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INFLUENCE OF INTERNAL HEAT ON SANDY-LOAM SOIL AND HOW THEY ARE BEING INFLUENCED BY MOISTURE AND MAGNETIZATION

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Abstract

This work investigates the correlation between the internal heat and sandy-loam soil, specifically looking at how moisture and magnetization impact this relationship. The heat transfer equation was employed to formulate the equations that govern the work with appropriate conditions at which the flow took place. The physical factors of concern, that is, the internal heat and magnetic parameter were examined on the equation of the ambient temperature of the soil of choice. Specific moisture contents of the soil were also put into consideration. The results showed that all the three factors play significant role in influencing the properties and behavior of this type of soil, especially its temperature. Overall, this work provides valuable insights into the behavior of sandy-loam soil under various conditions, giving researchers better understanding of how to manage and optimize this widely-used soil type.

***Keywords**: Heat transfer, magnetization, moisture, internal heat, sandy-loam soil.*

1. Introduction

Internal heat refers to the heat generated within the soil due to various factors, such as microbial activity, chemical reactions, such as the radiogenic heat which was produced by naturally radioactive isotopes or elements decay inside earth crust, and temperature changes due primordial heat being left over from earth formation (Turcotte and Schubert, 2002). Sandy-loam soil is a common type of soil found in many regions and is known to have a high water-holding capacity. Moisture is an important factor that can affect the physical and chemical properties of soil, while magnetization is a measure of the soil's ability to retain magnetic properties. All these important factors make the study an interesting one.

Akinpelu *et al.* (2020) in their work made a comparison between Sandy-loam and clay-loam; how they are being influence by solar radiation. Their results established that fact that the solar radiation shoot up the temperature of both soils as its intensity also rises; though the increase is more noticeable in sandy-loam than that of clay-loam. Without the presence of magnetic field, Ogunsola *et al,* (2022) considered how saturation can affect temperature of some selected soil samples.

In all the soils sampled, the solar radiation was found to boost the temperature of these soils. This boost was more prominent when the soils became saturated with water. Investigation conducted by Nwankwo & Ogagarue in 2012 using a thermometer of mercury-in-glass type in measuring depths of soils in some areas along southern Nigeria recorded variations in the temperature of the soils in examination. These variations occurred at various depths and ranges from soil to soil.

Few among many others whose interests have been published along this line of study include Xiaodan *et al.* (2009) who studied soil moisture variability and the relationship it has with surface albedo amid the soil thermal factors on loess plateau. Mahmoodi and Kianmehr (2008) determined and compared thermal conductivity of varieties of pomegranate in Iran.

The study however, intends to investigate the effects of internal heat on sandy-loam soil and how these effects are influenced by moisture and magnetization. Understanding these effects is crucial for developing effective strategies for sustainable land management. This study is capable of providing valuable insights into the complex interplay between internal heat, moisture, and magnetization in sandy-loam soil and serves as a base for further research in this area.

2. Mathematical Analysis

Heat transfer equation is deployed in the formulation of the model. It is considered that the flow is more of the vertical direction that horizontal. In other words, the horizontal flow is taken to be infinite, leaving the equation to be of the function of z (which represents the vertical direction) and that of t (time), that is, it is unstable. The internal heat active in the soil, and the soil is optically thin, permitting easy flow of heat. Utilizing Boussinesq's approximation, base on the above mentioned suppositions, the equations that govern the flow became:

Continuity equation

$$\frac{\partial \overline{w}}{\partial \overline{z}} = 0 \qquad (1)$$

Energy equation

$$\rho C_p \sigma \frac{\partial \overline{T}}{\partial \overline{t}} + \rho C_p \varphi \frac{\partial \overline{T}}{\partial \overline{z}} = \frac{\partial}{\partial \overline{z}}\left(k \frac{\partial \overline{T}}{\partial \overline{z}}\right) - \varphi \frac{\partial \overline{q}_r}{\partial \overline{z}} + Q_0(\overline{T} - \overline{T}_\infty) - \sigma B_0^2 w^2 \qquad (2)$$

Subject to:

$$\overline{T}(t,0) = \overline{T}_w + \overline{\lambda}\cos(\overline{\omega}\bar{t}) \quad (3)$$

$$\overline{T}(t,\infty) \to \overline{T}_\infty \quad (4)$$

where, $\bar{z}$ = soil depth (dimensional),

$\overline{T}$ = Temperature (dimensional),

$\overline{w}$ = suction velocity dimensional,

$\bar{t}$ = time (dimensional),

$\overline{T}_\infty$ = free stream temperature (dimensional),

k = thermal conductivity,

$\overline{T}_w$ = wall temperature (dimensional),

$\overline{q}_r$ = heat flux (dimensional),

ρ = density, C_p = specific heat capacity

Bringing in some standardized dimensionless parameters which are in line with some existing works such as Akinpelu *et al*. (2017):

$$t = w^{-1}\bar{t}w_0^2,\ \zeta_0 = \frac{\overline{\lambda}}{\overline{T}_w - \overline{T}_\infty},\ n = \frac{w\overline{n}}{w_0^2},\quad \theta = \frac{\overline{T} - \overline{T}_\infty}{\overline{T}_w - \overline{T}_\infty},\quad z = w^{-1}w_0\bar{z} \quad (5)$$

In addition, following the work of Mohammed (2013), suction velocity is taken to be constant:

$$\overline{w} = -w_0 \quad (6)$$

where

w_0 = initial suction velocity

Consequently, heat flux, according to Akinpelu *et al.,* (2020) is:

$$\frac{\partial \overline{q}_r}{\partial \bar{z}} = 4\mu^2(\overline{T} - \overline{T}_\infty) \quad (7)$$

μ = absorption coefficient

Besides, considering the work of Ogunsola *et al.,* (2022) and Nwaigwe (2010) among others, thermal conductivity is taken to be time-dependent and linear:

$$k = k_0 + \beta k_0 t \quad (8)$$

where,

β = variable thermal conductivity parameter, k_0 = constant thermal conductivity,

t = time

Depositing equations (5) to (8) into that of (2):

$$\gamma \frac{\partial \theta}{\partial t} - \frac{\partial \theta}{\partial z} = \frac{1}{P_r}\left\{\frac{\partial}{\partial z}\left((1+\beta t)\frac{\partial \theta}{\partial z}\right)\right\} + (Q - R^2)\theta - (Ha)^2 Ec \quad (9)$$

Subject to:

$$\theta(t,0) = 1 + \zeta_0 \cos(\omega t) \quad (10)$$

$$\theta(t,\infty) \to 0 \quad (11)$$

where,

$$\gamma = \frac{\sigma}{\varphi}, \qquad P_r = \frac{w\rho\varphi C_p}{k_0}$$

$$Q = \frac{Q_0 w}{\rho C_p \varphi w_0^2}, \qquad R^2 = \frac{4\alpha^2 w}{\rho C_p w_0^2}$$

$$Ec = \frac{w^3}{w_0^2 C_p (\bar{T}_w - \bar{T}_\infty)}, \qquad Ha = (B_0)\sqrt{\frac{\sigma}{\rho\varphi}}$$

Pr is Prandtl number, Q is Internal Heat, R is radiation parameter, Ec is Eckert number and Ha is Hartman number.

3. Method of Solution

Equation (9) which is the non-dimensionalized form of the equation (2) is first lessened to be ordinary differential equation with the use of perturbation method. The supposed solution is specified as:

$$\theta(z,t) = \theta_0(z) + \varepsilon\delta e^{nt}\theta_1(z) + \dots \tag{12}$$

Placing equation (12) with its derivatives into equation (9), and ignoring upper order terms $o(\varepsilon\delta)^2$:

$$\theta_0'' + A\theta_0' + (Q - R^2)A\theta_0 = A(Ha)^2 Ec \tag{13}$$

$$\theta_1'' + A\theta_1' + \left\{(Q - R^2) - n\gamma\right\}\theta_1 = 0 \tag{14}$$

By means of equation (12), equivalent boundary conditions (10) & (11) become:

$$\theta_0 = 1 + \zeta_0 \cos(\omega t) \ , \quad \theta_1 = 0 \qquad \text{on} \qquad z = 0 \tag{15}$$

$$\theta_0 \to 0, \qquad \theta_1 \to 0 \qquad \text{as} \qquad z \to \infty \tag{16}$$

Solving (13) & (14) under the boundary settings (15) & (16):

$$\theta = (1 + \zeta_0 \cos(\omega t) - D_1 - D_2)e^{m_2 z} \tag{19}$$

where,

θ is the transient temperature gradient

$$A = \frac{P_r}{1 + \beta t}$$

$$D_1 = -D_2 e^{-m_1 z}$$

$$D_2 = \frac{(Ha)^2 Ec}{Q - R^2}$$

$$m_1 = -\frac{A}{2} + \sqrt{\left(\frac{A^2}{4} + AR^2 - AQ\right)}$$

$$m_2 = -\left(\frac{A}{2} + \sqrt{\left(\frac{A}{4} + AR^2 - AQ\right)}\right)$$

4. Results and Discussion

In line of the study, the internal heat which is the main focus and one of the physical parameters that emerged from the work, alongside Hartman number (magnetic parameter) were examined on equation (19) which represents the temperature gradient of the sample soil. The soil of choice is sandy-loam which thermal conductivity base on the level of moisture content is given on table 1 (below).

Besides, some important standardized parametric values adopted in the work are given below except/otherwise affirmed.

$$P_r = 0.71,\ Ha = 0.01,\ Q = 0.01,\ n = 1.00,\ t = 0.10,\ \omega = \pi/2,\ \zeta_0 = 1.00$$
$$R = 0.01,\ s = 0.19,\ Ec = 0.01$$

Table 1: Thermo-physical property of Sandy-Loam soil (Abu-Hamdeh and Reeder, 2000)

Soil	Thermal Conductivity (W/m K)	Moisture Content (%)
Sandy-Loam	0.19	1.4
Sandy-Loam	1.12	21.2

Figure 1 is the impact that internal heat has on the temperature of sandy-loam soil. It is glaring that there is corresponding increase in the soil temperature as the internal heat is enhanced. This aligns with existing researches along this area. Such includes Ogunsola *et al.*, (2022).

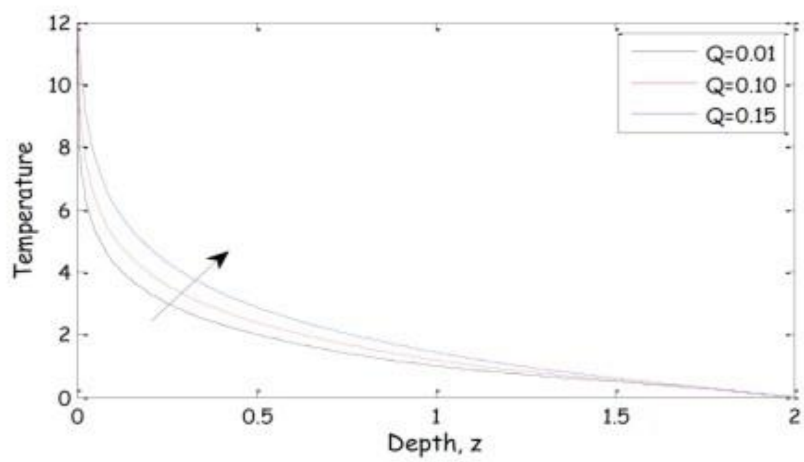

Figure 1: Result of increasing internal heat on sandy-loam temperature

In figure 2, the moisture level was increased from 1.4% to 21.1% for the soil while all other parameters were held constant. It is noted that the moisture level has significant effect on the soil temperature; increasing level of moisture content raises the soil temperature.

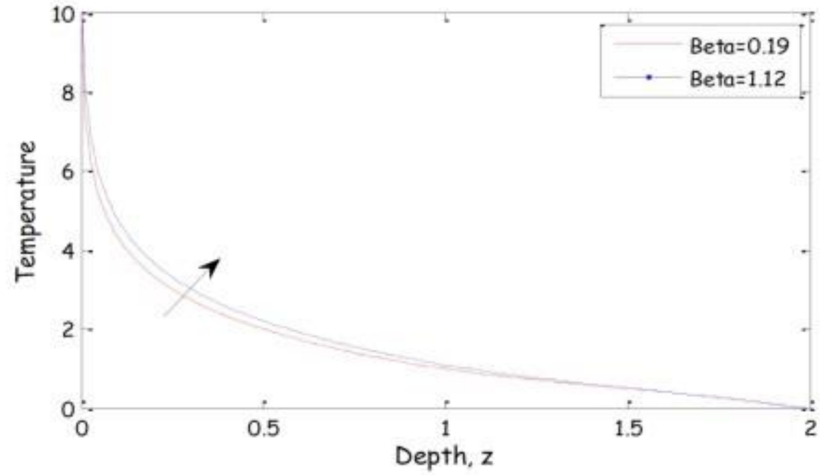

Figure 2: Temperature of sandy-loam at different moisture level

Figure 3 potrays the effect that magnetization has on sandy-loam temperature. According to the result, it is clear that magnetization heightens the warmth of sandy-loam soil.

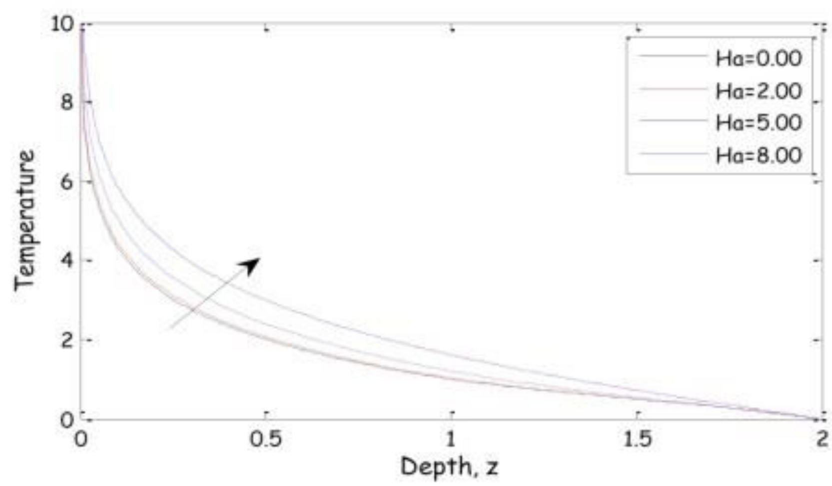

Figure 3: Result of magnetization on sandy-loam temperature

In figures 4 and 5, mounting internal heat was examined on the warmth of the soil at different moisture content without magnetization and when the soil was magnetized respectively. The results reveal temperature increase in the soil in both cases. The enhancement is however more prominent when the humidity level is higher.

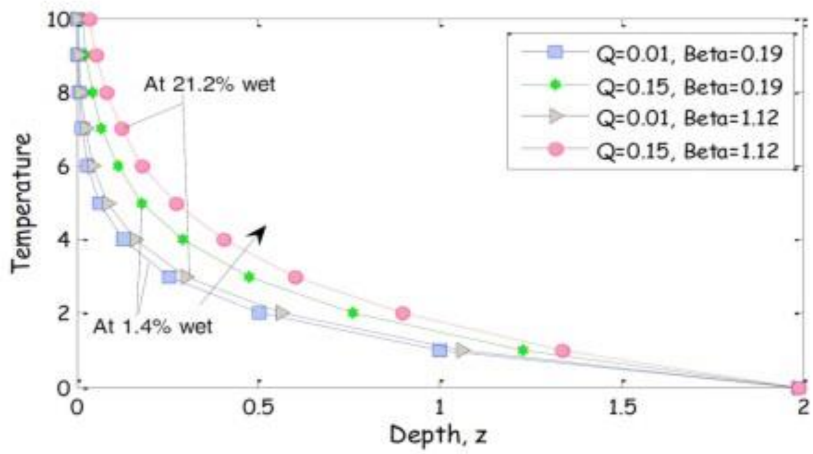

Figure 4: Result of increasing internal heat on sandy-loam temperature at different moisture content without magnetization

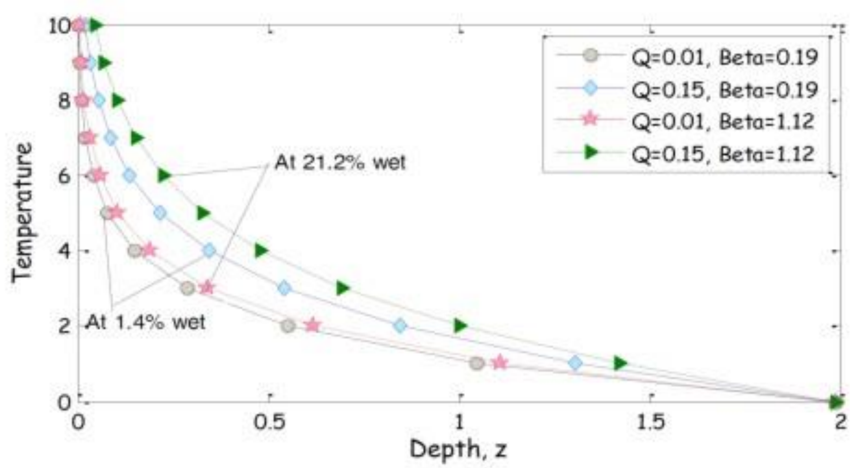

Figure 5: Result of increasing internal heat on sandy-loam temperature at different moisture content with magnetization

Internal heat was then scrutinized on the soil warmth in figure 6, without magnetization and when the soil was magnetized. It is generally noticed that soil temperature is boosted with or without magnetization. Nonetheless, the warmness of magnetized soil is more than that of the soil without magnetization.

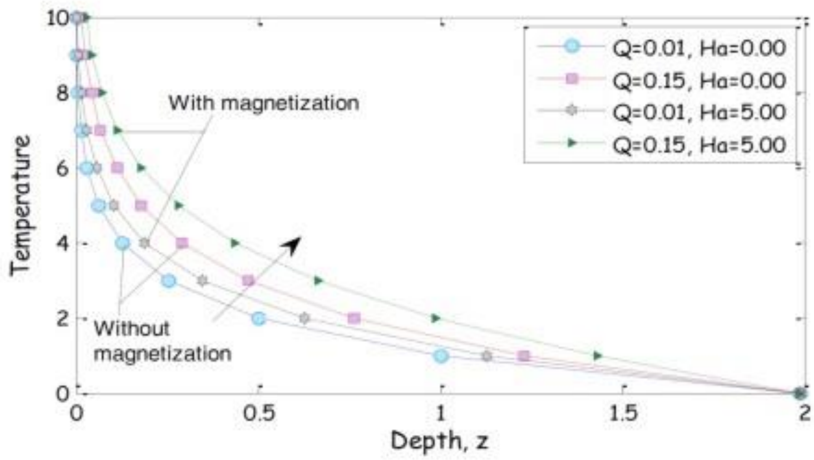

Figure 6: Results of increasing internal heat with and without magnetization on sandy-loam temperature.

5. Conclusion

The influence of internal heat on sandy-loam soil and how they are being influenced by moisture and magnetization was studied. To assess this, we conducted a series of examinations using the formulated Mathematical model at different levels of moisture and magnetization. Our findings show that internal heat has a significant impact on the overall behavior of the temperature of sandy-loam soil and this impact is amplified by changes in moisture and magnetization. The results indicate that as the internal heat increases, there is relative increase in hotness of the soil. This suggests that internal heat can alter the physical and chemical properties of sandy-loam soil, which can have a direct impact on plant growth and nutrient availability.

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