectional area of the conductor. It is inversely with the point of contact area and proportional to the contact length of conductor. Of course, the pressure and the degree of oxidation and other factors of the contact point are all related to it. Since the fabric is flexible material, the contact area of intersection will change if it is stretched and squeezed, which makes the conduction of coil

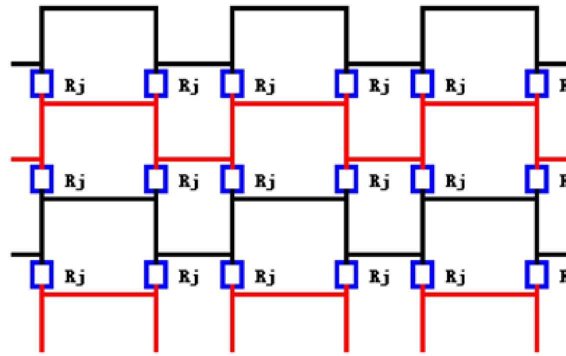

Fig. 8: Knitted coil interwoven point contact resistance model

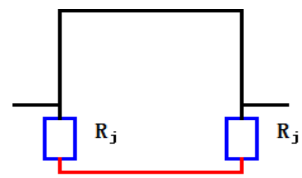

Fig. 9: The contact resistance model of coil

circuit seriously affected. Sometimes links, sometimes disconnected. Even measuring food grade knitted fabric in the stationary state, due to the yarn at the point of contact is connected with instability, which causes longitudinal circuit resistance increase and the resistance value of the lateral resistance made from a single yarn woven is almost not change. Therefore, at the time:

$$R_T \le R_L \le \infty$$

Due to the uneven of yarn structure and the decrease of the connection of the interlacing point and the contact resistance value of contact point is very large, which determines the connection quality of closed loop of coil. So it can be ignored that the value of the resistance coil itself. It can establish a new model as shown in Fig. 9 that the resistance model of coil contact.

CONCLUSION

As a result of the exist of contact resistance on the interleaving point, Conductivity of closed coil is weakened, the effectiveness of the closed loop produced by the transverse and vertical circuit have greatly weaken. The eddy current loss of coil is concerned with the size of the coil's resistance value. The resistance value greater is, the conductivity worse is, the eddy current loss smaller is, the shielding effectiveness of coil weaker is. Therefore, changing the conductivity of the contact point can effectively improve the electromagnetic shielding performance of the coil.

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