MODELLING OF ELECTRODYNAMIC FORCES IN MODEION CIRCUIT BREAKER

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ABSTRACT

This work describes electrodynamic forces in MODEION circuit breaker. The effects of these forces on its fixed and movable contact are most analysed because they have significant influence for limiting short-circuit currents. The first part of this contribution contains theoretical analysis of affecting electrodynamic forces on the parts of the current-carrying conductor. Performed calculations of forces are analysed in the next part. The forces are calculated by Finite Element Method (FEM). The computer program ANSYS is used.

1 INTRODUCTION

The limiting capability is one of the most important features of a circuit breaker. It means, among others, that it must assure disconnection of the contacts before the short-circuit current reaches its maximum value. In other words, it is less than one quarter of period of breaking current for AC power system. MODEION circuit breakers are constructed for heavy nominal currents so they have quite big and mass contacts as well as breaking mechanism, which must be accelerated. The tripping by a release of a circuit breaker always means some delay and in addition, the opening spring does not provide enough force for acceleration. But we can use electrodynamic forces caused by electromagnetic field to disconnect the contacts fast enough. This is the reason why I am interested in these forces. The type of analysed circuit breaker is MODEION, BD250S, which is manufactured by OEZ Letohrad.

2 ANALYSIS

2.1 ORIGIN AND EFFECT OF ELECTRODYNAMIC FORCES

Electrodynamic forces are caused by electric currents.

We can recognize particular cases of affecting of these forces from Figure 1, which shows the geometry of current-carrying conductor plus some iron sheets of the quenching chamber. There is an interaction between parallel parts of conductor plus influence of two loops. Other contribution to the forces is caused by current strait between contacts – the contact is not realized in full surface of contacts, but only in small straits. It is caused by rough surface. Finally, we have to consider ferromagnetic material of sheets in the quenching chamber. These sheets cause growth of both magnetic flux density and force.

Unlike other cases, the current strait between contacts is the source of **inaccuracies** in modelling of geometry. Instead of several straits, I use only one. Dimensions of strait were chosen after replacing real model with single one. The single model is appropriate for using in macro, which I have made for calculating of the forces caused by strait – see Figure 2. From these calculations I have chosen the strait width of **1 mm** for the other calculations.

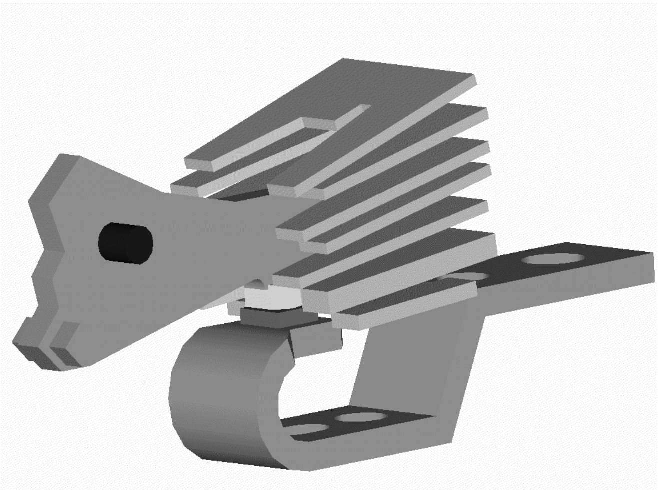

Fig. 1: *Geometry*

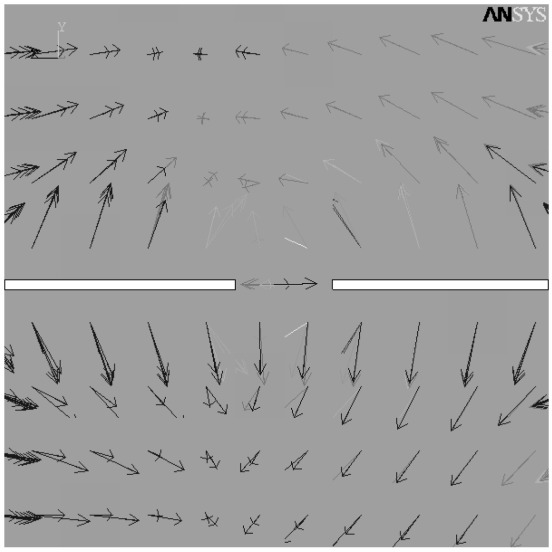

Fig. 2: *Forces around current strait*

2.2 PROCEEDING AND CONDITIONS OF CALCULATION

The **steady-state** problem is assumed for calculating the forces. It means that direct current (which creates steady-state electric and magnetic field) is considered. The real problem is quasi-static so the skin-effect in current-carrying conductor and eddy currents in sheets of quenching chamber are neglected. These presumptions can be done since the skin depth is much bigger for copper material (current-carrying conductor) in comparison with iron material, which is not involved in the current conduction. The geometry is not symmetrical so that **3D model has to be used**.

The proceeding of calculation is as follows:

- creating the geometry, choosing the proper finite elements, associating material properties, ...
- calculation of current density **J** in current-carrying conductor
- calculation of magnetic flux density **B** using the magnetic vector potential (**A**) approach
- calculation of distribution of electrodynamic forces using **J** and **B**
- calculation of resulting force **F** and torque **M** (movable contact rotate) by summation of element forces.

3 RESULTS

Figure 3 shows distribution of current density **J** in current-carrying conductor around contacts. Of course, the greatest density is in strait between contacts. Magnetic field caused by direct current is plotted in Figure 4.

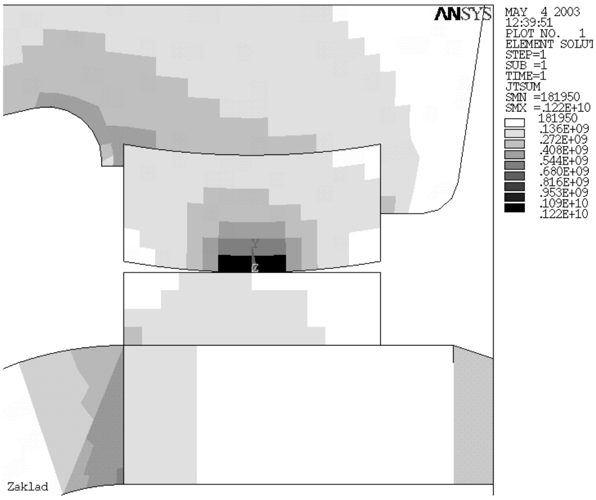

Fig. 3: *Current density*

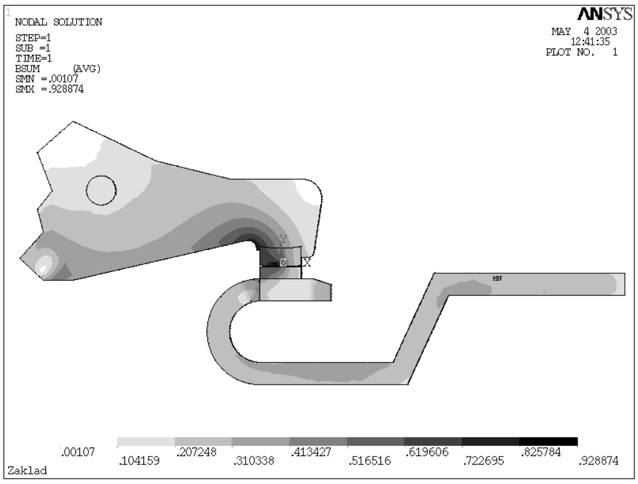

Fig. 4: *Magnetic flux density*

Figure 5 shows distribution of *y* component of electrodynamic forces in movable and partly fixed contact. The force acts in *y* and *x* direction can be seen in Figure 6, which represents vectors of forces. But the movable component is only in *y* direction. The z component of force is zero, which is caused by the symmetry. X component is significant for forcing the electric arc inside the quenching chamber. It can be seen that the force tries to move contacts asunder.

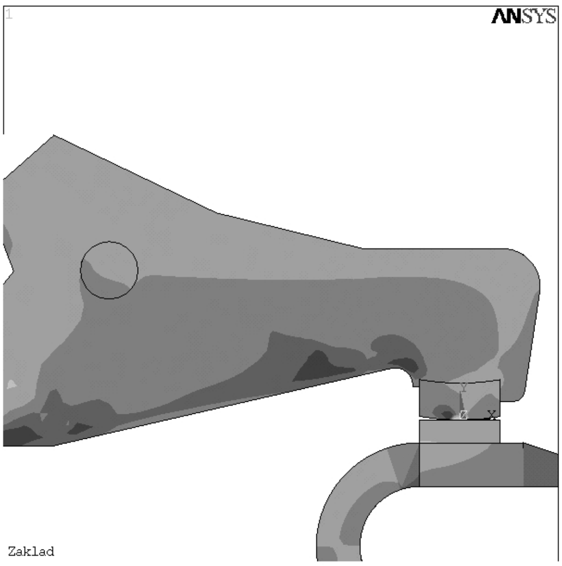

Fig. 5: *y component of force*

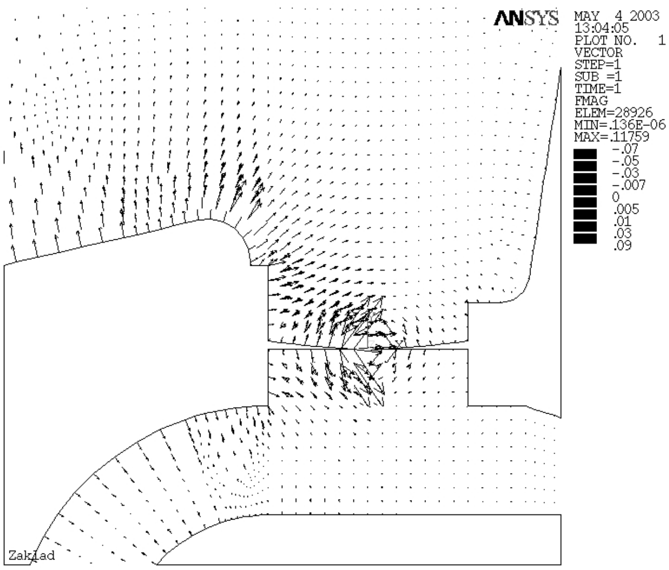

Fig. 6: *Vectors of forces*

I also analysed the influence of current value on the forces. If permeable materials are neglected, the force should be ascending according to the square power of current (dashed curve in figure 7). But when the permeable material saturates, the force is smaller (solid curve in Figure 7). Figures 8, 9 and 10 show saturation effect for 8.6, 18 and 36 kA.

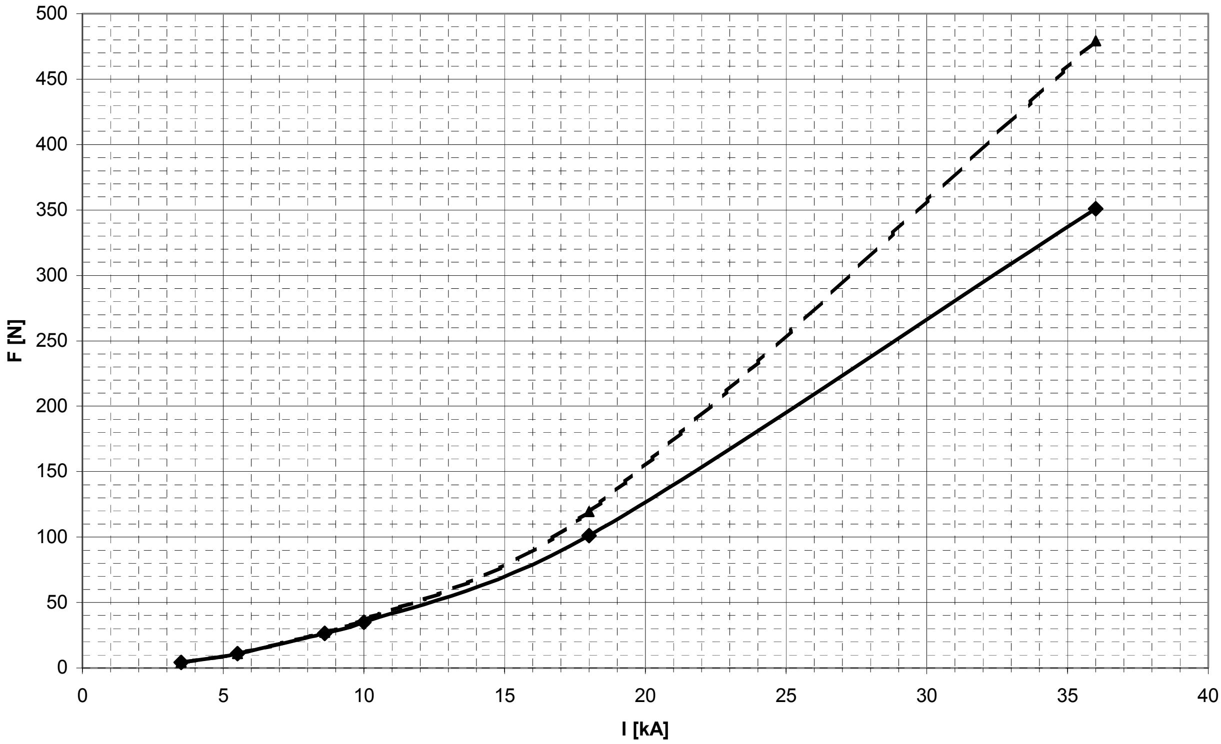

Fig. 7: *Force as a function of current*

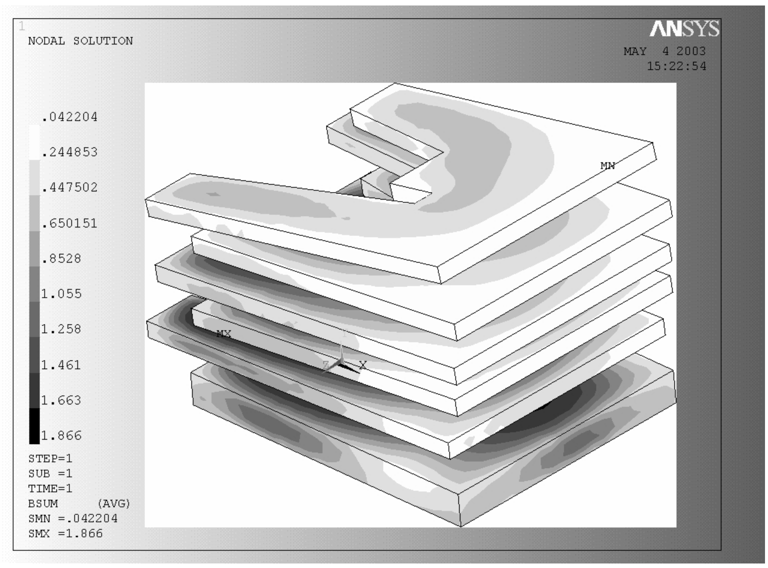

Fig. 8: B for 8,6 kA in quenching chamber sheets

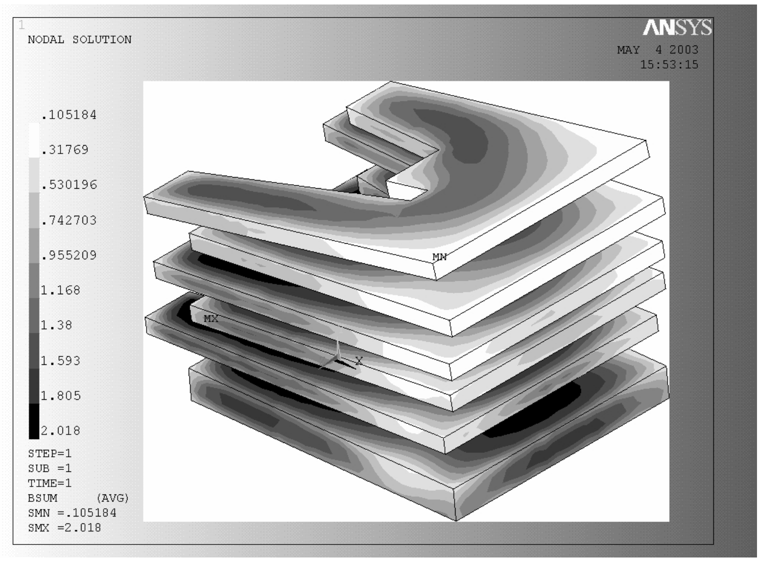

Fig. 9: *B for 18 kA in quenching chamber sheets*

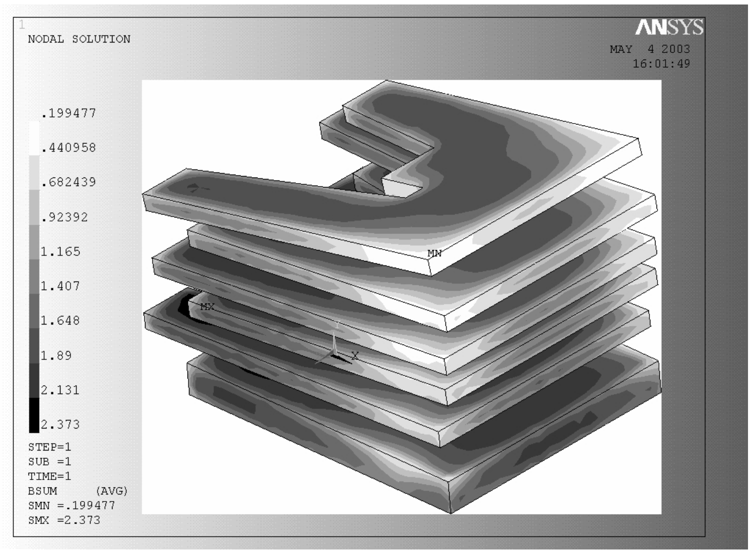

Fig. 10: *B for 36 kA in quenching chamber sheets*

4 CONCLUSION

The influences of current strait and sheets of the quenching chamber on forces have been analysed in this contribution. The analysis has shown that the force rises 1.5 times if the sheets of the quenching chamber are considered. The further work will lead up to exploration of influence geometry of current-carrying conductor on forces.

REFERENCES

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