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THE CONCEPT OF FORCE FOR THERMODYNAMIC FRICTIONAL SYSTEM

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ABSTRACT

Anew thermodynamic first Law is proposed to account for the effect of friction and gravity force. This Law proposes existence of thermal impulsive force which produces pressure force and overcomes the frictional and gravity forces. This new Law is verified experimentally by allowing a cylindrical piston made from AL, Cu, and fiber glass to move under the action of water vapor thermal force. Strikingly the empirical relations between the different parameter and physical quantities concerning thermal, pressure, friction and gravity force agrees completely with the proposed theoretical ones.

Keywords: *New first Law of thermodynamic, friction force, thermal force, pressure force, gravity force.*

1. INTRODUCTION

Newton's Laws of motion are of one of the famous physical Laws that are widely used to describe macroscopic world [1], They are used to describe the motion of astronomical objects as well as the motion of rockets, satellites, beside thermal motion of molecules [2] For example the pressure of the gas and the equation of state for any gas was found by using Newton's Laws of motion[3]. The Laws of thermodynamics also are based on Newton's Laws. Strictly speaking, the first Law of thermodynamics which relate heat energy, internal energy and work to each other is mainly based on Newton's mechanical Laws [4].The first Law of thermodynamics has wide variety of applications, especially in the field of fuel engines and refrigerators beside cooling and heating systems[5].But unfortunately this Law does not account the effect of friction. This drawback makes the first Law unable to describe physical systems in which friction plays an important role. For example the heat transfer in poor conductors cannot be easily explained by using Laws of thermodynamics, even thermocouples , behavior and thermodynamic behavior of insulators like ceramics needs taking into account the effect of friction on thermo dynamical Laws [6] Many attempts were made to account for the effect of friction on thermodynamic systems.

2. THERMODYNAMIC FIRST LAW FOR FRICTIONAL SYSTEM

Consider a thermodynamic system gaining thermal heat energy (dQ)

The system is in the form of a glass tube with a fictional piston inserted inside it, such that water vapor enters the tube. If the vapor tries to make the system moving against gravity force (F_g) with acceleration (a) and frictional force (F_r), the thermodynamic equation becomes

$$dQ - dU = F_T x = PdV + (F_r + F_g)x + xma$$
$$= (F_P + F_r + F_g)x + xma \qquad (1)$$

Where (x) is the displacement, while (F_T) is the thermal force which spent energy to produce pressure work:

$$F_P x = PdV \qquad (2)$$

Besides spending energy to overcome gravity force and frictional force, where:

$$F_g x = (mg \sin\theta)x$$

$$F_r x = (mg \cos\theta)x + \gamma_0 x \qquad (3)$$

The tube subtends an angle θ with respect to horizon.

γ_0 = Friction force due to the pressure exerted by the piston on glass walls.

Thus according to equation (1):

$$xma = (F_T - F_P - F_r - F_g)x = F_{Tprg}x$$

$$= (F_{TP} - F_r - F_g)x = (F_{TP} - F_{rg})x$$

$$= F_{Tprg}x \qquad (4)$$

Where:

$$F_{TP} = F_T - F_P \qquad (5)$$

$$F_{rg} = F_r + F_g$$

Thus:

$$ma = F_{TP} - F_{rg} = F_{T\Pr g} \qquad (6)$$

The acceleration (a) for a piston moving from rest is given by:

$$v = v_0 + at = 0 + at$$

$$a = \frac{v}{t} \qquad (7)$$

Also the displacement ( ) takes the form:

$$x = v_0 t + \frac{1}{2}at^2 = 0 + \frac{1}{2}at^2$$

$$a = \frac{2x}{t^2} \qquad (8)$$

Using:

$$v^2 = v_0{}^2 + 2ax = 2ax$$

One gets the kinetic energy in the form:

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$$K.E=\frac{1}{2}mv^2=xma \quad (9)$$

This new thermodynamic Law (1) accounts for the effect of friction.

3. MATERIALS AND METHODS

A heater was put under a container filled with water. The water is heated till vapor is formed. This vapor was allowed to enter the glass tube enclosed by a piston. Three pistons made from AL, Cu and fiber glass, were used in this experiment. Each piston was allowed to move under vapor force, the vapor temperature is $100^0 c$ Thus one expect the vapor pressure to be constant since:

$$PV=NKT$$

$$P=\frac{N}{V}KT=nkT \quad (10)$$

Thus the vapor pressure force:

$$F_P=PA=nkTA \quad (11)$$

Is expected to be constant as far as temperature (T) and particles density (n) are constants. The vapor temperature or heat force:

$$F_T x=Q-U=Q-CT=mC_L t-CT$$
$$=P_0 Ax=nKT_0 Ax \quad (12)$$

Is also constant as far as (Q) and (U) are constants. Where in is the vapor mass transfer rate, C_L is the water latent heat of evaporation, (t) is the time, (C) is the water specific heat. The piston was allowed to move from rest a certain distance (x) for certain time (t). The distance was measured by using ordinary meter, while time was measured by using ordinary stop watch. The acceleration (a) is found in terms of (x) and (t) by using equation (8), while the speed is obtained by using relations (7) and (8) where:

$$a=\frac{v}{t}=\frac{2x}{t^2}$$

$$v=\frac{2x}{t} \quad (13)$$

F_{TP} This is equal to:

$$F_{TP}=F_T-F_P$$

Was found by assuming F_P is small and by using equation (12) and the fact that normally:

$$P_0=101kPa$$

Since: A = piston area $=9.5\times10^{-5}m^2$

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Thus: $F_{TP} \approx F_T = P_0 A = 9.595 N$

4. RESULTS

Aluminum (AL):

($m = 1.37\times10^{-3} kg$), ($\rho = 2.7\times10^{3} kg/m^{3}$),($r = 5.5\times10^{-3} m$),

($g = 9.8 m/s^{2}$),

($A = \pi r^{2} = 9.5\times10^{-5} m^{2}$), ($T = 100^{0} c$), ($P = 101000 N/m^{2}$).

Table (4.1.1): Relation between Inclination angle θ and time t to travel x meter For AL:

No	θ^0	$t(s)$	$x(m)$	$v(m/s)$	$a(m/s^2)$	$ma(N)$	$\cos(\theta)$	$\sin(\theta)$
1	0	16	0.06	0.0075	4.6875E-4	6.42188E-7	1	0
2	10	18	0.06	0.00667	3.7037E-4	5.07407E-7	0.98481	0.17365
3	20	21	0.06	0.00571	2.72109E-4	3.72789E-7	0.93969	0.34202
4	30	23	0.06	0.00522	2.26843E-4	3.10775E-7	0.86603	0. 5
5	40	25	0.06	0.0048	1.92E-4	2.6304E-7	0.76604	0.64279
6	50	27	0.06	0.00444	1.64609E-4	2.25514E-7	0.64279	0.76604
7	60	30	0.06	0.004	1.33333E-4	1.82667E-7	0.5	0.86603
8	70	32	0.06	0.00375	1.17188E-4	1.60547E-7	0.34202	0.93969
9	80	35	0.06	0.00343	9.79592E-5	1.34204E-7	0.17365	0.98481
10	90	37	0.06	0.00324	8.76552E-5	1.20088E-7	0	1

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Table (4.1.2): Relation between F_g, $K.E$, xma, and F_r For AL :

No	θ^0	$F_g(N)$	$K.E(J)$	$xma(m.N)$	$F_{Tp}(N)$	$F_r(N)$	$F_{rg}(N)$	$F_{Tprg}(N)$	γ
1	0	0	3.85313E-8	3.85313E-8	9.595	9.595	9.595	6.42187E-7	714.6581
2	10	0.00233	3.04444E-8	3.04444E-8	9.595	9.59267	9.595	5.07407E-7	725.50498
3	20	0.00459	2.23673E-8	2.23673E-8	9.595	9.59041	9.595	3.72789E-7	760.16158
4	30	0.00671	1.86465E-8	1.86465E-8	9.595	9.58829	9.595	3.10775E-7	824.63464
5	40	0.00863	1.57824E-8	1.57824E-8	9.595	9.58637	9.595	2.6304E-7	932.08623
6	50	0.01028	1.35309E-8	1.35309E-8	9.595	9.58472	9.595	2.25514E-7	1110.61535
7	60	0.01163	1.096E-8	1.096E-8	9.595	9.58337	9.595	1.82667E-7	1427.58378
8	70	0.01262	9.63281E-9	9.63281E-9	9.595	9.58238	9.595	1.60547E-7	2086.77315
9	80	0.01322	8.05224E-9	8.05224E-9	9.595	9.58178	9.595	1.34204E-7	4109.83855
10	90	0.01343	7.20526E-9	7.20526E-9	9.595	9.58157	9.595	1.20088E-7	

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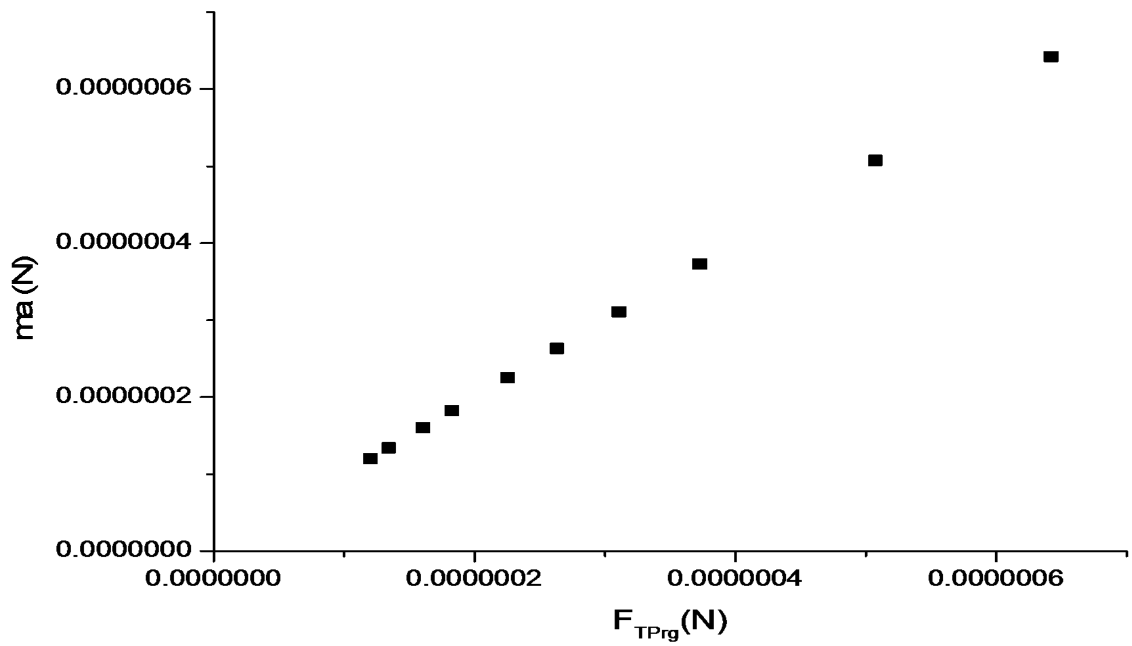

Fig (4.1.1): (F_{Tprg}) against (ma)

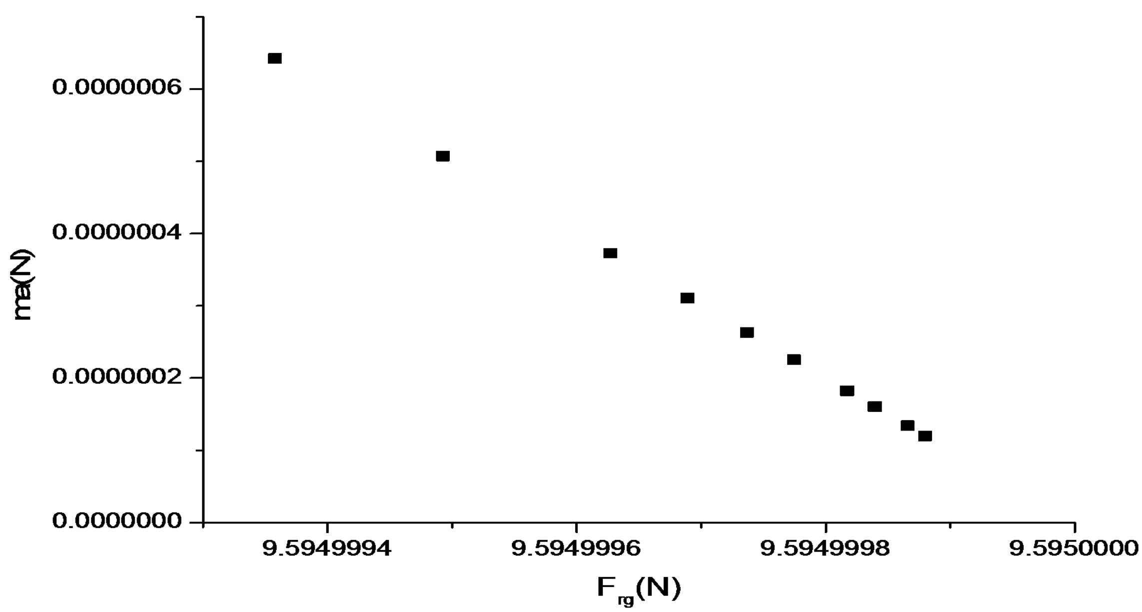

Fig (4.1.2): (F_{rg}) against (ma)

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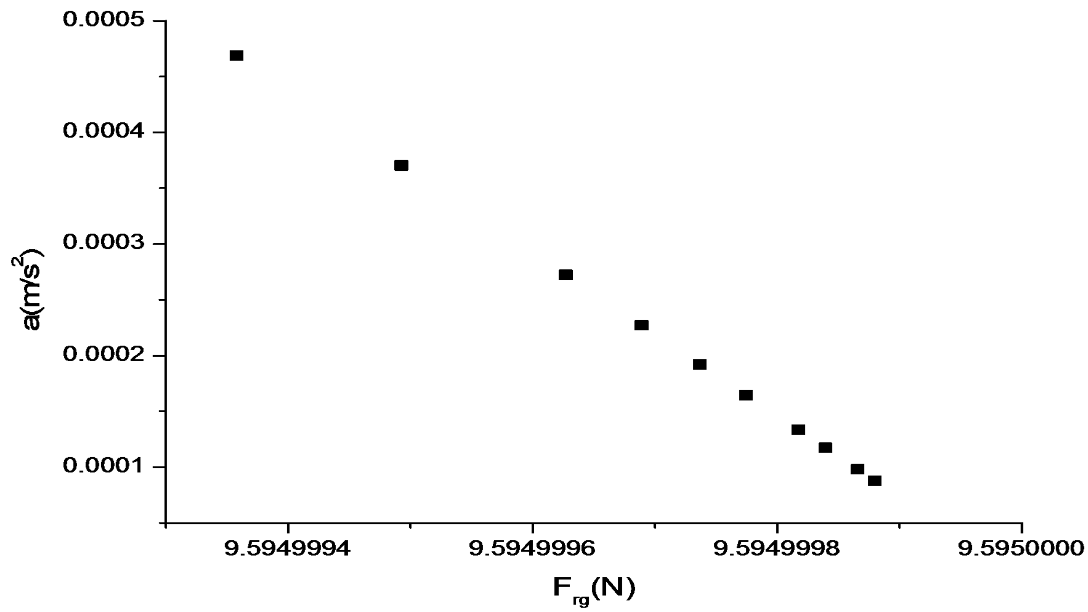

Fig (4.1.3): (F_{rg}) against (a)

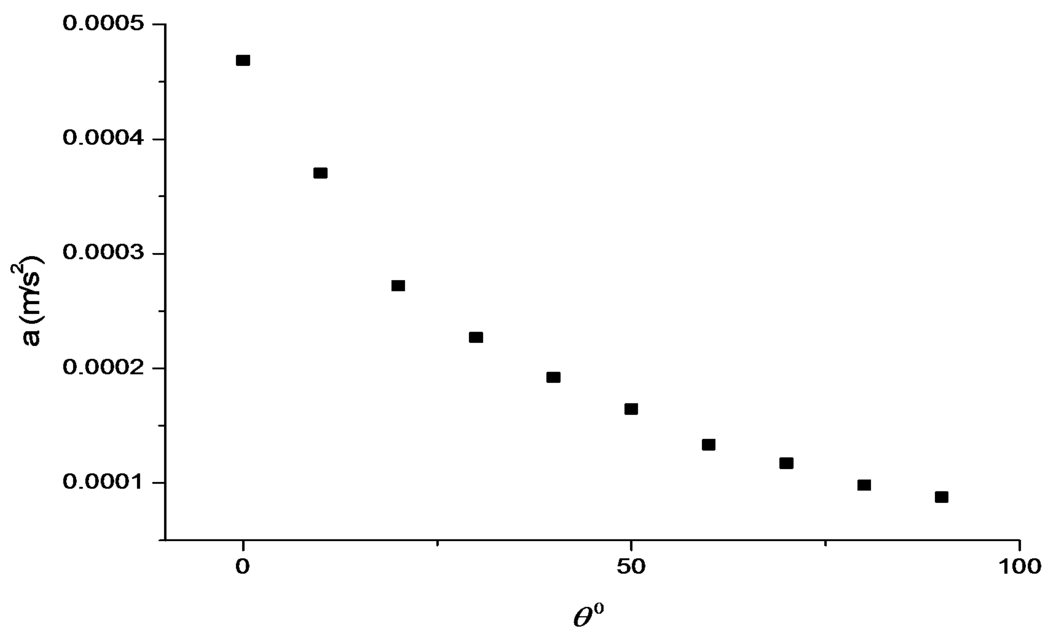

Fig (4.1.4): (θ^0) against (a)

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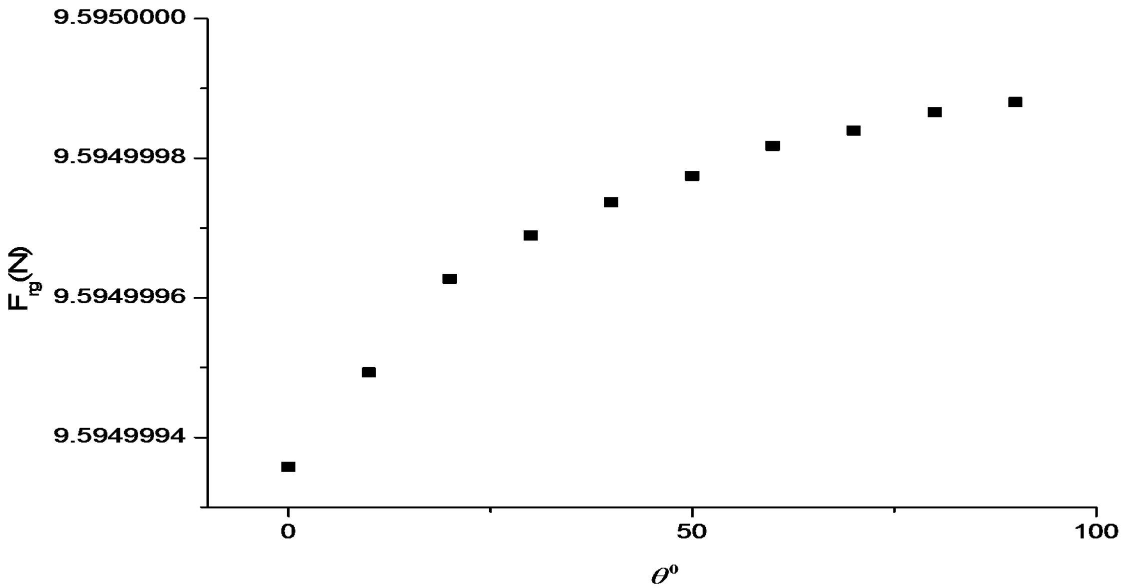

Fig (4.1.5): (^{0}) against (F_{rg})

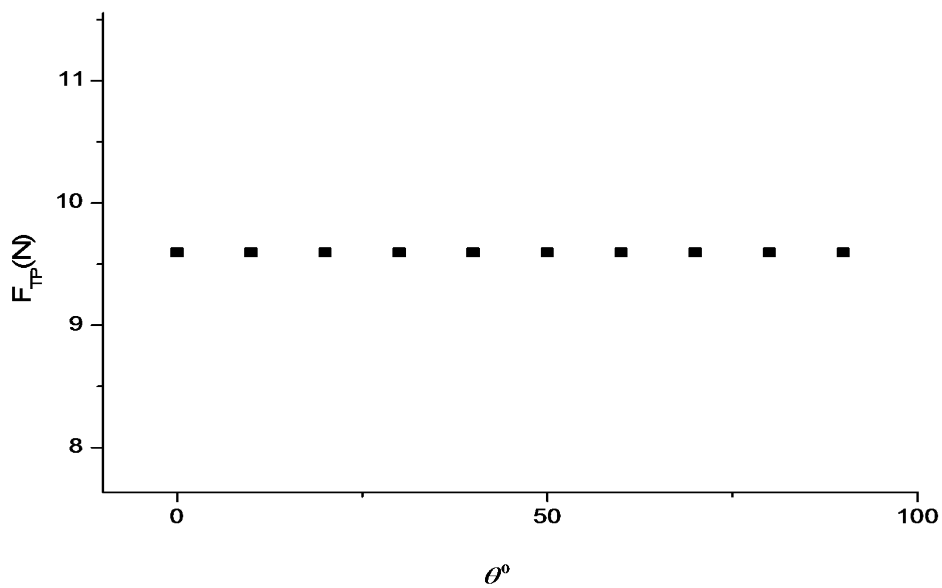

Fig (4.1.6): (^{0}) against (F_{TP})

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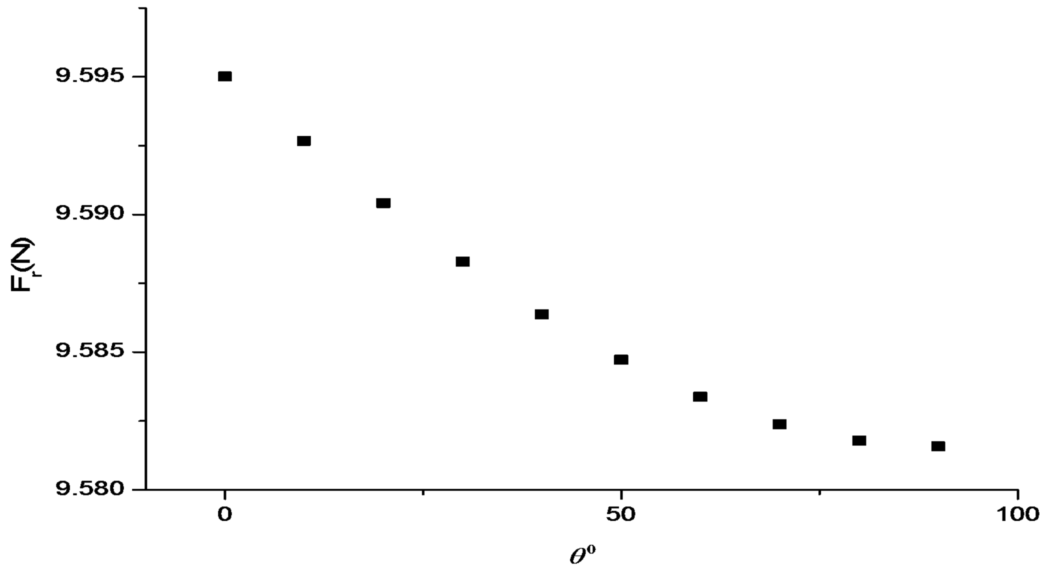

Fig (4.1.7): (⁰) against (F_r)

Cupric (Cu)

($m = 4.5757\times10^{-3}\,kg$),($\rho=8.9\times10^{3}\,kg/m^{3}$),
($r = 5.5\times10^{-3}\,m$),($g = 9.8m/s^{2}$), $\left(A=\pi r^{2}=9.5\times10^{-5}\,m^{2}\right)$,
($T=100^{0}c$),($P = 101000\ \ N/m^{2}$).

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Table (4.2.1): Relation between Inclination angle θ and time t to travel x meter For Cu:

No	θ^0	$t(s)$	$x(m)$	$v(m/s)$	$a(m/s^2)$	$ma(kg.m/s^2)$	$\cos(\theta)$	$\sin(\theta)$
1	0	18	0.06	0.00667	3.7037E-4	1.6947E-6	1	0
2	10	21	0.06	0.00571	2.72109E-4	1.24509E-6	0.98481	0.17365
3	20	25	0.06	0.0048	1.92E-4	8.78534E-7	0.93969	0.34202
4	30	27	0.06	0.00444	1.64609E-4	7.53202E-7	0.86603	0. 5
5	40	31	0.06	0.00387	1.2487E-4	5.71367E-7	0.76604	0.64279
6	50	35	0.06	0.00343	9.79592E-5	4.48232E-7	0.64279	0.76604
7	60	41	0.06	0.00293	7.13861E-5	3.26641E-7	0.5	0.86603
8	70	47	0.06	0.00255	5.43232E-5	2.48567E-7	0.34202	0.93969
9	80	52	0.06	0.00231	4.43787E-5	2.03064E-7	0.17365	0.98481
10	90	55	0.06	0.00218	3.96694E-5	1.81515E-7	0	1

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Table (4.2.2): Relation between F_g , $K.E$, xma , and F_r For Cu :

No	θ^0	$F_g(N)$	$x.ma(m.N)$	$K.E(J)$	$F_{Tp}(N)$	$F_r(N)$	$F_{rg}(N)$	$F_{Tprg}(N)$	γ
1	0	0	1.01682E-7	1.01682E-7	9.595	9.595	9.595	1.6947E-6	213.97416
2	10	0.00779	7.47053E-8	7.47053E-8	9.595	9.58721	9.595	1.24509E-6	217.09816
3	20	0.01534	5.27121E-8	5.27121E-8	9.595	9.57966	9.595	8.78534E-7	227.34314
4	30	0.02242	4.51921E-8	4.51921E-8	9.595	9.57258	9.595	7.53202E-7	246.49745
5	40	0.02882	3.4282E-8	3.4282E-8	9.595	9.56618	9.595	5.71367E-7	278.48607
6	50	0.03435	2.68939E-8	2.68939E-8	9.595	9.56065	9.595	4.48232E-7	331.69176
7	60	0.03883	1.95985E-8	1.95985E-8	9.595	9.55617	9.595	3.26641E-7	426.21648
8	70	0.04214	1.4914E-8	1.4914E-8	9.595	9.55286	9.595	2.48567E-7	622.87125
9	80	0.04416	1.21838E-8	1.21838E-8	9.595	9.55084	9.595	2.03064E-7	1226.54408
10	90	0.04484	1.08909E-8	1.08909E-8	9.595	9.55016	9.595	1.81515E-7	

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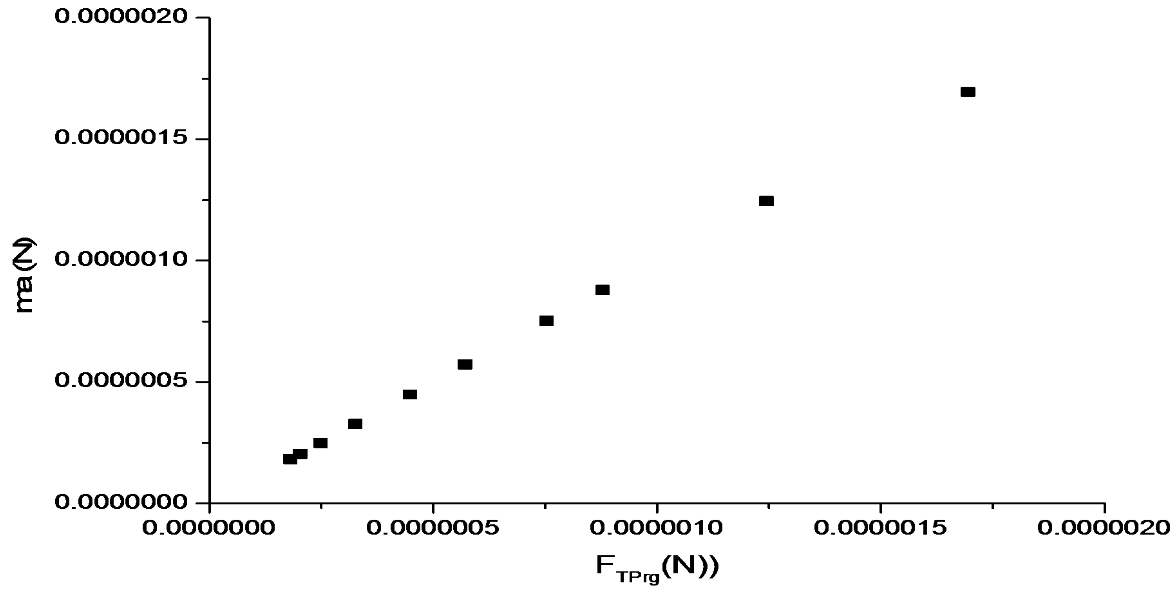

Fig (4.2.1): (F_{Tprg}) against (ma)

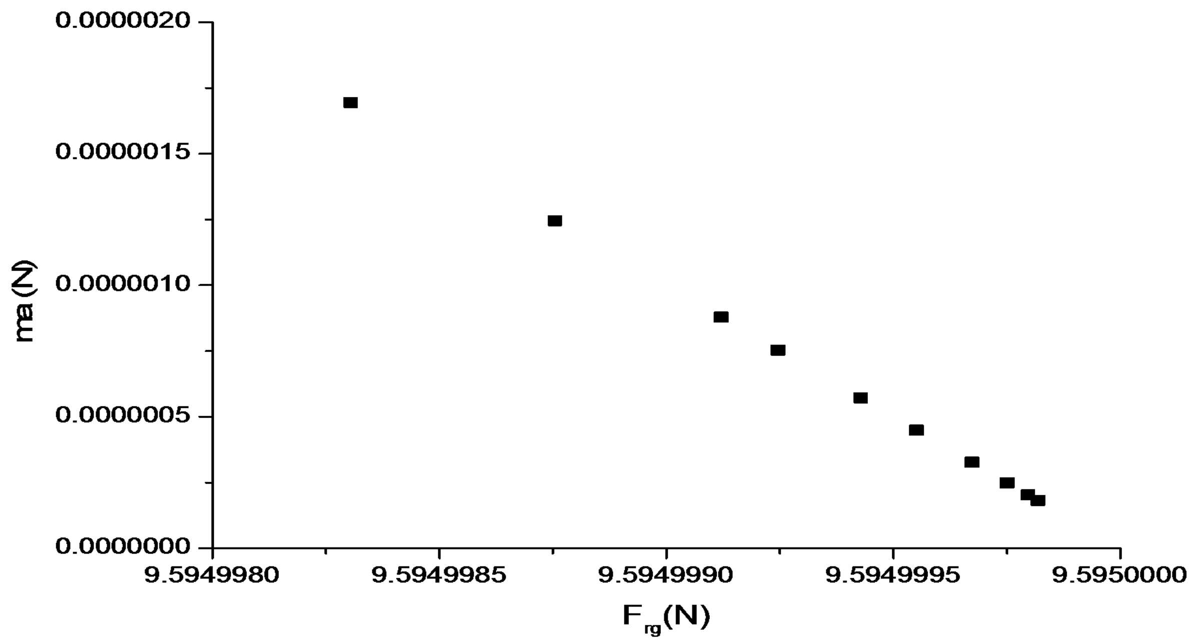

Fig (4.2.2): (F_{rg}) against (ma)

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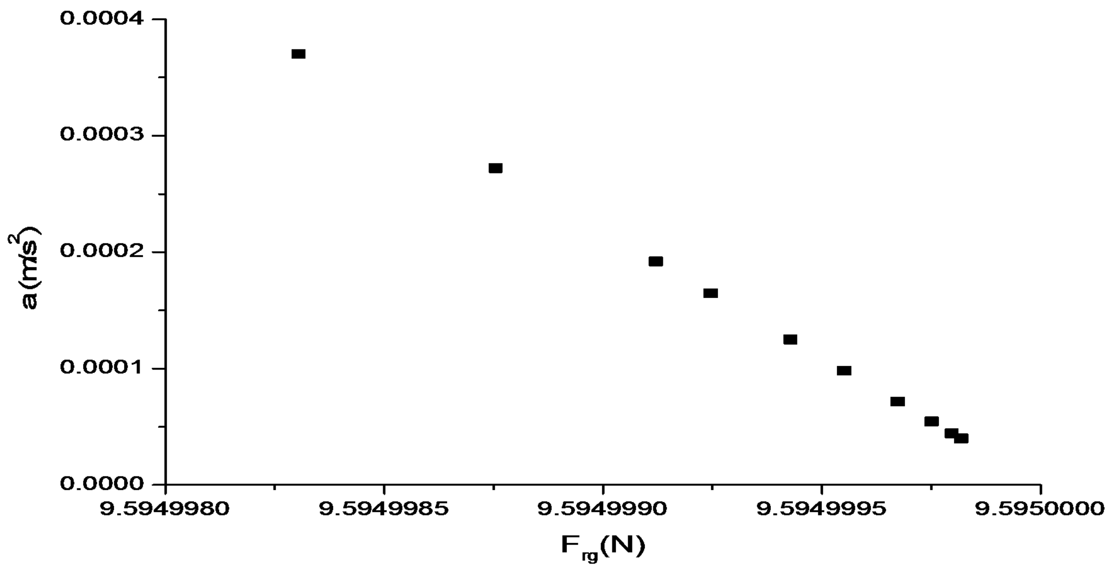

Fig (4.2.3): (F_{rg}) against (a)

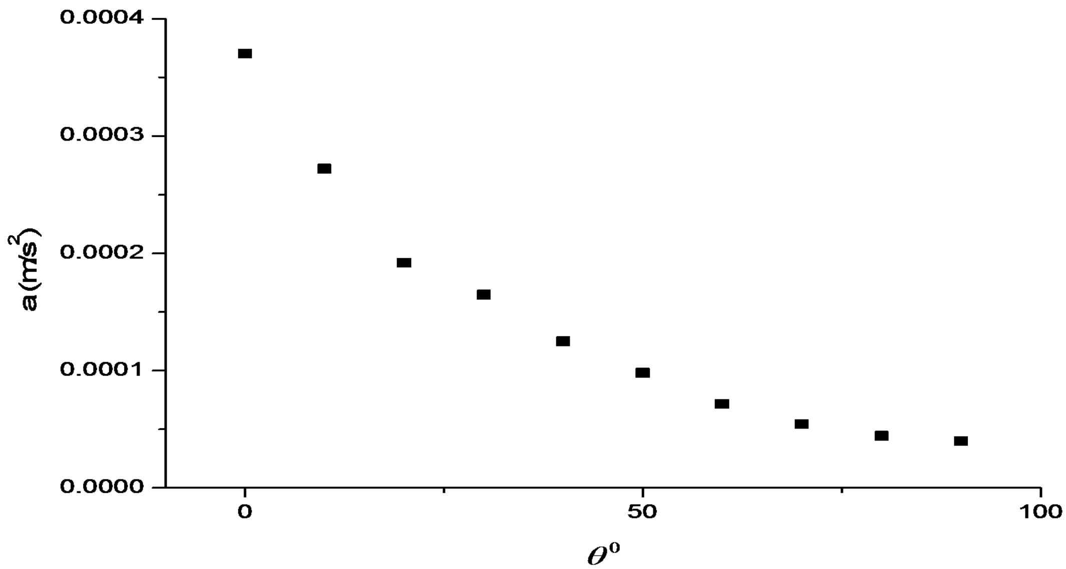

Fig (4.2.4): (θ^0) against (a)

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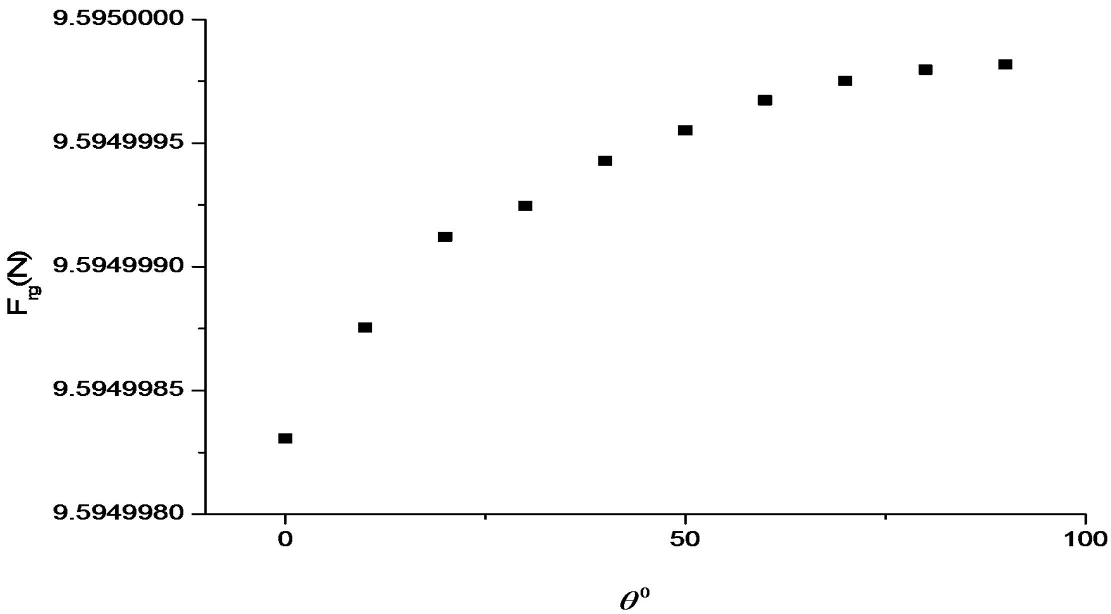

Fig (4.2.5): (^{0}) against (F_{rg})

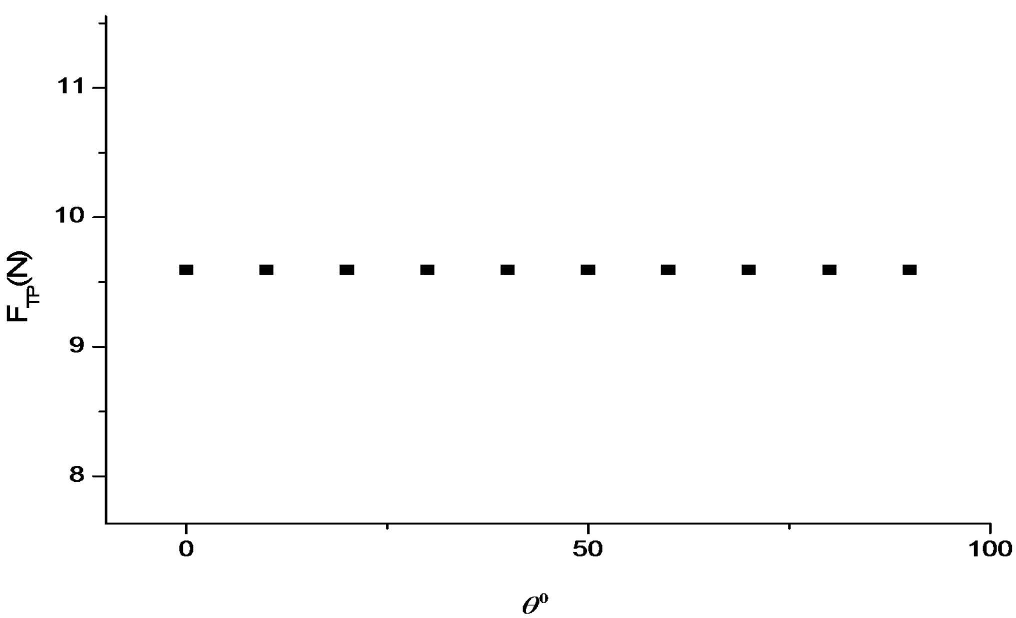

Fig (4.2.6): ( ) against (F_{TP})

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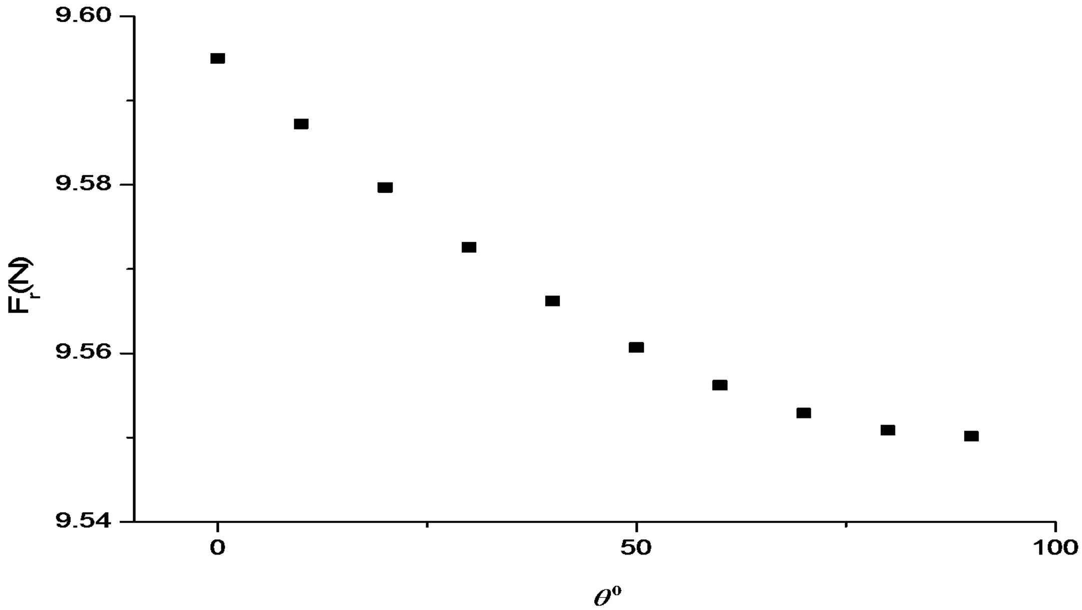

Fig (4.2.7): ( ) against (F_r)

Fiberglass

($m = 0.9239\times10^{-3}kg$),($g = 9.8m/s^2$),($\rho = 8.9\times10^3 kg/m^3$),
($r = 5.5\times10^{-3}m$),($A = \pi r^2 = 9.5\times10^{-5}m^2$),($T = 100\ ^0C$),
($P = 101000\ N/m^2$).

Table (4.3.1): Relation between Inclination angle θ and time t to travel x meter For Fiberglass:

No	θ^0	$t(s)$	$x(m)$	$v(m/s)$	$a(m/s^2)$	$ma(kg.m/s^2)$	$\cos(\theta)$	$\sin(\theta)$
1	0	7	0.06	0.01714	0.00245	2.26261E-6	1	0
2	10	9	0.06	0.01333	0.00148	1.36874E-6	0.98481	0.17365
3	20	11	0.06	0.01091	9.91736E-4	9.16264E-7	0.93969	0.34202
4	30	13	0.06	0.00923	7.10059E-4	6.56024E-7	0.86603	0. 5

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5	40	15	0.06	0.008	5.33333E-4	4.92747E-7	0.76604	0.64279
6	50	17	0.06	0.00706	4.15225E-4	3.83626E-7	0.64279	0.76604
7	60	19	0.06	0.00632	3.3241E-4	3.07114E-7	0.5	0.86603
8	70	23	0.06	0.00522	2.26843E-4	2.0958E-7	0.34202	0.93969
9	80	27	0.06	0.00444	1.64609E-4	1.52082E-7	0.17365	0.98481
10	90	31	0.06	0.00387	1.2487E-4	1.15367E-7	0	1

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Table (4.3.2): Relation between F_g , $K.E$, xma *, and* F_r *For Fiberglass:*

No	θ^0	$F_g(N)$	$x.ma\,(m.N)$	$K.E(J)$	$F_{Tp}(N)$	$F_r(N)$	$F_{rg}(N)$	$F_{Tprg}\,(N)$	γ
1	0	0	1.35757E-7	1.35757E-7	9.595	9.595	9.595	2.26261E-6	1059.72672
2	10	0.00157	8.21244E-8	8.21244E-8	9.595	9.59343	9.595	1.36874E-6	1075.89623
3	20	0.0031	5.49759E-8	5.49759E-8	9.595	9.5919	9.595	9.16264E-7	1127.37649
4	30	0.00453	3.93614E-8	3.93614E-8	9.595	9.59047	9.595	6.56024E-7	1223.08291
5	40	0.00582	2.95648E-8	2.95648E-8	9.595	9.58918	9.595	4.92747E-7	1382.54402
6	50	0.00694	2.30176E-8	2.30176E-8	9.595	9.58806	9.595	3.83626E-7	1647.44369
7	60	0.00784	1.84268E-8	1.84268E-8	9.595	9.58716	9.595	3.07114E-7	2117.72187
8	70	0.00851	1.25748E-8	1.25748E-8	9.595	9.58649	9.595	2.0958E-7	3095.68721
9	80	0.00892	9.12494E-9	9.12494E-9	9.595	9.58608	9.595	1.52082E-7	6096.98624
10	90	0.00905	6.92204E-9	6.92204E-9	9.595	9.58595	9.595	1.15367E-7	

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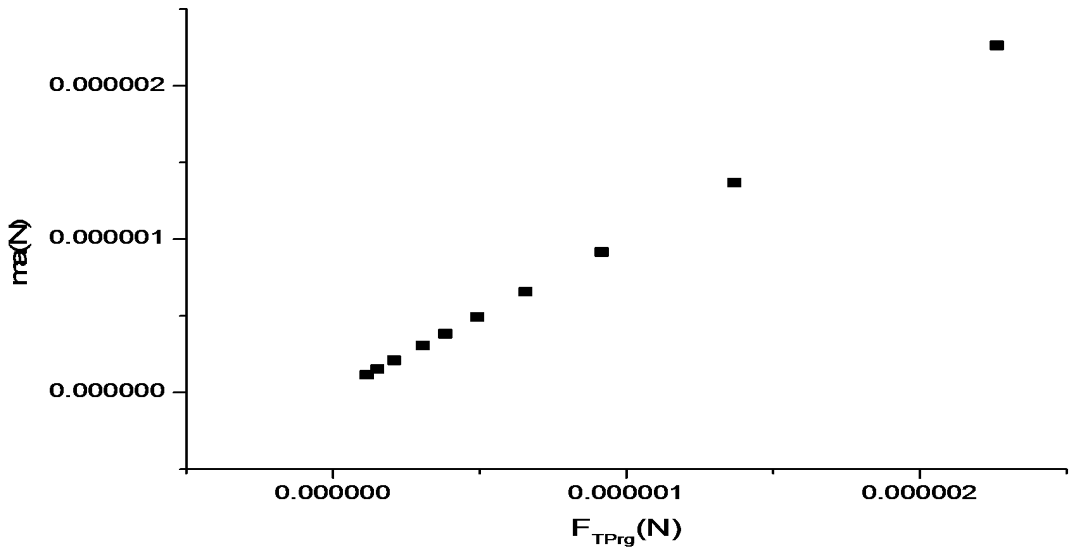

Fig (4.3.1): (F_{Tprg}) against (ma)

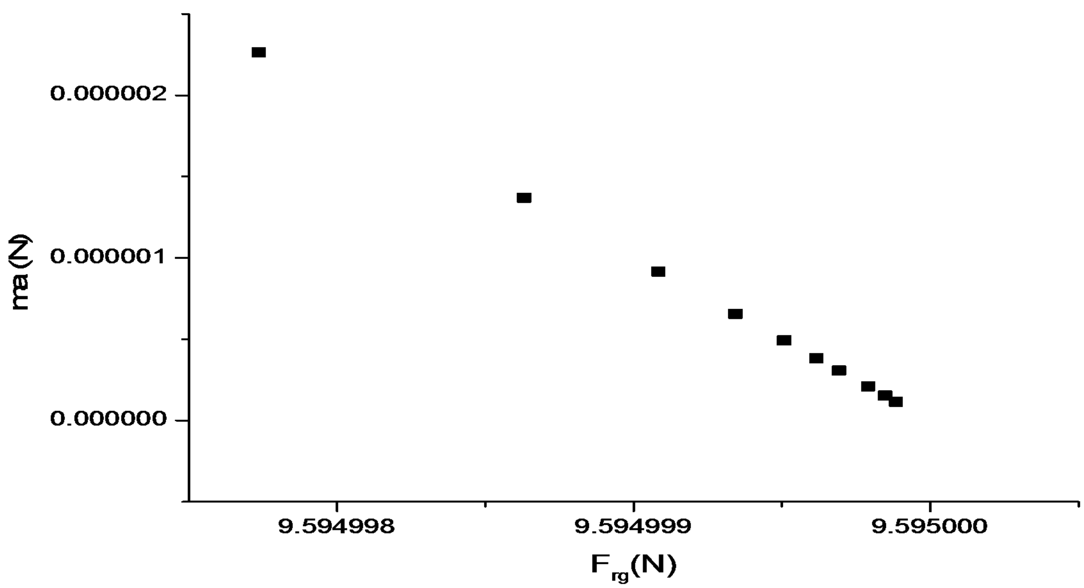

Fig (4.3.2): (F_{rg}) against (ma)

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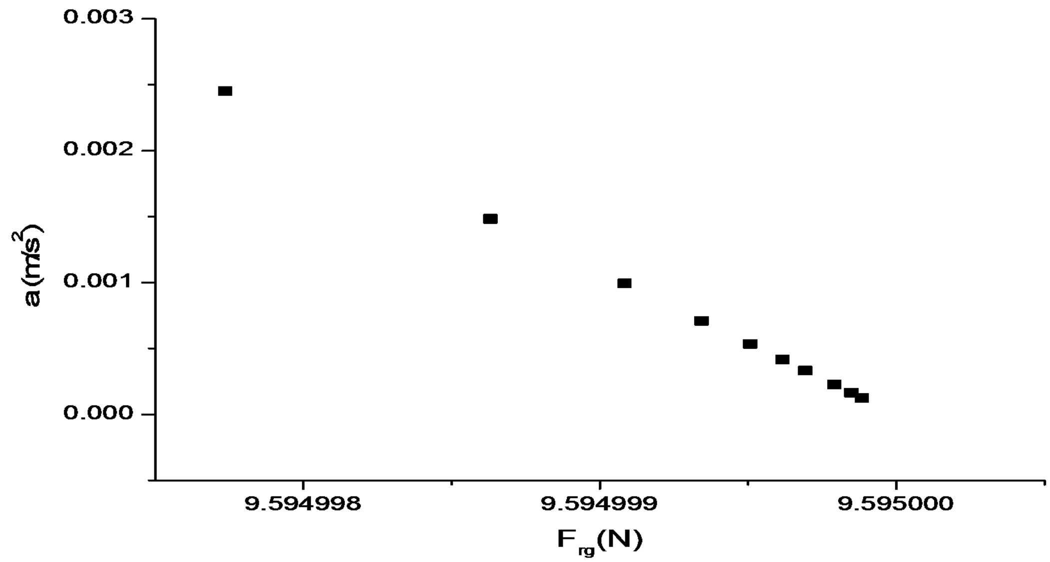

Fig (4.3.3): F_{rg} against a

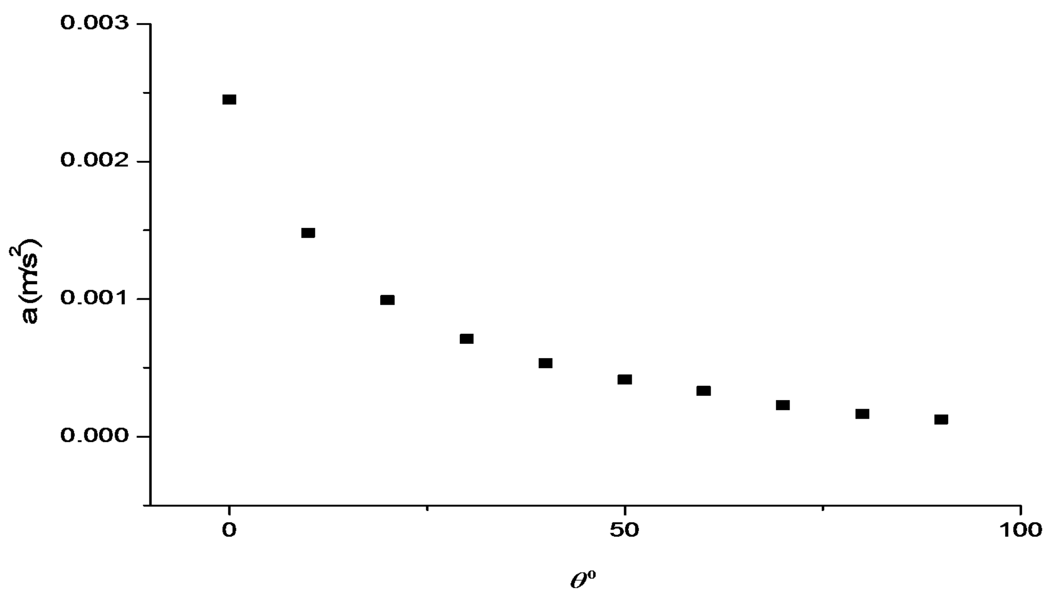

Fig (4.3.4): θ^0 against (a)

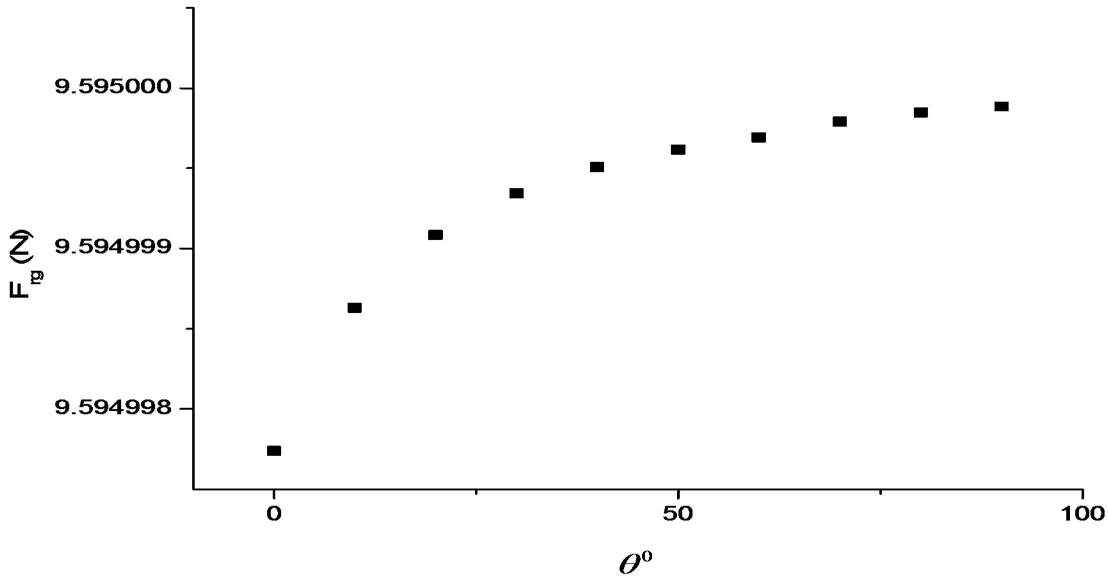

Fig (4.3.5): ( ) against (F_{rg})

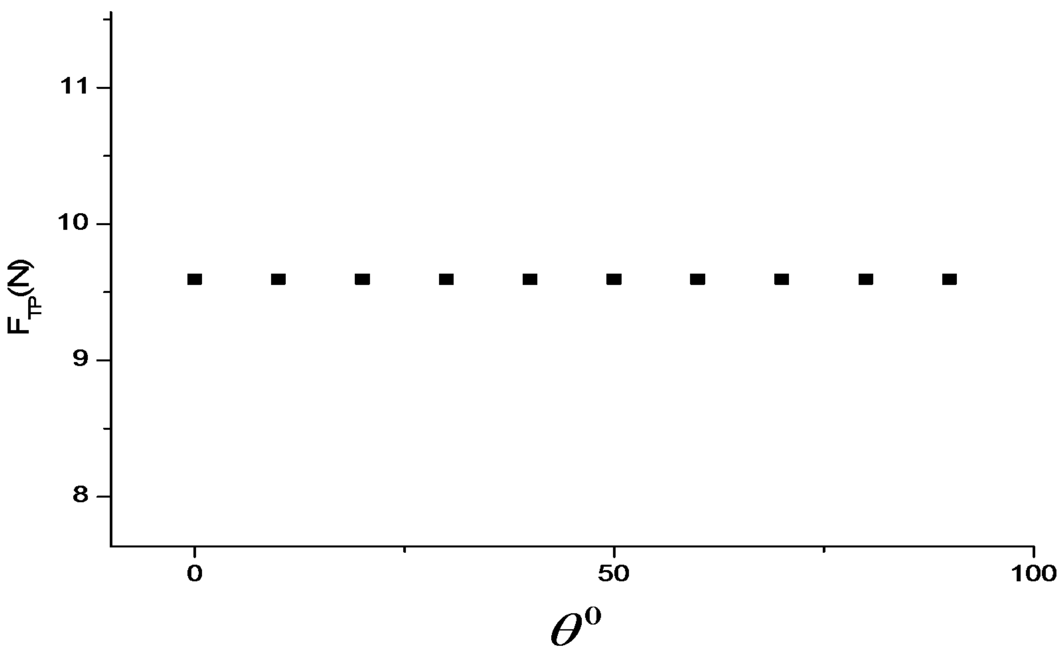

Fig (4.3.6): ( ) against (F_{TP})

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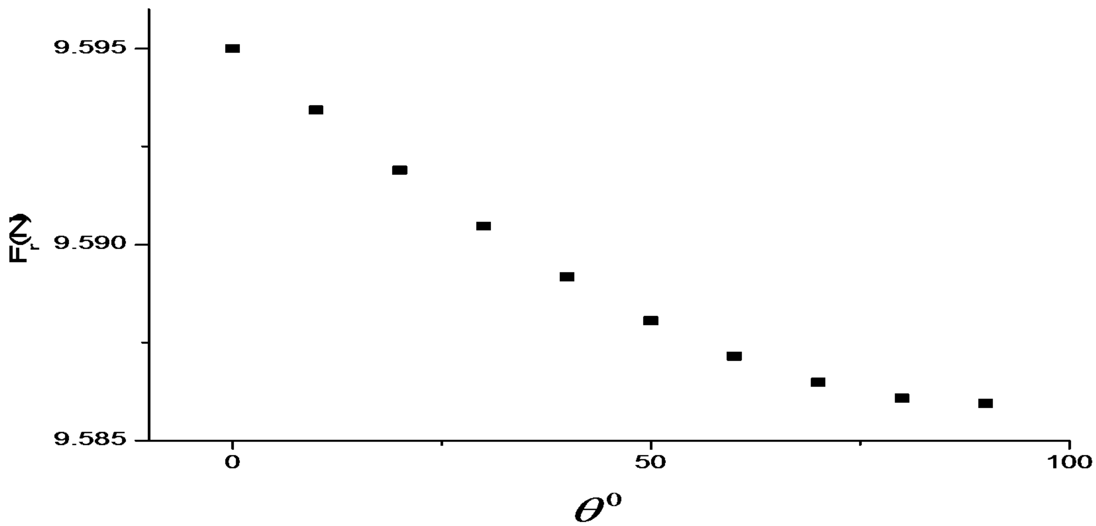

Fig (4.3.7): (   ) against (F_r)

5. DISCUSSION

The new first Law of thermodynamics(1) which suggests that thermal force F_T is responsible for generating pressure force beside overcoming frictional force and gravity force effects. This thermal force causes random collision which reflects itself as an internal energy, beside drift collision directed along the cylindrical tube axis. Fortunately this expression (1) conforms to the fluid energy equation which is given by:

$$dE = dQ - dW = dU + dK + dV + F_r x \quad (14)$$

$$dQ = dU + dK + dV + dW + F_r x$$

$$dQ - dU = dK + dV + PdV + F_r x = \frac{1}{2}mv^2 + F_g x + PdV + F_r x \quad (15)$$

When the piston starts from rest:

$$v_0 = 0$$

$$v^2 = v_0{}^2 + 2ax = 2ax \quad (16)$$

$$K = \frac{1}{2}mv^2 = xma$$

Thus:

$$dQ - dU = PdV + F_g x + F_r x + xma \quad (17)$$

Clearly equation (17) is typical to equation (1).

It is very interesting to note that the experimental work and the empirical relations agree completely with the theoretical ones. For example equation (6) which shows linear relation between $F_{T\Pr g}$ and ma agrees with the empirical linear relation between them shown in Figs (4.1, 2, and 3.1). According to the empirical relation in Figs (4.1, 2, and 3.2), the ma decreases as F_{rg} increases. This can be easily explained by using equation (6), where F_{TP} is constant (see Fig (4.1.6) and Fig (4.1.2)). The empirical relation which shows the constancy of F_{TP} is related to the fact that:

$$F_{TP} = \dot{m}v - PA = \dot{m}\sqrt{3KT} - nkTA = constant \qquad (18)$$

This is because the vapor container deliver the tube vapor mass at constant rate in, beside the fact that T is $100c^0$, is constant, where as the piston cross sectional area is also constant. Similarly the relation between F_{rg} and ma in Figs $(4.1,2,3.3)$ can be explained as far as m is constant. The fact that a decreases as θ increases can also be explained by using equation (3) and (4) besides ignoring the effect of gravity friction to get (see Figs $(4.1,2,3.4)$):

$$ma = F_{TP} - F_g - \gamma_0 = F_{TP} - mg\sin\theta - \gamma_0 \qquad (19)$$

Clearly, increasing θ increases $\sin\theta$ and decreases ma as shown in Fig $(4.1.1)$ .using the same argument one can neglect F_r since its θ dependence is small in general where equation (3) tells that:

$$mg\cos\theta = F_r - \gamma_0 \qquad (20)$$

For $\theta = 90$ tables $(4.1.1,2)$ shows that $\gamma_0 = F_r = 9.595$. Thus the maximum value of $mg\cos\theta$ is $(9.595 - 9.58157 = 0.00343)$

Which is Less than maximum $F_g = 0.01343$.

Thus: $F_{rg} = \gamma_0 + mg\sin\theta \qquad (21)$

Hence F_{rg} increases as θ increases (see Fig $(4.1.5)$:

Thus the empirical relations $(4.1,2,3.5)$ agrees completely with the theoretical one.

The empirical relation in Figs $(4.1,2,3.6)$ shows that the pressure force F_P is constant and is completely independent of θ .

This agrees completely with the fact that, according to the Laws of thermodynamics, where:

$$P = nkT$$

$$F_P = nkTA \qquad (22)$$

Which is constant as far as the density of vapor n, temperature T and piston area A are constants.

It is also very interesting to note that according to Figures $(4.1,2,3.7)$ the frictional force F_r decreases as θ increases. This conforms to relation (3), where:

$$F_r = mg\cos\theta + \gamma_0 \qquad (23)$$

Clearly $\cos\theta$ is max at $\theta = 0$, It decreases gradually cell $\theta = 90$ where F_r attains a minimum value 9.58157. This confirms also the relations (3) and (23) which suggests that friction consists of two components, one is variable and results from the reaction gravity force, the other is constant and depends on the pressure exerted by the piston on cylinder wall

6. CONCLUSION

To verify the new thermodynamic Law experimental work was done on a piston vapor thermal force beside pressure, friction and gravity force. It shows the viability of the new thermodynamic Law which accounts for the effect of friction and gravity force. This Law is also in complete agreement with the fluid energy equation.

REFERENCES

1. *A. Bueno, et al, High- temperature Superconducting Level Meter for Liquid Argon Detector, JINST3, 12001 (2014).*
2. *A. Manjavacas & F. J. Garacia, Vacuum Friction in rotating particles, Phys. Rev. Lett 105, 113601 (2014).*
3. *A.J. Hundhausen, Coronal expansion and the solar wind (Springer- Verlag, Berlin, Germany, 2016).*
4. *Arther Beiser, Concepts of Modern Physics, (Mc Hill, New York, 2013).*
5. *B. Hamilton & M. Crescimanno, Linear frictional forces cause orbits to neither circularize nor process, J. Phys. A: Math. Theor. 41 235205 (2008).*
6. *Baharat Bhushan, Hand Book of Nanotechnology (Springer VBH, New York, 2015).*
7. *Bo Thide, Electromagnetic field Theory, (Bo Thide, Uppsala, Sweden, 2014).*
8. *C.A. Coulson, Waves, (Long man Group, London, 2015).*