Reduction effect of electromagnetic radiation emitted from mobile phones on human head using electromagnetic shielding materials

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ABSTRACT: Since the development of wireless technology we have been benefitted in many ways while becoming more susceptible to the electromagnetic radiations as electromagnetic radiations are the basic means of transmission in this technology. There has been many advancements in the technology which leads to the increased possibilities of exposure to the radiations. The constant exposure to the radiations is found be hazardous to the health of the person. There has been many efforts made by the scientist and research community so as to mitigate the bad effects of radiations by using the shielding materials which absorb the radiations. In this paper we have tried reducing the effect of electromagnetic radiations coming from mobile phones on human head. We used 6 materials as shielding materials. They are germanium, silver, nickel, ferrite, polyurethane and ABS. We conducted thermal analysis in ANSYS workbench. The results are showing that the heat flux developed and the temperature rise is minimum in case of polyurethane while it is maximum with silver.

1. Introduction:

Mobile phone usage has become an integral part of our day today life. But the more we use the mobile phone the more we are prone to the exposure to the electromagnetic radiations emitted by them. The radiations emitted have a hazardous effect on the human body and health. Using the mobile phones for longer duration has many health risks associated with it. Taking the example of holding the mobile phone for longer duration near the ear phone which causes the rise in the temperature of the ear and the absorption of radio frequency energy by the tissues of the ear will lead to the hearing related disorder. Sometimes it creates the damage to the organs which are not even in direct contact with the mobile. Some of the disorders include Alzheimer’s disease, Parkinson's disease, brain tumor, infertility etc. To avoid these all problems the governments of all the countries have set a maximum limit of SAR value for all the mobile phones and all the electromagnetic energy source devices as well[3]. Specific Absorption Rate is the expanded definition of SAR. It shows how much energy the body tissue has absorbed when exposed to radiations. SAR value in India 1.6W/kg estimated over an average of 1g of human tissue. There have been many research works are been carried out to find a means to alleviate the effect of electromagnetic radiations on human body.
Some works focused on the study of SAR value variation in the human head[4]. Some focused on variation of SAR with respect to different holding positions of mobile phones near the cheek[6]. Few works targeted the solution realm where they worked on finding the suitable means to reduce the effects the radiations on human head[1]. Some worked on the variation of SAR value with different frequencies of mobile phone[5], some worked on particularly the variation of SAR in adult and child head by simulating the antenna. In this paper we are directing our efforts to analyze the variation of temperature around the human ear which often is exposed to the radiations. Variations of heat flux is also been studies in the paper pointing out the region of maximum heat flux and maximum temperature rise. Later in the paper effect of placing the shielding material in between head and the mobile phone on temperature rise and heat flux is also studied and conclusions made of which material best suits for the shielding purpose. Our paper distinguishes itself from the formerly published paper with its feature of using the modeled human head and simulating the model in ANSYS 18.2 workbench (steady state thermal is used to simulate the scenario). As it shows the heat flux and temperature variations in human head which any other paper has not done. It can be a novel approach for the study of effect of electromagnetic radiations on human head.

2. Materials and method
2.1 Simulation models:
2.1.1. Human head model:
The model we have used for the analysis are human head model, model of mobile phone and the model of the shielding material. The model is meshed in the ANSYS workbench, the loads and boundary conditions are assigned and solved in steady state thermal. In case of human head model we have divided it into 4 different layers of tissues. They are skin, fat, skull and the brain each of which occupy one layer. The human head model is shown in Figure 1. This model is imported from Grabcad library.

![Layers of skin, fat, skull and brain](image)

**Figure 1.** Human Head Model with different tissue layers on one side

2.1.2. Mobile phone model:
The mobile phone is modeled as a rectangular box with the dimensions as shown in Figure 2. The dimensions (Figure 3), for the model are taken from a research article[4] and is modeled in solid works.
As the analysis works are carried out in the Ansys steady state thermal analysis mobile phone has to be modeled as a heated element with an emissivity value which acts as a source of radiations. On extensive research we could able to find the temperature range our mobile phones can reach when they are heated while they are in use, that is from 40 degree Celsius to 80 degree Celsius. In this paper an average value of 60 degree Celsius is considered as the temperature of heated element. An average output radiated power of the mobile phone is considered and the value is 0.125w[2].The detailed calculations are shown below.

\[ T = \text{Power output of a radiation source is given by} \]

\[ P = E \times S_t \times A \times T^4 \]  \[ \text{……………………………(1)} \]

Where,
- \( P \) = Output radiated power
- \( E \) = Emissivity of the material
- \( A \) = Surface area of radiating surface
- \( S_t \) = Stefan Boltzmann constant
Temperature of the heated element or radiating surface=333
We know that, \( P=0.125 \), \( S=0.145\times0.075=0.010875\,m^2 \), \( S_t=5.67\times10^{-8}\,W/m^2\cdot K^4 \)
Now solving for \( E \) using the available data we will get \( E=0.016 \)
Using this value we can simulate the mobile phone in the analysis.

2.1.3. Shielding material model:
The shielding material modeled as a thin rectangular plate with the dimensions as shown in Figure 4.
The thickness is not shown in the Figure 5, which is equal to 1mm. This shielding plate is modeled in Solidworks and the dimensions are taken from a standard research article[4].

![Figure 4. shielding case model](image1)

![Figure 5. shielding case dimensions](image2)

2.1.4. Meshed model with mobile phone assembled:
The human head model is meshed in the Ansys workbench with coarse meshing and it is shown in Figure 6.
2.2. The simulation technique:

Mobile phone is used as a heated element and it acts as a source of radiations we assigned it a particular temperature in the range of 60-80 degree Celsius as I have quoted earlier in the paper. It is also assigned with an emissivity value which we have calculated. The analysis we have chosen for our project is steady state thermal analysis. In this radiation analysis is done. As it is not possible to simulate the mobile phone in this application, the mobile phone is modeled as a source of radiation (a heated element) which emits the radiations. The respective temperature and the emissivity values are also been assigned. The shield placed over the phone is also assigned with different shielding materials and boundary conditions such as temperature load. The 4 layers of human head are assigned with the respective thermal properties like thermal conductivity, specific heat and density. Later boundary conditions are applied to these 4 layers as well. Later the model is solved for heat flux and temperature values and the results are interpreted.

The detailed explanation of the boundary conditions used and the loading conditions used are explained below:

- As by analytical calculations in the previous section of the paper i.e, 0.016.
- The shielding material which is placed over the mobile phone is assigned with the respective shielding material properties and a normal room temperature of 28 degree Celsius.
- In the similar way the properties of skin, skull, fat and brain properties are applied to the respective layers of human head. Corresponding temperatures are also been applied to the layers which range from 30-37 degree Celsius. These temperature values are taken from a standard research article.
- Radiation boundary conditions are assigned to the two surfaces which are mobile phone and the skin. The analysis settings are made to surface to surface radiation.
- The model is solved for the temperature variation and the heat flux in the human head.
• The material of shielding is changed and the results are obtained to see how placing of different materials between the mobile phone and the human body affects the energy absorption by the various tissues.

2.3. Materials used and properties:

On doing a lot of research and literature review we found that there are several materials which shield the electromagnetic radiations. They are ferrite, nickel, silver, leather, germanium materials etc., In our study we have used the following materials. Table 1 gives the properties of the materials we have used and the properties of body tissues.

Table 1. Showing the properties of various materials used.

| Materials  | density(kg/m^3) | Thermal conductivity(w/m-k) | specific heat(j/kg-k) | emissivity | Conductivity(s/m) |
|------------|----------------|----------------------------|----------------------|------------|-------------------|
| Germanium  | 5323           | 58                         | 324                  | 0.55       | 2000              |
| Nickel     | 8880           | 60.7                       | 460                  | 0.08       | 1.43×10^7         |
| Silver     | 10419          | 419                        | 234                  | 0.055      | 6.3×10^7          |
| Ferrite    | 4800           | 80                         | 750                  | 0.5        | 1.1×10^4          |
| Skin       | 1010           | 0.21                       | 3770                 | 0.95       | 0.53              |
| Brain      | 1050           | 0.53                       | 3690                 | 0.8        | 0.441             |
| Skull      | 1990           | 0.39                       | 1300                 | 0.76       | 4×10^-4           |
| Fat        | 850            | 0.16                       | 2510                 | 0.68       | 0.16              |
| Polyurethane| 65           | 0.035                      | 1800                 | 0.9        | 5.9×10^-9         |
| ABS        | 1400           | 0.1                        | 2000                 | 0.92       | 10^-15            |

3. Simulation Setup in ANSYS 18.2

The below Figure 7 shows the setup we have made in Ansys 18.2 workbench for solving the model. It shows the setup of all the models[7,8,9].

![Figure 7. Simulation setup](image-url)
4. Finite Element Analysis Results:

4.1 Without using any shielding

Figure 8 and Figure 9 showing the temperature and heat flux in human head respectively.

![Figure 8. Temperature](image)

![Figure 9. Heat flux](image)

4.2 With shielding material germanium

Figure 10 and Figure 11 showing the temperature and heat flux in human head respectively.

![Figure 10. Temperature](image)
4.3 With shielding material ferrite

Figure 12 and Figure 13 showing the temperature and heat flux in human head respectively [10, 11].
4.4 With shielding material nickel
Figure 14 and Figure 15 showing the temperature and heat flux in human head respectively[12,13].

4.5 With shielding material silver
Figure 16 and Figure 17 showing the temperature and heat flux in human head respectively[14].
4.6 With polyurethane as shielding material
Figure 18 and Figure 19 showing the temperature and heat flux in human head respectively[15].
4.7 With ABS as shielding material

Figure 20 and Figure 21 showing the temperature and heat flux in human head respectively[16].

![Figure 20. Temperature](image)

![Figure 21. Heat flux](image)

The following Table 2 gives the results of analysis. It gives the initial temperature and finally reached temperature in the human head. It also shows the heat flux generated in the human head in different cases as mentioned in the analysis section.

| Materials     | Heat flux (W/m²) | Initial Temperature (°C) | Final Temperature (°C) | Temperature rise |
|---------------|------------------|--------------------------|------------------------|-----------------|
| Without shield| 1061            | 35                       | 46                     | 11              |
| Germanium     | 4427.7          | 35                       | 37                     | 2               |
| Nickel        | 7969.9          | 35                       | 40                     | 5               |
| Ferrite       | 7992.1          | 35                       | 41                     | 6               |
| Silver        | 8036.7          | 35                       | 43                     | 8               |
| Polyurethane  | 4073.5          | 35                       | 37                     | 2               |
| ABS           | 6198.8          | 35                       | 39                     | 4               |
The below Table 3 gives the percentage rise in the temperature for different cases as mentioned in the analysis section

| Material  | Percentage Rise(%) |
|-----------|---------------------|
| Without Shield | 31 |
| Germanium   | 5.7 |
| Nickel      | 14.2 |
| Ferrite     | 17.14 |
| Silver      | 22.8 |
| Polyurethane| 5.7 |
| ABS         | 11.4 |

5. Results and discussions

The table is plot based on the simulation results obtained from ANSYS workbench. The table reveals the variation of the heat flux and the temperature distribution in the human head with respect to different shielding materials like germanium, nickel, silver, ferrite, polyurethane and ABS. We could observe that the heat flux is peak around the ear surroundings as that region is more exposed to radiations. Comparison of the magnitude of heat flux in all the four cases shows that for polyurethane the heat flux is lesser and for silver it is minimum with the values of 4073.5 W/m² and 8036.7 Wm² respectively which are way greater than that of without any shielding material that is 10611 W/m². Similar results are posed before us from simulation for temperature variation as well. The temperature rises observed are in proportion with the heat flux values. The highest temperature rise observed is 11 c without any shielding materials. The lowest among the shielding materials is with polyurethane with only 2 degree Celsius variation from the normal skin temperature.

SAR value for different material shielding has to be calculated. But as our simulation is purely carried out in steady state thermal analysis it is not possible to calculate the SAR value here. Nevertheless an attempt is made to at least find the variation of SAR value with respect to the use of different shielding materials. This is made possible with the help of some analytical calculations. Which are discussed below

We know that the heat flux developed is directly proportional to the electric field[3] i.e, $q_αE_0^{[3]}$......(2)

From the analysis results we can see that minimum heat flux is developed in case of polyurethane shielding and is maximum for silver which implies that the SAR value in case of polyurethane is way minimum where as it is maximum in case of silver shielding.

6. Conclusion

From the results a cognitive decision can be made with respect to selecting the better shielding material for electromagnetic radiations. According to the cognitive inferences, made in the results and discussion section, it can be concluded that for polyurethane the SAR value obtained is minimum where as it is maximum for silver casing. Hence the polyurethane can be used to make the flip cover case for mobile phone. The flip cover case which acts as a barrier between human head and the mobile phone shields the radiations emitted out of the mobile phone and thereby alleviating the health effects of radiations.
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