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# VELOCITY HEAT CONDUCTIVITY (VHC) MODEL FOR TWO AUTONOMOUS MOBILE ROBOTS IN ENERGY WORKSPACE

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## ABSTRACT

*In this paper, the research study on velocity heat conductivity (VHC) model for two autonomous mobile robots in energy workspace is adopted. The model is applied to solve and address; the conversion of heat energy conductivity into kinetic (internal) energy conductivity of the robots, to obtain the velocity energy placement and to derive a velocity heat conductivity mathematical model for algorithm simulation drive using specific heat capacity and thermal diffusivity response in energy workspace. The experiment was conducted on MOBOT SIM software, MATLAB software program and Microsoft window 10 operating system.*

**KEYWORDS**: *Velocity, Heat, Kinetic energy, Conductivity, Workspace, Diffusivity, Robot*.

## 1. INTRODUCTION

Within this context, heat conductivity is the process of conducting heat properties or transfer of heat properties from one metal (robot) body to another metal (robot) body. Velocity energy placement is the energy placement where robots of different kinetic (internal) energy travel in an energy grid velocity around the conduction layers. Robot velocity is the rate of change of robot displacement in an energy workspace. Thermal conductivity is the product of thermal diffusivity, density of conductivity and specific heat capacity of robots conductivity within the energy workspace. There are series of Literature updates to this effect such as;

Storm M.L. [1] reported that partial differential equation of heat conduction is a nonlinear equation when the temperature dependence of the thermal parameter is taken into account and Antippa A.F. [2] established three alternatives traditional definition of kinetic energy and then proposed a new definition according to which the change in kinetic energy is equal to the scalar product of the velocity and the change in momentum while Lee J. [3] bounded on each joint velocity from a polytope in joint velocity space and the task space velocity is connected with joint velocity through jacobian matrices of each robot.

Lee J.A. [4] proposed a method application to the task velocity analysis for robot manipulators with joint velocity constraints and Erlinchson H. [5] reported that the definition of the internal energy of a thermodynamic system in most introductory text usually states or implies that the c.m. kinetic energy of the system is not part of the internal energy while Pellegrinelli et al. [6] proposed a methodology for the automatic generation of robot trajectories and sequencing of the robot while minimizing the energy consumption.

Maimon et al. [7] established that the energy required performing the robotic task in calculated while Chung D.D.L [8] said that his paper is a review of materials for thermal conduction, including material of high thermal conductivity and thermal interface materials.

## 2. PROBLEM IDENTIFICATION

This section highlighted the problems associated with; heat energy conductivity conversion into kinetic (internal) energy conductivity, the velocity energy placement layer and derivation of velocity heat conductivity within the energy workspace.

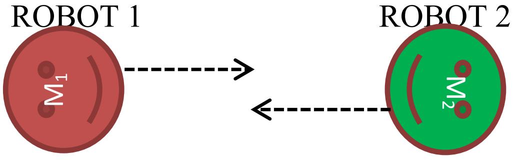

**Figure 1. Shows two neutral robots without energy workspace, velocity placement and velocity heat conductivity.**

The question asked relating the velocity heat conductivity (VHC) model includes;

(1). What kind of environment is suitable to have complete velocity heat conductivity within the energy workspace?

(2). Is there any derivation formula for velocity heat conductivity with respect to energy workspace?

(3). Can there be any velocity placement along the energy workspace?

(4). What mathematical algorithm is suitable for the two robots simulation within the energy workspace?

(5). Is there any energy conversion required to maintain the velocity heat conductivity?

## 3. SOLUTION PROPOSED

This section highlighted the solutions implemented to solve and address the problems identified in section 2.

### 3.1. BELOW ARE DEFINITIONS OF TERMS

[1]. **Velocity**: This is the rate of change of displacement.

[2]. **Displacement**: This is the distance covered in a specified direction.

[3]. **Conductivity**: This is the process of transferring heat (energy) through a material from one place to another.

[4]. **Thermal**: This is the process at which heat is applied to a body or material.

[5]. **Kinetic Energy**: This is the energy attained due to motion.

[6]. **Heat Capacity**: This is the heat required to raise the temperature of a body by 1K.

[7]. **Specific Heat Capacity**: This is the heat capacity required to raise the temperature of unit mass of 1Kg.

[8]. **Diffusivity**: This is the penetration of heat content owing to the kinetic nature of the molecule.

### 3.2. THE NATURE OF ENVIRONMENT

The nature of environment required for energy conversion, velocity partition within the energy workspace and the derivation of mathematical algorithm for the robots velocity heat conductivity is called completely unknown environment (CUE). At this point, the two neutral robots are completely unaware of the environment and the kind of algorithm application that would simulate the two robots with respect to velocity heat conductivity in energy workspace.

### 3.3. VELOCITY HEAT CONDUCTIVITY (VHC) ALGORITHM PROCEDURE

This section highlighted the mathematical algorithm procedure being applied on the robots simulator to drive the velocity heat conductivity concept.

Assuming, the energy workspace $E_s$ is the workspace where all the energy grid conductivity and projection takes place on the two mobile robots. The quantity of heat required for conductivity of the robots in the energy workspace is given as;

$$Q_d = M\,C_p\,\Delta T \qquad (1)$$

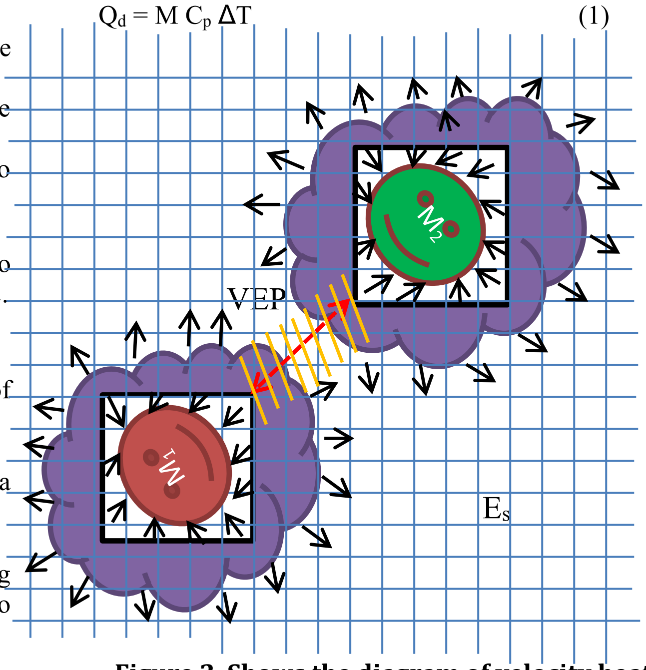

**Figure 2. Shows the diagram of velocity heat conductivity of two mobile robots in energy workspace.**

Then, making $C_p$ the subject of the formula;

$$C_p = Q_d / M\,\Delta T \qquad (2)$$

Where, $C_p$ = Specific heat capacity of heat conductivity of the robots, $Q_d$ = Quantity of heat required for conductivity, M = Mass of individual robot, $\Delta T$ = Temperature increment of heat conductivity of the robots.

But, the thermal conductivity of the two energetic mobile robots to the conductivity area of projection is given as;

$$k = \partial C_p \delta \qquad (3)$$

Then,

$$C_p = k / \partial \delta \qquad (4)$$

Where, $k$ = Thermal conductivity of the robots, $\partial$ = Thermal diffusivity of the robots, $\delta$ = Density of robots to the conductivity area.

But, the density of conductivity is the product of mass of the energetic mobile robots and its volume of occupied conductivity area.
Then,

$$\delta = M / V_L \qquad (5)$$

Substituting equation (5) into equation (4) then,

$$C_p = V_L k / \partial M \qquad (6)$$

Substituting equation (6) into equation (2), then,

$$Q_d / M \Delta T = V_L k / \partial M \qquad (7)$$
$$Q_d / \Delta T = V_L k / \partial$$
$$Q_d = V_L k \Delta T / \partial \qquad (8)$$

But, in energy workspace heat energy of conductivity in converted to kinetic (internal) energy of conductivity then,

K.E (internal) = Heat energy required

$$K.E = Q_d \qquad (9)$$

Substituting equation (8) into equation (9) then,

$$K.E = V_L k \Delta T / \partial \qquad (10)$$

From, motion on internal (energy) conductivity; the kinetic energy of the robots is given as;

$$K.E = \tfrac{1}{2} MV^2 \qquad (11)$$

Substituting equation (10) into equation (11) then,

$$\tfrac{1}{2} MV^2 = V_L k \Delta T / \partial \qquad (12)$$
$$V^2 = 2V_L k \Delta T / \partial M \qquad (13)$$

Taking the square root of both side then,

$$\sqrt{V^2} = \sqrt{(2V_L k \Delta T / \partial M)} \quad (14)$$
$$V = \sqrt{(2V_L k \Delta T / \partial M)} \quad (15)$$

But,

$$M = M_1 + M_2 \qquad (16)$$
$$\Delta T = T_2 - T_1 \qquad (17)$$

Substituting equation (16) and (17) into equation (15) then,

$$V = \sqrt{[2V_L k (T_2 - T_1) / \partial (M_1 + M_2)]} \quad (18)$$

Where, K.E = Kinetic (internal) energy of conductivity, $M$ = Total mass of heat conductivity in energy workspace, $V$ = Velocity heat conductivity of robots in energy workspace, $T_1$= Initial heat temperature of conductivity, $T_2$ = Final heat temperature of conductivity.

## 3.4 THE VHC CONCEPT FLOW CHART PROCEDURE

This section highlighted the velocity heat conductivity model (VHC) flow chart procedure being applied on the algorithm during simulation drive in section 3.3.

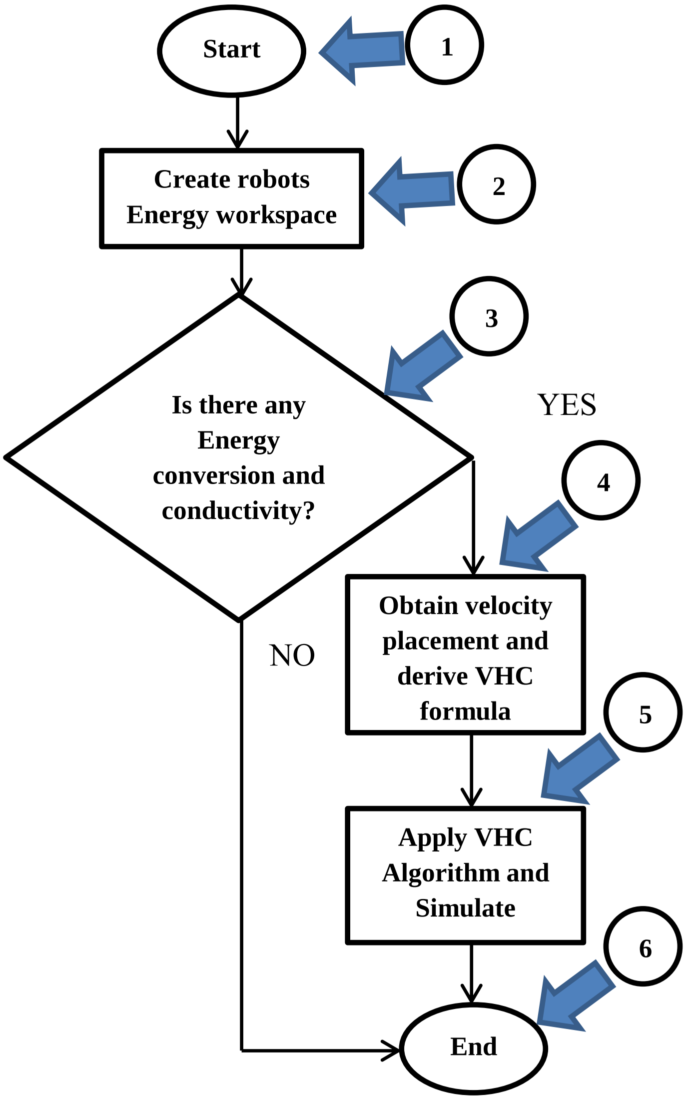

**Figure 3. Shows the VHC model flow chart procedure.**

## 4. RESULT AND DISCUSSION

This section highlighted the results obtained from the velocity heat conductivity (VHC) algorithm during simulation and the general discussion of the experimental analysis.

The following parameters were adopted during the algorithm simulation;

$M_1$ = 25kg, $M_2$ = 20kg, $V_L$ = 1.5m$^3$ to 20.5m$^3$, k = 0.62W/mK, $\partial$ = 0.35m$^2$/s, $T_1$ = 300K to 2200K, $T_2$ = 310K to 2210K.

Table 1: Shows the simulation table of velocity heat conductivity (VHC) algorithm for two mobile robots in energy workspace.

| S/N | $M_1$(kg) | $M_2$(kg) | $V_L$(m$^3$) | $T_1$(K) | $T_2$(K) |
|---|---|---|---|---|---|
| 1 | 25.0 | 20.0 | 1.50 | 300.0 | 310.0 |
| 2 | 25.0 | 20.0 | 2.50 | 400.0 | 410.0 |
| 3 | 25.0 | 20.0 | 3.50 | 500.0 | 510.0 |
| 4 | 25.0 | 20.0 | 4.50 | 600.0 | 610.0 |
| 5 | 25.0 | 20.0 | 5.50 | 700.0 | 710.0 |
| 6 | 25.0 | 20.0 | 6.50 | 800.0 | 810.0 |
| 7 | 25.0 | 20.0 | 7.50 | 900.0 | 910.0 |
| 8 | 25.0 | 20.0 | 8.50 | 1000.0 | 1010.0 |
| 9 | 25.0 | 20.0 | 9.50 | 1100.0 | 1110.0 |
| 10 | 25.0 | 20.0 | 10.50 | 1200.0 | 1210.0 |
| 11 | 25.0 | 20.0 | 11.50 | 1300.0 | 1310.0 |
| 12 | 25.0 | 20.0 | 12.50 | 1400.0 | 1410.0 |
| 13 | 25.0 | 20.0 | 13.50 | 1500.0 | 1510.0 |
| 14 | 25.0 | 20.0 | 14.50 | 1600.0 | 1610.0 |
| 15 | 25.0 | 20.0 | 15.50 | 1700.0 | 1710.0 |
| 16 | 25.0 | 20.0 | 16.50 | 1800.0 | 1810.0 |
| 17 | 25.0 | 20.0 | 17.50 | 1900.0 | 1910.0 |
| 18 | 25.0 | 20.0 | 18.50 | 2000.0 | 2010.0 |
| 19 | 25.0 | 20.0 | 19.50 | 2100.0 | 2110.0 |
| 20 | 25.0 | 20.0 | 20.50 | 2200.0 | 2210.0 |

| S/N | k(W/mK) | $\partial$(m$^2$/s) | $Q_d$(J) | K.E(J) | V(m/s$^2$) |
|---|---|---|---|---|---|
| 1 | 0.62 | 0.35 | 26.57 | 26.57 | 1.09 |
| 2 | 0.62 | 0.35 | 44.29 | 44.29 | 1.40 |
| 3 | 0.62 | 0.35 | 62.00 | 62.00 | 1.66 |
| 4 | 0.62 | 0.35 | 79.71 | 79.71 | 1.88 |
| 5 | 0.62 | 0.35 | 97.42 | 97.42 | 2.08 |
| 6 | 0.62 | 0.35 | 115.13 | 115.13 | 2.26 |
| 7 | 0.62 | 0.35 | 132.84 | 132.84 | 2.43 |
| 8 | 0.62 | 0.35 | 150.55 | 150.55 | 2.59 |
| 9 | 0.62 | 0.35 | 168.26 | 168.26 | 2.74 |
| 10 | 0.62 | 0.35 | 185.97 | 185.97 | 2.88 |
| 11 | 0.62 | 0.35 | 203.68 | 203.68 | 3.01 |
| 12 | 0.62 | 0.35 | 221.39 | 221.39 | 3.14 |
| 13 | 0.62 | 0.35 | 239.10 | 239.10 | 3.26 |
| 14 | 0.62 | 0.35 | 256.81 | 256.81 | 3.38 |
| 15 | 0.62 | 0.35 | 274.52 | 274.52 | 3.49 |
| 16 | 0.62 | 0.35 | 292.23 | 292.23 | 3.60 |
| 17 | 0.62 | 0.35 | 309.94 | 309.94 | 3.71 |
| 18 | 0.62 | 0.35 | 327.65 | 327.65 | 3.82 |
| 19 | 0.62 | 0.35 | 345.36 | 345.36 | 3.92 |
| 20 | 0.62 | 0.35 | 363.07 | 363.07 | 4.02 |

$$Q_{d(1)} = V_{L(1)}\ k\ [\ T_{1(1)} - T_{2(1)}\ ]\ /\ \partial$$
$$= 1.5 \text{ x } 0.62 \text{ x } (310\text{-}300) / 0.35$$
$$= 26.5\text{J}$$

$$Q_{d(2)} = V_{L(2)}\ k\ [\ T_{1(2)} - T_{2(2)}\ ]\ /\ \partial$$
$$= 2.5 \text{ x } 0.62 \text{ x } (410\text{-}400) / 0.35$$
$$= 44.29\text{J}$$

$$K.E_{(1)} = Q_{d(1)}$$
$$= 26.57\text{J}$$
$$K.E_{(2)} = Q_{d(2)}$$
$$= 44.29\text{J}$$

$$V_{(1)} = \sqrt{[2V_{L(1)}\ k\ (T_{2(1)} - T_{1(1)})\ /\partial\ (M_1 + M_2)]}$$
$$= \sqrt{[2\text{x}1.5\text{x}0.62\text{x}(310+300)]/(25+20)\text{x}0.35}$$
$$= 1.09 \text{ m/s}^2$$

$$V_{(2)} = \sqrt{[2V_{L(2)}\ k\ (T_{2(2)} - T_{1(2)})\ /\partial\ (M_1 + M_2)]}$$
$$= \sqrt{[2\text{x}2.5\text{x}0.62\text{x}(410+400)]/(25+20)\text{x}0.35}$$
$$= 1.40 \text{ m/s}^2$$

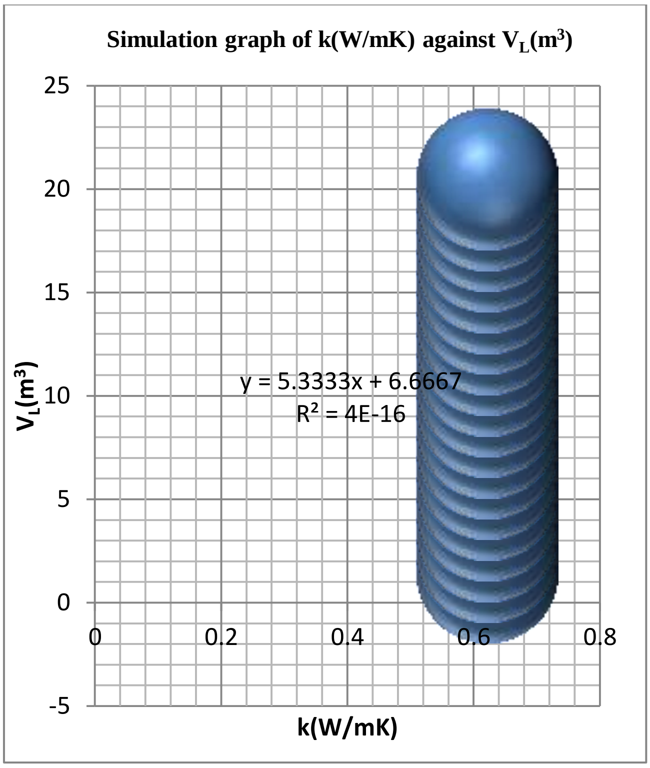

**Figure 4. Shows the simulation graph of thermal conductivity of robots against volume of occupied conductivity in energy workspace.**

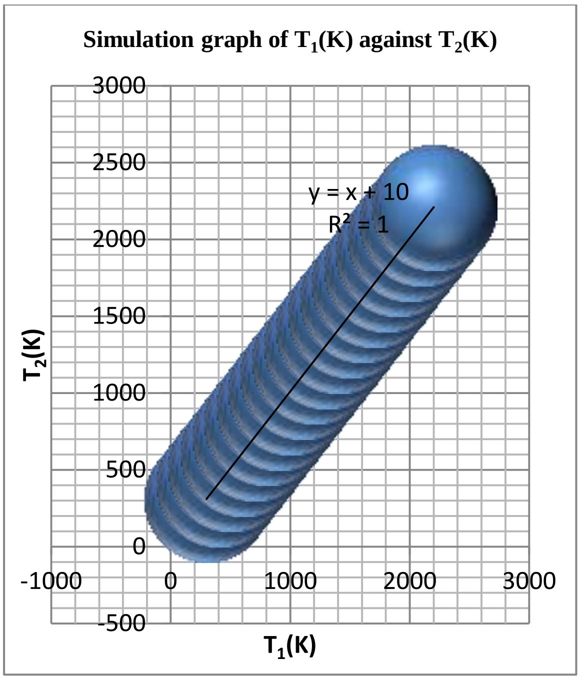

**Figure 5. Shows the simulation graph of initial heat temperature of conductivity against final heat temperature of conductivity.**

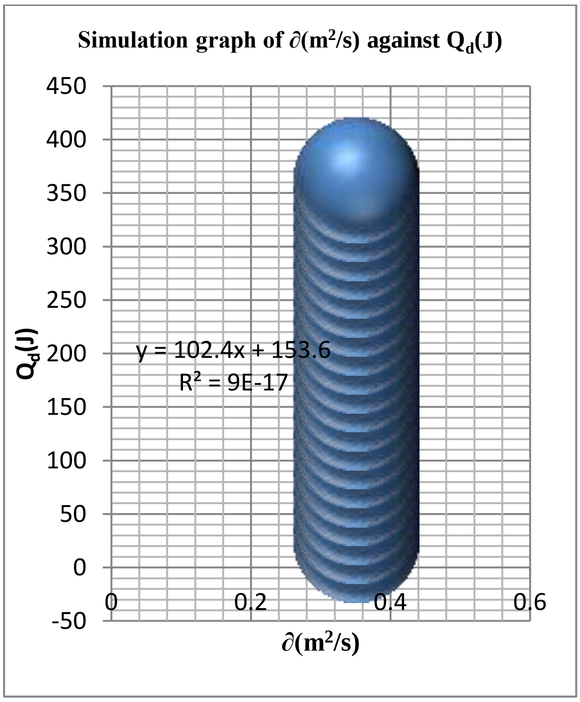

**Figure 6. Shows the simulation graph of thermal diffusivity of robots against quantity of heat required in the energy workspace.**

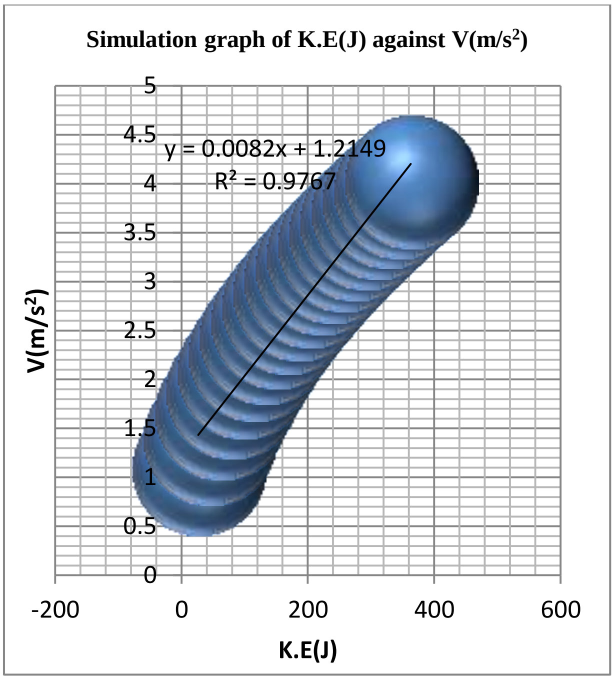

**Figure 7. Shows the simulation graph of kinetic (internal) energy of conductivity against velocity heat conductivity of the robots in energy workspace.**

In figure 1, the two neutral robots are without energy workspace, velocity placement and without velocity heat conductivity. They do not experience energy workspace and could not tell the algorithm for the velocity placement while in figure 2 the diagram represents the energy workspace $E_s$ where all the energy grid conductivity, algorithm implementation and simulation projection takes place on the two mobile robots. The brown colour is robot 1 and the green colour is robot 2.

Figure 3, represents the velocity heat conductivity (VHC) model flow chart which explain the step by step procedure and implementation of the algorithm up to simulation while table 1, which represents the simulation table of velocity heat conductivity (VHC) algorithm for two mobile robots in energy workspace. From the table, at 20 count the highest velocity heat conductivity is 4.02 $(m/s^2)$.

Figure 4, represents the simulation graph of thermal conductivity of robots against volume of occupied conductivity in energy workspace. From the simulation graph, the blue colour is the two cascaded mobile robots in velocity heat conductivity such that the longitudinal linear equation generated between the thermal conductivity and volume of occupied conductivity is $y = 5.3333x + 6.6667$ and the energy gradient area is $R^2 = 4E - 16$ while in figure 5, which represents the simulation graph of initial heat temperature of conductivity against final heat temperature of conductivity. From the simulation graph, the blue colour is the two cascaded mobile robots in heat conductivity such that the longitudinal linear equation generated between the initial heat temperature of conductivity and final heat temperature of conductivity is $y = x + 10$ and the energy gradient area is $R^2 = 1$.

Figure 6, represents the simulation graph of thermal diffusivity of robots against quantity of heat required in the energy workspace. From the simulation graph, the blue colour is the two cascaded mobile robots in velocity heat conductivity such that the longitudinal linear equation generated between the thermal diffusivity of robots and quantity of heat required in the energy projection is $y = 102.4x + 153.6$ and the energy gradient area is $R^2 = 9E - 17$ while in figure 7, which represents the simulation graph of kinetic (internal) energy of conductivity and velocity heat conductivity of the robots in energy workspace. From the simulation graph, the blue colour is the two cascaded mobile robots in velocity placement area such that the longitudinal linear equation generated between the kinetic (internal) energy of conductivity and velocity heat conductivity of the robots in energy workspace is $y = 0.0082x + 1.2149$ and the energy gradient area is $R^2 = 0.9767$.

## 5. CONCLUSION

The velocity heat conductivity (VHC) model for two autonomous mobile robots in energy workspace has scientifically proven to be robust, 100% technical, efficient and effective. The mathematical algorithm and simulation of the algorithm have made the end results to be accurate for the velocity heat conductivity. The figures applied, the simulation table, the flow chart analysis and the raw data's used in the research are true raw data's adopted from the simulation which gave 100% results achievement and real velocity heat conductivity. More research work expected in the future includes; the adiabatic heat temperature concept for autonomous mobile robot and hybrid virtual dynamic force control model for two autonomous mobile robots.

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