

FEM SIMULATION OF VACUUM CIRCUIT BREAKER BY ANSYS

MÔ PHỎNG SỬ DỤNG PHƯƠNG PHÁP PHẦN TỬ HỮU HẠN CHO MÁY CẮT CHÂN KHÔNG BẰNG PHẦN MỀM ANSYS

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ABSTRACT

In this paper, the analytical method has been calculated 3-D diffuse vacuum arcs with an axial magnetic field using a commercial FEM package, ANSYS. The vacuum arc has been modeled with the sequential coupling method of two different fields, which are on the electromagnetic force. Arc constriction with applied currents could be predicted with the results of temperature distribution, and further modeling procedures will be followed for the detailed constriction phenomena of vacuum arcs with an axial magnetic field. The method of computing electric field and electric potential with ANSYS in a VS_m-type vacuum breaker arc quenching chamber is introduced. ANSYS is used to analyze the influence of different boundaries on electric field and electric potential in vacuum circuit breaker arc-quenching chamber, which lays a basis for the simulation of electric field and exact quantitative analysis and computation.

Keywords: ANSYS; arc-quenching chamber; electric field; electric potential; finite element analysis (FEA); interruption; reliability; numerical analyses; vacuum circuit breaker.

TÓM TẮT

Trong bài báo này, phương pháp phân tích đã được tính toán các tiếp điểm chân không mô hình 3-D với từ trường hướng trục bằng cách sử dụng gói FEM trong ANSYS. Hồ quang chân không đã được mô hình hóa bằng phương pháp phần tử hữu hạn dựa trên hai thành phần trường để cho ra kết quả lực điện từ. Việc hạn chế hồ quang với dòng điện kích thích có thể được ước lượng dựa với kết quả phân bố nhiệt độ và các quy trình mô hình hóa tiếp theo sẽ được tuân theo đối với hiện tượng co thắt chi tiết của các cung chân không với từ trường dọc trục. Phương pháp tính toán điện trường và điện thế với ANSYS trong buồng dập hồ quang máy cắt chân không kiểu VS_m - cấp điện áp được giới thiệu trong bài báo này. Công cụ tính toán ANSYS được sử dụng để phân tích ảnh hưởng của các điều kiện khác nhau đối với điện trường và điện thế trong buồng dập tắt hồ quang của bộ ngắt mạch chân không, tạo cơ sở cho mô phỏng điện trường và phân tích và tính toán định lượng chính xác.

Từ khóa: ANSYS; buồng dập hồ quang; điện trường; điện tích; phân tích phần tử hữu hạn (FEA); gián đoạn; độ tin cậy; phân tích số; máy cắt chân không.

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ABBREVIATION

VS _m	Voltage Supply Magnetic
PMA	Permanent Magnetic Analysis
FEA	Finite Element Analysis
VCB	Vacuum Circuit Breaker

1. INTRODUCTION

ANASYS is a large universal finite element analysis (FEA) software combined with structure, liquid, electric magnetic field, sound field and couple field [1]. In recent years, with the development of computer technology and numerical technology, the constant analysis of all kinds of parameters in arc-quenching chambers will be realized. As a key part of the circuit breaker, the development and research on the arc-quenching chamber becomes one of key contents in increasing reliability and miniature, which requires a correct analysis on the electric field changes in the arc-quenching chamber [4-7]. A special design in VS_m vacuum circuit breaker arc-quenching chamber is employed, further improving the interruption ability of the arc-quenching chamber, which greatly has shortened glass-shape touch head diameter, causing the volume reduction of the circuit breaker accordingly. Numerical calculation of the electric field has come into practical application stage [2-4].

2. ANALYTICAL CALCULATION

In this paper, finite element analysis (FEA) software is employed in numerical calculation in the arc-quenching chamber of the electric field and electric potential of the VS_m Vacuum circuit breaker. First, the rapid part of the electric field and electrode vicinity is separated densely while remote field area is separated sparsely, the separation of which can constantly change with the sites. Second, as the separation has nothing to do with the coordinates, for example, it's possible to separate touch head surface in the direction of normal, in such way, unknown numerical can be reduced, meanwhile with the same unknown numerical, calculation accurateness can be increased. ANSYS software mainly includes three parts: previous process module, analysis calculation module and later process module. The previous process module supplies a powerful solid model and mesh

separation tool, such forming finite element analysis model with great convenience; analysis calculation module can analyze electric field in the arcquenching chamber, electric potential and the coupling of metaphysical field; while the later process module can display the calculation results in colorful isoclines form, terraced form, vector form, participle flow form, cubic slice-up form, transparent or semitransparent form (the structure inside can be seen here) and figure forms and so on; it can also display or print out the calculation results in the form of diagrams or curves.

The characteristics of the PMA were obtained by solving a multi-physics coupling problem, including electric circuit, magnetic field, and mechanical motion. The magnetic field can be regarded as a magneto-static field by ignoring eddy currents. The magneto-static field equation is described as:

$$\nabla \times \left(\frac{1}{\mu} \nabla \times A \right) = J_c \tag{1}$$

where μ is the permeability of the material, A is the magnetic vector potential, J_c is the current density vector.

In addition to the magnetic field equations, the PMA also follows the voltage balance equation and D'Alembert Equation. The state equations for the PMA are described as

$$\begin{cases} \frac{d\psi}{dt} = U_c - iR; & \frac{dv}{dt} = \frac{F_{mag} - F_r}{m} \\ \frac{dU_c}{dt} = -\frac{i}{C}; & \frac{dx}{dt} = v \\ \psi|_{t=0} = \psi_0; v|_{t=0} = v_0; x|_{t=0} = x_0; U_c|_{t=0} = U_{c0} \end{cases} \tag{2}$$

where ψ is the flux linkage across the coil; U_c and C represent the voltage and capacitance of the capacitor, respectively; i and R represent the coil current and coil resistance, respectively; F_{mag} is the magnetic force exerted on the moving part; F_r is the reaction force; m , v , and x denote the mass, velocity.

3. VCB FEM MODEL

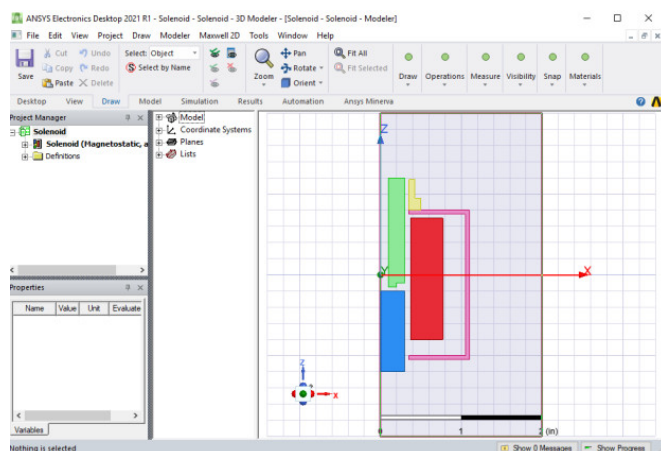


Figure 1. The geometric model

The VCB Model is made up of five objects: a plugnut, core, coil, yoke, and bonnet. All objects are created using the Draw

commands as described in the following sections. The dimensions of the solenoid that you will be modeling are shown below. For axi-symmetric structures, the axis of symmetry is the Z-axis, and drawing is performed in the XZ plane with all objects in the $X > 0$ portion of the plane. the dimensions are given in mm to create the geometric model.

The geometric model has assigned materials with the appropriate material attributes to each object in the geometric model. The boundary conditions and sources need to be specified, such as the source current of the coil which the force acting on the core be calculated during the solution.

To access the Material Database, select the coil object by clicking in the Model Window or by selecting it in the history tree. Once you have selected the coil, click in the Material Value field of the Properties Window and select Edit. The Select Definition dialog appears to allow material definitions to be assigned to the selected object.

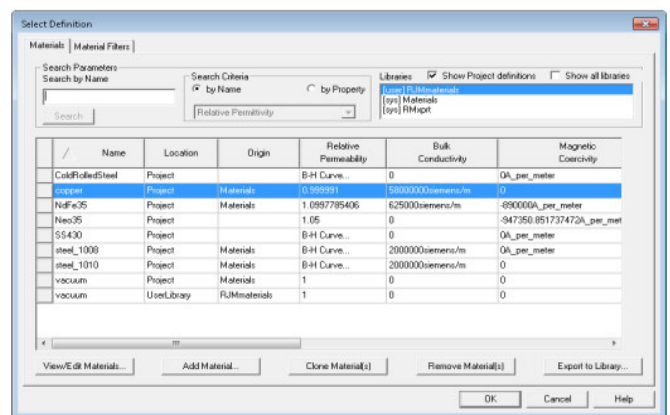


Figure 2. Access Material Database

In the actual solenoid, the coil is made of copper. Scroll the database table to the definition of copper in the Material Manager and select it by clicking on the name field. The Properties will now show copper in the materiav field for the coil object and coil will be listed under copper in the Object list.

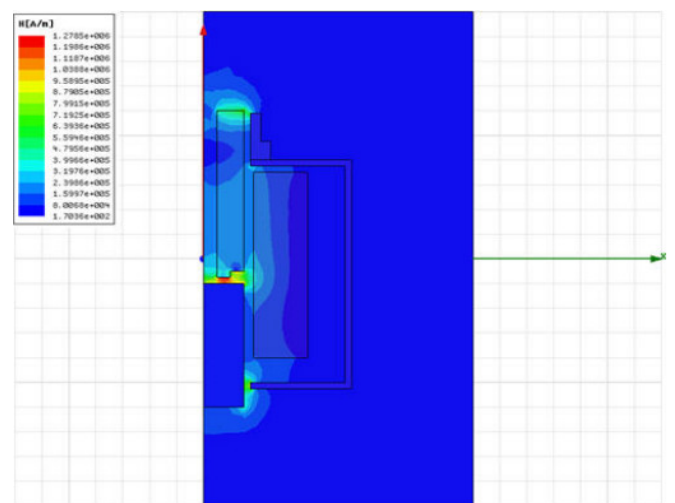


Figure 3. Magnetic Field Plot

The bonnet and yoke of the solenoid are made of cold rolled steel. Since this material is not in the database, This material is nonlinear and its relative permeability is not constant and must be defined using a B vs. H curve. Therefore, r the material attributes for cold rolled steel is defined by a B-H curve.

4. FEA SIMULATION RESULT

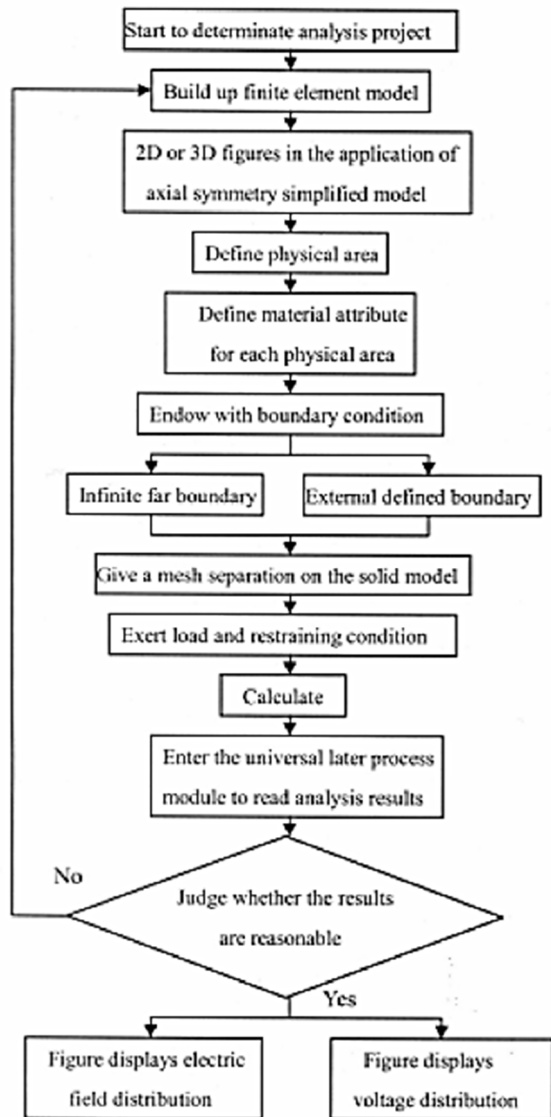


Figure 4. Diagram of computing the electric field and electric potential procedure with ANSYS

First, build up a mathematic model by using application finite element analysis software ANSYS on VSm type vacuum circuit breaker arc-quenching chamber. ANSYS program supplies two kinds of solid structure model methods from top to bottom or from bottom to top. When setting up solid model from top to bottom, the user defines a highest grade picture unit for a model. For example, balls, rhombic column are called basic unit. The program will automatically defines the relative surface and line detached from the crucial point. The users use these high picture units directly to construct geometry models, such as 2-dementional rounds, rectangles

and 3-dementional pieces, balls, awls and columns. Whether the method from top to bottom or from bottom to top is used to construct models, the uses all can form data collection by using Boer calculation, therefore sculpturing a solid model.

ANSYS program offers a complete Boer calculation, such as adding, subtracting, intersecting, separating, gluing and overlapping. When constructing complicated solid models, considerable model-constructing workload can be reduced in Boer's operating line, surface, body and basic unit. ANSYS program also offers the function of pulling, extending, and spinning, moving and copying solid model picture units. The additional function also includes the structure of circular arc, tangent structure. Surface and body are formed by pulling and spinning and line and surface hard point is also formed, moved, copied and deleted. When setting up models from bottom to top, the users construct models from the lowest picture unit upward, that is, the users have to define the crucial point first, then come to the relative line, surface and body.

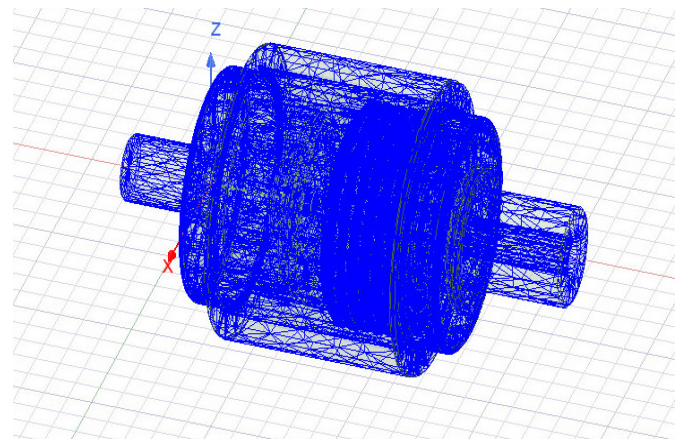


Figure 5. Three-dimensional mesh separating chart of arc-quenching chamber

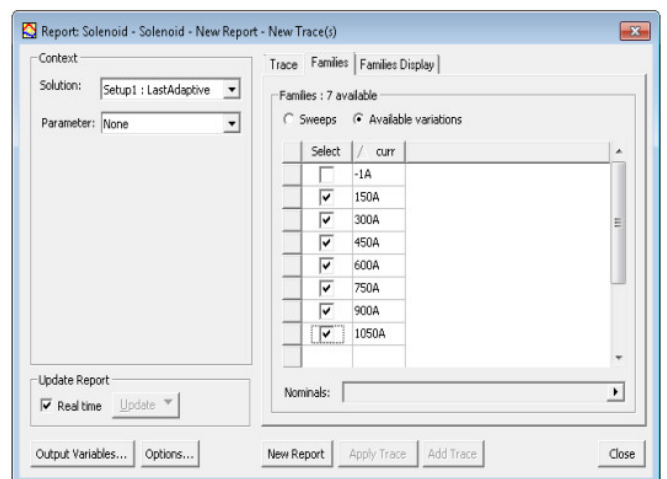


Figure 6. Plot the force versus gap spacing for various current values

In order to plot the fields from a particular design variation, the simulation has been saved the fields from the parametric analysis during the setup process. The ariable ranges for parametric analysis section is shown in Figure 7.

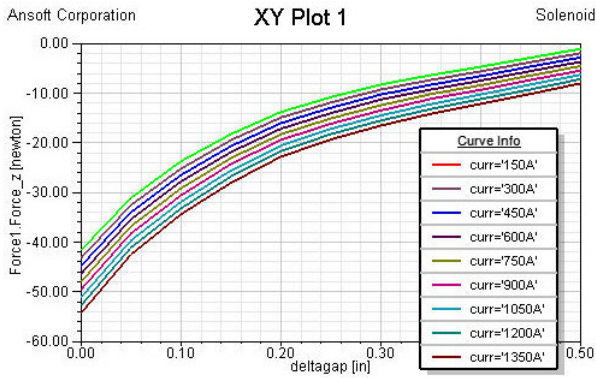


Figure 7. Plotting Fields of a Design Variation

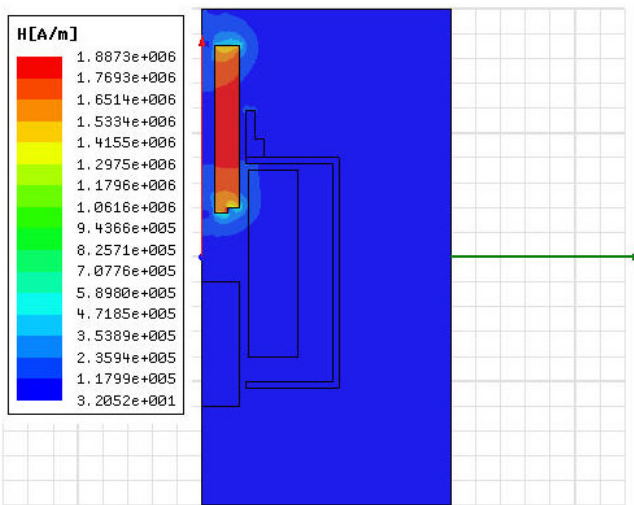


Figure 8. Plot Fields for the Variation

The Plot Fields for the Variation have been evaluated from zero to 1mm which is the moving distance of VCB. It is useful for further design and manufacturing of actual VCB.

5. CONCLUSION

As is clearly seen from the above results, in different boundary conditions, electric field intensity and varying conditions of electric potential in each point can accurately simulate the original shape of the object by using ANSYS. Finite element method can give numerical calculation to electric field and electric potential, and at the same time it can also transform the past qualitative analysis on the change of electric field and electric potential into present quantitative calculation in the arc-quenching chamber, thereby having the numerical value analysis. This paper has investigated a 3D Model of VCB. It is useful for manufacturing of real VCB and application.

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