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Effects of a High Voltage Line on a Biological Tissue.

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Abstract: Living tissues are highly heterogeneous, with very specific properties; and in order to determine the interactions between electromagnetic fields generated by different sources to which we are exposed, it is imperative to be able to calculate the induced electromagnetic currents and to find out the resulting reactions. To apprehend the field nuisance on people's health, this paper highlights some of these effects from a simulation study of biological tissues (muscle sample) subjected to the electromagnetic field created by a 440 kV HV line. Induced currents in these tissues and their effects on blood microcirculation will be emphasized.

Key words: induced currents, blood velocity, electromagnetic phenomena, living tissue.

I. Introduction

The electromagnetic fields applications have become more evident in our domestic, professional and medical environments. They interact with human body and this interaction depends strongly on their frequency and intensity and some short-term effects can be observed [1-2].

Despite the numerous studies carried out on the effects of the electromagnetic field (EMF) over the last few decades, there is no consensus in the scientific community on the negative effects as they are considered a double-edged weapon. While some argue that EMFs have negative implications [3-6], others, contrarily certify that they can be used for diagnosis such as medical imaging (MRI) or for treatment of some cancer tumors by the technique of hyperthermia or in magneto therapy [7-9].

Laboratory: LEB (University Batna2)

This contradiction can be explained by the fact that the physical mechanisms through which these effects take place remain largely

unexplained and yield contradictory results or rely on restricted population specimen.

The modelling of the distribution of EMF in biological tissues must take into account the particularities of the "system" studied, such as the tissues electromagnetic properties, which constitutes a major difficulty, both in mathematical analysis and in numerical implementation [10-13].

Bad shoddy blood circulation is an increasingly common problem in people's health and is considered to be the main cause of a large number of pathologies such as diabetes, cancer and cardiovascular accidents, in order to enhance the blood flow parameters in the vessels, mainly viscosity and flow velocity, several investigations have been carried out using the effect of magnetic fields to reduce thickening, or viscosity of blood, which could be an alternative to drugs designed to ensure the fluidity of blood in humans [14-18].

Sample Dimensions	Thickness	1 [cm]
	Length	10 [cm]
	Width	10 [cm]

Table 1– Model dimensions

This can be explained by the fact that when blood, the conductive liquid, circulates through the magnetic field caused by the magnets, electric micro-currents are created and stimulate blood circulation, chemical exchanges are boosted and cells regenerated.

The currents induced in the tissues and their effects on the blood circulation rate will be highlighted in this paper. A modelling of the distribution of the electromagnetic fields in human body will be undertaken.

II. Sample Study

The sample deals with a model of muscular tissue with a 3D configuration (figure1) characterized by a unidirectional capillary blood flow in response to the electromagnetic field.

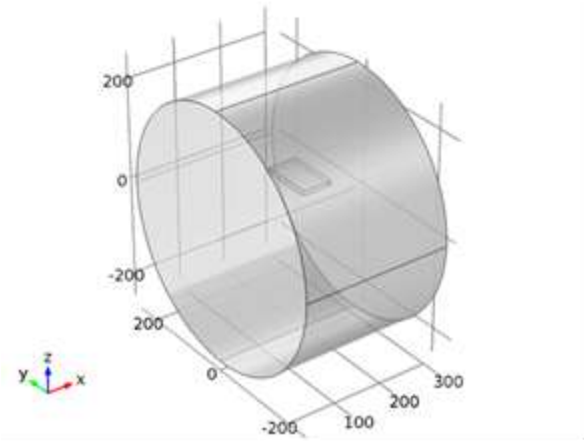

Figure 1 –Sample presentation: Tissue model, HV line and the air domain

III.Model presentation

The studied sample represents the skin of a worker's hand under the electric line exposed to its electromagnetic field. The dimensions of the sample and the properties of the tissue are indicated in tables 1 and 2:

Density	1000 [kg.m^{-2}]
Viscosity	0.005 [Pa.s]
Conductivity	0.23329 [S.m^{-1}]
Relative permittivity	1.7719e+07

Table 2– Blood properties [20]

To simulate the tissue responses to the effects of a 50Hz electromagnetic field, it is necessary to present the adopted mathematical model.

IV. Mathematical model

To study the effect of an applied magnetic field on blood velocity and direction in the capillaries that irrigate the muscles, a simulation was performed to solve the Maxwell and Navier-Stokes coupled equations.

IV.1. Magneto static Modelling

When solving a magnetic or electrical problem, it is often useful to use the appropriate potentials instead of the fields. The partial differential equations (PDE) obtained using the Maxwell equations in terms of magnetic vector potential A are adopted in the present work.

Law of conservation of magnetic flux:

$$Div\vec{B} = 0 \quad (1)$$

Ampere law:

$$\overrightarrow{Rot}\,\vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t} \quad (2)$$

Lenz law :

$$\overrightarrow{Rot}\,\vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (3)$$

and the constituent relations of materials:

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$$\vec{J} = \sigma.\vec{E} \qquad (4)$$

$$\vec{D} = \varepsilon.\vec{E} \qquad (5)$$

$$\vec{B} = \mu.\vec{H} \qquad (6)$$

In harmonic regime, these equations become:

$$\overrightarrow{Rot}\,\vec{B} = \mu(\sigma + j\omega\varepsilon)\vec{E} \qquad (7)$$

Introducing the operator ($\overrightarrow{Rot}$) in equation (7), we get:

$$\begin{aligned}\overrightarrow{Rot}\left(\overrightarrow{Rot}\vec{B}\right) &= \mu(\sigma + j\varepsilon\omega)\overrightarrow{Rot}\vec{E} \\ &= \mu(\sigma + j\varepsilon\omega)(-j\omega\vec{B}) \\ &= -\mu(j\omega\sigma - \varepsilon\omega^2)\vec{B}\end{aligned} \qquad (8)$$

So,

$$\overrightarrow{Rot}\left(\overrightarrow{Rot}\vec{B}\right) = -\mu(j\omega\sigma - \varepsilon\omega^2)\overrightarrow{Rot}\vec{A} \qquad (9)$$

Then,

$$Rot\vec{B} = -\mu(j\omega\sigma - \varepsilon\omega^2)\vec{A} \qquad (10)$$

Finally, the equation that governs the mathematical model is:

$$\left(j\omega\sigma - \varepsilon\omega^2\right)\vec{A} + \vec{\nabla} \wedge \left(\frac{1}{\mu}\vec{\nabla} \wedge \vec{A}\right) = 0 \qquad (11)$$

IV.2. Navier-Stokes Equations:

The effect of the magnetic field on the tissue is felt as a Lorentz force acting in the circulating blood and obeys the Navier-Stokes equations:

-Energy equation expressed by:

$$\frac{\partial \vec{\upsilon}}{\partial t} + (\vec{\upsilon}.\vec{\nabla})\vec{\upsilon} = -\frac{1}{\rho}\vec{\nabla}p + \nu\nabla^2\vec{\upsilon} + \vec{f} \qquad (12)$$

-Continuity equation given by:

$$\frac{\partial \rho}{\partial t} + \vec{\nabla}.(\rho\vec{\upsilon}) = 0 \qquad (13)$$

Taking into account the hypothesis that the blood is an incompressible fluid: $\rho = cst$

Then equation (13) becomes:

$$\frac{\partial \upsilon_x}{\partial x} + \frac{\partial \upsilon_y}{\partial y} + \frac{\partial \upsilon_z}{\partial z} = 0 \qquad (14)$$

The coupling term represented by the Lorenz force vector is given by:

$$\vec{f} = \vec{J} \wedge \vec{B} \qquad (15)$$

Where the current density is expressed by:

$$\vec{J} = \sigma\left(\vec{E} + \vec{\upsilon} \wedge \vec{B}\right), \qquad (16)$$

With directions used in the model, the only remaining component is:

$$f_z = \sigma B^2 \upsilon \qquad (17)$$

Where the different parameters denote:

ν	the cinematic viscosity [m^2·s-1],
ρ	the density [kg·m^{-3}], υ the velocity vector [m·s^{-1}],
μ_r	the relative magnetic permeability,
μ_0 0	the vacuum magnetic permeability [H.m^{-1}],
ω	the angular velocity of the applied signal [rad.s^{-1}],
f	the frequency
ε_0, ε_r	the vacuum electric permittivity [F.m^{-1}], the relative electric permittivity,
σ	the electric conductivity [S.m^{-1}],
f_z	the external vector force applied to the sample[N·kg^{-1}]
p	the pressure[N.m^{-2}],
A	the magnetic vector potential [Wb.m^{-1}]
B	the magnetic induction field [T].

The capillary is considered as a cylindrical elastic tube of the circular cross section containing an incompressible Newtonian fluid. The blood flow is modeled to be laminar, steady, two-dimensional and axisymmetric. The tissue model is as shown in the meshed figure 2 where the cylinder represents the simulation space.

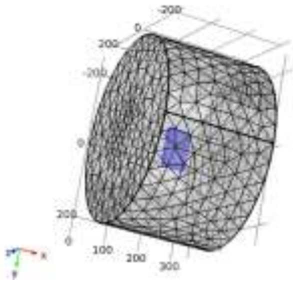
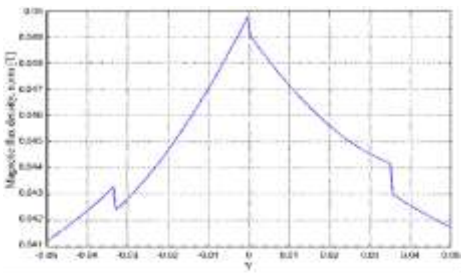


Figure 2 Sample mesh.

V. Simulation and results

The simulation was conducted by coupling the different elements and setting the appropriate boundary and initial conditions. We started with a zero blood speed (initial value $\upsilon(0)=0$ at the start of a heart beat cycle) at the entrance and selected a model with no slip conditions on the lateral faces of the tissue and atmospheric pressure at the output. Different parameters were analyzed and the results show an increase in blood speed and in the induced current which reaches a maximum value of 1.4 [A.m^{-2}]. The magnetic flux density distribution along the width of the sample is shown in figure 3 ((a) and (b)) and the induced current density distribution in figure 4. The maximum value is obtained at the middle of the sample because of its symmetry.

(a)



(b)

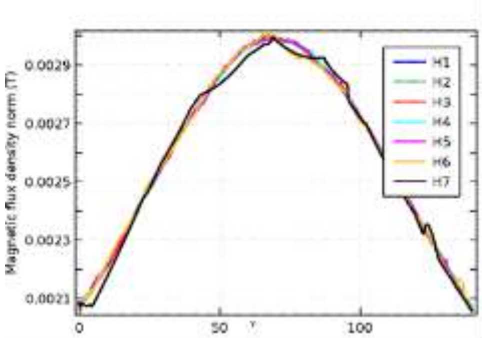


Figure 3 –Magnetic flux density distribution.

The magnetic time-variation of the field induces currents in the model which reach a peak at the middle of the sample are shown in figure 4.

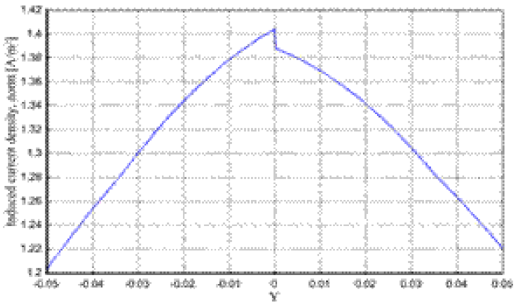


Figure 4 – Induced current density distribution

The effects of these two fields create the Lorentz force which, in turn, accelerates the blood and the speed reached three and half times its nominal value (0.005 [m.s^{-1}]).

The blood flow increasing the blood velocity in the capillaries could cause problems in the microcirculation, which could affect blood circulation in a general way[19-22]. This intensification is shown in the transverse direction (see figure 5) and along the x- direction (In the flow direction) as shown in figure 6.

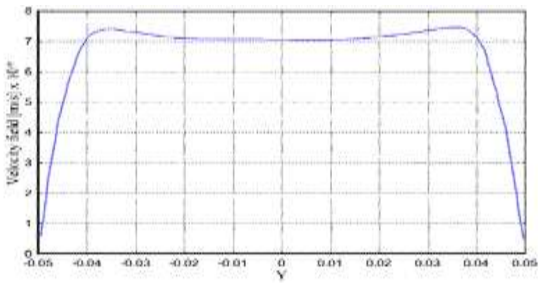


Figure 5 – Blood speed variations in the transverse direction.

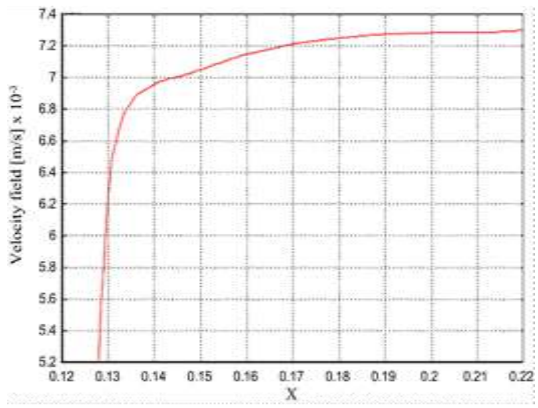


Figure 6 – Blood speed variations along the x-direction (In the flow direction)

VI. Conclusion

The results clearly show that this irradiation could be harmful to humans because of the increase of the flow velocity.

With this increase in velocity, the blood will flow faster, which could reduce the exchanges at the capillaries, and the concerned cells will have less glucose and dioxygen.

Knowing that one of the essential functions of microcirculation is to ensure a supply of oxygen and nutrients in line with the cellular metabolic demand. The dysfunction of micro vascular regulation mechanisms is at the center of tissue hypoxia, which contributes to organ dysfunction as observed in shock states.

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