IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 5, May 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

The Concept of Energy for Thermodynamics Friction System

[1]Mubarak Dirar Abdallah, [2]Abdelbagi Ahmed DafaAllah, [3]AbdelAzeem Mohammed Ali & [4]Sawsan Ahmed Elhouri Ahmed

[1]International University of Africa- College of Science-Department of Physics & Sudan University of Science& Technology-College of Science-Department of Physics-Khartoum-Sudan
[2]AL-Butana University -College of Science-Department of Physics-
AL-Butana –Sudan
[3]Alzaem-Alazhari University- College of Science-Department of Physics- Khartoum-Sudan
[4]University of Bahri-College of Applied & Industrial Sciences-Department of Physics- Khartoum-Sudan

Abstract:
Using the fluid energy equation, the first Law of thermodynamics for frictional system in the presence of gravity is formulated. According to this new model thermal energy is equal to pressure work beside kinetic energy in addition to work against gravity and frictional energy. This formula is verified experimentally by deriving a piston, moving inside a cylindrical tube, by water vapor. Three pistons made from AL, Cu, and fiberglass were used. The piston and cylinder system is inclined subtend the angles $0,10,20,...,90,$ in steps of 10 degree for each reading. The vapor thermal force tries to push the piston up word against frictional and gravity force. The relations between kinetic energy with net work done, frictional and gravity energy is in complete agreement with this new thermodynamic model.

Key words: Energy, friction, fluid energy equation, thermal force.

1. Introduction

Heat is very important for our day life. It is used in cooking, heat engines and turbines [1]. The concept of heat and temperature were developed by physics after Newton's Laws were proposed by Newton [2]. The heat is referred to the energy due to random motion of atoms and molecules, while temperature is related to hotness of a certain body compared to another body or a reference scale [3]. Later on the kinetic theory of gases and the Laws of thermodynamics were developed by scientists [4, 5]. Among them the first Law of thermodynamics plays a central role. This is because it is related to the concept of energy [6]. The first Law of thermodynamics successfully describes the behavior of heat engines when friction is neglected. However this Law says nothing for frictional systems [7, 8]. There are many thermodynamic and physical systems in which friction plays an important role, like electric heaters and thermocouples. There are many attempts made to cure this defect [9, 10] but no satisfactory general form was made. In this work attempt was made to develop thermodynamic friction concept. This is done in sections 2, theoretically, sections 3 and 4 empirically.

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

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

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:

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

The tube subtends an angle θ with respect to horizon.

$\gamma_0 =$ Friction force due to the pressure exerted by the piston on glass walls.

Thus according to equation (1):

$$xma = (F_T - F_P - F_r - F_g)x = F_{Tprg}x$$
$$= (F_{TP} - F_r - F_g)x = (F_{TP} - F_{rg})x \qquad (4)$$

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 (x) takes the form:

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

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

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

Using:

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

One gets the kinetic energy in the form:

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

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

The term F_{TP} which stands for thermal and pressure force F_T and F_P

Can be found by assuming F_P to be small such that (see equation (1))

$$F_{TP} = F_T - F_P \approx F_T = \frac{dQ - dU}{x} = \frac{P_0 Ax}{x} = P_0 A$$

One also assumes that normally:

$$P_0 = 101kPa$$

Since $A =$ piston area $= 9.5 \times 10^{-5} m^2$

Thus $F_{TP} = 9.595N$

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:

$$P = \frac{N}{V}kT = nkT \qquad (10)$$

Thus the vapor pressure force:

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

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

$$F_T x = Q - U = Q - CT = mC_L t - CT \qquad (12)$$

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:

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

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

4. Results:

Table $(4.1.1)$: Relations between (T, v, a) for different angles for AL :

($m = 1.37\times10^{-3}\,kg$), ($\rho = 2.7\times10^{3}\,kg/m^{3}$) , ($r = 5.5\times10^{-3}\,m$) , ($g = 9.8 m/s^{2}$), ($A = \pi r^{2} = 9.5\times10^{-5}\,m^{2}$) ,($T = 100^{0}C$) , ($P = 101000 N/m^{2}$).

No	θ^{0}	$t(s)$	$x(m)$	$v(m/s)$	$a(m/s^{2})$	$ma(kg.m/s2)$	$\cos(\theta)$	$\sin(\theta)$
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

Table (4.1.2) : Relations between $F_g, KE, xma, F_P, F_r, F_{rg}, andF_{T\Pr g}$ for AL :

No	θ^0	$F_g(N)$	$K.E(J)$	$x.ma(m.N)$	$F_{Tp}(N)$	$F_r(N)$	$F_{rg}x(J)$	$F_{Tprg}(N)$	$F_{T\Pr g}x(J)$	γ
1	0	0	3.85313E-8	3.85313E-8	9.595	9.595	0.5757	6.42187E-7	3.85313E-8	714.6581
2	10	0.00233	3.04444E-8	3.04444E-8	9.595	9.59267	0.5757	5.07407E-7	3.04444E-8	725.50498
3	20	0.00459	2.23673E-8	2.23673E-8	9.595	9.59041	0.5757	3.72789E-7	2.23673E-8	760.16158
4	30	0.00671	1.86465E-8	1.86465E-8	9.595	9.58829	0.5757	3.10775E-7	1.86465E-8	824.63464
5	40	0.00863	1.57824E-8	1.57824E-8	9.595	9.58637	0.5757	2.6304E-7	1.57824E-8	932.08623
6	50	0.01028	1.35309E-8	1.35309E-8	9.595	9.58472	0.5757	2.25514E-7	1.35309E-8	1110.61535
7	60	0.01163	1.096E-8	1.096E-8	9.595	9.58337	0.5757	1.82667E-7	1.096E-8	1427.58378
8	70	0.01262	9.63281E-9	9.63281E-9	9.595	9.58238	0.5757	1.60547E-7	9.63281E-9	2086.77315
9	80	0.01322	8.05224E-9	8.05224E-9	9.595	9.58178	0.5757	1.34204E-7	8.05224E-9	4109.83855
10	90	0.01343	7.20526E-9	7.20526E-9	9.595	9.58157	0.5757	1.20088E-7	7.20526E-9	∞

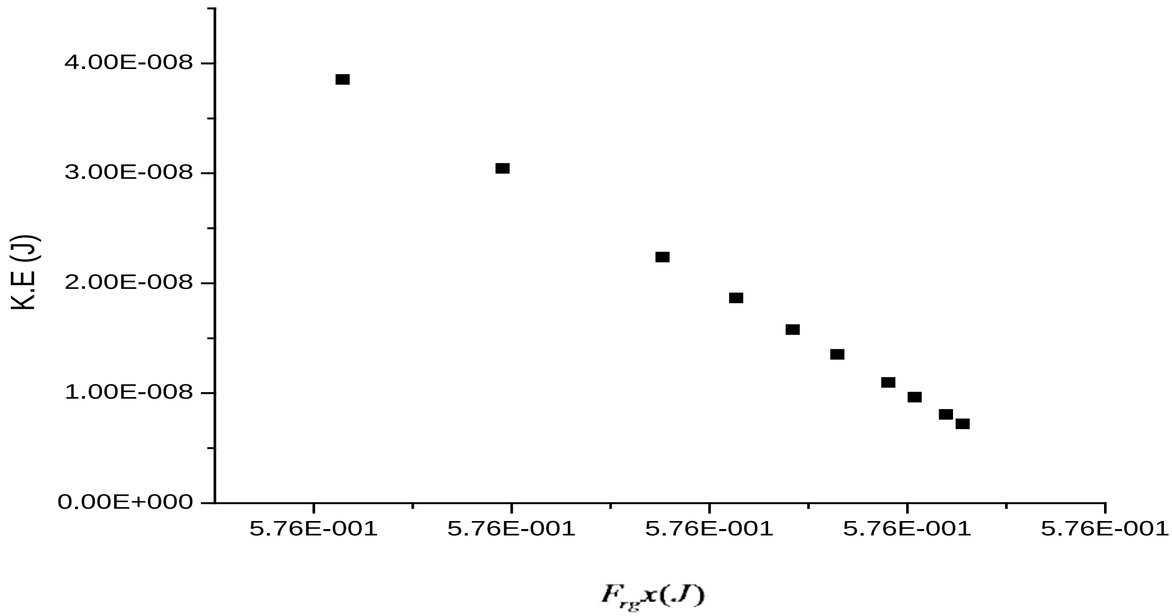

Fig (4.1.1): $(F_{rg}x)$ against $(K.E)$

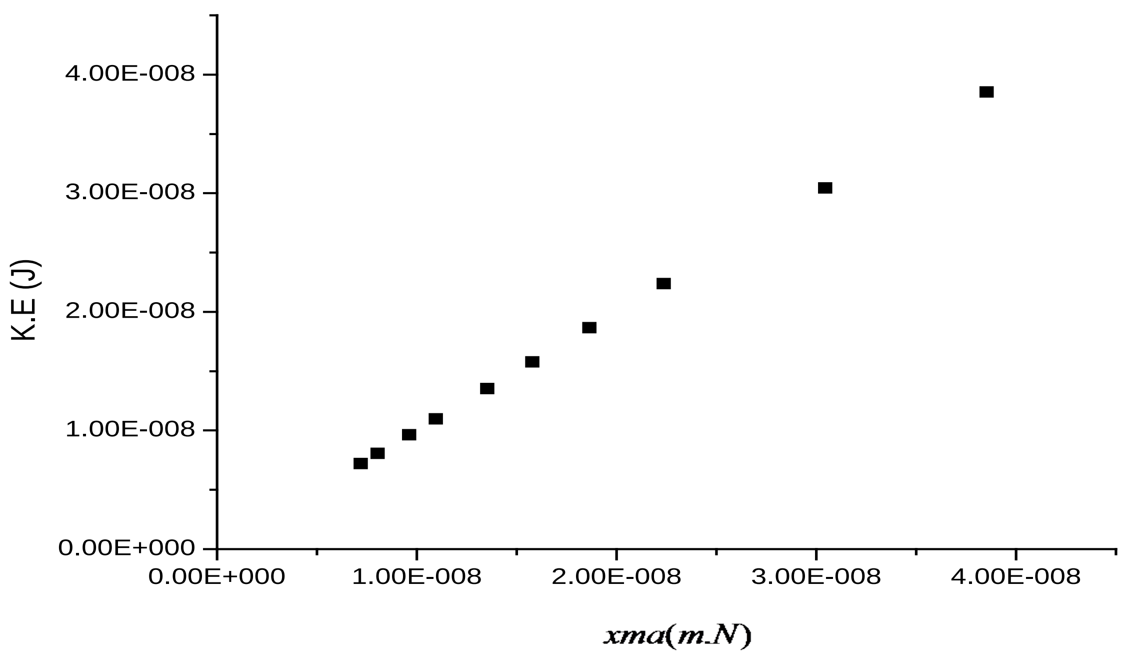

Fig (4.1.2): (xma) against $(K.E)$

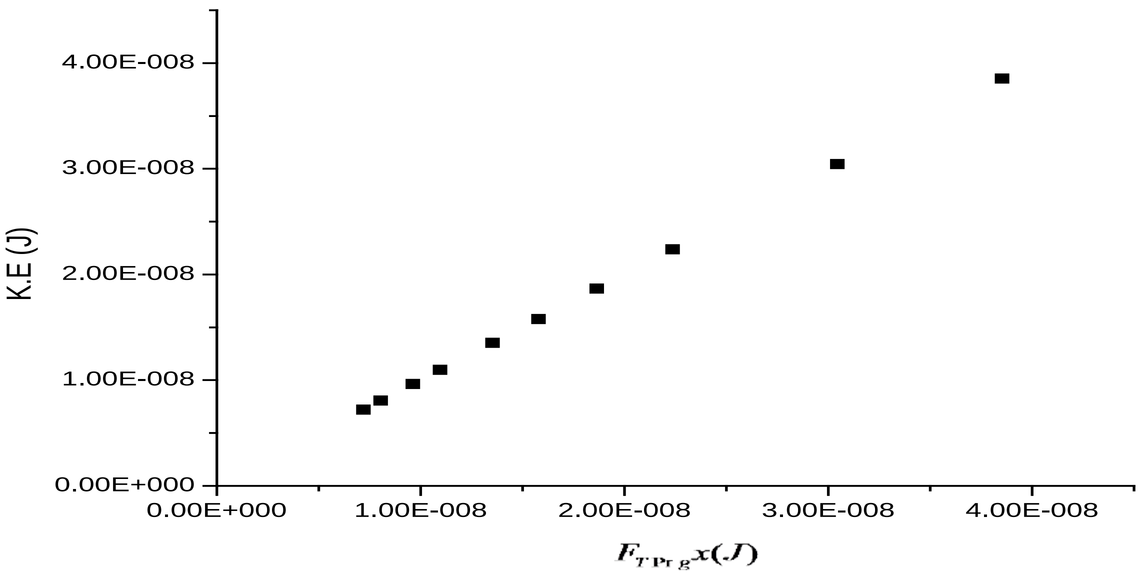

Fig (4.1.3): ($F_{T\,\Pr g}\,x$) against $(K.E)$

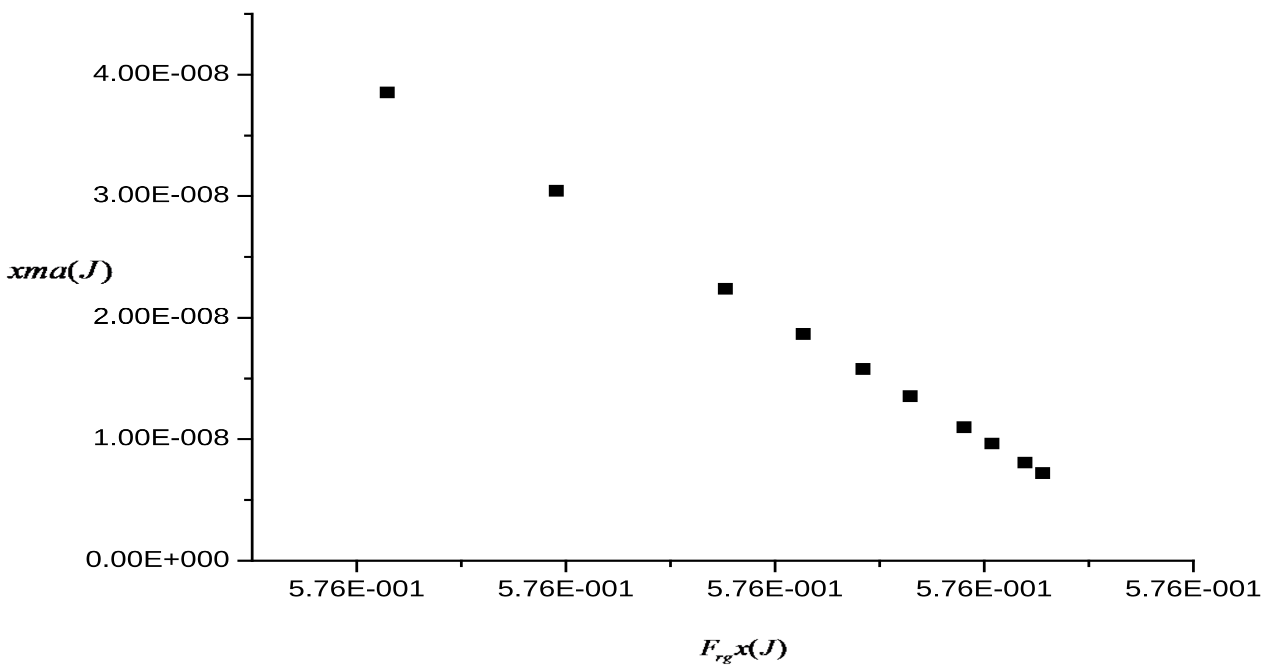

Fig (4.1.4): ($F_{rg}\,x$) against (xma)

2. Cupric (Cu):

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 5, May 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

Table $(4.2.1)$: Relations between (T, v, a) for different angles for Cu: $(m = 4.5757\times10^{-3} kg)$, $(\rho = 8.9\times10^{3} kg/m^{3})$,$(r = 5.5\times10^{-3} m)$,$(g = 9.8 m/s^{2})$, $(T = 100c^{0})$, $(P = 101000 N/m^{2})$,$(A = \pi r^{2} = 9.5\times10^{-5} m^{2})$.

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

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 5, May 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

Table (4.2.2) : Relations between $F_g, KE, xma, F_P, F_r, F_{rg}, andF_{T\Pr g}$ for Cu :

No	θ^0	$F_g(N)$	$xma(J)$	$K.E(J)$	$F_p(N)$	$F_r(N)$	$F_{rg}x(J)$	$F_{Tprg}(N)$	$F_{T\Pr g}x(J)$	γ
1	0	0	1.01682E-7	1.01682E-7	9.595	9.595	0.5757	1.6947E-6	1.01682E-7	213.97416
2	10	0.00779	7.47053E-8	7.47053E-8	9.595	9.58721	0.5757	1.24509E-6	7.47053E-8	217.09816
3	20	0.01534	5.27121E-8	5.27121E-8	9.595	9.57966	0.5757	8.78534E-7	5.27121E-8	227.34314
4	30	0.02242	4.51921E-8	4.51921E-8	9.595	9.57258	0.5757	7.53202E-7	4.51921E-8	246.49745
5	40	0.02882	3.4282E-8	3.4282E-8	9.595	9.56618	0.5757	5.71367E-7	3.4282E-8	278.48607
6	50	0.03435	2.68939E-8	2.68939E-8	9.595	9.56065	0.5757	4.48232E-7	2.68939E-8	331.69176
7	60	0.03883	1.95985E-8	1.95985E-8	9.595	9.55617	0.5757	3.26641E-7	1.95985E-8	426.21648
8	70	0.04214	1.4914E-8	1.4914E-8	9.595	9.55286	0.5757	2.48567E-7	1.4914E-8	622.87125
9	80	0.04416	1.21838E-8	1.21838E-8	9.595	9.55084	0.5757	2.03064E-7	1.21838E-8	1226.54408
10	90	0.04484	1.08909E-8	1.08909E-8	9.595	9.55016	0.5757	1.81515E-7	1.08909E-8	∞

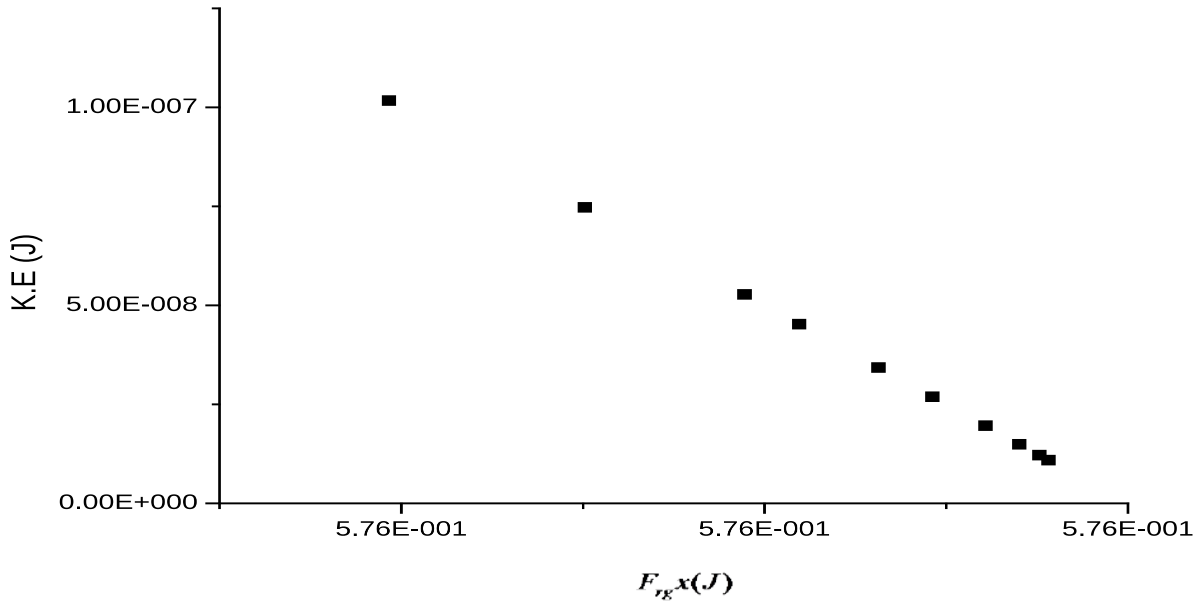

Fig (4.2.1): $(F_{rg}x)$ against $(K.E)$

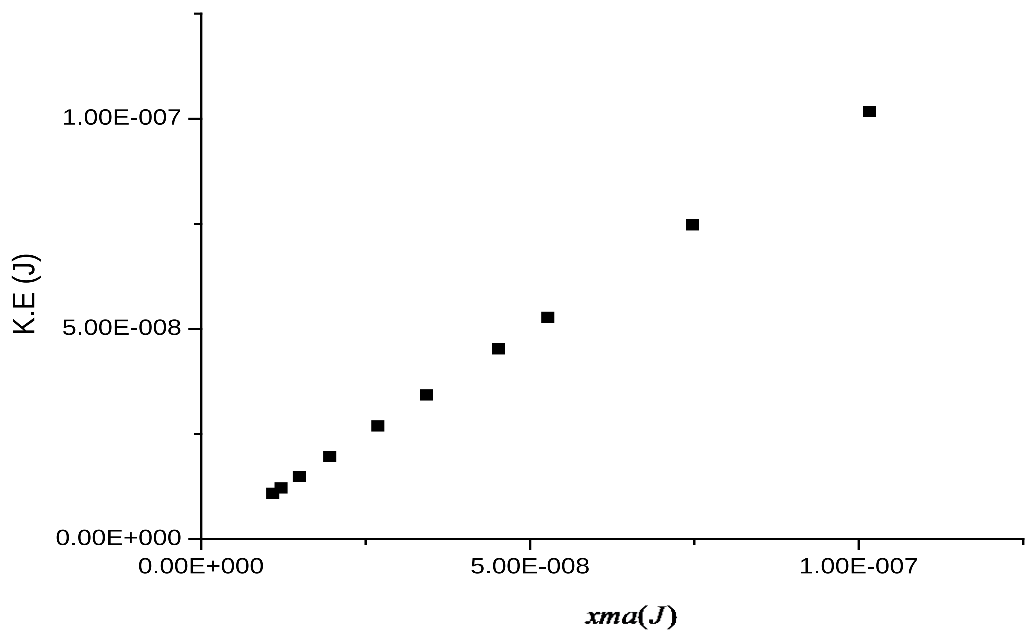

Fig (4.2.2): (xma) against $(K.E)$

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 5, May 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

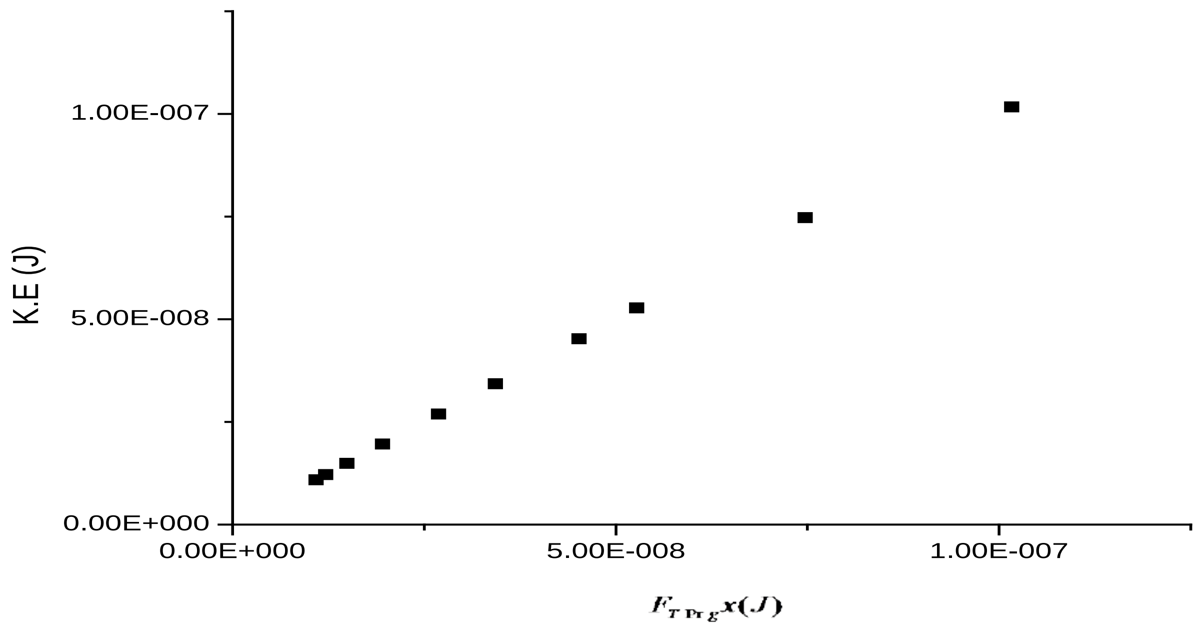

Fig (4.2.3): $(F_{T\,\Pr g}\,x)$ against $(K.E)$

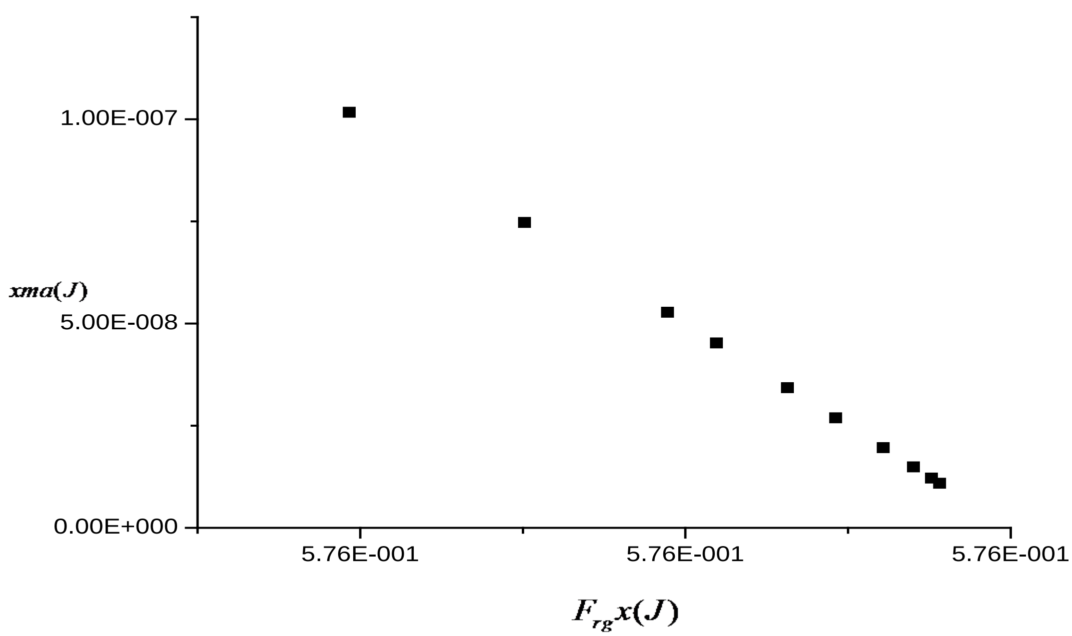

Fig (4.2.4): $(F_{rg}\,x)$ against (xma)

3. Fiberglass:

Table $(4.3.1)$: Relations between (T, v, a) for different angles for Fiberglass:
($m = 0.9239\times10^{-3} kg$),($g = 9.8m/s^2$),($r = 5.5\times10^{-3} m$),($A = \pi r^2 = 9.5\times10^{-5} m^2$),
($T = 100^0 c$),($P = 101000 N/m^2$).

No	θ^0	$t(s)$	$x(m)$	$v(m/s)$	$a(m/s^2)$	$ma(N)$	$COS(\theta)$	$\sin(\theta)$
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
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

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 5, May 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

Table (4.3.2) : Relations between $F_g, KE, xma, F_P, F_r, F_{rg}, andF_{T\Pr g}$ for Fiberglass:

No	θ^0	$F_g(N)$	$xma(J)$	$K.E(J)$	$F_P(N)$	$F_r(N)$	$F_{rg}x(J)$	$F_{T\Pr g}(N)$	$F_{T\Pr g}x(J)$	γ
1	0	0	1.35757E-7	1.35757E-7	9.595	9.595	0.5757	2.26261E-6	1.35757E-7	1059.72672
2	10	0.00157	8.21244E-8	8.21244E-8	9.595	9.59343	0.5757	1.36874E-6	8.21244E-8	1075.89623
3	20	0.0031	5.49759E-8	5.49759E-8	9.595	9.5919	0.5757	9.16264E-7	5.49759E-8	1127.37649
4	30	0.00453	3.93614E-8	3.93614E-8	9.595	9.59047	0.5757	6.56024E-7	3.93614E-8	1223.08291
5	40	0.00582	2.95648E-8	2.95648E-8	9.595	9.58918	0.5757	4.92747E-7	2.95648E-8	1382.54402
6	50	0.00694	2.30176E-8	2.30176E-8	9.595	9.58806	0.5757	3.83626E-7	2.30176E-8	1647.44369
7	60	0.00784	1.84268E-8	1.84268E-8	9.595	9.58716	0.5757	3.07114E-7	1.84268E-8	2117.72187
8	70	0.00851	1.25748E-8	1.25748E-8	9.595	9.58649	0.5757	2.0958E-7	1.25748E-8	3095.68721
9	80	0.00892	9.12494E-9	9.12494E-9	9.595	9.58608	0.5757	1.52082E-7	9.12494E-9	6096.98624
10	90	0.00905	6.92204E-9	6.92204E-9	9.595	9.58595	0.5757	1.15367E-7	6.92204E-9	∞

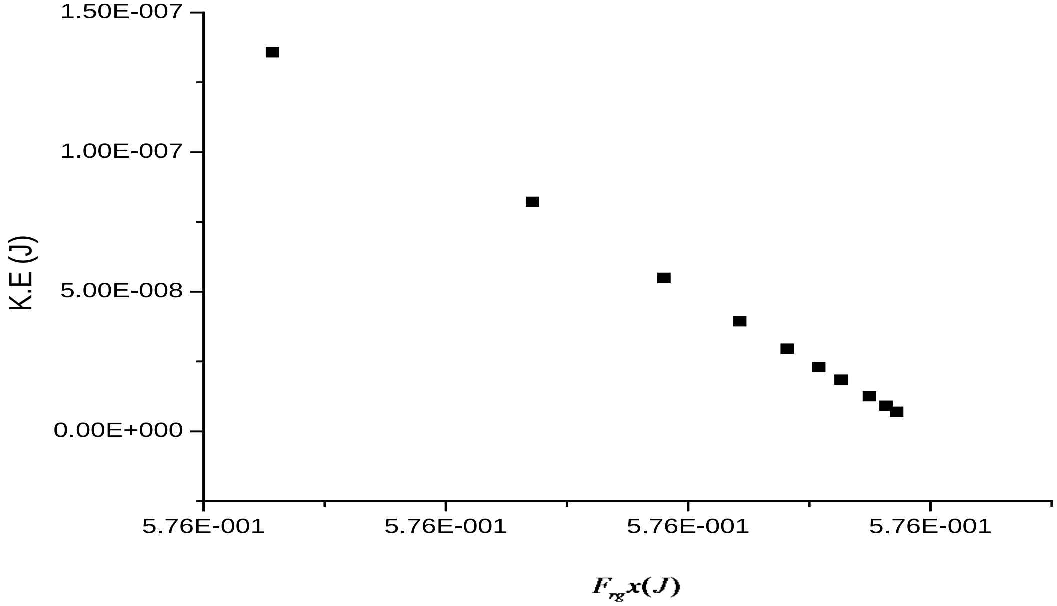

Fig (4.3.1): $(F_{rg}x)$ against $(K.E)$

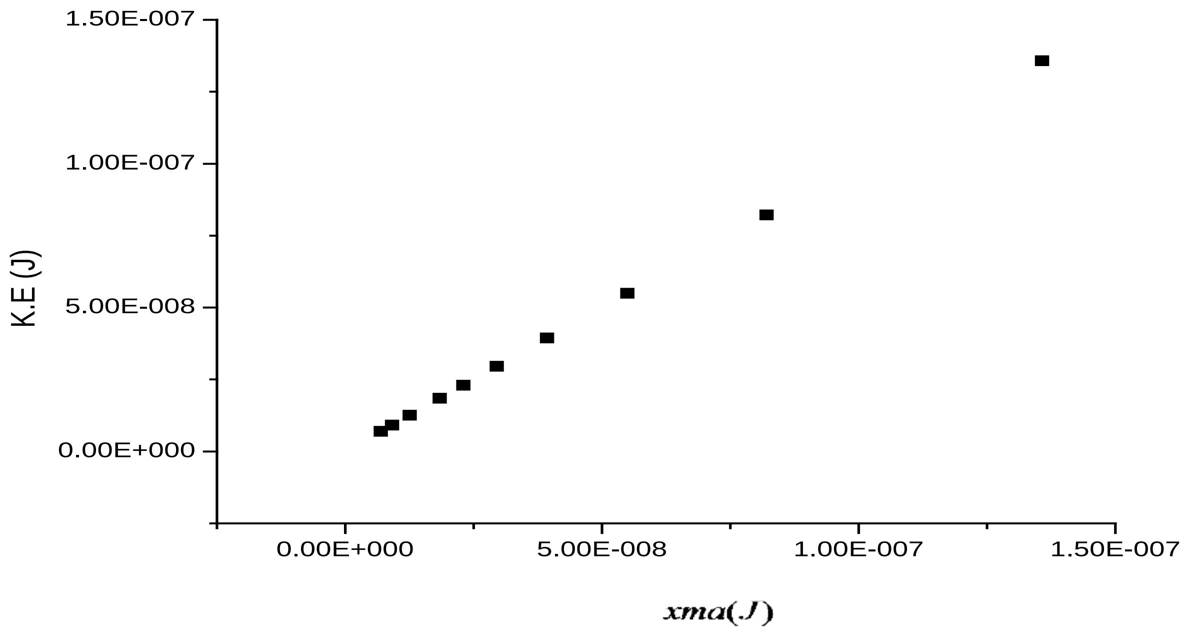

Fig (4.3.2): (xma) against $(K.E)$

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 5, May 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

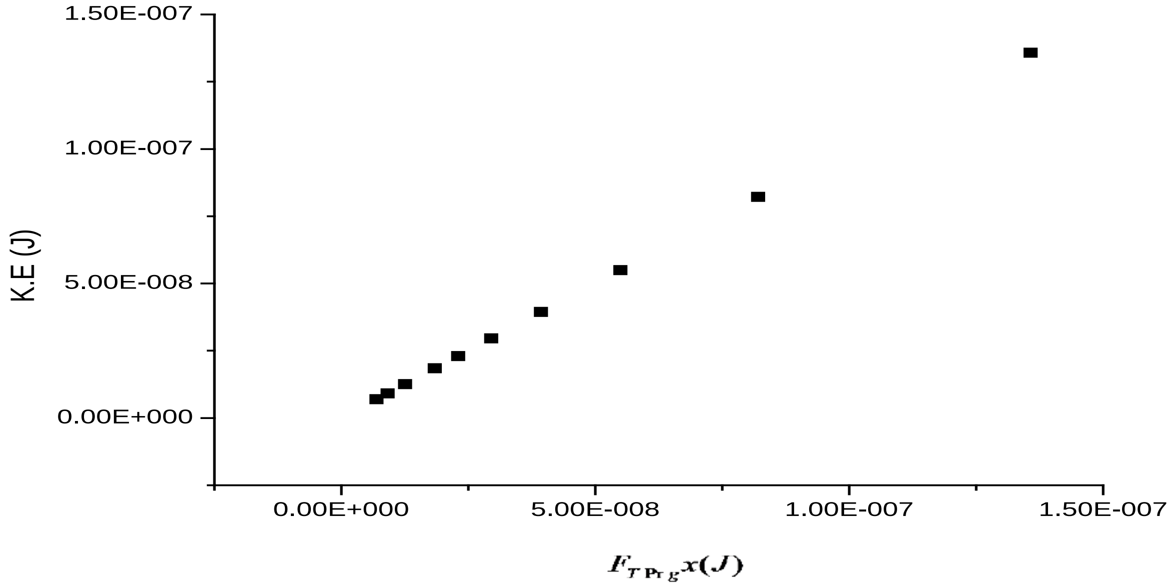

Fig (4.3.3): $(F_{T\,\mathrm{Pr}\,g}x)$ against $(K.E)$

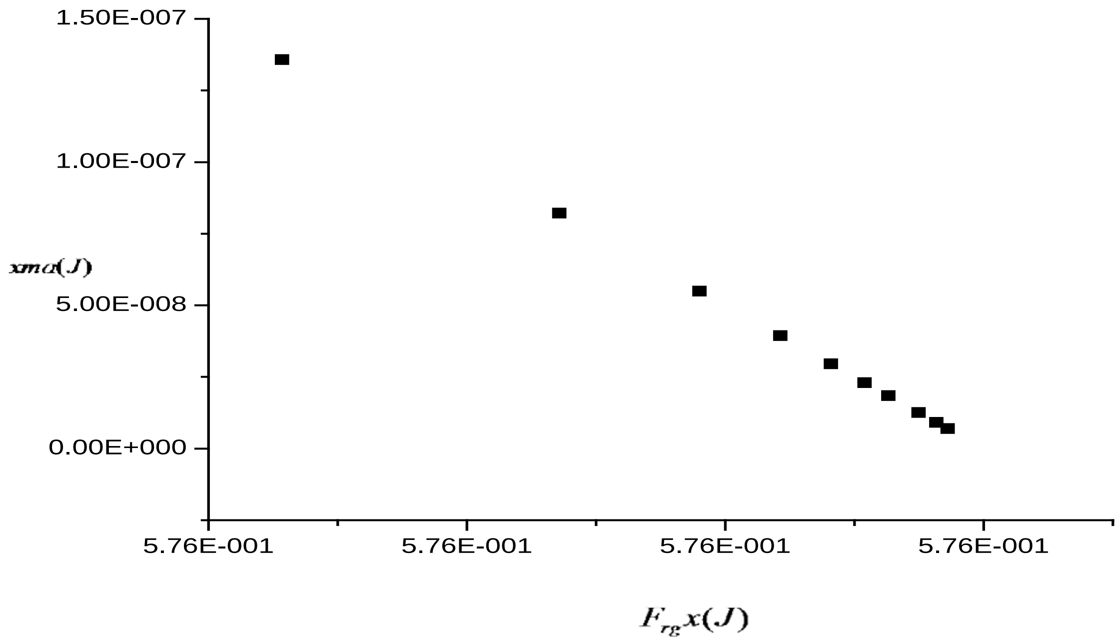

Fig (4.3.4): $(F_{rg}x)$ against (xma)

Discussion:

In view of equations (3), (6) and (9) the kinetic energy K is related to $F_{rg}x$ according to the relation.

$$K = \left(F_{TP} - F_r - F_g\right)x = \left(F_{TP} - mg\cos\theta - \gamma_0 - mg\sin\theta\right)x \qquad (14)$$

Table (4.1) for AL shows that the term $mg\cos\theta$ can be neglecter. This is since the maximum value of $mg\cos\theta$ is given to be:

For $\theta = 90 \quad F_r = \gamma_0 = 9.58157$

For $\theta = 0 \qquad mg\cos\theta = F_r - \gamma_0 = 9.595 - 9.58157 = 0.00343$ (15)

While the maximum value of F_g is given by [see table 4.1.2]

$$F_g = 0.01343 \qquad (16)$$

Thus one can easily neglect F_r to get:

$$K = (F_{TP} - F_g - \gamma_0)x = (F_{TP} - \gamma_0 - mg\sin\theta)x$$
$$= (F_{TP} - \gamma_0 - F_{rg})x \qquad (17)$$

According to equations (11) and (12) F_{TP} is constant. Since γ_0 is constant. Thus equation (17) shows that K decreases as θ increase. This is confirmed experimentally by the relations between K and F_{rg} in Figures (4.1, 2, 3.1).

It is very interesting to note that Figures (4.1, 2, 3.2) shows that the kinetic energy K and xma are proportional to each other. This agrees with the theoretical Newton's Laws:

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

$$K = \frac{1}{2}mv^2 = xma \qquad (18)$$

Where the piston starts motion from rest. It also confirms the new thermodynamic model for frictional system affected by gravity force, where:

$$F_T x = dQ - dU = PdV + F_r x + F_g x + xma$$

$$F_T x = PdV + F_r x + F_g x + xma \qquad (19)$$

Using equation (18), one gets:

$$dE = dQ - dU = dW + F_r x + F_g x + \frac{1}{2}mv^2 \qquad (20)$$

This is the well known fluid energy equation. Thus the equality of K and xma confirms the viability of the new thermodynamic equation since it make it reduce to the new thermodynamic equations.

According to the empirical relations in Figures (4.1, 2, 3. 3) K is directly proportional to $F_{T\Pr g}x$ and to $F_{T\Pr g}$, as far as x is constant (see tables (4.1, 2, 3.1)). This completely agrees with equations (6) and (9), where:

$$K = xma = F_{T\Pr g}x \qquad (21)$$

Since x is constant. Therefore:

$$K \propto F_{T\Pr g} \qquad (22)$$

The empirical relations in Figures (4.1, 2, 3.4) which relates xma to F_{rg} or $F_{rg}x$ shows decrease of xma as F_{rg} increase. This conforms to equation (6) where:

$$xma = F_{TP}x - F_{rg}x \qquad (23)$$

F_{TP}, x are constants. Thus increases F_{rg} decreases xma. However the empirical relations in Figures (4.1, 2, 3.5) shows increase of K as F_r increase. This can be explained.

Conclusion

The fluid energy equation can be used to obtain new first Law of thermodynamic for frictional system. This Law was verified and confirmed experimentally.

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 (2016).
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, 2016).
5- B. Hamilton & M. Crescimanno, Linear frictional forces cause orbits to neither circularize nor process, J. Phys. A: Math. Theor. 41 235205 (2016).
6- Baharat Bhushan, Hand Book of Nanotechnology (Springer VBH, New York, 2016).
7- Bo Thide, Electromagnetic field Theory, (Bo Thide, Uppsala, Sweden, 2012).
8- C.A. Coulson, Waves, (Long man Group, London, 1977).
9- Charles Kittel & Herbert Krociner, Thermal Physics, (Twenty-first printing U.S.A. 2015).