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INVESTIGATION OF THE MAGNETIC FIELD DISTRIBUTION ON THE SURFACE OF AMF CONTACTS

ABSTRACT *The axial magnetic field (AMF) distribution on the contact surface plays an important role in short circuit current interruption. To minimize erosion of the contact the AMF should be uniformly distributed over the contact plates. During theoretical analysis of bipolar contacts, the design of the contact coil and the slots made in the contact's plate, as well as the orientation of the steady contact relative to the moving contact were taken into account. The FLUX 3-D computer program was used for the calculation of the AMF and the results were compared and analyzed. To investigate the distribution of arc spots on the contact plate surface experiments were conducted in a dismountable vacuum chamber during a 15 kA short circuit current interruption.*

Keywords: *magnetic field distribution, AMF contact, diffusion arc*
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1. INTRODUCTION

The distribution of cathode spots on the contact surface plays a decisive role in a vacuum arc and can be considered as the source of the electrons and ions which form the continuous flow of current between the contacts. The traditional cup-shaped electrode typically generates a bell-shaped axial magnetic field (AMF) distribution, which at the breaking of the short circuit current concentrates arc spots at the contact plate's centre and ultimately causes erosion. This arc spot constriction increases the heat, raising the local temperature on the contacts and results in their degradation. Therefore the arc spots should be distributed over the whole contact surface to reduce their concentration at the centre. SADE (self arc diffusion by electrode) contacts expand the AMF over almost the whole contact surface [1, 2], and create a saddle-shaped AMF distribution. The aim of this paper is to analyze the AMF and, as far as possible, to equalize it over the whole contact surface. The form of the AMF distribution is strongly

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dependent on the design of the slots made in the contact plate's surface. The authors analyzed the AMF distribution for bipolar contacts with oblique and bow-shaped slots and with the contact oriented at both 0° and 90° relative to each other [3–8]. For these two contact designs the AMF was calculated and a chart of the AMF and the magnetic field distribution along X and Y axes were shown. For the purpose of this analysis the FLUX 3-D FEM computer program was used.

2. CALCULATION AND EXPERIMENTAL RESULTS

Bipolar contacts using 65 mm diameter contact plates with two different geometries were investigated. The AMF depends on the slots made in the contact plate's surface. Also the orientation of the contacts, relative to each other, affects the AMF [1]. Results of the calculations made for the bipolar contacts are shown in Figs. 1 to 4.

For contacts oriented at 0°, with contact plates with oblique slots, the calculated AMF, and the chart of the magnetic field over the contact plate's surface are shown in Figure 1. Figure 1A shows the contact design, Figure 1B the AMF distribution, Figure 1C the chart of the AMF distribution over the contact's surface and in Figure 1D

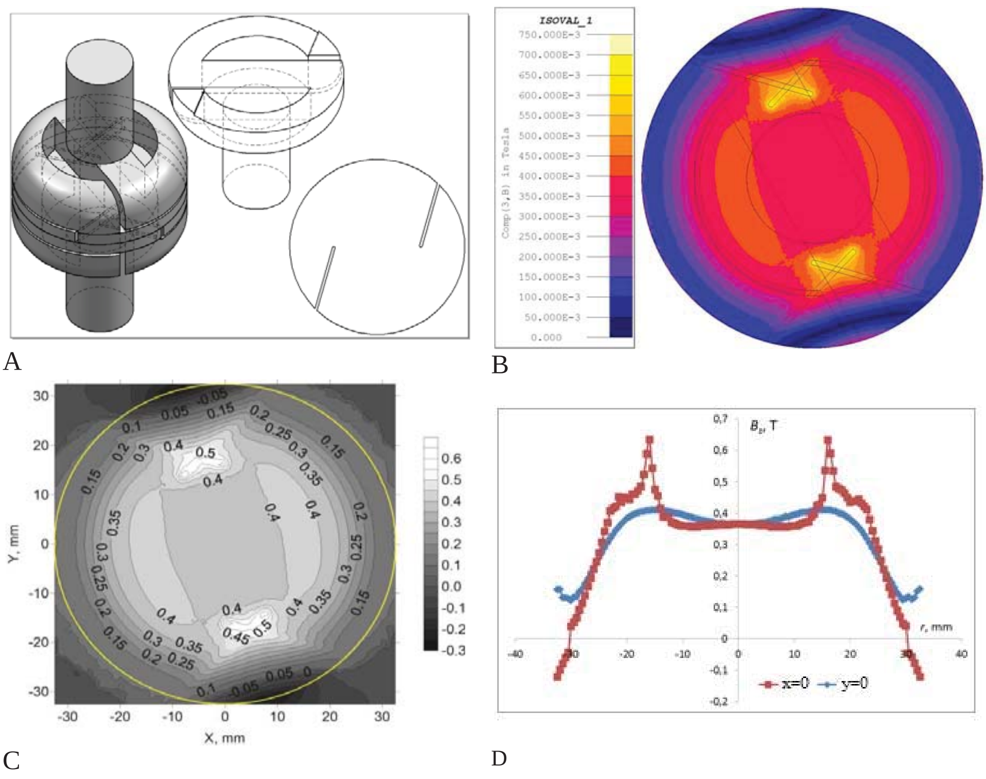

Fig. 1. Bipolar contacts oriented at 0° with oblique contact slots: A – contact design, B – AMF distribution ($|B_z|$, T), C – chart of the AMF distribution (B_z, T), D – AMF distribution along the X and Y axes

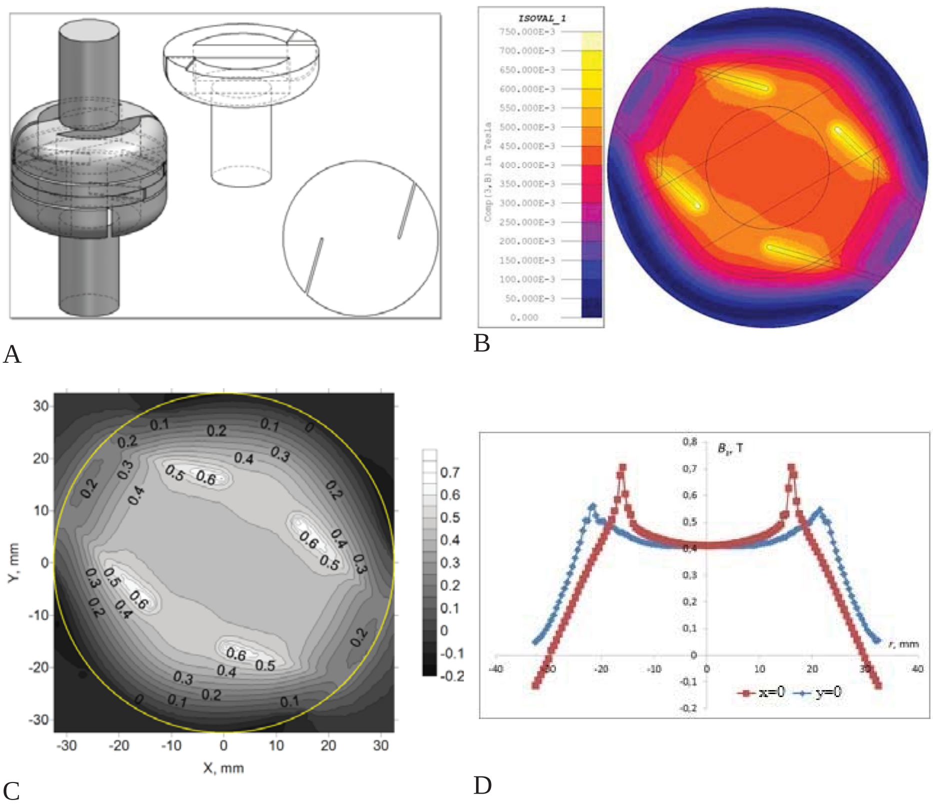

Fig. 2. Bipolar contacts shifted by 90°, with oblique contact slots: A – contact design, B – AMF distribution (|B_z|, T), C – chart of the AMF distribution (B_z, T), D – AMF distribution along the X and Y axes

a graph of the magnetic field along the X and Y axes is displayed. The same calculations were made for contacts oriented at 90° and the results are shown in Figure 2 [9, 10].

Figure 3 shows the results of analysis of bipolar contacts with bow-shaped slots in the contact plate's surface, oriented at 0°. In Figure 4 are the results of calculations for the same bipolar contacts but oriented at 90°. For both cases the calculation results of the AMF distribution, a chart of the AMF, and a diagram of the AMF along the X and the Y axes are shown.

As can be seen in Figures 1–4, the AMF distribution for the two contact designs considered above is different. For contacts using contact plates with oblique slots, oriented at 0°, as in Figure 1A, the maximum AMF value along the X and Y axes occurs at 20 mm from the contact's centre. At the centre of the electrodes, the AMF distribution has a saddle shape. Between the two maximums of the AMF the lower field value along the X and Y axes takes up 60% of the contact diameter. The AMF values at the centre of the contact's surface for both contact orientations are about the same – see Figures 1D and 2D.

For contacts with bow-shaped slots, oriented at 0° and 90°, as shown in Figures 3A and 4A, the AMF changes in almost the same way, but the maximum value appears 17 mm from the contact's centre along the X axis and 14 mm from the contact's centre along the Y axis. The magnetic field along the X and Y axes at the centre of the contact with bow-shaped slots is greater than the corresponding field for contacts with oblique slots (see Figs. 3D and 4D).

For both contact designs the AMF towards the edge of the contacts declines steeply from its maximum value.

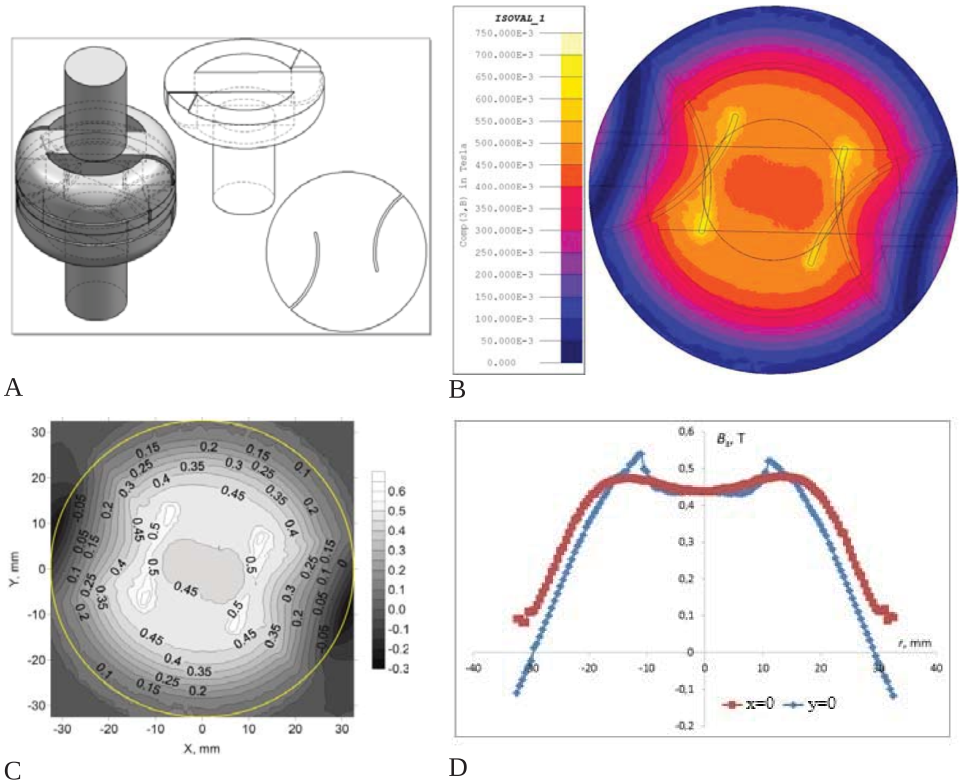

Fig. 3. Bipolar contacts oriented at 0° with bow-shaped contact slots: A – contact design, B – AMF distribution (|B_z|, T), C – chart of the AMF distribution (B_z, T), D – AMF distribution along the X and Y axes

Experimental results

To evaluate arc spot distribution on the contact's surface during short circuit current interruptions of 15 kA, tests were conducted with a circuit supplied from a capacitor bank.

The tests were done in a dismountable vacuum chamber using bipolar contacts with oblique slots. For the arc measurements a high speed Photron camera was used and images at resolution of 768x768 pixels were recorded. A typical recording is shown in Figure 5. The arc spots are uniformly distributed over the contact's surface and were not constricted at the centre of the contact surface. After a short circuit current interruption the surface of the contacts was largely clean, and only at the edge of the contacts were there some points where the arcs initiated caused erosion (see Fig. 6).

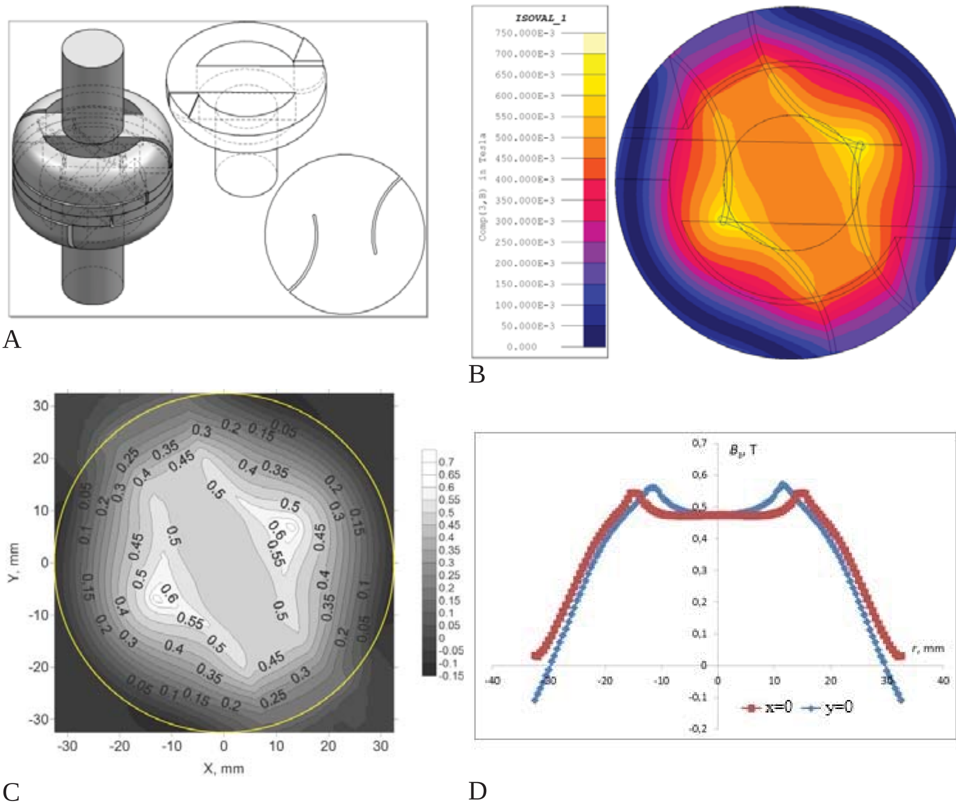

Fig. 4. Bipolar contacts shifted by 90°, with bow-shaped contact slots: A – contact design, B – AMF distribution ($|B_z|$, T), C – chart of the AMF distribution (B_z, T), D – AMF distribution along the X and Y axes

Fig. 5. Image at resolution of 768x768 pixels were recorded using high speed Photron camera

Fig. 6. Contacts after some 15 kA short circuit current interruptions

3. CONCLUSION

The design of the slots made in the contact's surface has a significant influence on the AMF distribution and on the arc behavior in terms of the arc spots' distribution and on the arc's characteristics. To minimize contact erosion the AMF should be uniformly distributed over the contact plates. It is possible to distribute the AMF uniformly over the contact's surface by the application of oblique and bow-shaped slots. In both cases the maximum AMF value is reduced at the centre of the contacts and is extended over the contact surface. For both contacts with oblique slots, and contacts with bow-shaped slots the AMF takes on a saddle shape.

In the experiment conducted in a dismountable vacuum chamber the arc spots are uniformly distributed up to the edge of the contacts (see the record in Fig. 5).

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BADANIA ROZKŁADU POLA MAGNETYCZNEGO NA POWIERZCHNI STYKÓW AMF

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STRESZCZENIE *Rozkład osiowego pola magnetycznego na powierzchni styków komór próżniowych odgrywa decydującą rolę w ograniczaniu erozji styków podczas wyłączania prądu zwarciowego. Ograniczenie erozji styków możliwe jest przez równomierny rozkład osiowego pola magnetycznego na całej powierzchni styku. Z tego względu, w projektowaniu styków, należy stosować metody obliczeniowe do sprawdzenia składowej osiowej rozkładu pola magnetycznego. W artykule podano wynik analizy rozkładu składowej osiowej pola magnetycznego dla styku bipolarnego z nacięciami ukośnymi i z nacięciami o kształcie łuku. Do analizy stosowano program komputerowy FLUX 3D. Wykonano również badania rozkładu strumienia łuku dyfuzyjnego w rozbieralnej komorze próżniowej podczas wyłączania prądu zwarciowego o wartości 15 kA.*

Słowa kluczowe: *rozkład pola magnetycznego, styk AMF, łuk dyfuzyjny*