Abstract Axial Magnetic Field (AMF) in a Vacuum Interrupter (VI) with cup-type electrode is calculated, which includes 3D static AMF, 3D harmonic AMF and induced eddy current in contacts. The current in the calculation is 1000A. The results show that harmonic AMF is different with that of the static AMF because eddy current exists. The eddy current influences the AMF distribution in the center area of contact most heavily, between the slots lightly, above the slots most lightly.

1. INTRODUCTION

There are 2 popular ways for vacuum interrupter to interrupt high current. The first one is to produce a Radial Magnetic Field (RMF) between the electrodes, which generates a magnetic motive force to the vacuum arc column. So the arc column rotates on the surface of the electrodes in arcing time. Spiral-type and contrate-type electrodes are typical types of the RMF electrode. The second one is to produce Axial Magnetic Field (AMF) between the electrodes, which parallels to arc column and diffuses the vacuum arc. Cup-type and coil-type electrodes are typical types of the AMF electrode. It is useful to calculate the magnetic field of each type Vacuum Interrupter (VI) and the results are helpful to obtain better design to control vacuum arc. The vacuum interrupter with cup type electrode is one of most popular VI in China market. So it is meaningful to analyze the magnetic field of this kind of VI. The static AMF of the VI has been analyzed [1]. But the VI will be used in ac circuit. So the former analyses is not enough. When ac current passes through the electrodes, it produces harmonic AMF and eddy current is induced in the contacts. In order to get deep understanding of AMF in the electrodes gap and the induced eddy current in the contacts are calculated by electromagnetic analysis software VectorFields.

The structure of cup-type electrode is shown in Fig.1. It has 6 90° coil segments and each one has 27° included angle with the contact surface. There are 6 slots on the contact surface in the radial direction. When current passes through the electrodes, AMF will be produced in the gap of electrodes, which is helpful to keep vacuum arc diffuse. The prototype electrode parameters are shown in table 1 and the electrodes are simplified as coil shape in calculation, which is shown in Fig.2. To keep the equivalence of the simplification, current in the coil is transformed.

Table 1 Parameters used in the calculation

<table>
<thead>
<tr>
<th>Contact Diameter</th>
<th>Coil Thickness</th>
<th>Highness of Coil</th>
<th>Gap Length</th>
<th>Contact Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>75mm</td>
<td>8mm</td>
<td>18mm</td>
<td>10mm</td>
<td>4mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length of Slot</th>
<th>Width of Slot</th>
<th>Current in Coil</th>
<th>Equivalence Current in Coil</th>
</tr>
</thead>
<tbody>
<tr>
<td>25mm</td>
<td>2mm</td>
<td>1000A</td>
<td>1.5=222.75A</td>
</tr>
</tbody>
</table>

AMF in the electrodes gap and the induced eddy current in the contacts are calculated by electromagnetic analysis software VectorFields.

Fig.1 prototype of cup-type electrodes
The static AMF in the gap of the electrodes is shown in Fig.3 and Fig.4. Fig.3 gives the distribution of AMF on the intermediate plane, which is parallel to the contact surface. And Fig.4 gives the distribution on the surface plane. When the current is 1000A, the maximum axial magnetic flux density on the intermediate plane is 5.74mT and that on the contact surface are 5.79mT. The distribution of AMF is homogeneous in the coil.

2. STATIC AXIAL MAGNET FIELD

The harmonic AMF in the gap of the electrodes is shown in Fig.5 and Fig.6. The current is 1000A(r.m.s). Fig.5 gives the distribution of AMF on the intermediate plane of the gap at current peak. And Fig.6 gives the distribution on the same plane at current zero. The AMF at current zero is important because it effects the diffusion of residual particles. Lower AMF at current zero is helpful for the particles diffusing quickly.

It is shown in Fig.5 that the distribution of harmonic AMF is different to that of the static one. The maximum axial magnetic flux density is 7.68mT, which means it is 5.43mT(r.m.s). This is lower than the static one, which is 5.74mT. The drop is related to the eddy current.

3. HARMONIC AXIAL MAGNETIC FIELD

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center peak is the highest, which means eddy current effects the area most. The other 6 peaks are between the slots. Because these peaks are lower than the center one, it means that eddy current effects these areas lightly.

The AMF distribution on the contact surface at current zero is shown in Fig.8. The maximum axial magnetic flux density is -0.54mT in center area. Generally its distribution is similar to that on the intermediate plane. But there are 6 peaks above the slots.

The harmonic AMF on the contact surface is shown in Fig.7 and Fig.8. Fig.7 gives the distribution of AMF on the contact surface at current peak and Fig.8 gives that at current zero.

The AMF distributions in Fig.7 and Fig.8 are also related to the eddy current. It effects the center area most heavily, the area between slots lightly and the area above the slots most lightly. The following eddy current analysis gives the detail information.

4. EDDY CURRENT ANALYSIS

The eddy current distribution in the contact is shown in Fig.9 and Fig.10. Fig.9 gives the distribution at current peak and Fig.10 gives that at current zero.

The maximum eddy current is 0.3463A/mm² at current peak and it is near to the internal end of the slots. The minimum eddy current is 0.03963A/mm² at current zero and it is in the center of contact. The eddy current at current zero is higher than that at current peak and it is near to the internal end of the slots.
peak.

Because eddy current is high near the center area and it is low in the area between the slots, it effects the center area heavily and the area between the slots lightly. And because eddy current is opposite in the two sides of a slots, it effects the area above the slots most lightly.

Fig.9 Distribution of eddy current in the contact at current peak

Current in the electrode is ac 1000A
Arrows is amplified to 500 times

Fig.10 Distribution of eddy current in the contact at current zero

Current in the electrode is 1000A ac current
Arrows is amplified to 30 times

5. CONCLUSION

The axial magnetic field analysis of a vacuum interrupter with cup-type electrodes is given, which include static AMF, harmonic AMF and eddy current in the contacts. The electrodes are simplified to coils. To keep the equivalence, the current in the electrode is transformed to the coil. It is shown from the calculation that

1. Harmonic AMF distribution is different to that of static one because eddy current exists and the axial magnetic flux density of the harmonic AMF are lower.
2. Eddy current effects the center area of contact most heavily, between the slots lightly, above the slots most lightly.

REFERENCE