Numerical optimization of blood viscosity to assess the impact of electromagnetic radiation using headphones

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1 INTRODUCTION

With the growth of technology, the use of electronic equipment, such as headphones, has become part of the daily life of the population. The use of electronic equipment has been increasing over the years, and they are a source of electromagnetic radiation usually located close to the human brain. For this reason, the aim of this study is to evaluate the effects of exposure to electromagnetic radiation emitting equipment such as headphones on blood rheology (Khongkhatithum et al., 2016; Lee et al., 2009). Assuming that a prolonged period of exposure to electromagnetic radiation from headphones can lead to disorder in blood rheology, a blood flow circuit and a coil model, which simulates the effects of electromagnetic radiation generated by headphones, were constructed (Lewicka et al., 2015; Mashevich et al., 2003; Padma et al., 2019). Blood viscosity analyses were performed to assess the characteristics before and after blood exposure to radiation. These parameters were obtained after one, two and four hours of exposure. Some changes were found. Leading us to the need for further investigations to find the problems that may be caused in other crucial components of the vascular system.

Changes in the rheological properties of blood have the potential to increase the risk of a range of health disorders and diseases, such as stroke (Alkuraishy *et al.*, 2014; Dhar *et al.,* 2012). Blood can have its rheological properties altered due to changes in the substances present in it, changes that can be either in concentration per standard unit volume, or by changing the substances themselves (composition and morphology).

Certain components present in blood, such as hemoglobin variants, are sensitive to the presence of magnetic forces, due to their diamagnetic or paramagnetic properties (Akar *et al.*, 2019; Furukawa et al., 2016). Thanks to these factors, external magnetic forces have the potential to interact with blood, and depending on the type of interaction have the potential to generate alteration in these substances, both in their behavior in blood flow, but also in their structures.

2 OBJECTIVE

In the present work, the studies of some rheological properties of blood when exposed to electromagnetic radiation and when not exposed will be presented. For this study, a model was created based on the properties of frequency and intensity of the magnetic field produced by a headset, a model to simulate the circulation of blood in a blood vessel.

3 METHODOLOGY

As magnetic forces, which come from magnetic fields, have the potential to cause rheological changes in the blood, emitters of such force fields have the same potential. Therefore, the longer the time spent and the greater the proximity to such emitters, the more worrisome the human interaction with equipment emitting electromagnetic radiation tends to be.

A good example of an electromagnetic radiation emitter that is so close to the user, added to the prolonged period of use, are headphones, equipment that is being used more frequently every day by the general population.

4 DEVELOPMENT

As the measured strain rates were not very high, the model used to obtain the curves relating viscosity and strain rate was the power law, as described below.

$$\mu = K\left(\frac{\partial u}{\partial y}\right)^{n-1} \tag{1}$$

Where μ is the viscosity, K is the consistency index, $\frac{\partial u}{\partial y}$ is the strain rate and n is the behavior index.

n > 1, dilatant fluids.

n = 1, Newtonian fluids.

n < 1, pseudoplastic fluids.

Blood viscosity data were computed for the samples of the time intervals 1 hour, 2 hours and 4 hours, with and without the presence of the incidence of electromagnetic waves (EMW). The range of measurements for the strain rate was from 75 s^{-1} to 750 s^{-1} .

In the graphs reported in Figure 1, Figure 2 and Figure 3 it is possible to see a trend of vertical displacement of the viscosity curve, demonstrating that variations in the behavior of the function occurred and its values moved to higher results, indicating an increase in viscosity, associated with a change in the behavior of the fluid with respect to the variation in the strain rate.

Figure 1: Comparison of blood viscosity at 0 and 4 hour conditions.

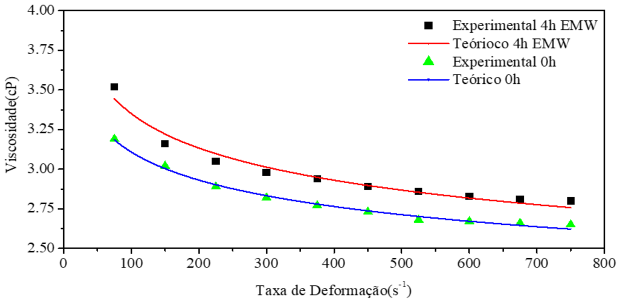


Figure 2: Comparison of blood viscosity at 0 and 2 hour conditions.

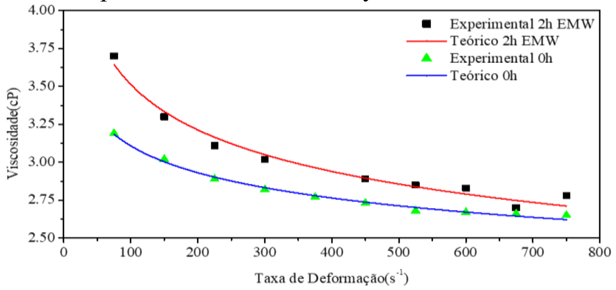
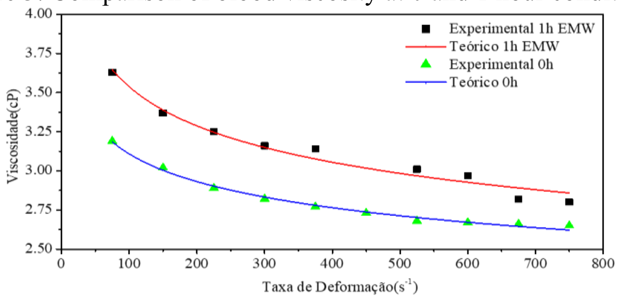


Figure 3: Comparison of blood viscosity at 0 and 1 hour conditions.



From the above graphs it was possible to obtain the fitted equations for each curve using the non-linear least squares method based on the model seen in Equation 1. With these results it is possible to have a better quantitative view of the differences in the viscosity of the samples exposed to electromagnetic radiation and the samples not exposed.

As seen in Table 1, it is shown that μ_{4h} and μ_{0h} represent the viscosities of the samples exposed for 4 hours and 0 hour respectively. Thus, it is possible to see that the model of Equation 1 was satisfactory due to the values very close to 1 (one) for R^2 , which demonstrates that the curve represents well the values obtained experimentally and with low error rates. The value of X^2 close to 0 (zero) shows that the experimental values for viscosity have a dependence relationship, which was expected.

Table 1: Regression results in the 4-hour and 0-hour conditions.

4 Hours of Exposure	0 Exposure Time
$\mu_{4h} = 5{,}22\left(\frac{du}{dy}\right)^{-0{,}09659}$	$\mu_{0h} = 4{,}58484\left(\frac{du}{dy}\right)^{-0{,}08443}$
$R^2 = 0.96447$	$R^2 = 0.99211$
$^2 X = 1.96 \times 10^{-3}$	$^2 X = 2.8 \times 10^{-4}$

Analyzing the equations for μ_{4h} and μ_{0h}, in Table 1, it is possible to see a change in the graph of Figure 1, the behavior of the curve changed with exposure n-1, varying from $-0,08443$ to $-0,09659$, this shows an absolute increase of approximately 14%, concomitantly there was a vertical displacement of the curve, with K values changing from 4.58484 to 5.22 (an increase of approximately 13%.).

Table 2: Regression results in the 2 hour and 0 hour conditions.

2 Hours Exposure	0 Exposure Time
$\mu_{2h} = 6{,}34602\left(\frac{du}{dy}\right)^{-0{,}12844}$	$\mu_{0h} = 4{,}58484\left(\frac{du}{dy}\right)^{-0{,}08443}$
$R^2 = 0.97858$	$R^2 = 0.99211$
$^2 X = 2.42 \times 10^{-3}$	$^2 X = 2.8 \times 10^{-4}$

In Table 2 it is possible to obtain the values for the curve for the sample exposed for 2 hours in the equation of μ_{2h}. The statistical data (R^2 and X^2) for this curve has similar properties to those seen in Table 1, indicating the good approximation of the model for the range of strain rate measured. The behavior remained similar to that seen previously, with increases for the values of K and n-1, where K was changed from 4.588484 to 6.34602, and n-1 decreased from $-0,08443$ to $-0,12844$.

Table 3: Regression results for the 1 hour and 0 hour conditions.

1 Hour Exposure	0 Exposure Time
$\mu_{1h} = 5{,}75188\left(\frac{du}{dy}\right)^{-0{,}10561}$	$\mu_{0h} = 4{,}58484\left(\frac{du}{dy}\right)^{-0{,}08443}$
$R^2 = 0.97031$	$R^2 = 0.99211$
$^2 X = 2.41 \times 10^{-3}$	$^2 X = 2.8 \times 10^{-4}$

From Table 3 it is possible to obtain the data for the 1-hour radiation exposure curve, μ_{1h}. As seen in Figure 3, the values of R^2 and X^2 also showed a similar behavior to that seen for the previous curves, indicating again that the non-linear regression model, based on the Equation 1 model, fitted well to the experimentally measured data.

The values found in Table 3 for μ_{1h} show a similar variation to that seen for the 4-hour and 2-hour exposures, with an increase in the consistency index, K, and a decrease in the behavior index, n-1. The K values increased from 4.58484 to 5.75188, while the n-1 values decreased from $-0,08443$ to $-0,10561$.

For the four samples, 4 hours of exposure, 2 hours of exposure, 1 hour of exposure and no exposure (0 hours of exposure), the blood remained with its pseudoplastic behavior unchanged, $n<1$, demonstrating that the behavior of the fluid was not altered.

As the viscosity measurements were made at a time longer than the end of the electromagnetic wave (EMW) exposure, ranging from a few minutes to a few hours, these results indicate a possible permanent change in the viscosity properties of the blood, not just momentary effects due to instantaneous exposure to the magnetic field.

The results contained in this study present evidence for the possible effects on blood viscosity of exposure to electromagnetic radiation generated by sources such as headphones.

The *in vitro* test was developed for small distances between the blood flow and the radiation emitting source.

During the measurements, the blood viscosity values took a considerable time to stabilize the reading in the equipment, a time in which aggregation and sedimentation of the red cells present in the blood occur, generating possible inaccuracies in the sample readings (Tripette *et al.*, 2015).

In all cases, the largest viscosity differences between the EMW-exposed and non-exposed samples were for shear rate within the first half of the measured range.

5 FINAL CONSIDERATIONS

This study provides some evidence of the effect of electromagnetic radiation on blood viscosity properties. In all samples seen the effects of change in viscosity were noticeable, which reinforces the hypothesis that exposure has an effect on blood viscosity, not only instantaneously during use, but permanently as well.

The data obtained so far encourage more in-depth studies on the subject with regard to possible other changes in the rheological properties of blood that also contribute to the appearance of worsening health conditions of the user.

More specific studies on some of the blood components could lead to answers of the behavior of viscosity after exposure, demonstrating possible changes in their structure or concentration, in particular hemoglobin and its variants.

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