HEAT LOSSES IN DIFFERENT GEOMETRIES

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Abstract: This work describes analysis heat losses in different type geometries. Used type of geometry of the current path is square, rectangular and circular cross section. The size of heat loss is affected by the frequency of passing current. Heat losses are calculated with Finite Element Method (FEM). The computer program ANSYS is used.

Keywords: FEM, ANSYS, Heat loss, Skin effect

1. INTRODUCTION

Heat losses are caused by passing electrical current in the conductor. In the case of the passage of direct current conductor are heat losses approximately the same in the whole cross selection. And in the case of the passage alternating current created on the surface of the conductor skin effect. Skin effect causes unequal distribution of current density in the conductor. Unequal distribution of the current density creates unequal heat loss in the conductor. The higher frequency passing current causes a greater influence skin effect.

2. ANALYSIS

2.1. PARAMETERS SIMULATION

In the case of the problem solved is based on the assumption that it is **transient role**, i.e. that the passage electrical current creates a transient electric and magnetic fields. The calculation can not ignore electrical skin effect, because it affects the distribution of the vector current density. Role, due to its geometry, was designed as a **three-dimensional**. Current paths material is **copper** with resistivity $1{,}77\times10^{-8}\ \Omega.m$. Current path passes alternating current 100A with frequency 1000Hz. All current paths have a cross section $16mm^2$. Exact dimensions of the geometry current paths are in Table 1.

Type geometry	Cross-section	Average	Side a	Side b
	S [mm^2]	d [mm]	a [mm]	b [mm]
Square	16	-	4	4
Rectangular	16	-	2	8
Circle	16	4,515	-	-

Table 1: Used geometry

2.2. PROCEDURE SIMULATION

- Current path was created in **Solidworks** software and for converting geometry into **Ansys** environment an exchange format was used. Selected types of geometry are showed in Figure 1 to 3. Used exchange format is **SAT**.

Figure 1: Square type geometry

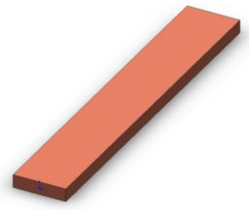

Figure 2: Rectangular type geometry

Figure 3: Circle type geometry

- Choice of a suitable **Preferences**, in this case is it **Magnetic-Nodal**

- Choice of a suitable element for calculating the finite element method. Selected element was **SOLID97** models 3-D magnetic fields. The element is defined by eight nodes, and has up to five degrees of freedom per node out of six defined DOFs; that is, the magnetic vector potential (AX, AY, AZ), the time-integrated electric potential or the electric potential, the electric current (CURR), and the electromotive force (EMF). SOLID97 is based on the magnetic vector potential formulation with the Coulomb gauge, and is applicable to the following low-frequency magnetic field analyses: magneto statics, eddy currents (AC time harmonic and transient analyses), voltage forced magnetic fields (static, AC time harmonic and transient analyses), and electromagnetic-circuit coupled fields (static, AC time harmonic and transient analyses). SOLID97 geometry is showed in Figure 4. [1]

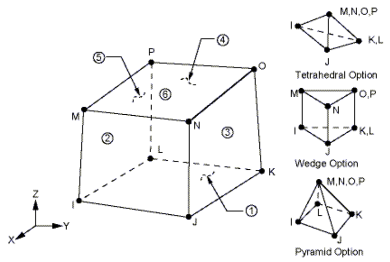

Figure 4: SOLID97 geometry [1]

- Enter the boundary conditions
- Calculate heat loss **P [W]** on the current path

2.3. SKIN EFFECT

Skin effect is a tendency for alternating current (AC) to flow mostly near the outer surface of a solid electrical conductor. The effect becomes more and more apparent as the frequency increases.

The main problem with skin effect is that it increases the effective resistance of a conductor for alternating current at moderate to high frequencies, compared with the resistance of the same conductor at direct current (DC) and low AC frequencies. Skin effect can be reduced by using stranded rather than solid conductor. This increases the effective surface area of the wire for a given wire gauge. [2]

Electromagnetic wave, which spreads in an environment which is highly conductive, it is very strongly damped in the direction of their spread as a result of losses of energy conversion into heat. The effects of electromagnetic waves in such an environment flow of electric currents. Current density $\vec{J}(\vec{r},t)$ in isotropic conductive environment with conductivity σ on the basis of Ohm's Law

$$\vec{J}(\vec{r},t) = \sigma\vec{E}(\vec{r},t) \tag{1}$$

Where **J** is the magnitude of current density (measured in ampere per meter, A/m^2), σ is electric conductivity (measured in Siemens per meter, S/m), **E** is intensity electric field (measured in volt per meter, V/m), **r** is conductor radius (measured meter, m), **t** is time (measured second, s)

In the case of harmonic current is the harmonic electromagnetic field and the Equation (1) is possible to rewrite the complex amplitudes depend on the coordinates, i.e.

$$\vec{J}(\vec{r}) = \sigma\vec{E}(\vec{r}) \tag{2}$$

Skin effect may be characterized by variable

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}} \tag{3}$$

where δ is the skin depth (measured in meter, m), ω is angular frequency (measured in radian per second, rad/s), μ is permeability (measured in henry per meter, H/m).

Skin depth is a characteristic depth of the current density and simultaneously the electric and magnetic fields decrease exponentially direction the inside of environment (material). In depth δ decreases the amplitude of all three variables falls to 1/e of its value near the surface.

This phenomenon is called a surface phenomenon, or skin effect.

3. RESULTS

For example, heat losses in the conductors by passing DC current are shown in Figure 5.

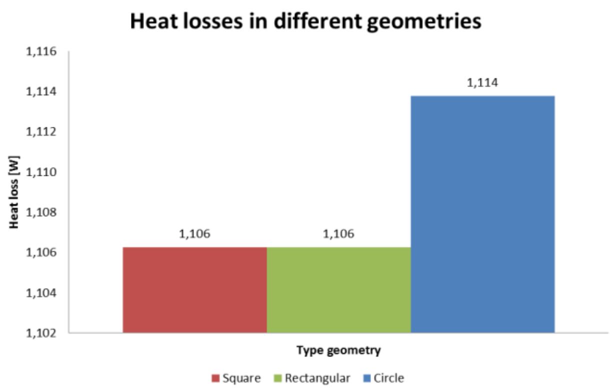

Figure 5: Heat losses in different geometries in the passage direct current

Heat losses in the conductors by passing AC current are shown in Figure 6.

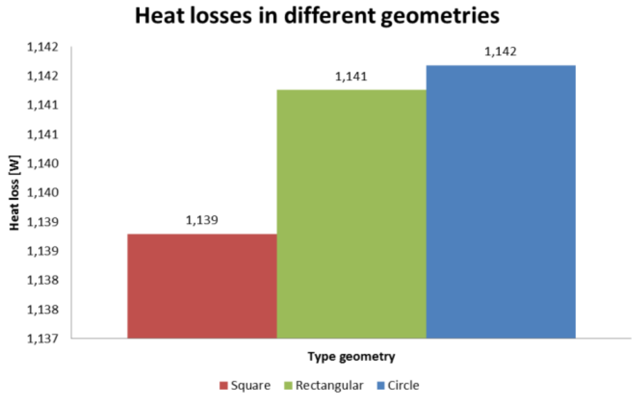

Figure 6: Heat losses in different geometries in the passage alternating current

Graphic representation of the distribution Joules loss is show in Figure 7 to 9.

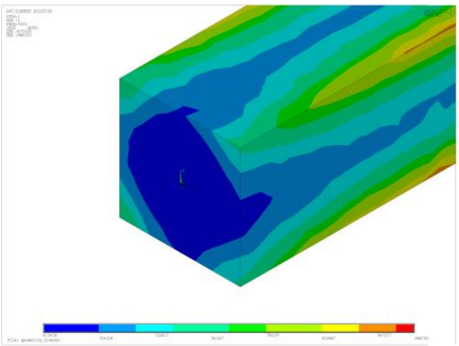

Figure 7: Square type geometry

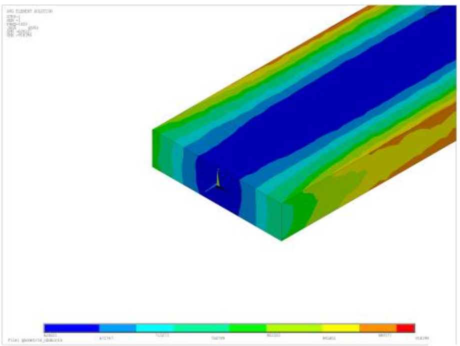

Figure 8: Rectangular type geometry

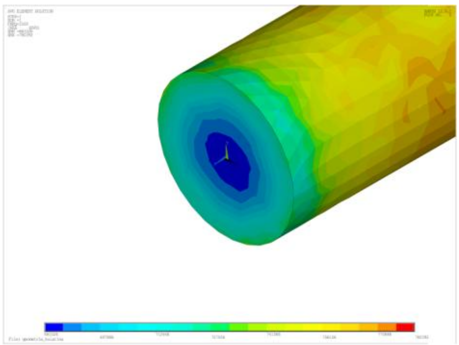

Figure 9: Circle type geometry

4. CONCLUSION

The aim of this study was to show the increase in heat loss during the passage of alternating current versus direct current passage and to change the current density distribution in the conductor. It was chosen AC frequency 1000 Hz to be significant due to skin effect, which contributes to the change in the distribution of current density and the associated increase in heat loss in the conductor.

Heat losses during the passage of direct current are shown in Figure 5. These values should be all the same, but because to the different geometry of the network element succored in the case of circular cross-section of the deviation compared to square and rectangular cross-section.

In the case of the passage of alternating current is to change the current density and an increase in heat loss as shown in Figure 6. Graphical representation of distribution Joule heat passing alternating current is shown in Figure 7 to 9, where skin effect is evident on the distribution Joules heat.

Heat losses have a negative effect on the operation of electrical machines and devices. These losses are more pronounced in the case of operation demand at the higher frequencies of alternating current than the nominal frequency.

For all calculations was used program ANSYS.

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