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Mechanical & Mechanics Engineering

Aerodynamic Design Issues

Construction of Concrete Wall

Highlights

Modified Stepped Solar Still

Performance of a Capstone Gas

Discovering Thoughts, Inventing Future

VOLUME 22 ISSUE 1 VERSION 1.0

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Gravitomagnetics a Simpler Approach Applied to Dynamics within the Solar System

By H. Ron Harrison
University of London

Abstract- Galileo studied bodies falling under gravity and Tycho Brahe made extensive astronomical observations which led Kepler to formulate his three famous laws of planetary motion. All these observations were of relative motion. This led Newton to propose his theory of gravity which could just as well have been expressed in a form that does not involve the concept of force. The approach in this paper extends the Newtonian theory and the Special Theory of Relativity by including relative velocity by comparison with electromagnetic effects as shown in section 1.4 based on the Lorentz force. It is also guided from the form of measured data. This enables the non-Newtonian effects of gravity to be calculated in a simpler manner than by use of the General Theory of Relativity (GR). Application to the precession of the perihelion of Mercury and the gravitational deflection of light gives results which agree with observations and are identical to those of GR. It also gives the accepted expression for the Schwarzschild Radius. This approach could be used to determine non-Newtonian variations in the trajectories of satellites.

Keywords: *gravity, relativity, lorentz force, speed of light.*

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Gravitomagnetics a Simpler Approach Applied to Dynamics within the Solar System

H. Ron Harrison

Abstract- Galileo studied bodies falling under gravity and Tycho Brahe made extensive astronomical observations which led Kepler to formulate his three famous laws of planetary motion. All these observations were of relative motion. This led Newton to propose his theory of gravity which could just as well have been expressed in a form that does not involve the concept of force. The approach in this paper extends the Newtonian theory and the Special Theory of Relativity by including relative velocity by comparison with electromagnetic effects as shown in section 1.4 based on the Lorentz force. It is also guided from the form of measured data. This enables the non-Newtonian effects of gravity to be calculated in a simpler manner than by use of the General Theory of Relativity (GR). Application to the precession of the perihelion of Mercury and the gravitational deflection of light gives results which agree with observations and are identical to those of GR. It also gives the accepted expression for the Schwarzschild Radius. This approach could be used to determine non-Newtonian variations in the trajectories of satellites.

An extra term is then added to the initial basic equation which acts in the direction of the relative velocity. The amended basic equation now predicts a change in the speed of light due to gravity and derives the accepted measured result for the Shapiro time delay. It also gives the accepted value for the Last Stable Orbit. Further, it shows that light passing through a gravitational field refracts in accordance with Snell's Law. It also shows that anti-gravity is possible but only when relative speeds get close to that of light.

Because the extra term is a function of $(v/c)^4$ the previously mentioned predictions are not significantly changed.

The prime action in this paper is to show the reasons for creating the form of gravitomagnetics. The applications are discussed to justify the equations. As shown in [32].

Keywords: *gravity, relativity, lorentz force, speed of light.*

I. The Basics

a) Newtonian Gravity

Galileo studied bodies falling to Earth under gravity and concluded that all bodies fell with the same acceleration independent of size and material. Tycho Brahe made extensive astronomical observations which led Kepler to formulate his three famous laws of planetary motion relative to the Sun. All of these observations were of relative motion but the mass of one body was, in each case, much greater than that of the other. These led Newton to propose his theory of gravity using the concept of force and yielding an equation which gives the acceleration of a body relative to the centre of mass. He could just as well have presented it in the form

$$a_{B/A} = -\frac{G(m_A + m_B)}{r_{B/A}^2} \tag{1}$$

without invoking the concept of force and only requiring one definition of mass. This means that the principal of equivalence does not appear.

That is, the acceleration of body B relative to A, in the radial direction, is proportional to the sum of their masses and inversely proportional to the square of their separation. *G* is the gravitational constant.

b) Gravitomagnetics

It is now proposed that equation (1) be extended to include the relative velocity. The axioms are.

a) It is assumed that in mass-free space light travels in straight lines. This defines a non-rotating frame of reference.
b) Because all motion is relative there are no other restrictions on the frame of reference.
c) Gravity propagates at the same speed as light.
d) Mass, or rest mass, is simply the quantity of matter and is regarded as constant. It could be a count of the number of basic particles.

See section I d for the similarity with the Lorentz force.

The initial proposed equation is based on comparisons with electromagnetics. This equation gives results which agree with the measured results of the precession of the perihelion of Mercury and with the deflection of light grazing the Sun. Also it gives the correct definition for the Schwarzschild Radius. However, it suggests that the speed of light is constant. As a result it does not predict the Shapiro Time Delay. An extra term is then added which gives agreement with the time delay and also generates the accepted value for the Last Stable Orbit. See equations (2a), (3a), (4a) and (5a).

The proposed equation is

$$\boldsymbol{a} = -\frac{K}{r^2}\left(1 - \frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2K}{r^2c^2}\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{e}_r) \tag{2}$$

or

$$\boldsymbol{a} = -\frac{K}{r^2}\left(1 + \frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2Kv_r}{r^2c^2}\boldsymbol{v} \tag{3}$$

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where $\boldsymbol{a}$ = acceleration of body B relative to body A, $\boldsymbol{v}$ = the relative velocity, r = the separation and e_r = the unit vector from body A to body B. Also c = speed of light, $K = G\ (m_A + m_B)$ and v_r is the radial component of velocity. Note that G is a constant which could be incorporated into the definition of the quantity of matter. These equations reduce to equation (1) when $v << c$.

The equation can also be written in terms of the Newtonian part plus the gravitomagnetic part

$$\mathbf{a} = \mathbf{a_N} + \mathbf{a_V} = -\frac{K}{r^2}\mathbf{e_r} + \frac{K}{r^2}\left(\frac{v}{c}\right)^2 \mathbf{e_{2\phi}} \qquad (4)$$

where ϕ is the angle between the velocity and the radius.

It should be noted that the velocities of the individual bodies do not appear in these equations, only the relative velocity. For two isolated bodies the relative motion is the only measureable value.

A convenient definition of force is

$$\mathbf{P} = \mu\mathbf{a} = -\frac{Gm_Am_B}{r^2}\left(1-\frac{v^2}{c^2}\right)\mathbf{e_r} + \frac{2Gm_Am_B}{r^2c^2}\mathbf{v}\times\left(\mathbf{v}\times\mathbf{e_r}\right) \qquad (5)$$

where $\mu = m_A m_B/(m_A + m_B)$, the reduced mass.

By definition of the centre of mass (or the centre of momentum) the total momentum is zero with reference to the centre of mass. It is now proposed that the motion of the centre of mass of two bodies is not affected by collision. From this it follows that for a group of particles the motion of the centre of mass is unaffected by internal impacts.

The relative acceleration is only radial when the relative velocity is either radial or tangential. In general the moment of momentum can be shown to be a function of the relative position. So, for an elliptic orbit it remains within bounds.

General inferences from equation (2).
Reverts to Newtonian form when $v << c$.
The second term of (2) is normal to the velocity.

If $v = c$ the first term of (2) vanishes so that there is no change of speed.

Moment of velocity (or moment of momentum per total quantity of matter) is shown to be a function of r.

The equivalence of inertial mass to gravitational mass does not arise.

c) Modified Equations

An extra term is added in the direction of the relative velocity. This will affect the speed of light but not its deflection. As the term is a function of c^4 it only has a very small effect on the motion of large bodies in Solar orbits.

The new equation is

$$\mathbf{a} = \mathbf{a_N} + \mathbf{a_V} + \mathbf{a}_T = -\frac{K}{r^2}\mathbf{e_r} + \frac{K}{r^2}\left(\frac{v}{c}\right)^2\mathbf{e_{2\phi}} + \frac{2K}{r^2}\frac{v_r}{c}\left(\frac{v}{c}\right)^3\mathbf{t} \qquad (4a)$$

Where $\boldsymbol{v}$ is the relative velocity and v_r is the radial component. Also $\boldsymbol{t} = \boldsymbol{v}/|v|$ is the vector in the direction of the velocity. The angle between the velocity and the radius is ϕ. For the third term the sign of the acceleration depends only on the sign of the radial velocity. $K = G(m_A + m_B)$ and c is the speed of light in a gravity free vacuum.

This equation will be considered to be the basic for Post Newtonian Gravity. Justification will come from agreement with verified experimental data.

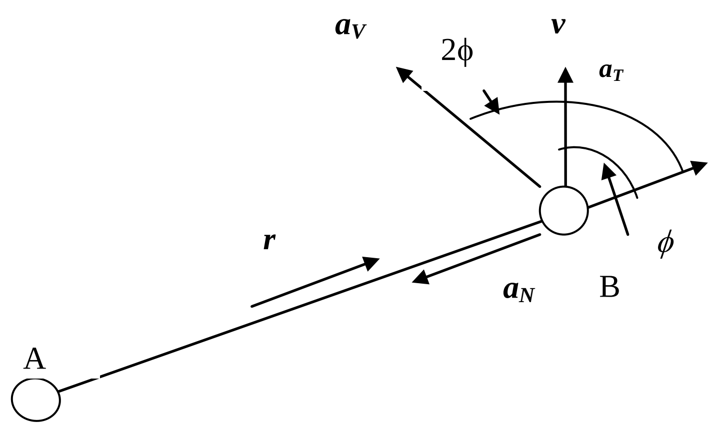

Figure 1

Equation (4a) may be re-written as

$$\mathbf{a} = -\frac{K}{r^2}\left(1-\frac{v^2}{c^2}\right)\mathbf{e_r} + \frac{2K}{r^2c^2}\mathbf{v}\times(\mathbf{v}\times\mathbf{e_r}) \quad + \frac{2K}{r^2}\frac{v_r}{c}\left(\frac{v}{c}\right)^3\mathbf{t} \qquad (2a)$$

or

$$\mathbf{a} = -\frac{K}{r^2}\left(1+\frac{v^2}{c^2}\right)\mathbf{e}_r + \frac{2Kv_r}{r^2c^2}\mathbf{v} + \frac{2K}{r^2}\frac{v_r}{c}\left(\frac{v}{c}\right)^3\mathbf{t} \qquad (3a)$$

From which it is seen that the additional term is negligible when *(v/c)*^{4} is small compared to unity

Again, noting that $\boldsymbol{t} = \boldsymbol{v}/|v|$ means that (3a) may be written as

$$\mathbf{a} = -\frac{K}{r^2}\left(1+\frac{v^2}{c^2}\right)\mathbf{e_r} + \frac{2Kv_r}{r^2c^2}\left[1+\left(\frac{v}{c}\right)^2\right]\mathbf{v} \quad .$$

or $$\boldsymbol{a} = -\frac{K}{r^2}\left(1+\frac{v^2}{c^2}\right)\boldsymbol{e_r} + \frac{2Kv_r}{r^2c^2}Q\boldsymbol{v} \quad \text{. where} \quad Q = \left[1+\left(\frac{v}{c}\right)^2\right]$$

And

$$\mathbf{P} = \mu\mathbf{a} = -\frac{Gm_Am_B}{r^2}\left(1-\frac{v^2}{c^2}\right)\mathbf{e_r} + \frac{2Gm_Am_B}{r^2c^2}\mathbf{v}\times(\mathbf{v}\times\mathbf{e_r}) + \frac{2Gm_Am_B}{r^2c^2}\frac{v_r}{c}\left(\frac{v}{c}\right)^3\mathbf{t} \qquad (5a)$$

where $\mu = m_Am_B/(m_A+m_B)$, the reduced mass.

Equations (2 - 5) will account for the precession of the perihelion of Mercury and will predict the observed value for the deflection of light grazing the Sun. These results were heralded as confirmation of Einstein's General Theory of Relativity. They also give the accepted value for the Schwarzschild Radius.

Equations (2a – 5a) will generate the same results as mentioned above but will also give the accepted value for the Shapiro Time Delay because the speed of light is now affected by gravity. Light is slowed down by gravity which is the opposite of mass particles. The value generated for the Last Stable Orbit is the accepted value.

d) Lorentz force

We shall look at the standard theory of electromagnetism, but this is only to obtain some guidance as to the possible form of a gravitomagnetic theory. The electromagnetic notation is based on reference [7] for SI units.

The force on a charge q_2 in an electromagnetic field is

$$\mathbf{F}_2 = q_2\mathbf{E} + q_2\mathbf{v}_2\times\mathbf{B} \qquad (1.4.1)$$

B is the magnetic field and *E* is the electrostatic field and v_2 is the velocity of the charge. This equation defines the Lorentz force. The magnetic field, due to a length of conductor dl_1 carrying a current i_1 is

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$$\mathbf{B} = \frac{\mu_o}{4\pi r_{2/1}^2} i_1 d\mathbf{l}_1 \times \mathbf{e}_{2/1} \quad . \qquad (1.4.2)$$

but $$i_1 d\boldsymbol{l}_1 = q_1 \boldsymbol{v}_1$$

so, for point charges, we can write for the force on charge 2 due to charge 1 is

$$\boldsymbol{F}_{2/1} = \frac{1}{4\pi\ \varepsilon_0} \frac{q_1 q_2}{r_{2/1}^2} \boldsymbol{e}_{2/1} + \frac{\mu_o\ q_1 q_2}{4\pi\ r_{2/1}^2} \boldsymbol{v}_2 \times (\boldsymbol{v}_1 \times \boldsymbol{e}_{2/1})$$

(see also page 256 of ref. [7])

More detailed analysis of the electrodynamics shows that the right hand side of the above equations should be multiplied by γ, but is usually omitted for small velocities.

The speed of light $c = \frac{1}{\sqrt{\varepsilon_o \mu_o}}$ so we have

$$\boldsymbol{F}_{2/1} = \frac{\gamma q_1 q_2}{4\pi\varepsilon_o r_{2/1}^2}\left[\boldsymbol{e}_{2/1} + \left(\frac{\boldsymbol{v}_2}{c}\right) \times \left(\frac{\boldsymbol{v}_1}{c} \times \boldsymbol{e}_{2/1}\right)\right] \qquad (1.4.3)$$

For mass elements we assume that

$$\boldsymbol{F}_{2/1} = -\frac{\gamma G m_1 m_2}{r_{2/1}^2}\left[\boldsymbol{e}_{2/1} + \left(\frac{\boldsymbol{v}_2}{c}\right) \times \left(\frac{\boldsymbol{v}_1}{c} \times \boldsymbol{e}_{2/1}\right)\right] \qquad (1.4.4)$$

Here c, the speed of gravity waves, is assumed to be the same as that of light.

The form of this equation will be taken as a guide; the problem is to choose the most appropriate values for the velocities. The assumptions that are made in the following development are:

a) That the field generated by body (1) depends on the velocity of body (1) relative to body (2) i.e. ($v_{1/2}$) and
b) The force on body (2) depends on the velocity of body (2) relative to the field i.e. ($v_{2/1}$). Let $v_{2/1} = v$, therefore $v_{1/2} = -v$.

It must be emphasised that force and force fields are inventions solely for the purpose of visualisation.

Substituting these values into equation (1.4.4) gives

$$\boldsymbol{F}_{2/1} = -\frac{\gamma G m_1 m_2}{r_{2/1}^2}\left[\boldsymbol{e}_{2/1} - \left(\frac{\boldsymbol{v}}{c}\right) \times \left(\frac{\boldsymbol{v}}{c} \times \boldsymbol{e}_{2/1}\right)\right] = -\boldsymbol{F}_{1/2} \qquad (1.4.5)$$

For the Newtonian case the acceleration of body (2) relative to body (1) is

$$\boldsymbol{a} = \ddot{\boldsymbol{r}}_2 - \ddot{\boldsymbol{r}}_1 = \frac{\boldsymbol{F}_{2/1}}{m_2} - \frac{(-\boldsymbol{F}_{2/1})}{m_1} = \boldsymbol{F}_{2/1}\left(\frac{1}{m_1} + \frac{1}{m_2}\right)$$

$$= \boldsymbol{F}_{2/1}\left(\frac{m_1 + m_2}{m_1 m_2}\right) = \frac{\boldsymbol{F}_{2/1}}{\mu}$$

where $\mu = \frac{m_1 m_2}{m_1 + m_2}$ is known as the reduced mass.

For the relativistic case we shall define force as

$$\boldsymbol{F} = \frac{d}{dt}(\gamma\mu\boldsymbol{v}) = \left(\gamma\boldsymbol{a} + \frac{\gamma^3}{c^2}(\boldsymbol{v}\cdot\boldsymbol{a})\boldsymbol{v}\right)\mu$$

where $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

Using this definition of force we obtain, using equation (1.4.5),

$$\gamma\ \boldsymbol{a} + \frac{\gamma^3}{c^2}(\boldsymbol{v}\cdot\boldsymbol{a})\boldsymbol{v} = -\frac{G(m_1+m_2)\gamma}{r_{2/1}^2}\left[\boldsymbol{e}_{2/1} - \left(\frac{\boldsymbol{v}}{c}\right) \times \left(\frac{\boldsymbol{v}}{c} \times \boldsymbol{e}_{2/1}\right)\right]$$

or

$$\boldsymbol{a} + \frac{\gamma^2}{c^2}(\boldsymbol{v}\cdot\boldsymbol{a})\boldsymbol{v} = -\frac{G(m_1+m_2)}{r_{2/1}^2}\left[\boldsymbol{e}_{2/1} + \boldsymbol{e}_{2/1}\left(\frac{v}{c}\right)^2 - \frac{\boldsymbol{v}}{c}\left(\frac{\boldsymbol{v}}{c}\cdot\boldsymbol{e}_{2/1}\right)\right] \qquad (1.4.6)$$

Where m_1 and m_2, are the respective rest masses.
Change the suffix of the unit vector to r,
let $K = G(m_1 + m_2)$ and
let $r = |r_{2/1}|$ be the separation. Equation (1.4.6) now becomes

$$\boldsymbol{a} + \frac{\gamma^2}{c^2}(\boldsymbol{v}\cdot\boldsymbol{a})\boldsymbol{v} = -\frac{K}{r^2}\left[1 + \frac{v^2}{c^2}\right]\boldsymbol{e}_r + \frac{K v_r}{r^2 c^2}\boldsymbol{v} \qquad (1.4.7)$$

Note that this equation is symmetric with regard to the two bodies.

The scalar product of equation (1.4.7) with $\boldsymbol{v}$ yields

$$(\boldsymbol{a}\cdot\boldsymbol{v})\left[1 + \gamma^2\frac{v^2}{c^2}\right] = -\frac{K v_r}{r^2}$$

By definition, $\gamma^2 = 1/\left(1 - v^2/c^2\right)$ therefore

$$\gamma^2(\boldsymbol{v}\cdot\boldsymbol{a}) = -\frac{Kv_r}{r^2} \quad (1.4.8)$$

Substituting equation (1.4.8) into equation (1.4.7) gives

$$\boldsymbol{a} = -\frac{K}{r^2}\left(1-\frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2K}{r^2c^2}\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{e}_r) \quad \text{as (2)}$$

$$\boldsymbol{a} = -\frac{K}{r^2}\left(1+\frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2Kv_r}{r^2c^2}\boldsymbol{v} \quad \text{as (3)}$$

II. Application to Two Mass Problem

a) Polar Coordinates

The following development is based on the conventional treatment of the two body gravitational problem. For the dynamics of bodies in Solar orbits the modified equations are not required. Here, r is the separation and $\boldsymbol{e}_r$ is the unit vector in the direction of body 2 as seen from body 1. θ is the orientation of the unit vector with respect to the 'fixed' stars and $\boldsymbol{e}_\theta$ is the unit vector normal to $\boldsymbol{e}_r$ in the plane of the motion.

Now $$\boldsymbol{a} = (\ddot{r} - r\dot{\theta}^2)\boldsymbol{e}_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})\boldsymbol{e}_\theta$$

and $$\boldsymbol{v} = r\boldsymbol{e}_r + (r\dot{\theta})\boldsymbol{e}_\theta$$

Equation (3a) can now be expressed in component form

$$\ddot{r} - r\dot{\theta}^2 = -\frac{K}{r^2}\left[1+\left(\frac{v}{c}\right)^2\right] + \frac{2Kv_r^2}{r^2c^2}Q \quad (6)$$

$$r\ddot{\theta} + 2\dot{r}\dot{\theta} = \frac{1}{r}\frac{d}{dt}\left(r^2\dot{\theta}\right) = \frac{2Kv_rv_\theta}{r^2c^2}Q \quad (7)$$

but for low values of *(v/c)* the term Q will be taken to be unity.

Define $h = r(r\dot{\theta})$, the moment of momentum per reduced mass, and $u = 1/r$. So that $h = \dot{\theta}/u^2$ thus

$$\dot{r} = -\frac{1}{u^2}\frac{du}{d\theta}\frac{d\theta}{dt} = -h\frac{du}{d\theta},$$

$$\ddot{r} = -u^2h^2\frac{d^2u}{d\theta^2} - \dot{h}\frac{du}{d\theta},$$

and

$$\ddot{\theta} = -\frac{2h\dot{r}}{r^3} + \frac{\dot{h}}{r^2} = 2u^3h^2\frac{du}{d\theta} + u^2\dot{h}$$

Equations (6, 7) may now be written

$$\frac{d^2u}{d\theta^2} + \frac{du}{d\theta}\frac{\dot{h}}{u^2h^2} + u = \frac{K}{h^2} + \frac{Ku^2}{c^2} - \frac{K}{c^2}\left(\frac{du}{d\theta}\right)^2 \quad (8)$$

and

$$u\dot{h} = -\frac{2K}{c^2}u^3h^2\frac{du}{d\theta} \quad (9)$$

Since $\dot{h} = \frac{dh}{d\theta}\dot{\theta} = \frac{dh}{d\theta}u^2h$ combining with equation (9) gives, $\frac{dh}{h} = -\left(\frac{2Kdu}{c^2}\right)$ (10)

Integrating equation (10) leads to

$$h = h_0e^{-2K(u-u_0)/c^2} \quad (11)$$

Therefore, for small variations

$$h^2 \approx h_0^2(1-4K(u-u_0)/c^2) \quad (12)$$

where the suffix 0 refers, in this case, to the position $\theta = \pi/2$ measured from the periapsis.

Substituting in equation (8) for h, using equation (12), we obtain

$$\frac{d^2u}{d\theta^2} + u = \frac{K}{h_0^2} + \frac{K}{c^2}\left[\frac{4K(u-u_0)}{h_0^2} + \left(\frac{du}{d\theta}\right)^2 + u^2\right] \quad (13)$$

b) Precession of the Periapsis

Equation (4) is very much easier to apply. This equation is equally applicable to the prediction of satellite trajectories. Because in these aces the relative speeds are not close to the speed of light.

The equation which was developed in reference [19] for calculating the precession of the perihelion of Mercury per orbit is

$$\theta_P = \frac{6\pi G(m_1+m_2)}{c^2a(1-e^2)} \quad (14)$$

where a is the semi-major axis and e is the eccentricity. This generates 42.89 arcsec/century.

For the binary pulsar PSR 1913+16, which was discovered by Hulse and Taylor in 1974, (see reference [22]), the accepted data is that the masses of the two stars are 1.441 and 1.387 times the mass of the Sun, the semi-major axis is 1,950,100 km, the eccentricity is 0.617131 and the orbital period is 7.751939106 hr. Using equation (14) we obtain the result 4.22 deg/yr, which is in agreement with the measured value and that predicted by General Relativity. The orbital decay, or inward spiralling, of binary pulsars is said to be simply due to energy loss caused by gravitational wave emission. This may be the case but energy loss alone will not account for the phenomenon. The loss of mass alone would cause outward spiralling as do most cases of tidal drag.

c) *Moment of Momentum*

If the additional term is negligible then it can be shown that the moment of momentum is

$$h_2 = h_1 \exp\left(\frac{2K}{c^2}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)\right)$$

which depends on separation but is constant when c = infinity.

d) *Schwarzschild Radius*

For a constant radius $v_r = 0$ and $v = v_\theta$ so equation (3) or (3a) becomes

$$-\frac{K}{r^2}\left(1+\frac{v_\theta^2}{c^2}\right)\boldsymbol{e_r} = -\frac{v_\theta^2}{r}\boldsymbol{e_r} \quad \text{so if } v_\theta = c \text{ then} \quad r = \frac{2K}{c^2} = \frac{2G(M+0)}{c^2} = r_g$$

which is known as the Schwarzschild Radius.

e) *Last Stable Orbit*

Numerical integration of equation (3a) shows that the Last Stable Orbit occurs when the radius of the orbit is 3 times the Schwarzschild Radius, which is the accepted result based on General Relativity. If equation (3) is used then a value of 2.62 r_g may be calculated algebraically. However if Q is not unity, as shown in equation (3a), then equation (12), with Q included is,

$$h^2 \approx h_0^2(1 - 2r_g(u - u_0)Q) \qquad (12a)$$

where the suffix 0 refers to circular motion when $u = u_o$

Substituting in equation (8) for h, using equation (12a), equation (13) becomes

$$\frac{d^2u}{d\theta^2} + u = \frac{K}{h_0^2} + \frac{K}{c^2}\left[\frac{4K(u-u_0)Q}{h_0^2} + \left(\frac{du}{d\theta}\right)^2 + u^2 - \left(\frac{du}{d\theta}\right)2(Q-1)\right] \qquad (13a)$$

If $u = u_o + \varepsilon$ then, for small variations

$$\varepsilon'' + \varepsilon\left(1 - r_g u_o(2Q+1) + (r_g u_o)^2 Q\right) = 0 \qquad (13b)$$

For circular motion it can be shown that

$$\left(\frac{v}{c}\right)^2 = \frac{u_o r_g}{2 - u_o r_g} \quad \text{so} \quad Q = \left[1 + \left(\frac{u_o r_g}{2 - u_o r_g}\right)\right]$$

For a stable near circular orbit then

$\left(1 - r_g u_o(2Q+1) + (r_g u_o)^2 Q\right) > 0$ so when the factor of ε in equation (13b) is zero, algebraic manipulation of (13b) gives $r_o/r_g = 3$, which is the accepted value. It also gives a value of 0.5.

f) *Deflection of Light*

In equation (3a) terms 2 and 3 are parallel to the velocity so the component normal to the velocity is

$$\boldsymbol{a}\cdot\boldsymbol{n} = -\frac{K}{r^2}\left(1+\left(\frac{v}{c}\right)^2\right)\boldsymbol{e_r}\cdot\boldsymbol{n} = v\frac{d\psi}{dt}$$

For small variation of the speed of light assume that $v = c$. Also, for small deflections the scalar product of $\boldsymbol{e_r}$ and $\boldsymbol{n}$ can be seen from Figure (2) to be R_s / r.

Therefore

$$\boldsymbol{a}\cdot\boldsymbol{n} = -\frac{2K}{r^2}\frac{R_s}{r} \qquad \text{now} \quad r = \sqrt{x^2 + R_s^2} \quad \text{so}$$

$$\boldsymbol{a}\cdot\boldsymbol{n} = -\frac{2KR_s}{\left(x^2+R_s^2\right)^{3/2}} = c\frac{d\psi}{dt}c\frac{d\psi}{dx}\frac{dx}{dt}$$ or, as dx/dt is approximately c

$$d\psi = -\frac{2K}{c^2}R_s\frac{1}{\left(x^2+R_s^2\right)^{3/2}}dx \qquad \text{integrating gives}$$

$$\psi = \frac{2K}{c^2R_s}\left(\frac{x}{\sqrt{\left(x^2+R_s^2\right)}}\right).$$ When $x = 0$ $\psi = 0$ and when x goes to infinity

$$\psi = -\frac{2K}{c^2R_s}$$

Therefore the total deflection $\delta = 2\psi$ so

$$\delta = \frac{4K}{c^2R_s} \qquad (15)$$

With $K = M_{sun}G$ and R_s being the radius of the Sun the deflection is 1.75 arcsec. This value agrees with the measured value and with General Relativity. This confirms the assumption that the deflection of light grazing the Sun is small.

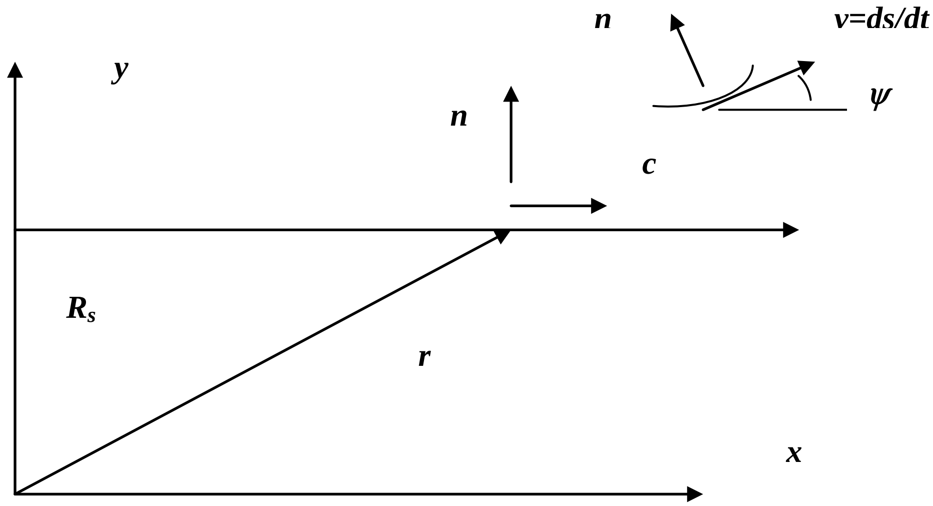

Figure 2

g) Shapiro Time Delay

When $v = c$ equation (2a) gives $\mathbf{a}\cdot\mathbf{t} = \frac{2K}{r^2}\frac{v_r}{c} = \frac{dc}{dt}$

Therefore $\frac{2K}{r^2}\frac{\dot{r}}{c} = \frac{dc}{dr}\frac{dr}{dt}$ or $\frac{2K}{r^2 c}dr = dc$

Integration leads to $[c]_i^{\infty} = \left[-\frac{2K}{rc}\right]_i^{\infty}$, $c - c_i = 0 + \frac{2K}{r_i c}$

where c is now the speed of light where r tends to infinity.

$$c_i = c\left(1 - \frac{2GM}{rc^2}\right) \quad (16)$$

Or

Consider the case of light grazing the Sun at a radius R_s and calculate the journey time. As an approximation assume the path to be a straight line.

Then, since $c_i = \frac{dx}{dt}$

$$c\ dt = \frac{dx}{1 - 2GM/(rc^2)}$$ where $r = \sqrt{x^2 + R_s^2}$ also as $\frac{2GM}{rc^2} << 1$

$$\int c\ dt = \int\left(1 + \frac{2GM/c^2}{\sqrt{x^2 + R_s^{\ 2}}}\right)dx = x + \frac{2GM}{c^2}\ln\left[2\left(\sqrt{x^2 + R_s^{\ 2}} + x\right)\right]$$

Between the limits x = 0 to x and t = 0 to t we have the total time

$$t = \frac{x}{c} + \frac{2GM}{c^3}\ln\left(2\sqrt{x^2 + R_s^2} + 2x\right) - \frac{2GM}{c^3}\ln(2R_s)$$

so the additional time due to the gravitational effect is

$$\Delta t = \frac{2GM}{c^3}\ln\left[\frac{\sqrt{x^2 + R_s^2} + x}{R_s}\right] \quad (17)$$

This gives a time delay of 232µs for the double transit time from Earth to Venus. This is exactly the same as quoted by Bertotti, reference made to C. M. Will. The value for Mars is 247µs which is as quoted by Reasenberg, Shapiro et. al., is also given by the above equation.

This shows that the speed of light is reduced by gravity. In the case of light grazing the Sun the reduction in speed/c_o is $\frac{2GM_s}{c^2 R_s} \approx 4\times 10^{-6}$, that is, only four parts per million. The variable speed of light has been incorporated into the basic equation however this would not have any major effect on the motion of material bodies. The valuation of the deflection of light is not changed. Because the light path is slightly curved the increase in path length will add to the delay but as the

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speed change is so small the additional time is less than 1%.

h) Gravity and the refraction of light

The form of the extended equation is based on the known observations or deductions. The extra term is required to be in the direction of the relative velocity. Also, because the speed of light is at its maximum then passing though empty space it must reduce when moving into a gravitational field so assume that it depends on the magnitude of the radial speed. From this it follows that the acceleration will be repulsive. Also, for circular orbits the speed remains constant, which is true when $v_r = 0$.

The additional term could be

$\boldsymbol{a_t} = \lambda \frac{K}{r^2}\left(\frac{v_r}{c}\right)\frac{\boldsymbol{v}}{c}$, where λ is a constant depending on application.

When applied to the Last Stable Orbit with $\lambda = 2\left(\frac{v}{c}\right)^2$ the value agrees with the generally accepted value. The constant seems reasonable, so

$$\boldsymbol{a}_t = \frac{2K}{r^2}\left(\frac{v}{c}\right)^2\left(\frac{v_r}{c}\right)\frac{\boldsymbol{v}}{c}$$

This is the form shown in equation (2a) which leads to predicting the speed of light due to gravity.

Consider the case when speed is very close to the speed of light in a gravity free vacuum.

Equation (2a) gives the acceleration parallel to the velocity

$$\boldsymbol{a}\cdot\boldsymbol{t} = \left(\frac{2K}{r^2 c}v_r\right)$$

From equation (3a) the acceleration normal to the velocity

$$\boldsymbol{a}\cdot\boldsymbol{n} = -\frac{2K}{r^2}\boldsymbol{e}_r\cdot\boldsymbol{n}$$

With ∅ being the angle between the radius from the gravity source and the velocity

$v_r = c\cos\emptyset$ and $\boldsymbol{e_r}\cdot\boldsymbol{n} = -\sin\emptyset$

therefore

$a_t = \boldsymbol{a}\cdot\boldsymbol{t} = \left(\frac{2K}{r^2}\right)\cos\emptyset$ and

$a_n = \boldsymbol{a}\cdot\boldsymbol{n} = \left(\frac{2K}{r^2}\right)\sin\emptyset$

So $a_n = a_t\tan\emptyset$ (a)

The refractive index *n* is defined as speed of light in a gravity free vacuum/ speed of light in a transparent media.

For light passing through different media Snell's Law states that

$$\frac{n_1}{n_2} = \frac{c/c_1}{c/c_2} = \frac{\sin\emptyset_2}{\sin\emptyset_1} = \frac{c_2}{c_1}, \text{ or } c_1/\sin\emptyset_1 = c_2/\sin\emptyset_2 = constant$$

With $c/\sin\emptyset = B\ (a\ constant)$, then $c = B\sin\emptyset$, differentiating with respect to time gives

$\frac{dc}{dt} = B\cos\emptyset\frac{d\emptyset}{dt} = \frac{c}{\tan\emptyset}\frac{d\emptyset}{dt}$, using path coordinates

$a_t = \frac{dc}{dt}$ and $a_n = c\frac{d\emptyset}{dt}$

Thus $a_n = a_t\tan\emptyset$ as equation (a).

This is applicable to the passage of light through the Earth's atmosphere. Hence light passing through a strong gravity field will be affected in the same way as light passing through the atmosphere.

This result gives more confirmation of the applicability of the basic equation of the paper.

III. Gravitomagnetics Applied to Rotating Bodies

a) Basic Equations

When equation (2) is applied to two body systems the equation generated is identical to the de Sitter form and agrees with the measurement of precession of the perihelion of Mercury and of the Binary Pulsar PSR 1913+16. The equation is equally applicable if one spherical body is large and non-rotating. Note that the additional term, which is a function of c^3, is negligible for Solar dynamics.

$$\boldsymbol{a} = -\frac{K}{r^2}\left(1-\frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2K}{r^2c^2}\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{e}_r)$$

(2rpt) (18a)

where *c* is the speed of light, ***a*** is relative acceleration, ***v*** is relative velocity and *r* is relative position. Also $\boldsymbol{e}_r$ is the unit vector from body A to body B.

$K = G(m_A + m_B)$ where *G* is the gravitational constant

The calculations are made easier for multi-body systems by the use of a defined force as shown in equation (5).

$$\boldsymbol{P} = \mu\boldsymbol{a} = -\frac{Gm_Am_B}{r^2}\left(1-\frac{v^2}{c^2}\right)\boldsymbol{e}_r + \frac{2Gm_Am_B}{r^2c^2}\boldsymbol{v}\times(\boldsymbol{v}\times\boldsymbol{e}_r) \quad \text{(5rpt) (18b)}$$

μ is the reduced mass $m_Am_B/(m_A+m_B)$

b) Gravity Probe B

Gravity Probe B is the study of the precession of a gyroscope in a polar orbit about the Earth. The spin axis of the gyroscopes is perpendicular to the spin axis of the Earth. After over 3 decades of study and design at Stanford University the final results of the experiment were published in 2011 [27].

When the new theory is applied to Gravity Probe B the following equations are derived algebraically using equation (5). The modified equation is not required because the relative velocities are not close to the speed of light.

$$\dot{\phi}_x = \frac{Gm_E\dot{\alpha}}{c^2R_c} \quad \text{Geodesic or de Sitter. (North to South)}$$

$$\dot{\phi}_z = \frac{GI_E\Omega}{2c^2R_c^3}\left(2-3\cos^2\alpha\right) \quad \text{frame dragging or Lense - Thirring. (West to East)}$$

where R_E = Radius of the Earth, m_E = Mass of the Earth, I_E = Moment of inertia of the Earth, R_c = Radius of orbit, G = Gravitational constant and c = Speed of light.

Also, α is the location of the satellite in its orbit and Ω is the angular velocity of the Earth. These equations yield,

$$\dot{\phi}_x \; 4.4 \;\pm 0.0 \;\; \frac{\text{arcsec}}{\text{yr}} \quad (\,6.6 \;\pm 0.0 \text{ based on GP} - \text{B update}\,)$$

$$\dot{\phi}_z = 0.02 \;\pm 0.06 \,\frac{\text{arcsec}}{\text{yr}} \quad (0.037 \pm \; 0.007 \text{ based on GP-B update})$$

Gravity Probe B Status Update 2011 Ref [27}. Note that one arc second equals 1/3600 degrees of angle. Also, one year is a long time. All four of the gyros give results for de Sitter value which are very close to each other. However two of the gyros give results for the Lense -Thirring value which are very close to the value quoted in this paper.

c) Precession of the Periapsis of a small body orbiting a large rotating mass

This problem is similar to the discussion of the precession of the perihelion of Mercury except that now the rotation of the Earth is taken into account. For Mercury the rotation of the Sun has negligible effect. The LAGEOS satellites yield results for the so called frame dragging, or Lense Thirring effect, which results from the rotation of the Earth.

The Earth is regarded as a uniform spherical body which can be regarded as a set of uniform spherical shells. The sphere, of mass *M* and moment of inertia *I,* rotates about the Z axis at a constant angular speed Ω.

Consider a test body in orbit around the Earth performing an elliptical orbit where *e* is the eccentricity and *a* is the semi-major axis and a period of *T*. The plane has an inclination (inc) relative to the equatorial XY plane of the Earth.

Again, based on equation (5).the rate of precession of the periapsis, as seen from the plane of the orbit, in radians per orbit, is

$$\Delta\phi_P = \frac{6\pi GM}{c^2a\left(1-e^2\right)} - \frac{2GI\Omega}{c^2a^3\left(1-e^2\right)^{3/2}}\cos(inc)T \quad (19)$$

The first term, the de Sitter precession, has been derived algebraically from equation (2). It agrees exactly with the generally accepted form and agrees with the measured results for the precession of the perihelion of Mercury and for the binary pulsar PSR 1913+16. However, the second term, the Lense-Thirring term, justified by numerical integration, is only half of the generally accepted value.

d) Anti-Gravity

Weight loss of a rotating ring.

Consider a ring rotating about a horizontal axis above a large body, such as the Earth. Using equation (3a) evaluate the component of the acceleration in the radial direction.

$$\mathbf{a} = -\frac{K}{r^2}\left(1+\frac{v^2}{c^2}\right)\mathbf{e}_r + \frac{2Kv_r}{r^2c^2}\mathbf{v} + \frac{2K}{r^2}\frac{v_r}{c}\left(\frac{v}{c}\right)^3\mathbf{t} \quad (3a)$$

Noting that $\boldsymbol{t} = \boldsymbol{v}/|v|$ means that (3a) may be written as

$$\mathbf{a} = -\frac{K}{r^2}\left(1+\frac{v^2}{c^2}\right)\mathbf{e_r} + \frac{2Kv_r}{r^2c^2}\left[1+\left(\frac{v}{c}\right)^2\right]\mathbf{v} \quad \text{or}$$

$$\frac{\boldsymbol{a}}{K/r^2} = -\left(1+\frac{v^2}{c^2}\right)\boldsymbol{e_r} + \left(1+\frac{v^2}{c^2}\right)\frac{2v_r}{c}\frac{\boldsymbol{v}}{c}$$

Also as *K* is *G* times the total mass therefore as the mass of the ring is very small compared to the large body its mass is negligible. So, *K* = G (mass of the large body).

Now $v_r = v\cos\theta$ also $\boldsymbol{v}\cdot\boldsymbol{e_r} = v\cos\theta$, where θ is the angle between the velocity and the radius from the large mass.

$$\frac{\boldsymbol{a}\cdot\boldsymbol{e_r}}{K/r^2} = \left(1+\frac{v^2}{c^2}\right)\left[-1+2\left(\frac{v}{c}\right)^{\mathbf{2}}\cos^2\theta\right]$$

This equation is the radial acceleration divided by the magnitude of the Newtonian gravity acceleration. If *v/c* is negligible then the right hand side is -1, as expected. This equation is applicable to a point mass so for the whole ring we need to integrate for point mass *md/2π* divided by total mass of the ring *m.*

$$\int_0^{2\pi}\left(1+\frac{v^2}{c^2}\right)\left[-1+2\left(\frac{v}{c}\right)^2\cos^2\theta\right]\frac{d\theta}{2\pi}$$

Note that the integral of $\cos^2\theta$ between *0 and 2π* equals *π*.

The second term in the square bracket is always positive therefore this term of the acceleration will be radially outwards for all parts of the ring. Integration for all parts of the ring leads to

$$\frac{a\cdot e_r}{K/r^2}=(-1+\beta^4)\text{, where } \beta={}^{v}/_{c}.$$

The value runs from -1, which is the Newtonian, to 0, which means weightless. When the spinning speed is small compared that of light then the chance of a measurable change in gravitational acceleration, or weight, is very unlikely since it depends of the forth power of *v/c*.

If negative gravity ever existed then start with a pool of particles with mixed gravity and electrical charge. Electrical charge is stronger than gravity so the positive electrical charged particles will attract the negative ones and will have zero electrical charge. The particles with gravitational positive charge will repel the negatively charges ones so the groups will separate.

IV. Discussion

Equation (4a) is easier to apply than the theory of General Relativity (GR) and therefore leaves less room for misinterpretation. That force is a secondary quantity was strongly advocated by H. R. Hertz who regarded force as "a sleeping partner". Force is to dynamics as money is to commerce. Once force has been demoted to a defined quantity then force fields and inertia are also defined quantities, similarly for work and energy. Equation (2) is loosely modelled on the Lorentz force but this relationship is for guidance only in the same way that Maxwell used a mechanical model to form his equations. However, he abandoned the reference in his final paper on the subject once he had established that his equations predicted the then known observations.

As shown above, when the new approach is applied to two body systems it agrees with the well verified observations of the precession of the perihelion of Mercury, deflection of light passing the Sun and the definition of the Schwarzschild Radius. All agree with the results obtained from the General Theory of Relativity. The third term in equation (4a) was added as it agrees with the measurements of the Shapiro Time Delay and generates a value equal to the accepted value for the Last Stable Orbit.

The Gravity Probe B experiment testing the precession of gyroscopes in Earth orbit displays two equations, one for the geodesic term and one for the frame-dragging effect. The geodesic term does not involve the rotation of the Earth but the frame-dragging term does. The same form of equations have been generated algebraically using equation (5). The frame-dragging term is half of the published value, however, the geodesic term is about two thirds of the published value.

The de Sitter effect agrees with the accepted results of analysis whether algebraically or by numerical integration for two body systems or large non-rotating bodies. This is true whether using equation (2) or equation (5). However, for the Lense-Thirring terms there is an unresolved factor which affects the periapsis precession. The published nodal precession test on the Earth satellites LAGEOS I & II, see reference [28], appear to agree with the accepted theory. The inclination of the satellites is approximately 90^0 +/- 20^0. The reason for this is that the accepted Lense-Thirring term does not depend on the inclination but all other effects do and therefore can be cancelled out. See also references [10] and [29].

The gravitational effect on the speed of light is still discussed but apart from the Shapiro Time Delay the effect is negligible when dealing with the motion of bodies. The decrease of the speed of light grazing the Sun is only 4 parts per million. Gravitational Redshift it is sometimes regarded as a proof of GR, however, it can be derived from other fundamental theories. As shown, light passing through a gravitational field refracts in accordance with Snell's Law.

It has proved to be impossible, so far, to find any modification to equation (4) such that it gives the generally accepted value for the Lense-Thirring effect without changing the de Sitter effect applications. The de Sitter results have been obtained by several observations but the Lense-Thirring effect is very small compared to other effects. In the LAGEOS experiments for the precession of the periapsis the Lense-Thirring effect is less than 1% of the de Sitter effect, which makes it more difficult to evaluate. The GP-B test results have recently been published, reference [27]. There are four gyroscopes, two of which have original frame-dragging results which are close to that predicted by the new theory. The geodesic results are, on average, close to those of the accepted value. Nevertheless, over a one month period two of the gyroscopes precess at a rate close to the new theory predictions.

It is widely stated that the inward spiralling of a binary star system is due to gravitational radiation. The loss of energy alone is not the cause of this effect. Energy loss can be related to outward spiralling, as is the case for the Earth Moon system. However, radiation pressure could be the cause.

When general relativity is applied to multiple body systems several authors have produced slightly different results. Some results even do not return to the

Newtonian form when the velocities are zero but only if the speed of light is taken to be infinite. This new approach does not undermine the General Theory of Relativity but because it is a simpler method it leaves less room for misinterpretation. Many of the extensions of GR are very complex mathematically, making errors more likely.

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Performance of a Modified Stepped Solar Still

By Ali. F. Muftah

Abstract- Distillation represents one of the earliest methods of treating water, and it remains as such in many parts of the world. A basin type solar still remains the simplest desalination technology, made up of a hermetic basin that is covered with a transparent airtight material such as glass or plastic. The system is simple, easy to construct, requires minimal maintenance, and cost effective. It is difficult maintaining minimum depth in conventional basin type solar still, as the area is large. However In an attempt to increase production per unit area by decreasing the thermal inertia of the water mass, this can be achieved in basin-type stepped solar still in which the area of the basin is minimized by having small trays. The purpose of this study were to design, fabricate and evaluate the performance of a modified stepped solar still. The theoretical analysis was conducted to determine the optimum design of the basin. The productivity and solar still efficiency were obtained by solving the energy balance equations for the absorber plate, saline water and glass cover, temperature difference between saline water and the glass cover. The results indicated that, the productivity of the modified stepped still is higher than that for conventional solar still approximately by 103%.

Keywords: solar desalination, stepped solar still, solar thermal energy.

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PERFORMANCEOFAMODIFIEDSTEPPEDSOLARSTILL

Strictly as per the compliance and regulations of:

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I. Introduction

Desalination is one of the most primitive forms of water treatment, and it is still a popular treatment solution throughout the world. Desalination methods utilize large amount of energy (fossil fuels) to remove a portion of pure water from seawater. The fossil fuels create pollution on environment. A solar still is a device, which used in solar desalination process to produce drinkable water from brackish and saline water by using solar energy. Although solar still is a very simple device, easy to fabricate and require less maintenance, it is economical and not familiarly used because of its lower productivity. Numerous solar distillation systems were developed over the years using the above principle for water purification in many locations in the world. Many researchers analyzed the works carried out on the solar still to augment the productivity of the simple solar still. [Sebaii et al. 2009], [Madhlopa and Johnstone 2011]. Glass, rubber and pebble are some of materials that used as thermal storage materials [Abdel-Rehimaand Lasheen 2005], [Nafey et al. 2001]. A solar still was tested with a special phase changing material as energy storage media at its base. [Naim and Abd El Kawi 2002], [Bassam and Himzeh 2003] reported that, as providing of energy storing materials, wick materials, reducing water depth in basin increases the output. The productivity of a solar still increased from 18% to 27% with different size sponge cubes placed in the basin. [Velmurugan et al. 2008], [Velmurugan et al. 2009a] designed and analyzed a stepped still. Where a maximum increase in output of 98% is reported in stepped solar still when fin, sponge and pebbles are used in this basin. As well as [Velmurugan et al. 2009b] studied the augmentation of salt water streams in solar stills integrated with a mini solar pond. a highest production of 100% was obtained when the fin type solar still was integrated with pebble and sponge. When solar pond, basin type stepped solar still and a single basin solar still are located in series, a highest productivity of 80% is found, when fins and sponges are used in both the solar stills. When solar pond, stepped solar still and wick type solar still are coupled in series, It is found that maximum productivity of 78% occurred, when fins and sponges are used in the stepped solar still. [Tabrizi et al. 2010] Constructed two cascade solar stills with and without latent heat thermal energy storage system (LHTESS). It was observed that the total productivity of still without LHTESS is slightly higher than the still with LHTESS.

II. Theoretical Analysis

Theoretical analysis have been performed at the same conditions for two types of the solar still included modified stepped solar still and conventional solar still. The schematic diagram of the conventional solar still is shown in Figure 1. Basin area of conventional solar still (single basin solar still) 1 m^2 (0.5 m$\times$2.0 m) Basin of the still fabricated from a black painted galvanized iron sheet to increase the absorptivity. The cover of the still is made up of glass. Figure 2 shows the schematic diagram of stepped solar still. The stepped still has the same dimension and construction of conventional still. As well as absorber plate of stepped still is made up of 5 steps, (each of size 0.1 m$\times$2 m). the stepped solar still integrated with an external condenser to increase the evaporation, fins to increase the absorptivtiy, and an external and an internal mirrors to increase the solar radiation on the still. The water vapour inside the still condensed on the cooler inner surface of the glass, thus, forming droplets and running down the glass. The covering glass prepares the smooth surface to flow the condensate. The distilled water dripped into tilted troughs attached to the lower edges of the glass cover. The condensed water was collected in the V-shaped

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cross section channel drainage provided below the glass lower edge on one sides. The distillates were collected in a bottle.

However, MS-Excel/VBA computer program is used to predict the results of the developed energy balance model for all types of solar stills, which in turn require the computation of thermodynamic and transport properties for water/vapor substance the analytical results are obtained by solving of the energy balance equations for the basin plate, saline water and glass cover of the solar still. The temperature of saline water, basin plate and glass cover can be evaluated at every 30s.

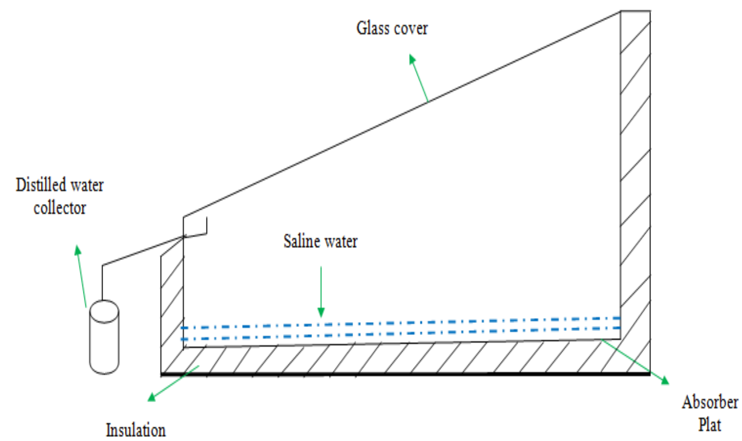

Figure 1: Schematic diagram of conventional solar still

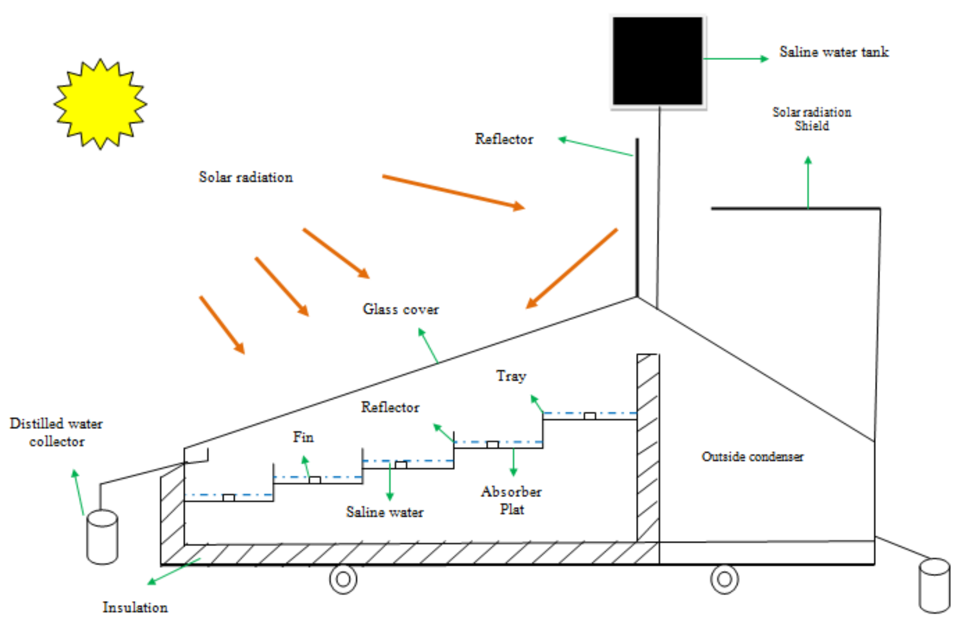

Figure 2: Schematic diagram of modified stepped solar still

III. Results and Discussions

Numerical calculations have been performed at the same conditions for three type of the solar still included modified stepped solar still, stepped solar still without modification, and conventional solar still. The variation of solar radiation, ambient temperature, water temperature and glass temperature of solar stills are shown in Figure 4. It is observed that the temperatures at all points increase as the time increase till a maximum value at noon and decrease after that. This is due to the increase of solar radiation intensity in the morning and its decrease in the afternoon. From the results shown in Figure 3, it is seen that the solar radiation achieve maximum values of 1100 W/m^2. Increase in solar radiation increases the saline water temperature. This in turn increases the productivity rate. Ambient air temperature proportionately increased with increase of solar intensity and decreasing trends were noticed during off-sunshine hours. Maximum ambient temperature was found at 36.2°C at 12:10 PM whereas lowest ambient temperature reached up to 27°C at 07:00 AM. In addition From Figure 3 it can be observed that the maximum basin water temperature of modified stepped solar still and conventional solar still was about 73.7°C and 54.6°C. The maximum value of glass temperature of modified stepped solar still and conventional solar still was about 69°C and 49.1°C, respectively. The solar still performance was improved at mid-noon, and this due to the increase of solar radiation which leads to higher ambient temperature and higher solar still temperature. From Figure 3, it can be indicated that the saline water temperature and glass temperature of modified stepped solar still are higher than that of conventional solar still by about 14.1°C, 19.9°C respectively. This is because adding reflector of the stepped still. This reflector reflects a fraction of the radiation onto the water surface, thus consequently increase the water and glass temperatures of the stepped solar still. So, the evaporation condensation rates in stepped solar stills were higher than that of conventional still.

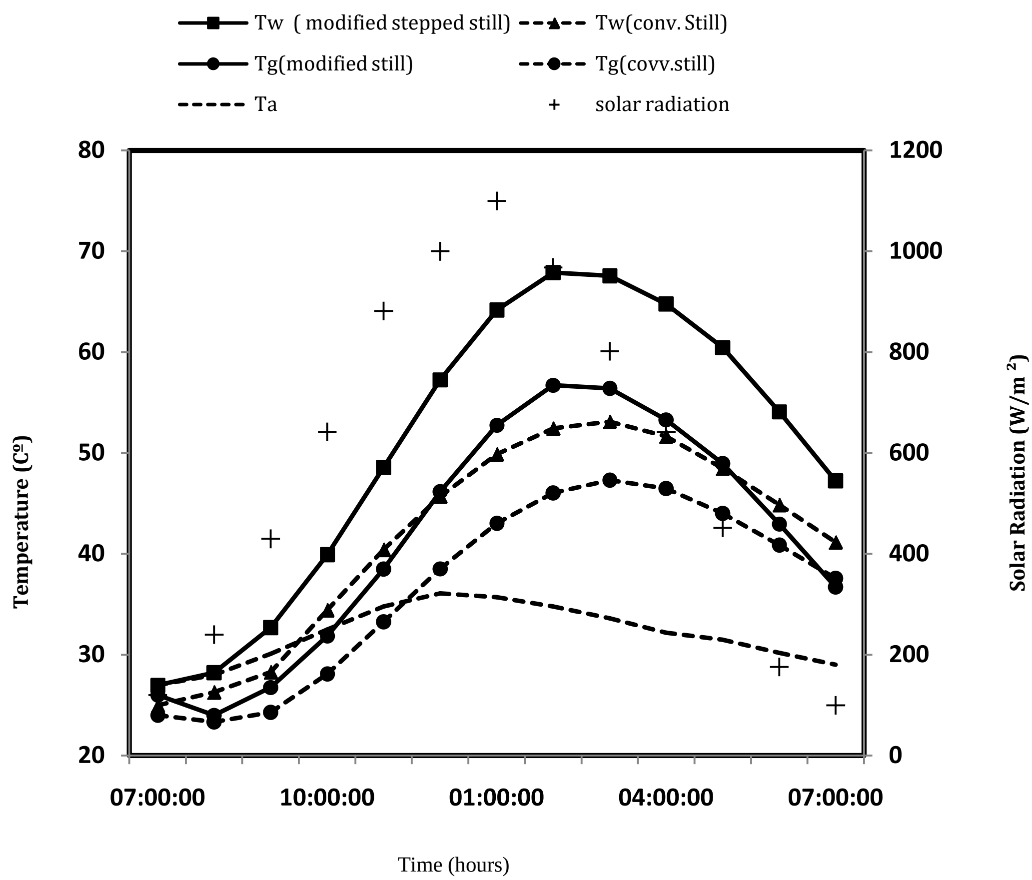

Figure 3: The hourly temperature variation and solar radiation for modified stepped solar still, stepped solar still without modification, and conventional solar still

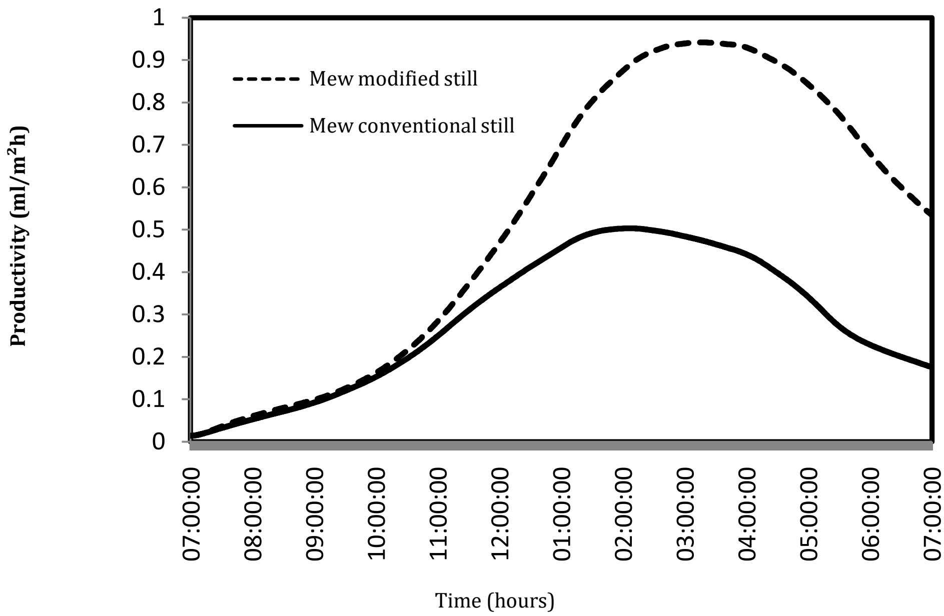

Figure 4: Presents comparisons between variations of hourly productivity of modified stepped solar still, stepped solar still without modification and conventional solar still

The hourly productivity is seen to increase dramatically during sunshine hours when the stepped solar still modified is used. The maximum values of hourly productivity of modified stepped solar still and conventional solar still are found to be 1.158 and 0.541 (kg/m^2h) respectively. Therefore, the corresponding daily productivities are obtained as 9.9 and 4.3 (kg/m^2 d) respectively. It is seen that the daily productivity of the modified stepped solar still is higher than that of conventional solar still by 103%.

IV. Conclusion

For augmenting the evaporation rate, a transient mathematical model was presented for a modified stepped solar still, and a conventional solar still which could maintain minimum depth in the basin. The performance of a modified stepped solar still was investigated and compared with a conventional solar still. The results show that the thermal performance of a modified stepped solar still can be considerably improved through the new modification the corresponding daily productivities are obtained as 9.9 and 4.3 (kg/m^2 d). The production rate of the modified stepped solar still is higher than that of conventional solar still by 103%.

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Performance of a Capstone Gas Turbine based Power Plant Working on High Butane LPG

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Abstract- In this paper there are presented the results of the operational performance of a 30 kW microturbine generator (MTGs) fed with high butane content liquefied petroleum gas, while subjected to a stand-alone test procedure involving steady and transient load conditions. Neither modifications, nor regulations were made to the micro-turbine system for operation on the liquefied petroleum gas. To evaluate the performance, measurements of turbine and generator parameters were gathered from its original unit controller, as load changes were applied by changing load-bank values. For the stand-alone mode detailed graphs of the test results are presented, showing the transparency and robustness of the turbine-generator set to the used fuel, judging by the quality of the output electric parameters. The results from this performance testing provide good insight into the use of high-butane content liquefied petroleum gas as fuel for the tested microturbine. The continuous use of a fuel would need more tests to establish that the life of the critical components of the microturbine are not hampered from what they are on the baseline fuel.

Keywords: gas turbine, high butane LPG, electrical generator, performance, power generation.

GJRE-A Classification: FOR Code: 091399p

PERFORMANCEOFACAPSTONEGASTURBINEBASEDPOWERPLANTWORKINGONHIGHBUTANELPG

Strictly as per the compliance and regulations of:

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Abstract- In this paper there are presented the results of the operational performance of a 30 kW microturbine generator (MTGs) fed with high butane content liquefied petroleum gas, while subjected to a stand-alone test procedure involving steady and transient load conditions. Neither modifications, nor regulations were made to the micro-turbine system for operation on the liquefied petroleum gas. To evaluate the performance, measurements of turbine and generator parameters were gathered from its original unit controller, as load changes were applied by changing load-bank values. For the stand-alone mode detailed graphs of the test results are presented, showing the transparency and robustness of the turbine-generator set to the used fuel, judging by the quality of the output electric parameters. The results from this performance testing provide good insight into the use of high-butane content liquefied petroleum gas as fuel for the tested microturbine. The continuous use of a fuel would need more tests to establish that the life of the critical components of the microturbine are not hampered from what they are on the baseline fuel.

The course of selected performance parameters in the microturbine generator fuelled with LPG is described in this document. The analysis of test results of the microturbine under steady-state and transient operation have been made. Both in steady state and transient conditions, values of output power, speed fluctuation, emissions, noise levels, and exhaust gas temperatures remained under acceptable levels.

Keywords: gas turbine, high butane LPG, electrical generator, performance, power generation.

I. Introducción

The need to respond in a safe, efficient and environmentally sustainable manner to the growing energy needs in the different sectors of the national economy, demands the rationalization, technical improvement and expansion of the sources of electricity supply. Responding to this demand, the Colombian Ministry of Mines and Energy, the Unit for the Mining-Energetic Planning (UPME), and the Energy and Gas Regulation Commission (CREG) lead a comprehensive policy that promotes, generates and stimulates programs and projects for the generation, saving and efficient use of energy and particularly for self-generation [1] [2] [4- 9].

The Colombian Government issued Decree 2143 of 2015 [9], through which tax incentives are regulated for the promotion, development and efficient use of energy. The micro-grids find their way, with sources of distributed generation, local storage, controlled loads, and the possibility of developing electrical islands. Colombia is promoting programs for distributed generation (DG) and will probably encourage more projects for self-generation in the commercial, residential and service sectors, emulating initiatives as that of the US Department of Energy, which promoted the Advanced Alternative Engine Systems program (ARES), designed to develop small micro-generators units of high efficiency [12]. If incentives are created for self-generation in commercial, residential and service sectors, the incorporation into the system of micro-generation units could be attractive, and the introduction of microturbine generators could be favored.

On the other hand, Colombia is currently exporting LPG, a part of which is obtained as a byproduct of natural gas purification in known fields as Cusiana. Some energy suppliers have had interest in exploring the performance behavior of power generators when they are run on high butane liquefied petroleum gas for electricity generation in oil fields. Considering the fact that to date, to the authors' knowledge, there has not been reported any experimental tests related to the performance of microturbine generator (MTG) sets fuelled with LPG from Cusiana, a 30 kW Capstone MTG fed with Cusiana LPG was tested, as a pilot experience, to judge about its power output, step response, power quality, and fuel consumption.

Microturbines are lightweight and compact in size combustion turbines with outputs of 30 kW to 400 kW that can be used for stationary energy generation applications at sites with space limitations for power production. They can be run on natural gas, biogas, propane, butane, diesel, and kerosene. Particularly, the Capstone MTG consists of a compressor, recuperator, combustor, turbine and permanent magnet generator; the air drawn through the inlet system refrigerates the generator, discarding the need of a liquid cooling system. Intake air is compressed and injected into the recuperator, a heat exchanger where it is heated by turbine exhaust. Fuel enters the system through an injection port and is mixed with the heated compressed air. The ignition system causes the air-fuel mixture to burn in the combustion chamber under constant pressure conditions; the resulting gases are allowed to expand through the turbine section to perform work, rotating the turbine blades to turn a generator, which produces electricity. The rotating components, which

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can reach 96,000 min^{-1}, are mounted on a single shaft supported by low-maintenance air bearings.

The MTG has been tested in stand-alone mode, as a power source that meets the current consumption demanded by the coupled load.

The general goals of the load test were:

- To get onsite experimental information related to the performance of the Capstone microturbine when fueled with Cusiana LPG.
- To measure the electric generation performance of the MTG under a load cycle, for the given open ambient conditions, with the available instrumentation, and the time allowed to perform the test, adjusting as far as possible to the rules of operation and tests of the MTG.
- To provide an appropriate stable medium for the reliable evaluation of electrical efficiency, and MTG performance.

The work here presented refers to the evaluation study, and is organized as follows: first, the properties of the LPG used are related, and a brief description of the Capstone micro-turbine is given. After that, this paper describes the experimental procedure and constraints. Next, the test program is described, followed by a summary of the results. Finally, the main conclusions of the work are presented.

II. Materials and Methods

a) *Particularities of the LPG from Cusiana*

The term LPG applies widely to any mixture of propane and butane, the two constituents occurring naturally in oil and gas reservoirs that are gaseous at normal atmospheric conditions but can be liquefied by pressure alone. Components heavier than butane are liquids at normal conditions and components lighter than propane cannot be liquefied without refrigeration. The presence of butane, pentane, and heptane at concentrations of up to 40% characterize this particular LPG from Cusiana, which analysis is presented in table 1.

Table 1: Composition and physical properties of Cusiana LPG (*)

Compositional Analysis of GLP to C12+			
SamplingLocation		ALSABANA	
CylinderNumber		CLM009	
SamplingConditions		30,0 psig @ 66.0°F	
Component		Mole %	Weight %
CO2	CarbonDioxide	0,01	0,01
N2	Nitrogen	0,10	0,06
C1	Methane	0,01	0,00
C2	Ethane	3,36	2,14
C3	Propane	71,45	66,84
iC4	i-Butane	13,13	16,20
nC4	n-Butane	11,91	14,70
iC5	i-Pentane	0,03	0,05
______		______	
Totals :		100,00	100,00
Note: 0,00 meanslessthan 0,005.			
Calculated Whole Gas Properties			
Gas Gravity	1,6272	(Air = 1 @ 14,73 psia& 60°F)	
WholeSample Mole Weight	47,13	g mol^{-1}	
Ideal Gas Density	1,9831	kg m^{-3} @ 14,65 psia, 60°F	
Ideal GrossCalorificValue	2665,7	BTU·ft^{-3} @ 14,65 psia, 60°F	
Ideal Net CalorificValue	2454,5	BTU·ft^{-3} @ 14,65 psia, 60°F	
PseudoCriticalPress.	598,7	psia	
PseudoCriticalTemp.	682,1	Rankine	
Gas Compressibility Factor, Z	0,979184	@ 14,65 psia& 60°F	
GPM (C2+)		28,49	
GPM (C3+)		27,60	
Additional Information			
Real GrossCalorificValue	2722,4	BTU·ft^{-3} @ 14,65psia, 60°F	
Real Net CalorificValue	2506,6	BTU·ft^{-3} @ 14,65psia, 60°F	

* *Results of the Chromatographic test performed by Equion.*

b) Capstone micro-turbine

Microturbines have advantages over modern internal combustion engines, such as their high-power density, less moving parts and comparatively low emissions. They can be fuelled by liquid and gaseous fuels - fossil or renewable. Microturbine capacities are generally between 30 to 350 kW. The Capstone 330 MTG, made available by the company Supernova Energy Services, installed in Alsabana was subjected to service setting works, as it was new. Photographs in figure 1 allow to illustrate the general view of the MTG located at the test site.

Figure 1: Location of the MTG at the Alsabana Campus test site

The Model 330 MTG is a compact low emission solid-state controlled power generator, based on a 30 kW Capstone micro-turbine. The latter is designed for 30 kW output, uses power electronics to convert the high-frequency output of the generator to three-phase 480 volts voltages, at 50-60 Hz current frequency. The high-frequency AC current of the generator is converted to the 50-60 Hz AC current, after being processed through an inverter and a DC converter. Table 2 lists the rated capabilities of each microturbine based on available literature.

Table 2: Technical performance data of the Capstone 330 microturbine for different fuels [7]*

Fuel type	GNC (55 psig)	GLP (55 psig)	Diesel (5 psig)
Mean time to repair	20,000 h	20,000 h	20,000 h
Nominal full power	30 kW net (+/- 1 kW)	30 kW net (+/- 1 kW)	29 kW net (+/- 1 kW)
Peak efficiency (LHV**)	27% (+/- 2%)	27% (+/- 2%)	26% (+/- 2%)
Fuel consumption***	18,7 lb/h, 8,5 kg/h	19,0 lb/h, 8,6 kg/h	21,9 lb/h, 10,0 kg/h
Methane based fuel flow (Metan-HHV)	440,000 kJ/h (420,000 Btu/h)		
Methane based energy of exhaust gases	305,000 kJ/h (290,000 Btu/hr)		
Exhaust gases temperature	500°F, 261°C	500°F, 261°C	500°F, 261°C
Output voltage	250-700 VDC	250-700 VDC	250-700 VDC

* *Source: Capstone Turbine Corporation*

Since Capstone Microturbines use lean premix combustion system to achieve low emissions levels at a full power range, they require operating at high air-fuel ratio; injectors control the air-fuel ratio. The MTG is instrumented to record operational parameters (of which, temperatures, pressures, fuel usage, turbine speed, internal voltages/currents, and status are of importance for the undertaken study). The average readings of two thermocouples indicates the Turbine Exit Temperature (TET); a compressor inlet thermistor is installed to measure the air temperature at the inlet of the compressor wheel; the air flow, Wair, (in pounds per hour) and the amount of energy needed in the combustion chamber required to regulate fuel flow in the combustion chamber, W_{energy} (in Btu/sec), are calculated based on engine speed. Such data are available with a computer or modem connected to an RS-232 port on the microturbine. A schematic drawing of the built-in instrumentation supported by the microturbine generator is presented in figure 2.

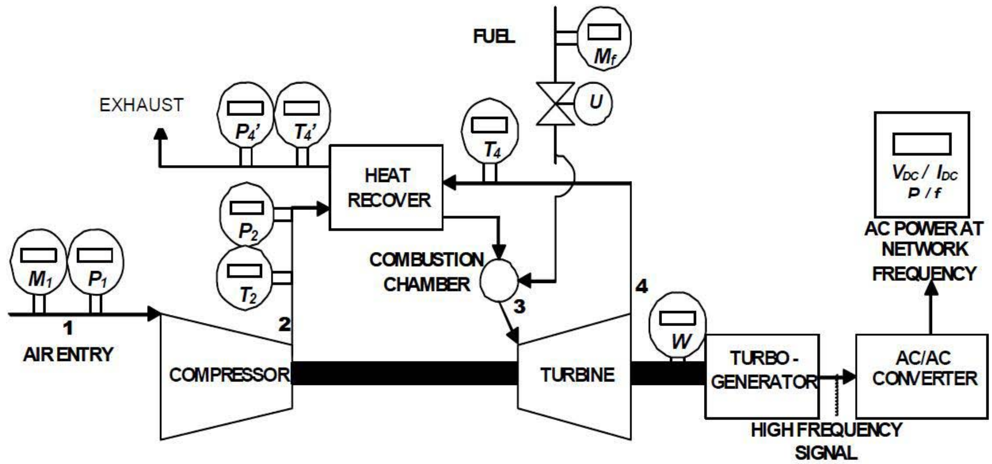

Figure 2: Schematic diagram of the instrumented power unit [3]

A large on-board battery pack is used to start the microturbine, and also to store energy when the microturbine decelerates to produce less power. To meet output power requirements automatically, the system can be configured in Auto Load mode. Auto Load ensures that the microturbine closes the output contactor to immediately produce the required output power once minimum engine load speed is reached. The output speed-power characteristic of the microturbine generator is reproduced in figure 3.

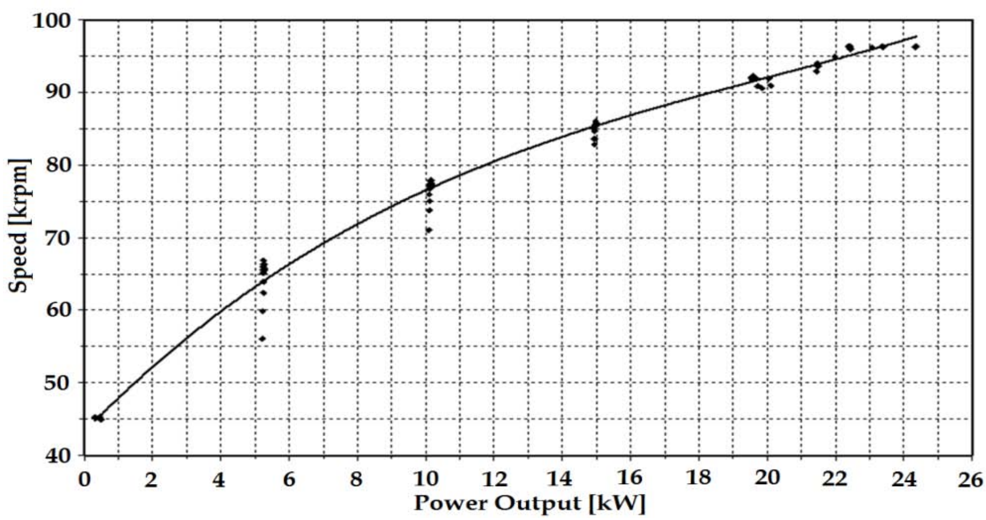

Figure 3: Microturbine speed at partial loads [3]

c) Experimental facility and procedures

LPG was supplied from an oil field to the test site by a tanker with a storage pressure ranged between 50 and 90 psia during the test; an intermediary damper tank was used to reduce pressure fluctuations due to consumption, and a bypass was used in the LPG supply line with its respective regulating valves before the entry of gaseous fuel to guarantee the pressure, as can be observed in the photographs of figure 4. The average ambient conditions at the time of the test were: temperature close to 14°C, 80,2% relative humidity, and 0,726 atmospheric pressure.

Figure 4: Tanker, lung tank and LPG supply bypass

The microturbine generator was connected to an Avtron 1000 kW capacity electrical resistance load bank, with a manual load setting; electric generation quality was measured with a FLUKE 434/PWR energy meter connected to the generator power output through clamp-on current transformers. This is a three-phase electrical power quality analyzer FLUKE 434/PWR with a measurement range Vrms (AC+DC) between 1-1000 V, and frequency range of 40-70 Hz. A schematic of the general layout of the test facility is shown in the figure 5.

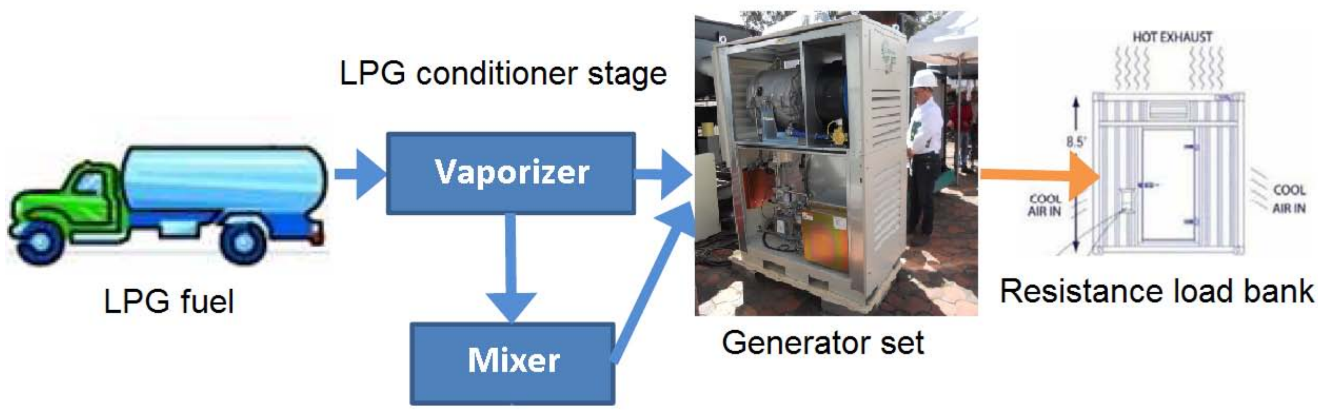

Figure 5: General layout of the test place

The procedure followed to assess electrical, thermal, and operational performance of the micro-turbine generator, comprised pretest activities, startup, idle, and a two-step load test during a short period of time. The software for the microturbine unit was configured for standalone operation through the local display panel; the turbine was started, controlled and monitored by a computer using Capstone's software.

The load test applied by the load bank, as it is shown in figure 6, consisted of a transient from idling to a 20-kW load at maximum speed of 96000 min^{-1}, a steady-state operation in this operation point for about eight minutes, followed by a drop to 3 kW power at 60000 min^{-1}, and a steady running at this load for about four minutes. In the last part of the test, the load was completed released and the microturbine was sustained idling at a speed of 45000 min^{-1}, as it is shown in figure 6. During the test, all available parameters were monitored and recorded from the MTG system. All electrical parameters (both single-phase and three-phase) were recorded at the load bank by the energy meter.

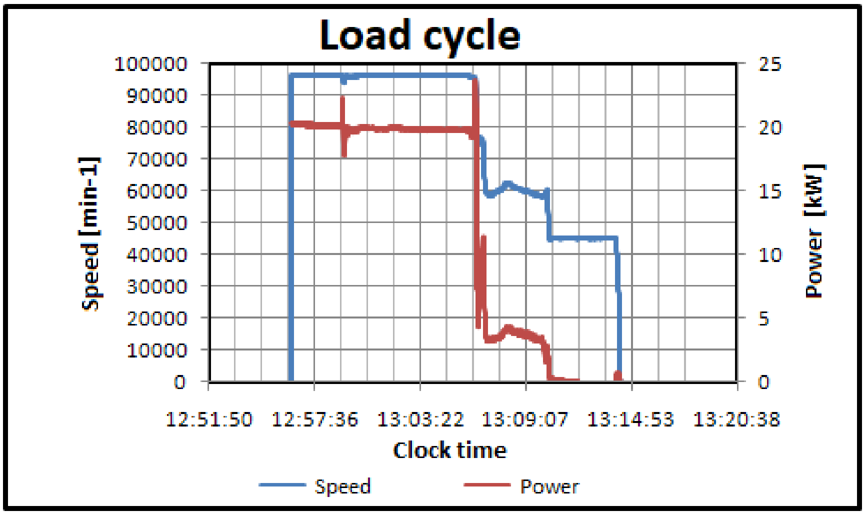

Figure 6: Load cycle followed for the MTG testing

III. Results during the Test Program

The study focused on the overall performance parameters related to engine operation. In the following, the results of the collected data during the operation cycle, and the response of the turbine-generator to load changes are presented. Initially, the results obtained from the proprietary MTG controller are presented: inlet to compressor and turbine exhaust gas temperatures, air flow, intake air temperature and pressure values. Once the behavior variables are described, the evolution graphs of the electrical power, voltage, and current delivered by the MTG are illustrated. The information thus presented allows to evaluate the behavior of the MTG operating with LPG, from the perspective of stable operating capacity and within the mechanical, thermal, environmental limits.

a) *Mean-variable measurement results*

The microturbine generator has presented a normal behavior during the test, judging by the values of the speed, power, inlet to the turbine and compressor temperatures, load percentage, among the operating parameters registered by the proprietary controller of the microturbine; a summary of those performance parameters is presented in table 3.

Table 7: MTG operating parameters registered during the test period

Tiempo [min:s]	Speed [min^{-1}]	Power [W]	TET [F]	TEC [F]	Wair [pph]	Amb. pressure [psia]	Suplied energy W_{energy} (btu/s)	Accel. [%]	Frequency [Hz]
00:0	96320	20277	1102,2	69,9	1694	10,7	46,6	60,8	60
00:01	96236	20369	1101,2	69,9	1695	10,7	47,2	60,3	60
02:49	94028	18104	1109,8	72	1614	10,6	41	57,1	60
10:00	91236	23675	1110,1	74,4	1532	10,6	42,3	58,5	60
10:01	86408	21181	1129,9	74,4	1394	10,6	35	53	60
10:02	81252	17794	1144,6	74,4	1265	10,6	32,4	49,4	60
10:03	76490	14693	1164,9	74,4	1138	10,6	29,1	80,9	60
10:04	73480	9882	1203,5	74,2	1057	10,6	22,5	42,4	60
10:43	58912	3206	1259,8	75,9	737	10,7	12,8	35,7	60
10:45	58678	3432	1258,4	76	728	10,7	14	36,7	60
13:51	59852	1629	1126,8	80,4	772	10,7	46,6	100	60
13:55	54208	2411	1097,5	80,4	667	10,7	0	0	60
13:56	52114	2144	1095,2	80,2	630	10,7	0	0	60
13:57	50106	1885	1094,5	80,2	594	10,7	0	0	60
14:36	44950	120	1029,2	78,8	518	10,6	0	0	60

14:37	45272	141	1026,9	78,8	523	10,6	0	0	60
14:45	45116	115	1008,4	78,6	522	10,6	0	0	60
14:46	45282	92	1007,2	78,6	524	10,6	0	0	60
15:06	44996	32	968,5	78,5	527	10,6	0	0	60
15:08	45032	23	964	78,5	530	10,6	0	0	60
15:15	45088	10	954,1	78,5	531	10,6	0	0	60
15:16	45124	-4	951,2	78,5	529	10,6	0	0	60
17:11	45310	-204	781,6	79,6	537	10,7	0	0	60
17:38	45024	-287	752,1	80,2	530	10,7	0	0	60
17:39	43280	463	751,4	80,2	501	10,7	0	0	60
17:43	35292	393	754,6	80,2	376	10,7	0	0	60
17:44	33390	749	758,9	80,2	349	10,7	0	0	60
17:45	31302	773	761,9	80,2	320	10,7	0	0	60
17:46	29324	701	762,8	80,2	293	10,7	0	0	60
17:48	25296	584	767	80,4	241	10,7	0	0	60
17:49	23254	506	769,6	80,4	216	10,7	0	0	60
17:50	0	0	785,1	79,9	0	10,7	0	0	60
18:50	0	0	818,6	104	0	10,6	0	0	0

* *W_{energy} stands for measurement of the amount of energy needed in the combustion chamber required to regulate fuel flow, value displayed in Btu/second.*

The general behavior of the MTG during the test, as a function of time, is presented in figure 7, where the history of output power, rotation speed, inlet to compressor and exit turbine temperatures, input amount of energy, and air flow is plotted. Analysis of the graphs shows that the Capstone microturbine responds to load changes rapidly, yet during steps up and down in the MTG real power output, turbine speed follows ramps up and down smoothly to the new operating point. When the load bank resistance is reduced, turbine shaft speed drops smoothly to its new operating point.

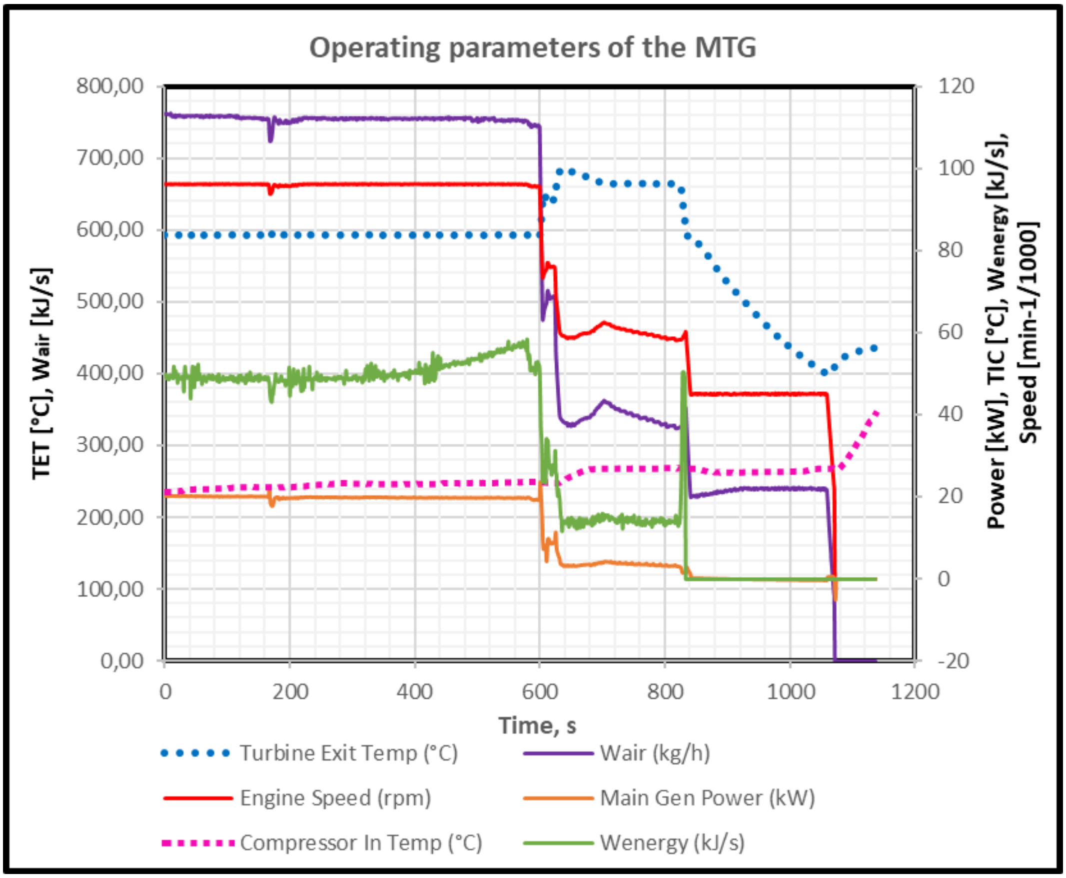

Figure 7: MTG operating parameters as a function of time during test

Microturbine output reacts without sensible delay to the changes in the bank load. The ramp-up rate is observed to be about 8 seconds for 0 to 20 kW. The ramp down rate is about 6 seconds for 20 to 3 kW. As for the fuel energy consumed, it is seen the fluctuation, associated to the mass flow rate adjustments, according to the control dynamics of the fuel valve and to the changes in fuel LHV and density. The variable speed control of the MTG relies on a system that sense load and optimize speed.

Considering the heat value given by the chromatographic analysis of the LPG, the energy flows are converted to fuel flows, which allows to approximate also the air/fuel ratio. The variation of these magnitudes is shown in the figure 8.

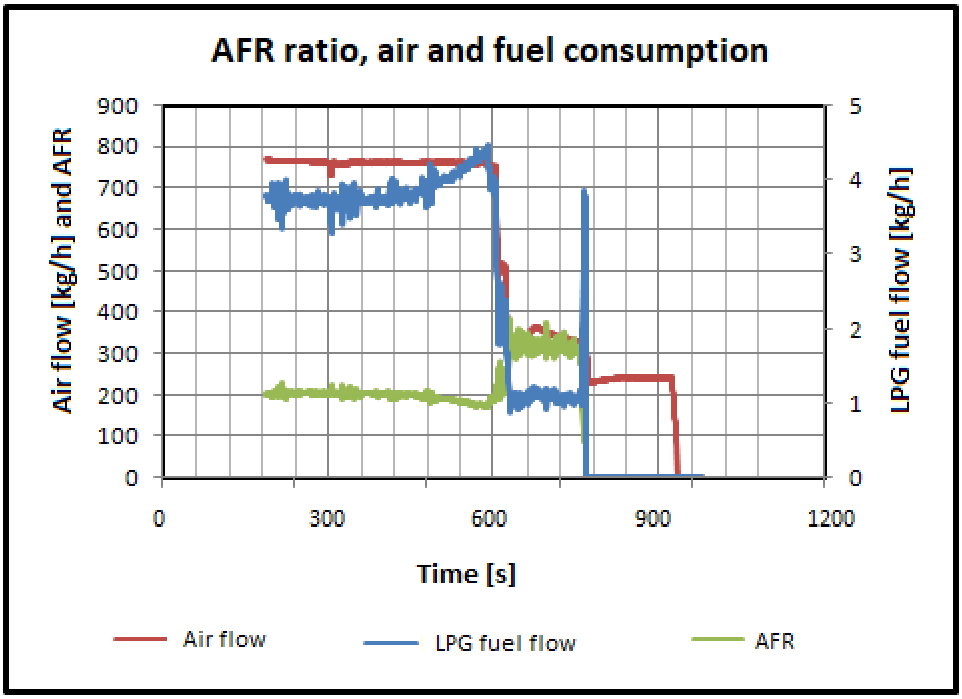

Figure 8: MTG air and fuel consumption, and calculated air/fuel ratio as a function of time during test

An estimate of the MTG efficiency is made by relating the power made by the engine generator and the equivalent energy content of the fuel, as is shown in figure 9.

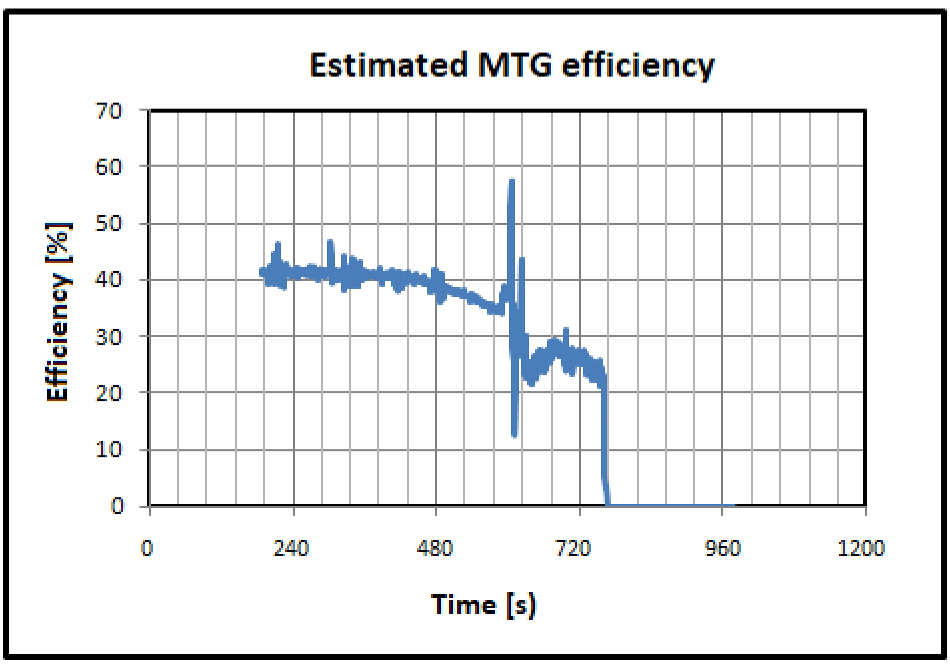

Figure 9: MTG efficiency calculated with the information logged by the controller

Microturbine generator exhibits the variation of rotational speed versus power output described in figure 10 by the experimental values and the adjusted trend line.

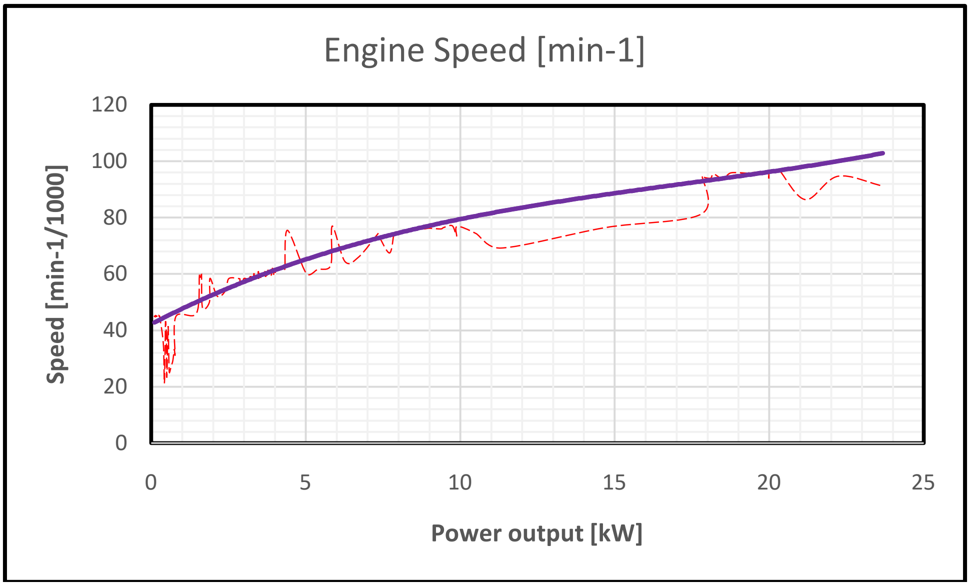

Figure 10: MTG rotational speed as a function of power output

IV. Results of the Electrical Energy Generated

The quality of the energy generated could be influenced by the quality of combustion process of the fuel. MTG with the Capstone microturbine meets the specifications demanded for class G1 generators, in terms of frequency and voltage deviations during transient processes. Observation of the voltage at the load banks during the test showed a small sensitivity to load level. There is little change in the balance of the three-phase voltages. There is no discernable pattern to the changes in the bus voltage; all three phases respond equally to the load changes.

V. Conclusions

Microturbine pilot test was carried out to determine performance characteristics, and to assess the possible inconveniences of using the particular high-butane-content LPG. To achieve the technical goals, it was considered a short test based on a two-step sequence of loads. The main conclusion drawn from the study is that, under the scope of this study, the output of the turbine generator was satisfactory, showing its adaptability to the change in fuel. The limited amount of testing done here restricts the applicability of these conclusions to the specific type of LPG used. Cold and warm starts performed well. The estimated efficiency of power generation appeared to be unchanged, as compared to the values indicated by the manufacturers.

It can be stated that, based on the short test carried out, gas turbines are an advantageous alternative to the use of reciprocating engines, due to their adaptability to the fuel, their low noise and vibration levels, their compact structure and their efficiency close to that of the diesel engine. The tests showed a higher-than-expected performance and it is about to find out with the supplier how close this value is, since in the literature itself a performance of more than 30% is not expected, while the conducted test showed an efficiency close to 40% for 66% of the load. It is yet to be proven.

Gas turbines are an excellent alternative and their technology is very mature for generation and cogeneration standalone applications; in the commercial and industrial sectors, microgrid power parks, remote off-grid locations, presenting only the defect of greater starting time (close to 2 minutes, value obtained from the literature).

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An Analysis of Aerodynamic Design Issues of Box Wing Aircraft

By Paul Olugbeji Jemitola & Paulinus Peter Okonkwo

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Keywords: box-wing, biplane, lift distribution, best wing system, aerodynamic efficiency, downwash.

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An Analysis of Aerodynamic Design Issues of Box Wing Aircraft

Paul Olugbeji Jemitola [α] & Paulinus Peter Okonkwo [σ]

Abstract- The potentials of the Joined/Box-Wing Aircraft as an environmentally friendly airliner that is capable of meeting current and future emission thresholds led to the investigation of this concept. This study reviews the evolution and current trends in the aerodynamics design of the Box-Wing aircraft with specific emphasis on Box-Wing theory, airfoil characteristics and aerodynamic issues of the Box-wing aircraft. The study was undertaken to highlight the distinct features of the Box-Wing configuration which makes it very attractive as a future airliner. The study reveals that the Box Wing Aircraft possesses a significant aerodynamic advantage over conventional aircraft. The Box-Wing Aircraft configuration is also a less radical departure from the conventional concept. It thus could be developed with existing tried and tested aircraft design technologies, methodologies and processes.

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I. Introduction

The need to reduce the negative impact of airline operations on the environment led to renewed interests in unconventional designs such as the Blended Wing Body and Joined/Box-wing concepts. The Joined/Box-wing aircraft configuration attracted the attention of researchers due to its claimed merits of reduced structural weight and low induced drag (1). The potentials for improved fuel efficiency and reduced direct operating costs were other reasons that motivated researchers to investigate the aerodynamic concepts of the Box-Wing configuration. Though the Blended Wing concept claims to have some of the preceding advantages, the Joined/Box-Wing aircraft configuration offers lower design risk than the Blended Wing Body concept because it is not a completely radical departure from conventional aircraft configuration. These considerations influenced the National Aeronautics and Space Administration to award a contract to Lockheed Martin to investigate the Box-Wing aircraft configuration. The Contract required Lockheed Martin to examine the Box Wing claims of being able to reduce fuel burn by 40%, nitrous oxide emissions by 75% and minimize noise by 42Db (2).

Wolkovitch (1) carried out extensive research on the Box-Wing aircraft configuration following Munk's (2) and Prandtl's (3) earlier work. Wolkovitch (1) viewed the Joined/Box-Wing aircraft configuration as a highly integrated concept that connects structural and aerodynamic properties in novel ways. This paper discusses the aerodynamic design issues of the Box-Wing aircraft with emphasis on the Box-Wing theory, aerofoil issues, aerodynamic considerations and optimization.

It is essential to state that even though the terms Joined Wing and Box-Wing are used interchangeably in literature, the two concepts are not necessarily the same as could be seen from Figures 1 and 2. In Box-Wing aircraft, both wings form a closed non-planar design, produce equal amounts of lift, whereas for the classical Joined Wing aircraft, the fore wing produces approximately 80% of the total lift. This paper focuses on the novel aircraft concept that has fins

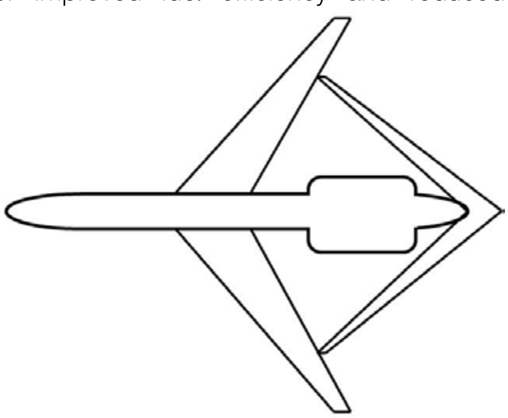

Figure 1: A Sketch of the Joined Wing Aircraft

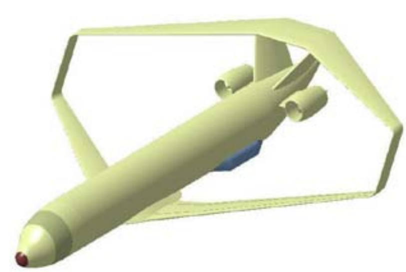

Figure 2: A Sketch of the Box Wing Aircraft

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linking the tips of the fore and aft wings together in what is appropriately called a Box-Wing aircraft.

II. Box Wing Theory

Prandtl's (3) *'Best Wing System'* states that a closed rectangular lifting system produces the least possible induced drag for a given span and height. In making this assertion, Prandtl (3) established that all biplanes have less induced drag than their equivalent monoplane with equal spans. The study further highlighted that biplane drag decreases as the wing gap increases (4). Accordingly, Prandtl (4) posits that the ideal arrangement for minimum induced drag is a closed biplane with equal lift distribution and total lift on each wing. In this arrangement, the top of the end-plates is exposed to outward pressure while the bottom parts experience inward pressure. Figure 3 shows a front view schematic of 2 lifting surfaces with equal spans joined at the tips thus positioning the ideal pressure distribution on the endplates. As the gap between the wings increases, trailing edge vortices are reduced, thus lowering induced drag (5). The lower induced drag makes the Box Wing configuration an attractive proposition for reducing the environmental impact of aviation. This is because induced drag accounts for a significant portion of the total drag count of a commercial flight. Hence, reduced induced drag lowers fuel burn and minimizes pollutants emission leading to reduced environmental impact.

Figure 4 depicts the effect of wing gaps on induced drag of a biplane as provided by Prandtl (3). In the plot, the horizontal axis represents the wing gaps while the vertical axis represents the induced drag. The Plot illustrates the inverse proportional relationship between the induced drag and wing-gap. This implies that the lower the wing gap, the higher the reduction in induced drag. For example, for a wing-gap/span (h/b) of 0.25, the induced drag is about 71% of an equivalent monoplane with the same aspect ratio while a wing gap/span (h/b) of 0.15 gives an induced drag reduction of almost 80% (78%). Consequently, a closed biplane arrangement produces the greatest reduction in induced drag. However, this aerodynamic benefit is relative as there is an attendant increase in wing mass increase and practicability of the design.

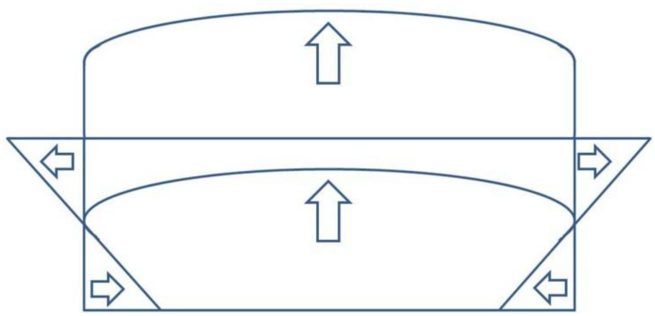

Figure 3: Lift Distribution on a Biplane

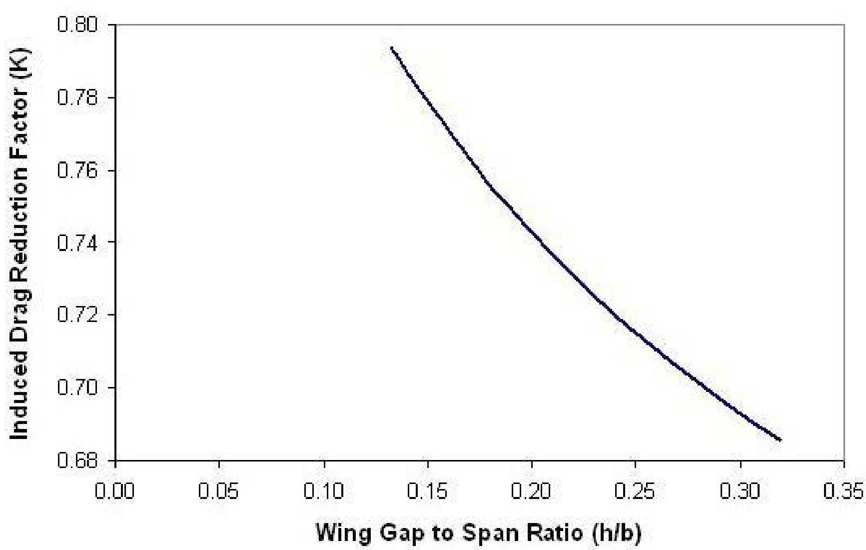

Figure 4: Effect of Wing Gap on Induced Drag Reduction

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Using Munk's (3) Equivalence Theorem, Prandtl's Theory can be extended to a staggered wing arrangement. Munk's Equivalence Theorem states that 'given a constant lift distribution, the total induced drag of any multiplane system is unaltered if any of the lifting elements is moved in the direction of motion. However, by staggering the wings, the induced flow between the wings changes. The forward wing experiences an upwash while the aft wing is subjected to a downwash. This results in the decrease of the lift-curve slope of the aft wing relative to the fore wing when the airfoil sections and angles of attack (assuming no fuselage is present) are equal (5). Consequently, one of the major challenges of developing the Box-Wing aircraft is the difficulty in optimizing the design to obtain equal lifts on the wings.

Combining the Prandtl Best Wing System and the Munk Equivalence Theorem, Frediani (5) posits that Prandtl's (4) *'Best Wing System',* if applied to conventional aircraft configuration, could reduce induced drag by up to 20-30% based on a h/b ratio of 10-15%. Frediani (5) further established that for a Box-Wing or 'Prandtl Plane', the aerodynamic efficiency obtained is strongly linked to the ease of creating a stable aircraft with equal lift distribution on the wings. Additionally, Frediani (5) determined that induced drag accounts for approximately 43% of the total aircraft drag during cruise flight in still air. Thus, a decrease in induced drag provides design benefits such as reduced aircraft weight and thrust requirements. This would ultimately minimize the negative impact on the environment. These findings led to widespread interest in the Box Wing Aircraft.

III. Airfoil Issues

According to Wolkovitch (1), airfoils used in the vicinity of Box-Wing aircraft inter-wing joints must consider the induced flow curvature. Consequently, the use of natural laminar flow airfoils was recommended (1). Subsequently, Addoms (4) corroborated this finding by proposing that biplane configurations must employ airfoils with remarkably different camber than those of a monoplane. This is because using monoplane airfoils on biplanes induces premature separation, leading to a low maximum lift coefficient. Wolkovitch (1) thus advocates for the design of tailor-made airfoils by exploiting the advanced state of current airfoil design technology.

In a similar vein, Wolkovitch (1) revealed that because the effective depth of a beam, d, of a Joined/Box-Wing is primarily determined by the chord of its airfoils, as sketched in Figure 5, their thickness is a significantly less important consideration. This finding justified the adoption of thin airfoils for Joined/Box-Wings aircraft design. Wolkovitch (1) thus concluded that twin fins of approximately 60 degrees dihedral reduce the unsupported column length of the aft wing, thereby decreasing drag and structural weight. Frediani (5) corroborated Wolkovitch views on the use of twin fins for Joined/Box-Wing aircraft when he disclosed that the aerodynamic channel created by the top of the rear fuselage, aft wing under-surface and the twin tail enhance the aerodynamic efficiency of the concept. These discoveries influenced Bernardini and Frediani (5) to design a Joined/Box-Wing configuration to harness the aerodynamic benefits of Frediani's (5) aft-wing/twin fin design.

IV. Aerodynamic Concepts and Considerations

Bagwill and Selberg (7) advanced that positively staggered Joined-Wing aircraft are more aerodynamically efficient than negatively staggered joined wings. Positive stagger refers to an arrangement where the higher wing is placed in front of a lower aft wing, while negatively staggering refers to the reverse configuration. Mamla and Galinski (8) agree with Bagwill and Selberg (7) on the superior aerodynamic efficiency of positively staggered joined wing aircraft over negative stagger. However, Smith and Jemitola (8) highlighted the beneficial influence of a maximized vertical separation between the fore and aft-wings on a negatively staggered joined wing arrangement. For a medium-range airliner, Smith and Jemitola's (8) study showed that the negatively staggered arrangement benefits from the use of the tail fin to maximize the wing's vertical separation. In contrast, positively staggered arrangement provides comparable aerodynamic benefit but with significant mass penalties and directional stability issues.

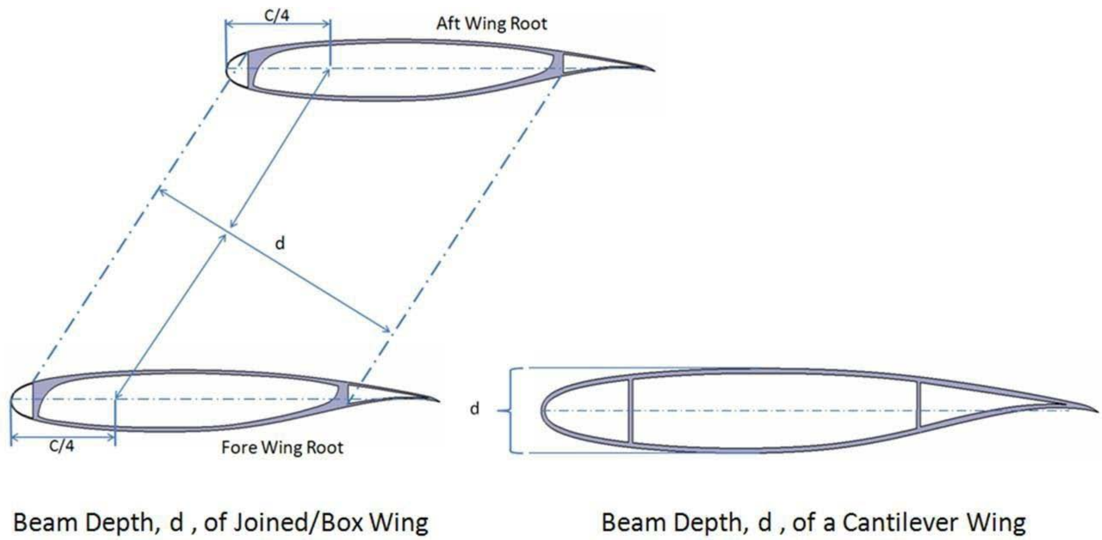

Figure 5: Effective Wing Depth, d

Schikantz and Scholz (8) undertook a study that examined the conflicting requirements of obtaining aerodynamic efficiency and static longitudinal stability for the Box Wing aircraft. They stated that to ensure the stability of their model, the fore wing lift coefficient was increased thereby increasing the ratio of the fore and aft wing lift coefficients. Furthermore, the centres of gravity of the airframe, engines, fuel and, payloads were carefully manipulated so they are located at approximately the same position. In a related study, Demasi (9) investigated the conditions for a minimum induced drag of closed wing systems and c-wings using the Lifting Line Theory and Small Perturbation Acceleration Potential. Applying numerical and analytical solution methods, Demasi (9) established that closed-wing systems (like biplanes) have practically the same induced drag as c-wings. This result is similar to what Kroo (12) obtained in his investigation of non-planar wing concepts.

Burkhalter et al. (13) investigated the downwash effects for Joined-Wing aircraft using experimental and theoretical aerodynamic approaches. The study revealed that there is only a 12% difference between the experimental and the semi-empirical methods. This suggests that there will be no need to develop new methodologies for designing the Box-Wing Aircraft. This is because existing design and analysis methods have proven that they could be used without loss of accuracy.

Corneille's (11) conducted a wind-tunnel experiment to compare the aerodynamic performance of a Joined-Wing and Conventional Aircraft. The study finds that the Joined-Wing configuration is aerodynamically superior to conventional cantilever wing aircraft. This finding agrees with the results from previous studies by Wolkovitch (1), Prandtl (4), and Frediani (5). However, just like those studies, Corneille's (11) focused only on the aerodynamic performance of the Box-Wing Aircraft over Conventional Aircraft and neglected other disciplines. Since aircraft is a complex mix of multiple disciplines including aerodynamics, structures, and stability and control; there is the need to investigate the combined effect of some of these disciplines on a configuration to arrive at a holistic conclusion. Consequently, Jansen et al. (12) performed a single-discipline aerodynamic optimization and multidisciplinary aero-structural optimization of non-planar lifting surfaces. For the aero-optimization, both the Box-Wing and Joined-Wing aircraft were optimal. However, when aero-structural optimization was performed, only the conventional configuration with a winglet was optimal. Jansen et al. (12) Study highlights the difficulty in developing a Joined Wing Aircraft with optimal multidisciplinary characteristics.

Nangia and Palmer (16) analyzed the effects of forward-swept outboard wings on a Joined/Box-Wing aircraft. They observed that a forward-swept outboard wing produces favourable lift distribution on the forward and aft wing through a forward placement of the Centre of Pressure. Yechout et al. (18) embarked on an aerodynamic evaluation and optimization of a joined wing concept model aircraft. They used general engineering rules of thumb and a University of Missouri biplane design to optimize the performance of Joined Wings aircraft. The authors varied the negative decalage angle and the taper ratio to less than one. Additionally, they increased gap, decreased the wing sweep and decreased the stagger. Yechout et al. (18) Study concludes that a wing gap of 4.75 inches and a decalage angle of -1.5 degrees will create optimal configuration for higher lift coefficients and a shallower drag polar. However, it was observed that Joined-Wing configurations create negligible performance advantage over a monoplane.

Khalid and Golson (18) undertook an aerodynamic analysis of a Box-Wing configuration for an unmanned aircraft system using computational fluid dynamics. Khalid and Golson (18) varied the winglet height to wing span ratio parameter from 5% to 25%. The Study finds that a 15% winglet to wingspan ratio gave the highest lift to drag ratio while a taper ratio of 0.4 provided the highest lift to drag ratio. Khalid and Kumar (19), however find that varying the airfoil, winglet height and aspect ratio resulted in a significant increase in lift to drag ratio relative to the baseline design. Specifically, the model with a 30% winglet to wing span ratio generated the highest increase in aerodynamic efficiency, equivalent to 15% increase in lift to drag ratio, when compared to a cantilever model.

Barcala et al. (20) studied the aerodynamics of an unmanned aircraft system of Box-Wing configuration at low Reynolds numbers through a wind tunnel experiment. By varying the positions of the wings along the fuselage and the sweepback angles of the wings, significant differences in aerodynamic efficiency were found. This result indicates that the relative positions of the wings affect the aerodynamic efficiency of the Box-Wing configuration (21). Another observation from this Study is the late separation of flow on the fore-wing at high angles of attack as the angle of attack is increased (21). Nonetheless, the flow separates at a higher angle of attack on the rear-wing relative to the fore wing as highlighted in Frediani's (5) work.

Gagnon and Zingg (22) undertook a study to minimize the drag of a Box-Wing aircraft configuration using high-fidelity aerodynamic optimization. The study finds that Box-Wing aircraft with a tip fin height-to-wing span ratio of about 0.2 creates up to 43% less induced drag than its conventional counterpart. This aerodynamic benefit was derived from the inherent characteristics *'of Box Wing Aircraft to redistribute its optimal lift distribution with almost no performance degradation' (22)*.

Balaji et al (23) explored different aerodynamic issues in the design of the Box-Wing aircraft using a wind tunnel. Experimental results revealed a decrease in drag due to *'the overall reduction in the downwash of the complete system' (23)*. In addition, the study established that adding an endplate to a lifting system further reduces the downwash thereby increasing the effective span and thus the aerodynamic efficiency of the Box-Wing aircraft (23).

Bagwill and Selberg (24) investigated twist and cant angles of the tip fins of Box-Wing aircraft. The results from the study conformed to Wolkovitch's (1) findings. These studies suggest that careful selection of twist and cant angles of a Box Wing aircraft, at higher aspect ratio, provides a greater increase in the lift to drag ratio compared to a conventional cantilever wing aircraft (24) This discovery was corroborated by Nangia et al. (25) in a study to investigate the effect of high aspect ratio on Joined-Wing aircraft. Nangia et al. (25) find that Joined/Box-Wing aircraft generate lower induced drag as well as higher wing stiffness compared to conventional cantilever aircraft.

In terms of stalling characteristics, Bell (26) study revealed that the rear wing of a Joined-Wing aircraft induces an upwash on the forward wing which then initiates a downwash on the rear wing. According to Bell (26), the higher angle of attack on the fore-wing of a Joined/Box-Wing aircraft ensures that it stalls before the rear wing. This prevents deep stall thereby improving stalling characteristics of the Box-Wing Aircraft. Accordingly, the Joined/Box-Wing configuration exhibits safer stall characteristics than a conventional aircraft.

V. Effect of Optimization on Aerodynamic Characteristics of Joined/Box Wing Aircraft

Gallman et al (27) performed a synthesis and optimization for a medium-range Joined-Wing transport aircraft. They developed a program to model joined-wing transport aircraft and measured their overall performance in terms of direct operating cost. The program predicted the aerodynamic interaction between the lifting surfaces and the stresses in the statically indeterminate structure. Aerodynamic forces were determined using a vortex lattice model of the complete aircraft in a LinAir program. Viscosity and compressibility were then added to compute compressibility drag while inextensible theory was used to simulate fully stressed lifting surface structures. The Study revealed that Joined/Box-wing aircraft is deficient in field performance owing to a low maximum lift capability.

Gallman et al (27) showed that Joined Wing aircraft is cheaper to operate than an equivalent conventional transport. Additionally, they opined that an in-depth study of wing sweep, flap span, and elevator span provides further gains in the aerodynamic performance of a Joined-Wing performance aircraft. Gallman et al. (27) posit that any design changes that reduce the tail sweep angle would likely improve the performance of a Joined Wing Aircraft. They identified take-off field length and horizontal-tail buckling as the critical design constraints for Joined/Box-Wing aircraft. Gallman et al. (27) attributes the significant increase in direct operating cost of Joined/Box-Wing aircraft to the poor field performance characteristics of the configuration. The Box Wing aircraft exhibits poor field performance characteristics due to its limited capacity to generate maximum lift in take-off mode.

VI. Conclusion

The investigation of aerodynamic design issues of the Joined/Box-Wing aircraft highlights the aerodynamic efficiency of the concept and the complex interactions of several disciplines within the configuration. The Joined/Box-Wing aircraft shows improved aerodynamic efficiency compared to a conventional cantilever wing aircraft due to lower induced drag. However, it suffers from poor field performance and greater complications in structural design. Additionally, this study revealed that while the Box-Wing Aircraft offers improved aerodynamic advantage over conventional cantilever aircraft concept, it is quite challenging to obtain optimal multidisciplinary performance improvement on the Box Wing Aircraft. Notwithstanding, the less radical departure of the concept from conventional configuration enables the use of existing analysis tools for the design of the Box Wing. This makes the Box-Wing Aircraft concept an attractive prospect for aircraft designers in the quest to reduce the environmental impact of aviation.

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Construction of Concrete Wall with Resistance to Explosions- A View

By Shaik Himam Saheb, Chandrashekhar & B. Sri Maniteja Goud
The ICFAI Foundation for Higher Education

Abstract- The research was to give the people a great protect against the explosions by using Fiber – reinforced concrete. The Fiber – reinforced concrete is very difficult to be used in the actual Construction as the Fiber can't be mixed up with the ready mixed concrete system. The Fiber has a high resistance against the blasts and also needed a huge load of fiber. The required amount of fiber can result in reduced in practicable and lacking quantity of fiber. It's been very tough to put fiber – reinforced concrete on site Placing with ready mixed concrete system plant for mixing and placing. Thus, it has analysed properties of Steel and polymeric fiber to increase practicable and shaking in mixer. The beginning experimental test mixing fiber reinforced concrete has been tested in the actual field Construction of chemical plant. As the result from the test, it is expected to present to the combined fiber for required mechanical performance with unfavourable effect on practicable of the Mixture.

Keywords: fiber reinforcement concrete, blast, steel.

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CONSTRUCTIONOFCONCRETEWALLWITHRESISTANCETOEXPLOSIONS-AVIEW

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Construction of Concrete Wall with Resistance to Explosions- A View

Shaik Himam Saheb [α], Chandrashekhar [σ] & B. Sri Maniteja Goud [ρ]

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I. Introduction

Against Explosions and any other shock waves the structure should have a capacity of protecting people. In some facilities like plants there are a lot of people working in the area where the usage of an explosive gas is used should be defend against blasts. To maintain the protection against these actions the wall should be constructed much thicken enough with normal strength- ranged reinforced concrete. The lateral stress caused by blasts and earthquake Fiber Reinforced concrete (FRC) which is a solution know for its high energy absorption capacity and high tensile strength. The difference between concrete and Fiber Reinforcement concrete (FRC) has high tensile strength and toughness. In FRC the fiber is the main substance to improve the properties of Material.

On the opposite addition of fiber in concrete mixer causes decrease workability and increase viscosity and Yield Stress, due to poor yield strength FRC with high fiber content has described as a fiber ball effect while the mixing process and negative reinforced concrete performance. Therefore, as to achieve the maximum mechanical performance without Practicable issue, Slurry Fiber Concrete was introduced. For FRC the fiber content should be equally fair between mechanical properties and workability.

The reinforcing fibers for improving the cement Material properties have different roles or performance depending on their condition length to diameter ratio, materials or different shapes. The materials, reinforced fiber can be classified into metallic and polymeric fibers. The Metallic fiber mainly used in steel fiber increases the toughness of the Mixture. The Metallic fiber includes a high elastic modulus and high tensile strength i.e., it gives an increasing tensile strength and elastic modulus while it is taken out from the cement mixer. As the Metallic fiber has high tensile strength than cement cast, the failure practice of fiber is pulling out of the fibers, so there are different types geometrics of the Metallic fibers such as hooks, bents and different cross sections. In other way, Polymeric fibers like polypropylene, polyethylene, nylon fibers etc., Comparatively have less tensile strength and elastic modulus than metallic fiber. So, the polymeric fiber can't advance the mechanical properties of the Mixture as compared to the Metallic fiber. Because of the good cement mechanical properties in fresh state, it has higher chance of increasing mechanical properties of mixture. Specifically, polymeric fiber has high length to diameter ratio with in diameter, and because of the flexibility of the shape it doesn't decrease the Practicability of the Mixture than metallic fiber. The combination of different types of attain synthetic effect which are known as Hybrid fiber or cocktailed fiber. Substances like Banthia et al and Markovic et al give a resulted much better in mechanical properties of FRC with two fibers with different materials and Peng et al resulted two different polymeric fibers with different length to diameter ratios and melting point for much better work of reducing spalling damage of high-performance concrete mixture. This has made us to see the improvement of the of the wanted properties of FRC with combined fibers or hybrid fibers with low fiber content to achieve the much better Workability. Therefore, mixing of different kinds of fibers has used as a solution of low workability by low fiber content with equivalent performance.

However, many research has Reported combination of fiber for increasing the Mechanical properties. More importantly the issue of securing the quality of fiber diffusion and relatively decreased Workability, it's has been made harder to use FRC on field using ready mixed concrete system which includes

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plant mixing, causes trouble in truck delivery and placing along the pump. The goal is to provide a protectable concrete against Explosions and Blasts, which is obtained the required act and agreeable practicable by combining the Fibers. Therefore, it is decided to place in both fresh concrete placing and in the protection of broken things. This experiment was conducted in field for a Real Plan Construction. The result of the research is to make a high performance fiber reinforced concrete properties which has an agreeable protecting performance and workability.

II. Literature Review

The types of methods available in prediction of Blast Effect on Structural Building are: - Empirical Methods, Semi Empirical Methods and Numerical Method. Empirical Method are basically parallel with experimental data. Most of the way are limited by the limit of the basic experimental database. The certain Empirical Equations lowered as the blast events have been become to greater extent near fields. Semi Empirical Methods are based upon easy made models of physical phenomena. The attempt is to model the fundamental essential physical processes in an easy manner. These methods are reliable on through data and case study. Numerical Methods are based on mathematical equations that explains the fundamental laws of physics commanding a problem. These laws containing mass, momentum and energy. In addition, the physical behaviour of materials is explained by essential relationship. These are very well known as Computational Fluid Dynamics (CFD) Models.

III. Methodology

a) Details of Blast Protection Wall Panel

RCC wall panel reduces the blast damage effect. RCC wall panels are placed in front of the boundary side by side which makes a large barrier of wall in front of the structure. The RCC wall panel is of size 10 ft in height, 3 ft in width, 8 inch in thick and 3 ft 4 inch thick from bottom of the panel.

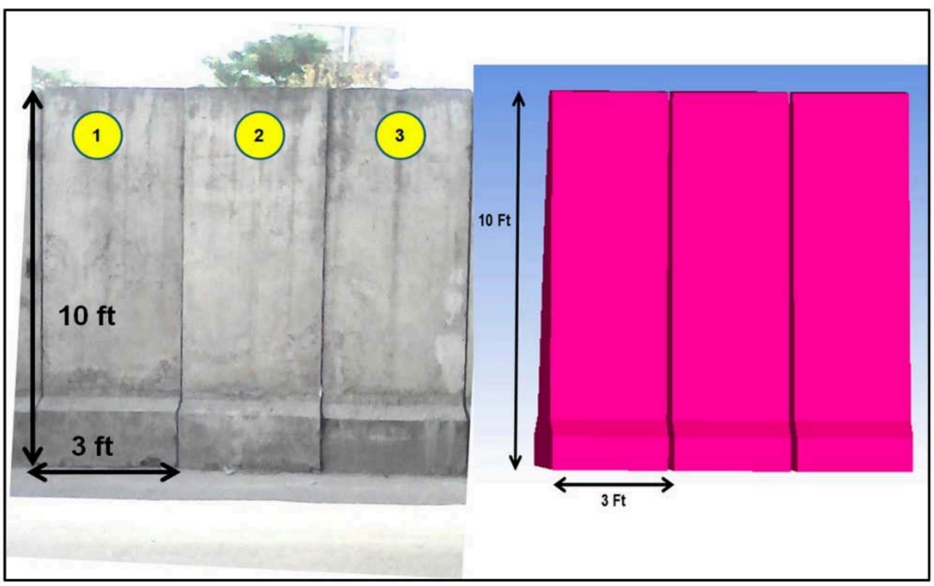

Figure 1: Blast protection wall panels

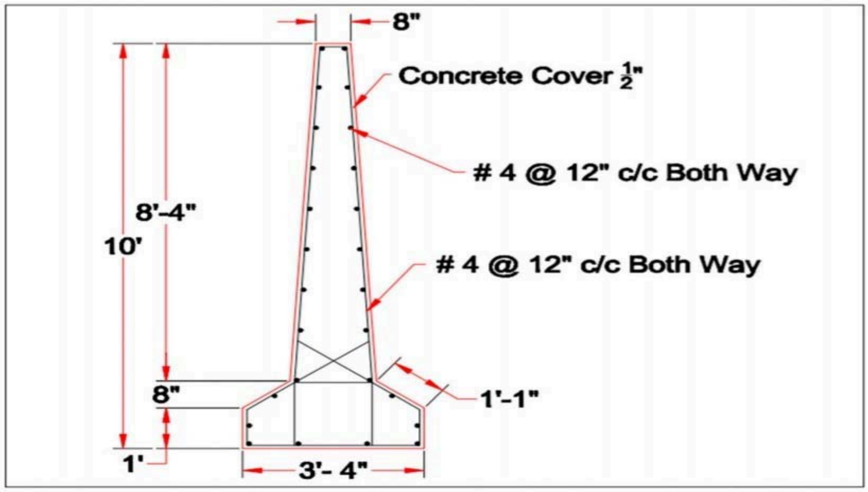

Figure 2: Reinforcement detail of reinforced cement concrete (RCC) wall panels

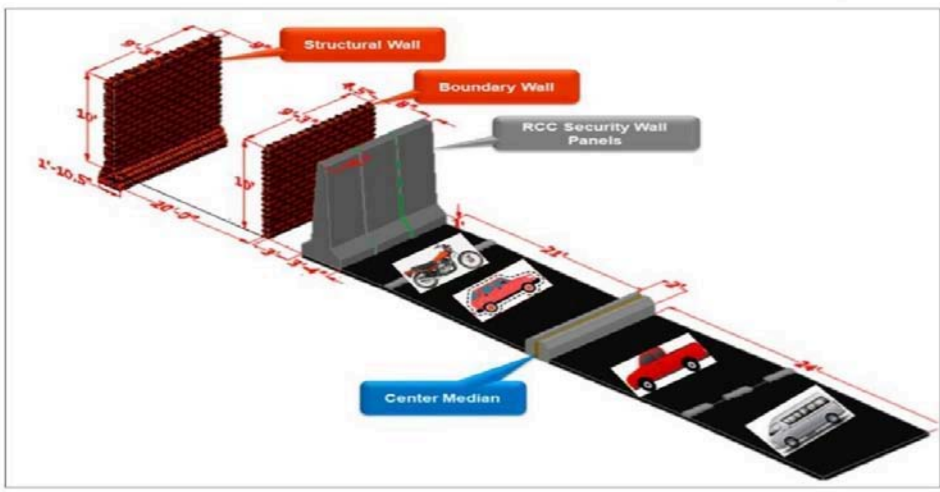

Figure 3: Existing arrangements of blast protection wall panels

b) *Material Properties*

Materials: Brick, Concrete, Mortar, TNT, Air and Mechanical Properties of RCC are not available as it is hard to model concrete and steel that requires a lot of Knowledge. However, the researchers worked on it and by several experiments has given them a result in modified properties and have been proposed to be use in reinforcing bars in concrete. Here are the different Properties used Materials.

c) *Techniques used for Strengthening of Structure against Blasts*

A lot of research had been made to improve the strength of the Existing Structure. The Structure Members Fail due to large dynamic load occurs. Different improvement techniques have made and used to strengthen the structure against the Blast Loading. The following are some of technique are being used to backfit the existing structure for Strengthening the structure against the blasts and to improve the overall uprightness of the Structure.

1. Aramid fibre reinforced plastics (AFRP)
2. Fibre reinforced polymers (FRP)
3. Ultra-high performance fibre reinforced concrete
4. Glass fiber reinforced polymers
5. Carbon fiber reinforced polymers
6. Polyurethane elastomers
7. Steel jacketing
8. Strain hardening cementations composites
9. Steel plates
10. Glass curtain walls
11. FRP composites
12. Use of GFRP
13. Use of steel jackets and strips

d) *Failures in Existing Plan*

1. The Base of the RCC wall panel is not Fixed
2. Intermediate space between RCC wall Panels
3. RCC wall Panels not designed for Blast Loading

Figure 5: Weaknesses observed in existing arrangements

e) The Technique used to Strengthening the Existing Structure against Blasts

The Steel Strips Technique is used to increase the resistance strength of the pre-existing structure against blasts. It's east for the installation and more effective and economic in compared to the other backfit Techniques. A Probabilistic Risk Assessment (PAR) has made to check or predict the risk of an explosive charge weight and its placement.

Table 2: Important blasts in last decade

Ser	Location	TNT (Kilograms)
1	U.S. Consulate Karachi	70
2	U.S. Consulate Karachi	100
3	Parachinar, Pakistan	50
4	Charbagh, Swat Valley, KPK	60
5	Police Checkpoint Peshawar	80
6	Orakzai Agency, FATA	95
7	Khyber Bazaar, Peshawar	30
8	Timergara, Lower Dir	75
9	Lakki Marwat District, KPK	79
10	Khyber Agency, FATA	56
11	Ghalanai, Mohmand Agency, FATA	50

The Concrete and Steel strips are attached with the help of anchors.

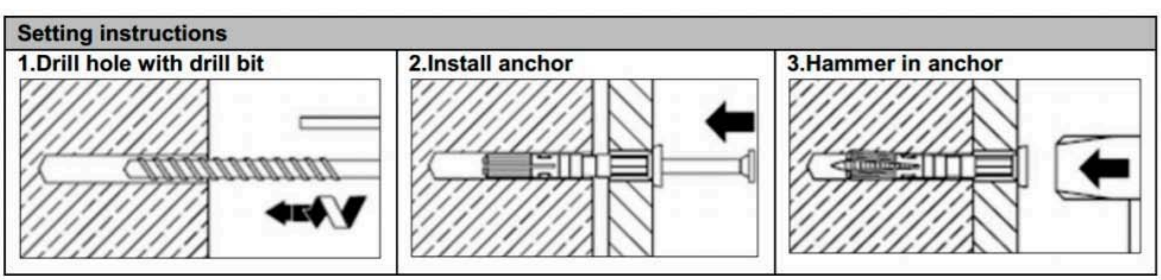

Figure 7: Procedure for installation of anchors

IV. Analysis of Field Application

a) Field Conditions for Site and Mixture

The Experiment was held at a chemical plant which manufactures Cosmetics. For the manufacturing of the Cosmetic high-pressured gas should be introduced which is cautious and we should allocate a special area for this process and it should be protected from any kind of sudden explosions or blasts. The main structure is made of reinforced concrete structure. In this research, the outer wall of the protected area was covered with High-performance fibre-reinforced Cementitious composites (HPFRCC). The applied amount of HPFRCC was about 50 m³ for 3 m depth of the protective wall. The concrete mixture was delivered by the truck with agitator (stirrer) was placed using the ready mixed concrete system mixing at the plant and to placed by the pump. The Target concrete mixture has target compressive strength at 28 days of 25 MPa, and 150 mm of target Slump. Apart from the laboratory test, the field applied concrete has a coarse aggregate of size of 25 mm. To develop workability, combined fiber of SF to PF of 1:1 was replaced by 1% of entire volume of the mixture.

Experimental items		Level of experiment
	Ready-mixed concrete specification	25-24-150
Mixture	Fiber mixing ratio (%)	1.0
	Combination of fibers	SF + PF

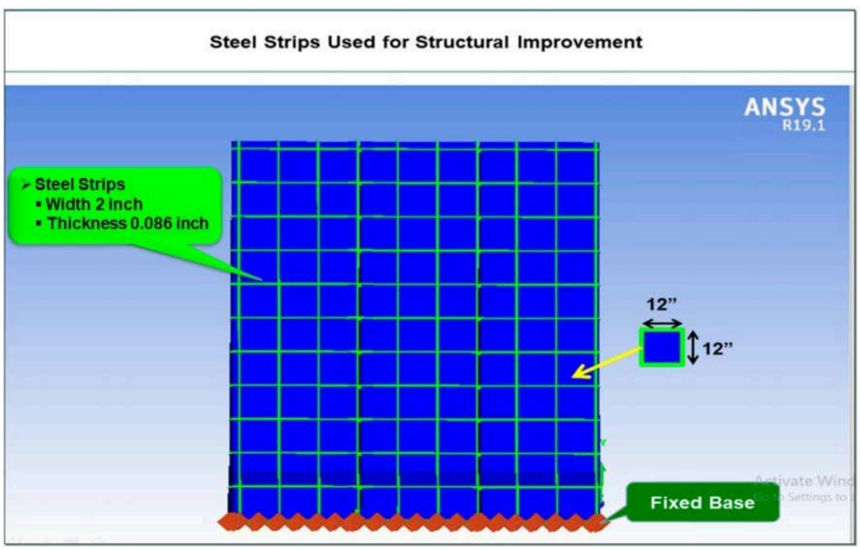

Figure 6: Steel strips modelled as a strengthening technique for structural improvement

The concrete was mixed with a method called Central Mix Method in the ready mixed concrete plant. As the plant doesn't have the framework of fiber in addition thus the fiber was introduced manually from the provided entrance of the premeasured quantity. The time taken for mixing of HPFRCC was around 1-2 minutes instead of 30-40 seconds of regular concrete to give required workability and diffusion of Fiber. Different methods of delivery and placing of concrete are done with the agitator (stirrer) truck and pump truck.

b) Test Method

To check the properties of the mixture for the real field Work, Slump and Slump flow test for Practicable, air condition and compressive strength for mechanical properties are Noted down. The testing samples were taken from the 1st and 3rd agitator (stirrer) truck arrived at the site. Each and every test was conducted following ASTM C143, C1611, C231 and C39 methods for Slump, Slump Flow, Air Condition and Compressive Strength. The Compressive Strength is conducted at 28 days age.

V. Result of Field Applications

The primary thing is that the slump and Slump flow results are taken.

Division		Slump (mm)	Slump flow (mm)	Air contents (%)	Compression strength (MPa) 7 days	Compression strength (MPa) 28 days
First agitator truck arrived in site	Before pumping	130	225/220	4.0	20.9	30.9
	After pumping	170	240/300	3.6	23.8	32.7
Third agitator truck arrived in site	Before pumping	135	230/240	3.8	21.8	31.0
	After pumping	160	310/280	3.5	24.2	33.1

The fluidity of the concrete mixture was raised after the pumping. In general workability of concrete is decreased in slump or flow after the pumping. In this research however the fiber reinforced concrete is throughout the fiber in concrete mixer was adjusted by the pressure of the pumping and it provided the improved fluidity of the fiber reinforced concrete mixture. In spite of increases fluidity of the mixture, air content of concrete was decreased. It is similar trend of already reported results of studies. However, in general, the properties of fresh-state fiber-reinforced concrete mixture were acceptable to use field construction, and there was no problem on placing process of the wall.

The field-processed HPFRCC's mechanical properties were evaluated with compressive strength. All concrete samples showed over 30 MPa and it absolutely was above the target compressive strength of 25 MPa. For the concrete mixture obtained after the pumping, slightly increased compressive strength was observed. It should be stated that decreased air content and well-oriented fiber can contribute to the improved compressive strength. For more detail, although it's a necessity to review the relation between pumping and performance of HPFRCC, during this research, the goal of the experiment was evaluating field applicability of HPFRCC, thus it is not discussed during this paper.

VI. Conclusion

Safe design of RCC wall is done by either increasing the thickness of wall or by increasing the share of steel. Just in case where there's restriction of space, such the wall thickness has been restricted it's desirable to increase the share of steel because it winds up in safer design from ductility point of view but should accommodates the minimum percentage of steel. This might cause cost effectiveness of RCC wall. It has been found that for a 200mm thick RCC wall, minimum percentage of steel required to resist blast loading is 0.75%. For a 250mm thick RCC wall, percentage of steel required to resist blast loading is 0.40%. For a 300mm, thick RCC wall percentage of steel required to resist blast loading is 0.25%.

In this research with a goal of applying HPFRCC on field conditions, the workability, mechanical properties, and protecting performance of combined fiber-reinforced concrete mixtures were evaluated, and field application was conducted with a ready-mixed concrete system. Per a series of experiment, some conclusions are obtained as follows:

1) By using combined fiber of SF and PF, fresh-state properties of HPFRCC were improved rather than the case with the unfavourable result with one fiber and showed better performances than the averaged value of each single-type fiber-reinforced mixture.
2) For mechanical properties of compressive, flexural, and tensile strengths, the mixture with combined fiber showed improved values rather than any single-type fiber-reinforced mixtures.
3) Regarding the protection performance against flying debris, the HPFRCC panel reinforced by combined fiber showed the foremost desirable performance of protecting the high-velocity projectile.
4) The combined HPFRCC showed improved mechanical and protecting performances with favourable workability. Supported these improved features of combined fiber reinforcement, field application of combined HPFRCC was successful under the ready-mixed concrete system including agitators, delivering, and placing.

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Vibrational Behaviour of a Quarter Car Travelling over Road Humps with Different Suspension Systems

By Waleed Dirbas, Hamza Diken & Khalid Alnefaie
King Abdulaziz University

Abstract- Due to the unawareness of some vehicles' drivers to abide by the limited speeds, many authorities have had to set up road speed humps to calm down the vehicles flow, especially in densely populated areas. And as a result, bad vehicles ride comfort is produced from the suspension system. Therefore, researchers and car manufacturers were interested in improving the vibrational behaviour of the vehicle while traveling over humps. In this study, the vibrational behaviour of the vehicle was studied while traveling over different types of road humps using passive, semi-active and active suspension systems.

Keywords: vehicle ride comfort, quarter car model, road humps, vehicle stability, and vehicle vibrational behavior.

GJRE-A Classification: *FOR Code: 091399*

Vibrational Behaviour of a Quarter Car Travelling over Road Humps with Different Suspension Systems

Waleed Dirbas [α], Hamza Diken [σ] & Khalid Alnefaie [ρ]

Abstract- Due to the unawareness of some vehicles' drivers to abide by the limited speeds, many authorities have had to set up road speed humps to calm down the vehicles flow, especially in densely populated areas. And as a result, bad vehicles ride comfort is produced from the suspension system. Therefore, researchers and car manufacturers were interested in improving the vibrational behaviour of the vehicle while traveling over humps. In this study, the vibrational behaviour of the vehicle was studied while traveling over different types of road humps using passive, semi-active and active suspension systems. A mathematical model was introduced to study the vibrational behaviour of the vehicle when traveling over various types of road humps such as the circular hump, trapezoidal hump, and cat-eye hump, using a passive, semi-active and active model. The parameters that were investigated in this study to evaluate the ride comfort are the body vertical acceleration, the suspension working space, the dynamic tire load, and the body displacement. The results show that the ride comfort is greatly affected by driving over humps especially at high speeds. The impact was most evident and tangible when traveling over the road humps, even at low speeds. Traveling over humps, whether circular or trapezoidal, has a great impact on the vehicle ride comfort as well as the stability of the car. There is a tangible improvement when using a semi-active and active suspension system. These improvements were obtained in the body vertical acceleration, the suspension working space, and the displacement of the body. While there was no significant change in the dynamic tire load levels. In the case of active suspension system, there is a greater improvement in both the suspension working space, the body vertical acceleration, and the body displacement.

Keywords: vehicle ride comfort, quarter car model, road humps, vehicle stability, and vehicle vibrational behavior.

I. Introduction

During the last century, the vehicle has become one of the basics of daily life. Wherever we are, the vehicle is considered as the companion of man in all parts of the earth. Wherever the human found the vehicle inherent to him. The vehicle is one of the ways to add more comfort and ease human life. Since the beginning of the production of vehicles, scientists and vehicle manufacturers have been interested in ride comfort as one of the most important factors in adding driving a pleasure.[1]

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Due to the unawareness of some vehicles' drivers to abide by the limited speeds, many authorities have had to set up road speed humps to calm down the vehicle's flow, especially in densely populated areas. And as a result, bad vehicle ride comfort is produced for the vehicle components.[2]

Semi-active suspension is a type of vehicle suspension system in which the force generated by the damping is variable to achieve better ride comfort and reduce the amplitude of the shock amplitude of the generated vibrations. The damping force is varied depending on the input outgoing naturally changing road surfaces. The purpose of this system is to apply the adaptive active suspension using variable shock absorbers that produce variable damping force. The semi-active suspension system can be managed in a variety of control methodologies. One of these methods is a rather ideal technology referred to as the Skyhook control system .[3]

As for the active suspension system, it is fundamentally different from other previous types, as it depends mainly on a control system that works to regulate the generation of additional power that is produced by an electrical or hydraulic actuator organized by a control algorithm based on the signals of the sensors indicating the road and driving conditions of the vehicle. In addition to the main suspension components; spring and damper; the active suspension includes the actuator to provide additional force to spring and damper forces that contribute to improving ride comfort. The active suspension is characterized by the generation of additional power from the actuator to reduce the impact of vertical forces generated by unexpected changes in road inputs.[4]

There are two main types of humps, the short type which is known as bumps that are typically used to smooth lanes in low-speed areas such as school fronts and shopping mall parking lots. This type of bump is designed to force cars to travel at extremely low speeds less than10 km/h. As for the other type of humps, it is to slow down traffic on a larger scale and is characterized by its large dimensions, relatively to the short type, and is used in the streets within the city to force cars over a range of 10-20 km/h. The humps usually lead to a sharp jolt in the car's suspension system, especially the short bumps, and it can reach severe damage to the suspension system if the driver tries to cross at speeds much greater than the established speed limits. It is necessary to design warning signs and lights before the hump to warn of the presence of a bump. There is a third type of bumps called the cat-eye hump, which is often used as a warning sign of an emergency, and this variety of road humps significantly worsens the ride comfort .[5]

To reach an optimal solution that guarantees the safety of driving on the roads inside the city, while obtaining an acceptable riding comfort, the car manufacturers tried to implement an intelligent system that is characterized by alignment in the suspension system to achieve the highest possible ride comfort. One of these systems is the active and semi-active suspension system. Therefore, the aim of this research is to study the vibrational behaviour of vehicle suspension system when the vehicle over humps using mathematical equations modelled in MATLAB Simulink. The research objectives are to create mathematical models for the vehicle and hence to build these models in MATLAB Simulink and then study to optimize the most used vehicle suspension system that gives the best ride comfort.

The road hump is an extension designed over the road to calm down the traffic flow. Many hump profiles are globally used. The circular hump is the most widespread one that is used on city roads. The circular hump is the most famous hump used in vehicle roads because of its design simplicity and its reasonable effectiveness. The circular hump is characterized by hump width and height. The recommended hump width is not less than 3-4 m while the maximum height is 10-15 cm. Recommended circular humps height is about 10 cm. Heights less than the assumed 10 cm will result in that the hump is not effective. Heights above 10 cm may cause severe damage to vehicles [1].

To force vehicle drivers to calm down the speed, there are several types of common road humps, such as speed bumps, speed humps, speed cushions, speed tables, and chicane.[2]

Abdulmawjoud et al. [5] have studied the drivers' behaviour when the vehicle is travelling over three main types of standard humps, which are single circular hump, double circular humps, and trapezoidal hump. The traffic calm installed along the main roads of one of the cities was studied, and they found that the rate of decrease in the vehicle speed reached more than 70% when the vehicles are travelling over the humps. It was noted that the trapezoidal hump causes a greater decrease in speed than the other species studied, with a decrease of approximately 80%. In terms of ride comfort, the worst ride comfort was recorded in the case of a single circular hump.

Pozuelo et al. [6] have presented theoretical and experimental study to investigate the vehicle vibrational behaviour when the vehicle is travelling over a circular hump. The main goal of the model and software that to introduce a prediction of the vertical dynamics of a vehicle when traveling over a hump using a half-car model. They also developed mathematical expressions to formulate the displacement behaviour resulting from the movement of the vehicle over the circular hump. The model signals are validated by comparing with the recorded experimental results of maximum vertical acceleration, maximum longitudinal pitch angle, maximum dynamic tire load of the front suspension, maximum dynamic tire of the rear suspension. The results showed that driving the vehicle over the hump leads to a severe deterioration in the ride comfort, as well as the stability parameters of the vehicle, especially at high speeds.

In another way, Mahmoud [7] presented the function of the circular hump in a simplified way, while he represented the rectangular hump as a function of the height and length of the hump and the speed of the vehicle. He presented the riding comfort factors as the suspension working space, the vertical body acceleration, and dynamic tire load as factors comparing the ride comfort and stability of the car on the road.

The suspension system of the vehicles is an important part of obtaining satisfactory ride comfort, as well as one of the components of the vehicle's safety requirement. A suspension system typically contains shock absorbers and springs. The shock absorbers compress and rebound with the help of springs when a force is applied to them. The suspension system provides a safe driving experience for the driver, passengers, and occupants of the vehicle by reducing or eliminating body roll in turns, bumps in the road, and vibrations [8].

A passive suspension system is a system in which the basic components are used to isolate the vibrations resulting from the movement of the vehicle on the road, such as springs and dampers. The design and selection of the spring and damper are chosen according to the vehicle's operating conditions and according to the design objectives and intended application [9].

A semi-active suspension system is an application of mechatronics to a suspension system. A semi-active suspension system is characterized by a switchable damper, and the damping coefficient can be adapted according to the driving conditions. The vehicle's ride comfort with a semi-active suspension system is improved in comparison with a passive suspension system. Vehicle stability is also performed with a semi-active suspension system when compared with a passive system [10-12].

To study the vibrational behaviour of the vehicle while travelling over roads, there are many methods to represent the road signals. Phalke et al. [13] have used the eccentric method of an external tire to generate the road excitation to the tire of a vehicle used as part of a quarter car model. This method has been applied in many previous studies such as Florin et al. [14] and Mehdi et al. [15].

Magnetorheological (MR) is one of the most recent and widely used applications in semi-active suspension systems. It consists of an intelligent device whose function is to dampen the vibrations to reach a relatively acceptable vibration amplitude that meets the requirements for vehicle ride comfort. Usually, the magnetorheological is based on the generation of a magnetic field using a direct current from the controller affecting the coil in the magnetorheological MR, and this causes the MR fluids to change from a viscous liquid state to a semi-solid state in the resistance gap [16-18].

The active suspension system is characterized by the presence of a linear actuator beside the spring and damper. The linear actuator can be either a hydraulic actuator or an electric motor. The role of the linear actuator is to generate the force required for the suspension system to be more comfortable and the vehicle more stable during varied driving conditions [19-21].

Modelling of vehicle suspension systems can be simulated as a quarter car, which deals with two degrees of freedom [22]. Two masses are used in the quarter-car model: a sprung mass and an unsprung mass. The sprung mass includes the chassis, body, engine, and cabin. The sprung mass is carried over the spring and damper system [23]. Un-sprung masses are the axle and tire masses and are installed down the spring and damper system [24]. The quarter model of vehicle suspension system performance can be introduced with sprung mass vertical acceleration, tire dynamic load, and suspension working space .[25]

To evaluate the vibrational behaviour of the vehicle while traveling over the bumps, Fakhraei et al. [28] assumed that the hump function is part of a sinusoidal wave for the circular humps, while for the rectangular humps, it was expressed as a function of the amplitude (height), the length of the bump and the frequency (vehicle speed). They studied the effect of traveling over humps on non-linear dynamic behaviours as well as ride comfort for the vehicle and driver. A mathematical model was presented, by solving the differential equations and then evaluating the ride comfort by calculating the RMS value of the vertical displacement of the vehicle body and the driver.

Other works have presented theoretical research aiming to reduce the cost of that which uses magnetorheological MR damper such as Ghoniem et al. [32] who have used a new, low-cost damper for the application of the vehicle's semi-active suspension systems. The strategy of this system is based on changing the damping coefficient is adapted using an artificial neural network controller by controlling the throttle opening area. A controller was trained based on the data obtained from the PID controller. The results showed that the proposed new suspension system provides a cheaper alternative to commercially available semi-active suspension systems based uses magnetorheological MR damper. The proposed new semi-active suspension could cost up to 20% of the cost of the magnetorheological MR damper.

In this work, to study the vehicle's vibrational behaviour, a mathematical model for a quarter of a vehicle was designed using the MATLAB Simulink program. Three models of passive, semi active and active suspensions were presented for use in this study. Comparison of the vibrational behaviour of the three types will be introduced when the vehicle is travelling over different types of road humps such as circular, trapezoidal, and cat eye hump to achieve the most ride comfortable system.

II. Methodology

To study the vehicle's vibrational behaviour, a mathematical model for a quarter of a vehicle was designed using the MATLAB Simulinkprogram. Three models of passive, semi active and active suspensions were presented for use in this study. Comparison of the vibrational behaviour of the three types will be introduced when the vehicle is travelling over different types of road humps such as circular, trapezoidal, and cat eye hump to achieve the most ride comfortable system.

MATLAB Simulink will be used in this study; a quarter car model will be investigated to achieve vibrational behaviours of the vehicle and these effects on vehicle ride comfort.

Moreover, a comparison between the three models will be introduced.

From the simulation results, we assume to find the following data for each case :

- Body Vertical Acceleration (m/s2).
- Tire Dynamic Loads (N).
- Suspensions Working Space (m).
- Body Displacement (m) .

Where these four outputs are directly affecting the ride comfort and stability of the vehicle. Moreover, the vibrational behaviours of the three types of suspension systems will be investigated.

A semi active suspension system is normally characterized by the presence of a control system. Mostly PID controller is used to adapt the body vertical acceleration within minimum level. The damping coefficient is used as the controller action. The proportional parameter $K_P$is firstly tuned. Then, the integrator factor $K_I$is adapted until the system noise reached until minimum levels and the error becomes too low. The differential parameter $K_D$is then adjusted to damp the noise of the signal. Saad et al [22] and Hanafi

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et al [23] have used PID controller in their work to control semi-active suspension system.

The active suspension system is characterized by the presence of a linear actuator beside the spring and damper. The linear actuator can be either a hydraulic actuator or an electric motor. The role of the linear actuator is to generate the force required for the suspension system to be more comfortable and the vehicle more stable during varied driving conditions [19-21].

Tremendous development has occurred in vehicle technology in most of the vehicle's components, especially the suspension system. Firstly, the suspension system has been presented in the economic vehicles as a major part of the vehicle's parts. The main role of the suspension system is to isolate or reduce the vibrations resulting from the movement of the vehicle is travelling over different roads according to the quality of the asphalt. Conventional suspension system is consisting of sprung mass and un-sprung mass connected by a spring and damper. The un-sprung mass is attached to the bottom by means of a tire stiffness. The conventional system is called the passive suspension system. To enhance the performance of the suspension system, a semi-active suspension system has been applied, in which the value of the damping coefficient is adapted based on changing operating conditions such as vehicle speed and road quality. Many references have proven the effectiveness of the semi-active suspension system.

On the other hand, the quality of roads in residential areas and highways is increasing day by day, which encourages some vehicle drivers to drive at high speeds more than the recommended limits set by the authorities. Therefore, decision makers have been forced to extend road humps, especially where accidents are frequent. Several shapes of humps and bumps have been presented such as circular, trapezoidal and circular bumps. Of course, these humps greatly affect the vehicle ride comfort, especially when traveling over them at high speeds.

Therefore, the aim of this work is to present a theoretical study (a mathematical model) using the MATLAB Simulink program to investigate the vibrational behaviour of a quarter a car with passive suspension and a semi-active suspension system with a comparison between each system when driving over the types of bumps by calculating - :

- Body Vertical Acceleration (m/s^2).
- Tire Dynamic Loads (N).
- Suspensions Working Space (m).
- Body Displacement (m).

III. Modeling & Analysis

Table 1: Below shows a medium sedan passenger car specification that will be used in this study.[6]

Table 1: Sedan vehicle specifications

Parameters	Value
Suspension Stiffness (k_s)	30000 (N/m)
Damping Coefficient (c_s)	3500 (N·s/m)
Sprung Mass (m_2)	381 (kg)
Un-Sprung Mass (m_1)	50 (kg)
Tire Stiffness (k_t)	220000 (N/m)
Tire Damping Coefficient (c_t)	140 (N.s/m)
Moment of Inertia (J)	1000 (kg.m^2)
Wheelbase (L)	2.69 (m)

Many types of road humps are globally used in urban areas. In this study, three well known types of road humps are used: circular hump, trapezoidal hump, and cat-eye hump.

a) Circular Hump

The circular humps are one of the common humps that are used in urban areas and cities. The circular hump is characterized by the arc radius "R", the hump length, and hump height.

It is required to calculate the time required that the vehicle is travelling over the hump. The time is the input of the model. The time can be expressed as follow:

$$t = \frac{L}{v} \quad (1)$$

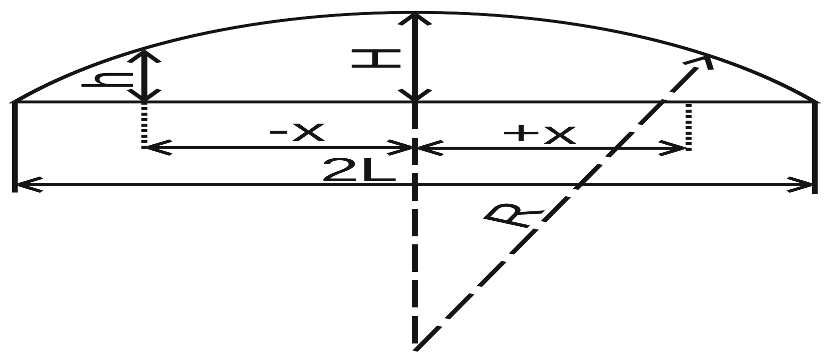

Figure 1: Circular hump profile

Fig. 1 shows the circular road hump profile where the radius R in meter and the length and the height of the hump.

$$R^2 = L^2 + (R - H)^2 \quad (2)$$

$$R = \frac{L^2 + H^2}{2H} \quad (3)$$

$$h = \sqrt{R^2 - x^2} - (R - H) \quad (4)$$

b) *Trapezoidal Hump*

Fig. 2 shows the configuration of the trapezoidal hump. The trapezoidal hump is characterized by total length "L", inclined length "L_1", flat top length "L2", and hump height "H".

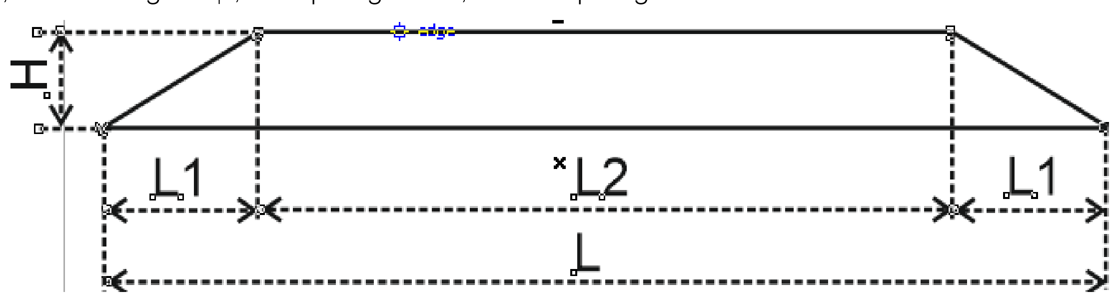

Figure 2: Trapezoidal hump profile

The hump height can be expressed as follow:

$$h = \begin{cases} H\frac{x}{L_1} & for \quad 0 < x < L_1 \\ H & for \quad L_1 < x < (L_1 + L_2) \\ H\frac{(x-L)}{L_1 + L_2 - L} & for \quad (L_1 + L_2) < x < L \end{cases} \quad (5)$$

c) *Cat-Eye Hump*

The cat-eye hump is arranged in a matrix configuration and distributed transversally to the roads. It is principally designed as a cushion or attention system. Fig. 3 shows the cateye hump configuration.

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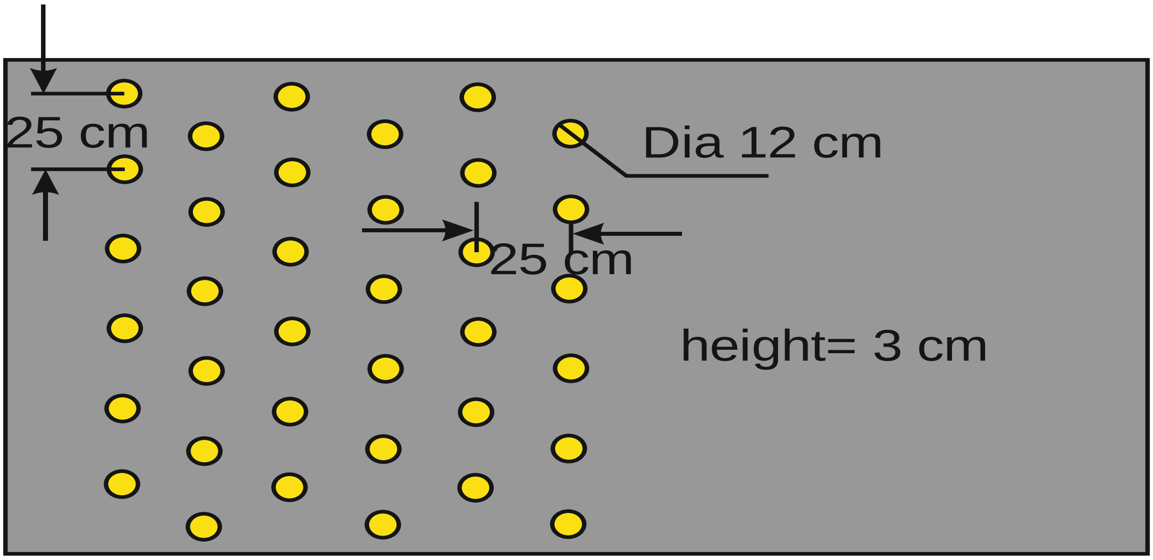

Figure 3: Cat-eye hump configuration

The same equations of circular hump can be applied with a cat-eye hump. It can be assumed that 6 columns of the cat-eyes are distributed with 25 cm intervals. Thus, the total distance is about 1.5 m. Table 2 below shows all types of humps with their specifications.[33]

Table 2: Circular, trapezoidal, and cat-eye humps specifications

Parameters / Type of Humps	Circular Hump	Cat-Eye Hump	Trapezoidal Hump
Maximum height (cm)	10.76	3.0	10
Length (m)	3.6	-	6.33
Arc radius (m)	15.11	0.075	-
Triangle length (m)	-	-	1.58
Top cat-eye diameter (cm)	-	12	-
Cat-eye horizontal interval (cm)	-	25	-

d) Passive Suspension System

Fig. 5 shows the configuration of the passive suspension system when the vehicle is travelling over a hump. The equations of motion can be expressed as follow:

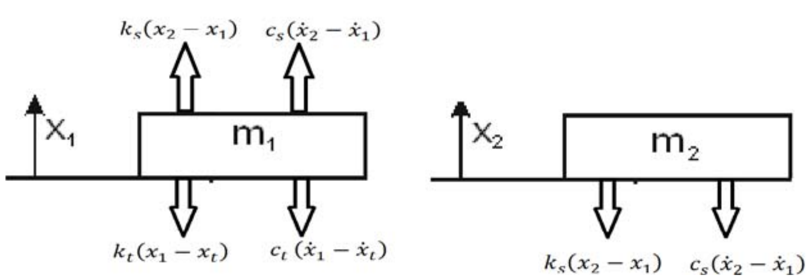

Figure 4: Free body diagram of passive system

For m_1:

$$m_1\ddot{x}_1 = k_s(x_2 - x_1) + c_s(\dot{x}_2 - \dot{x}_1) - k_t(x_1 - x_t) - c_t(\dot{x}_1 - \dot{x}_t)$$
$$m_1\ddot{x}_1 + (c_s + c_t)\dot{x}_1 - c_s\dot{x}_2 + (k_s + k_t)x_1 - k_sx_2 = k_tx_t + c_t \quad (6)$$

For m_2:

$$m_2\ddot{x}_2 = -c_s(\dot{x}_2 - \dot{x}_1) - k_s(x_2 - x_1)$$
$$m_2\ddot{x}_2 - c_s\dot{x}_1 + c_s\dot{x}_2 - k_sx_1 + k_sx_2 = 0 \quad (7)$$

Where,
m_1 *is the unprung mass,*
m_2 *is the sprung mass,*
x_1 *is unsprung mass displacement,*
x_2 *is the sprung mass displacement,*
Cs is sprung damper,
Ct is unsprung damper,
Ks is sprung stiffenes and
Kt is unsprung stiffenes

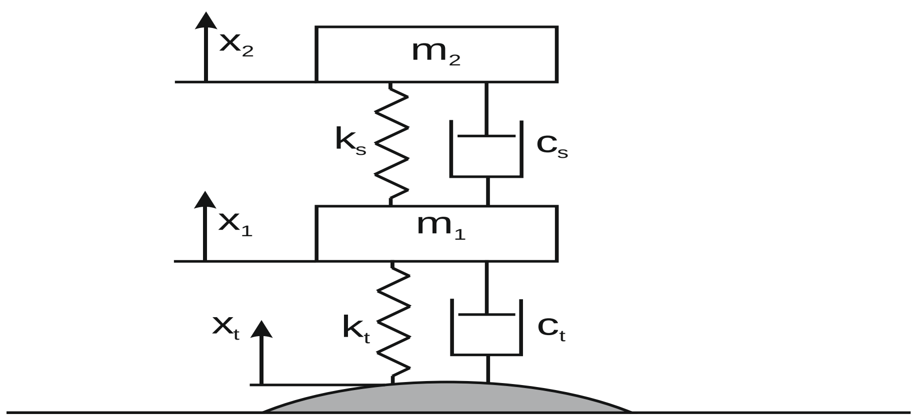

Figure 5: Passive suspension system of a quarter car model

e) Semi-active Suspension System

Fig. 6 shows the configuration of the semi-active suspension system when the vehicle is travelling over a hump. The semi-active suspension system is characterized by the presence of a controller that received the signals from the sprung mass vertical acceleration and treats them by adapting the damping coefficient of the suspension system. The equations of motion can be expressed as follow:

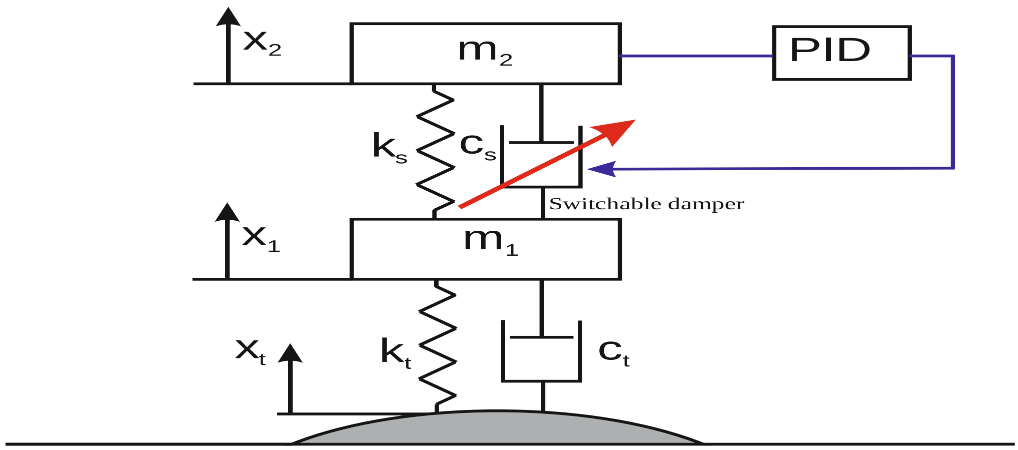

Figure 6: Semi-active suspension system of a quarter car model

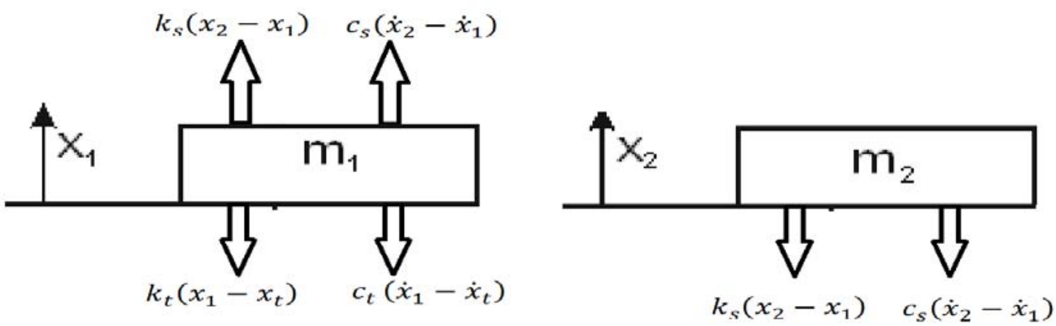

Figure 7: Free body diagram of semi-active system

For m_1 :

$$m_1\ddot{x}_1 = k_s(x_2 - x_1) + c_s(\dot{x}_2 - \dot{x}_1) - k_t(x_1 - x_t) - c_t(\dot{x}_1 - \dot{x}_t)$$
$$m_1\ddot{x}_1 + (c_s + c_t)\dot{x}_1 - c_s\dot{x}_2 + (k_s + k_t)x_1 - k_s x_2 = k_t x_t + c_t\dot{x}_t \quad (8)$$

For m_2:

$$m_2\ddot{x}_2 = -c_s(\dot{x}_2 - \dot{x}_1) - k_s(x_2 - x_1)$$
$$m_2\ddot{x}_2 - c_s\dot{x}_1 + c_s\dot{x}_2 - k_s x_1 + k_s x_2 = 0 \quad (9)$$

Matrix Form:

$$\begin{bmatrix} m_1 & 0 \\ 0 & m_2 \end{bmatrix}\begin{bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{bmatrix} + \begin{bmatrix} c_s + c_t & -c_s \\ -c_s & c_s \end{bmatrix}\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} + \begin{bmatrix} k_s + k_t & -k_s \\ -k_s & k_s \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} k_t x_t + c_t\dot{x}_t \\ 0 \end{bmatrix}$$

f) Active Suspension System

Fig. 9 shows the configuration of the active suspension system of a quarter car when the vehicle is travelling over a hump. The active suspension system is normally characterized by the presence of a linear actuator beside the suspension and the damper. The linear actuator force signals are received by the controller according to the body vertical acceleration. The equations of motion can be expressed as follow:

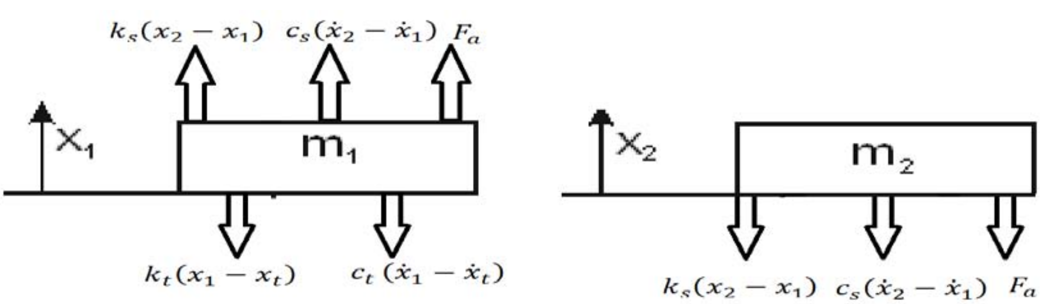

Figure 8: Free body diagram of the active system

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For m_1 :

$$m_1\ddot{x}_1 = k_s(x_2 - x_1) + c_s(\dot{x}_2 - \dot{x}_1) - k_t(x_1 - x_t) - c_t\,(\dot{x}_1 - \dot{x}_t) + F_a$$
$$m_1\ddot{x}_1 + \,(c_s + c_t\,)\,\dot{x}_1 - c_s\dot{x}_2 + \,(k_s + k_t)\,x_1 - k_s x_2 = \,k_t x_t + c_t\,\dot{x}_t + F_a \quad (10)$$

For m_2:

$$m_2\ddot{x}_2 = -c_s(\dot{x}_2 - \dot{x}_1) - k_s(x_2 - x_1) - F_a$$
$$m_2\ddot{x}_2 - c_s\dot{x}_1 + c_s\dot{x}_2 - k_s x_1 + k_s x_2 = -\,F_a \quad (11)$$

Matrix Form:

$$\begin{bmatrix} m_1 & 0 \\ 0 & m_2 \end{bmatrix}\begin{bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \end{bmatrix} + \begin{bmatrix} c_s + c_t & -c_s \\ -c_s & c_s \end{bmatrix}\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} + \begin{bmatrix} k_s + k_t & -k_s \\ -k_s & k_s \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} k_t x_t + c_t\,\dot{x}_t + F_a \\ -\,F_a \end{bmatrix}$$

Where, $\boldsymbol{F_a}$ is the actuator force.

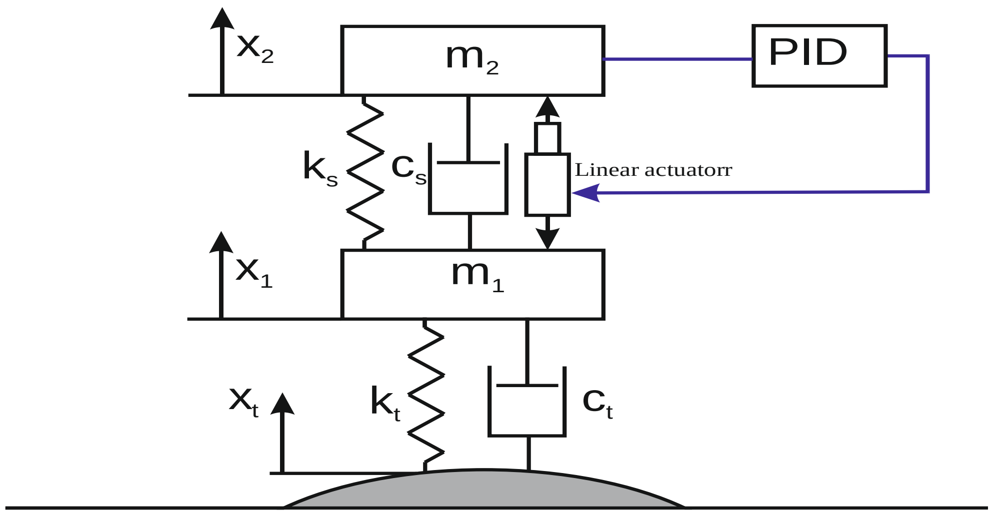

Figure 9: Active suspension system of a quarter car model

g) Output Criteria

Table 3 below shows the parameters that affect the ride comfort and the stability of the vehicle in the quarter car model and half car model, where the optimum design is to minimize the parameters as can be possible for the best ride comfort and stability.[7]

Table 3: Outputs parameter criteria

No.	Parameters / Quarter Car Model	Affect
1	Body Vertical Acceleration (m/s^2)	Ride Comfort
2	Dynamic Tire Load (N)	Stability
3	Suspensions Working Space (m)	Stability
4	Body Displacement (m)	Ride Comfort

IV. Results and Discussion

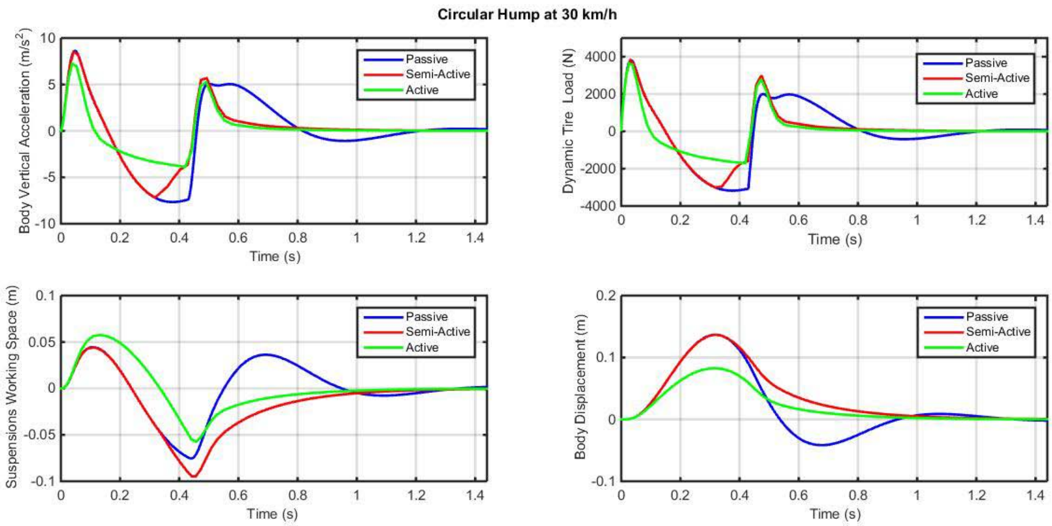

Figure 7: Vibrational behaviour of vehicle over circular hump at 30 km/h

Fig. (7) shows the dynamic vibrational behaviour of a quarter car travelling over circular hump at 30 km/h with passive, semi-active and active suspension systems. The vehicle ride comfort parameters such as body vertical acceleration and body displacement become important element especially with passive suspension system. From the other hand the body vertical acceleration is improved with semi-active while it is better for ride comfort and stability of the car when active suspension system. However, the maximum value of the body vertical acceleration is about 9 m/s^2 as a passive suspension system is used while, this value is reduced to about 6 m/s^2 as active suspension system is applied. In the same context, the suspension working space is considerably reduced as the active suspension system is applied in comparison with passive suspension system. Moreover, dynamic tire load reduced as the active suspension system is applied in comparison with passive suspension system. The body displacement of the vehicle, there is a slight improvement 0.06 m, especially when using active suspension system compared with passive suspension system.

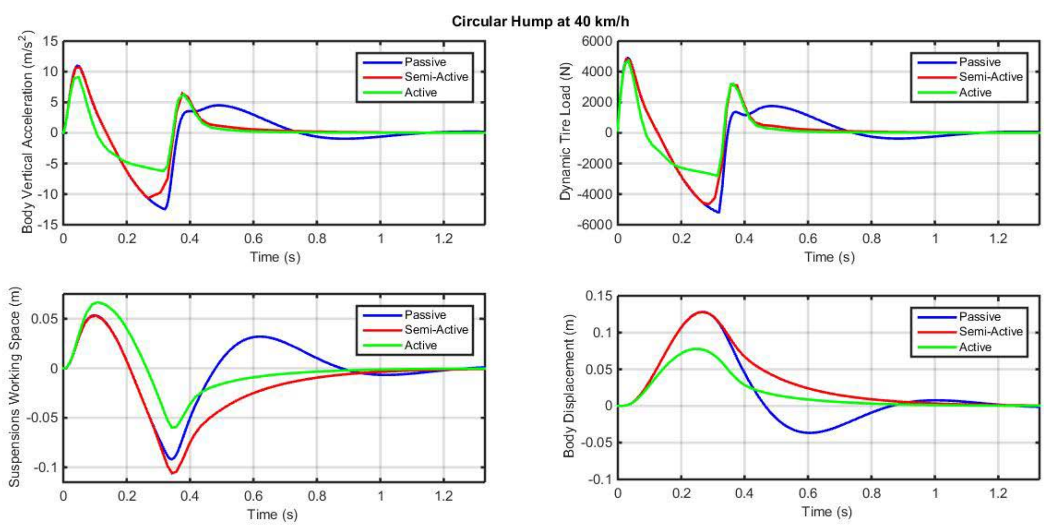

Figure 8: Vibrational behaviour of vehicle over circular hump at 40 km/h

Fig. (8) shows the dynamic vibrational behaviour of a quarter car travelling over circular hump at 40 km/h with passive, semi-active and active suspension systems. As the vehicle speed increases, the vehicle ride comfort become important element especially with passive suspension system. By using of semi active suspension system, the body vertical acceleration is improved as with semi-active suspension system. However, the maximum value of the body vertical acceleration is about 10 m/s^2 as a passive suspension system is used while, this value is reduced to about 7 m/s^2 as active suspension system is applied. In the same context, the suspension working space is considerably reduced as the semi-active suspension system is applied in comparison with passive suspension system. Moreover, dynamic tire load reduced as the semi-active suspension system is applied in comparison with passive suspension system. Looking at the body displacement of the vehicle, there is a slight improvement when using active suspension system compared with passive suspension system.

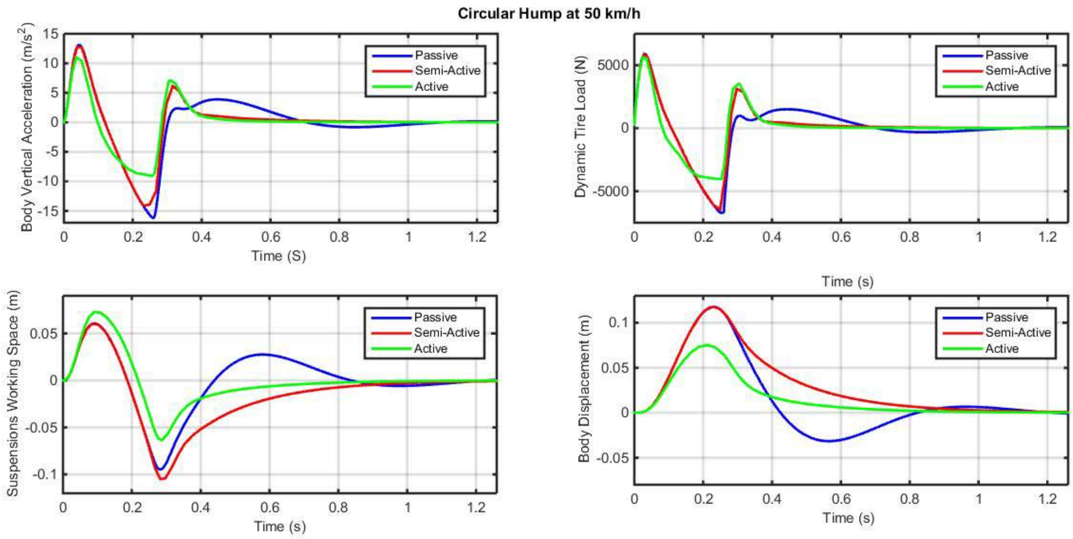

Figure 9: Vibrational behaviour of vehicle over circular hump at 50 km/h

Fig. (9) illustrates the dynamic vibrational behaviour of a quarter car that is travelling over a circular hump at 50 km/h with the passive, the semi-active and the active suspension systems. The body vertical acceleration is severely increased because of the vehicle speed is higher and hence the vehicle ride comfort is important element. The using of the semi-active suspension resulted in a slight improvement in the beginning of the hump crossing and this improvement increased at the end of the hump as a result of the controller response. By using of the active suspension resulted in a significant improvement in ride comfort compared to other suspension systems. However, the maximum value of the body vertical acceleration is about 13 m/s^2 as a passive suspension system is used while, this value is reduced to about 10 m/s^2 as active suspension system is applied. The suspension working space is considerably reduced for both suspension systems. As the semi-active suspension system is applied, a considerable reduction in suspension working space is achieved in comparison with passive suspension system. The body displacement of the vehicle, there is a slight improvement when the semi-active suspension system is used referred to the passive suspension system.

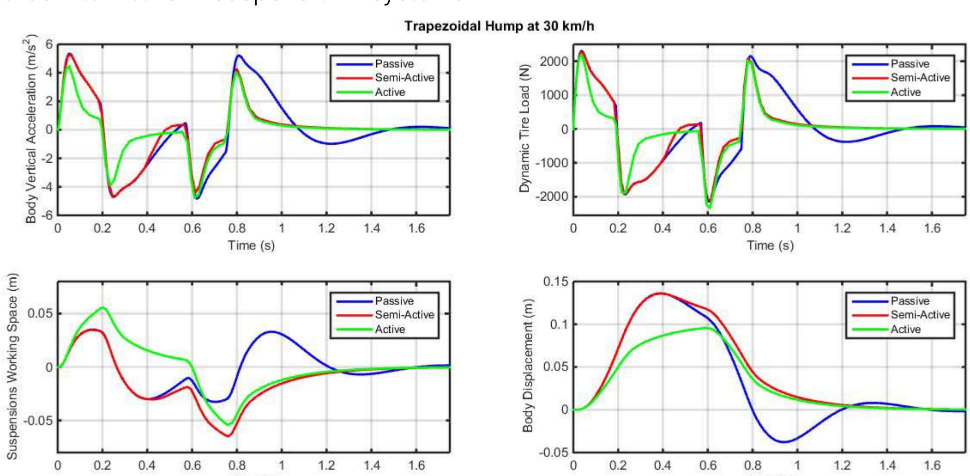

Figure 10: Vibrational behaviour of vehicle over trapezoidal hump at 30 km/h

Fig. (10) shows the dynamic vibrational behaviour of a quarter car travelling over trapezoidal hump at 30 km/h with passive, semi-active and active suspension systems. The body vertical acceleration is improved as the active suspension system is applied referred to the passive suspension system. However, the maximum value of the body vertical acceleration is about 5 m/s^2 and the body maximum deceleration is about 5 m/s^2 as the passive suspension system is used. This value is reduced to about 4 m/s^2 as active suspension system is applied. The suspension working space is considerably reduced as the active suspension system is applied in comparison with passive suspension system. No changes were prompted in dynamic tire load in both cases. The body displacement of the vehicle is slightly improved with the active suspension system compared with the passive one.

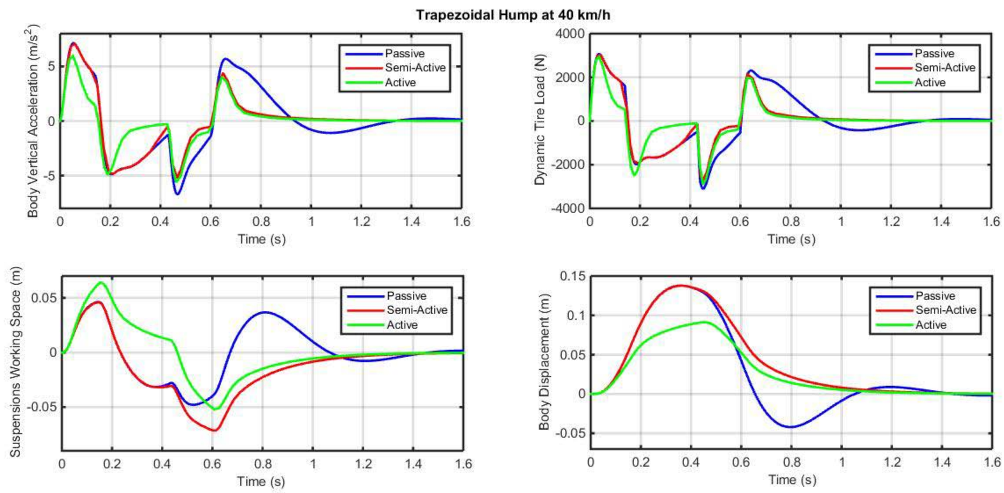

Figure 11: Vibrational behaviour of vehicle over trapezoidal hump at 40 km/h

Fig. (11) shows the vibrational behaviour of a quarter car that is travelling over trapezoidalhump at 40 km/h vehicle speed using passive, semi-active, and active suspension systems. The body vertical acceleration is recorded at high levels especially with passive suspension system and it is considerably reduced as semi-active as well as active suspension systems are applied. However, the maximum value of the body vertical acceleration is about 8 m/s^2 with a passive suspension system and is reduced to about 6 m/s^2 with the active suspension system. In the same context, the suspension working space is considerably reduced as the active suspension system is applied in comparison with the passive suspension system. Ignored changes were prompted in dynamic tire load in semi-active suspension system related to the passive suspension system. However, there are slightly reductions in dynamic tire load with the active suspension system. The body displacement of the vehicle is severely affected by the travelling over the hump with the passive and the semi active suspension system. This effect was less in the case of active suspension.

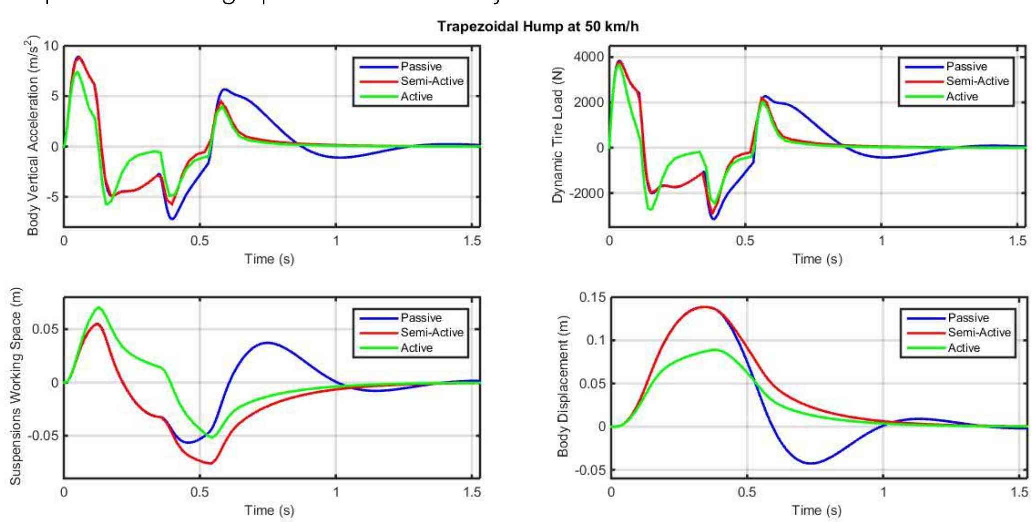

Figure 12: Vibrational behaviour of vehicle over trapezoidalhump at 50 km/h

Fig. (12) shows the dynamic vibrational behaviour of a quarter car travelling over trapezoidal hump at 50 km/h with the passive, the semi-active and the active suspension systems. The body vertical acceleration is improved as with active suspension system is used referred to the passive one. However, the maximum value of the body vertical acceleration is about 9 m/s^2 as a passive suspension system is used while, this value is reduced to about 7 m/s^2 as active suspension system is applied. The suspension working space is considerably reduced as the semi-active suspension system is applied in comparison with active suspension system. The dynamic tire load is slightly improved with the active and semi active suspension systems referred to the passive one. The body displacement of the vehicle is considerably improved with the active and the semi-active suspension systems referred to the passive one.

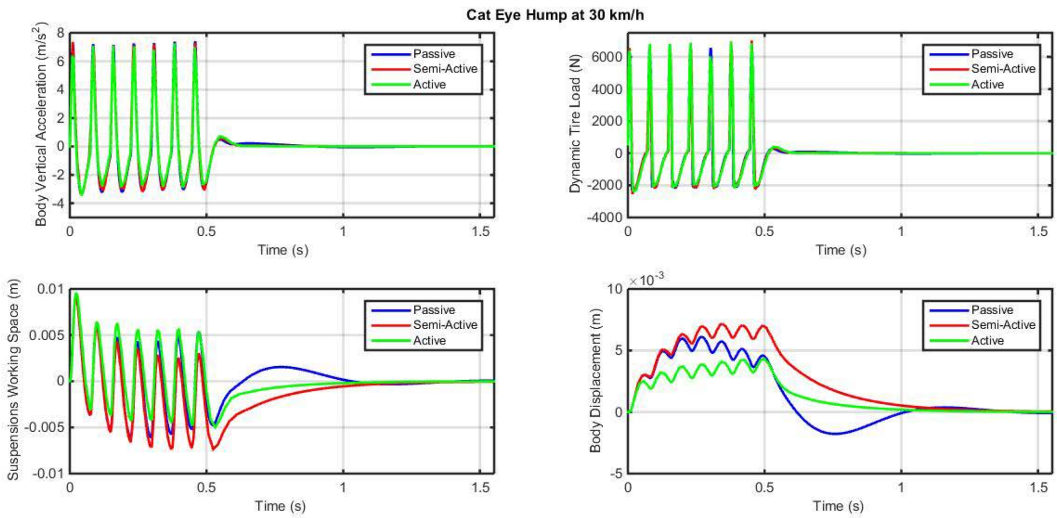

Figure 13: Vibrational behaviour of vehicle over cat-eyehump at 30 km/h

Fig. (13) shows the dynamic vibrational behaviour of a quarter car travelling over cat-eyehump at 30 km/h with passive. semi-active and active suspension systems. The vehicle ride comfort is worthily affected as the vehicle travelling over the cat eye hump at 30 km/h. No considerable changes in the body vertical acceleration were achieved with the using of the active and the semi-active suspension systems related to the passive one. However, the maximum value of the body vertical acceleration is about 7 m/s^2 as a passive suspension system is used while, this value is reduced to about 6 m/s^2 as active suspension system is applied. In the same context, the suspension working space is slightly reduced as the active suspension system is applied in comparison with passive suspension system. Differently, no change was prompted in dynamic tire load in both cases. The body displacement of the vehicle is considerably reduced as the using active or semi-active suspension systems compared with the passive suspension system.

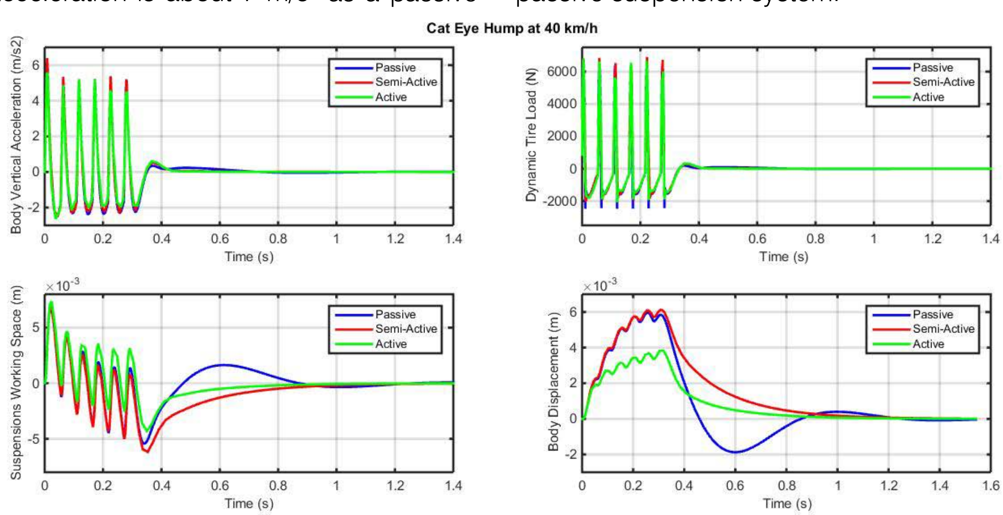

Figure 14: Vibrational behaviour of vehicle over cat-eyehump at 40 km/h

Fig. (14) shows the dynamic vibrational behaviour of a quarter car travelling over cat-eyehump at 40 km/h with the passive, the semi-active and the active suspension systems. As the vehicle speed is increased from 30 km/h to 40 km/h, the body vertical acceleration is reduced to about 5 m/s^2 referred to 30 km/h vehicle speed there is no change prompted in. However, the maximum value of the body vertical acceleration is about 7 m/s^2 as a passive suspension system is used while, this value is reduced to about 5 m/s^2 as active suspension system is applied. In the same context, the suspension working space is considerably reduced as the active suspension system is applied in comparison with passive suspension system. Differently, no change was prompted in dynamic tire load in both cases. Looking at the body displacement of the vehicle, there is a slight improvement when using active suspension system compared with passive suspension system.

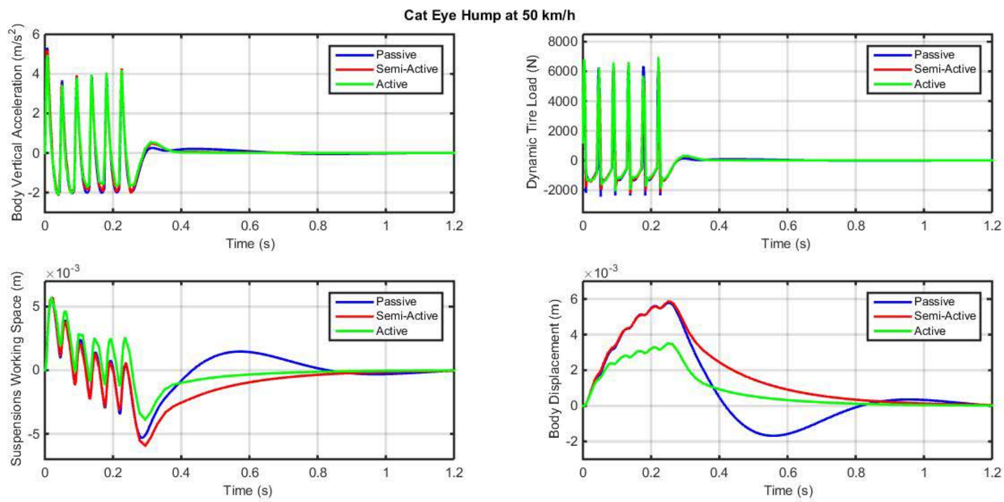

Figure15: Vibrational behaviour of vehicle over cat-eyehump at 50 km/h

Fig. (15) shows the dynamic vibrational behaviour of a quarter car travelling over cat-eyehump at 50 km/h with passive. semi-active and active suspension systems. The body vertical acceleration are improved as the vehicle speed increased. There are no tangible changes prompted in the body vertical acceleration when the semi-active or the active suspension system are used. However, the maximum value of the body vertical acceleration is about 4m/s^2 as a passive suspension system is used while, this value is reduced to about 3.8 m/s^2 as active suspension system is applied. In the same context, the suspension working space is slightly reduced as the active suspension system is applied in comparison with passive suspension system. Differently, no change was prompted in dynamic tire load in both cases. Looking at the body displacement of the vehicle, there is a slight improvement when using active suspension system compared with passive suspension system.

V. Conclusions

The following conclusions can be achieved:

- Mathematical models were introduced to study the vibrational behaviour of the vehicle when traveling over various types of road humps such as the circular, the trapezoidal and the cat-eye humps, using a passive, a semi-active and an active suspension systems.
- The parameters that were investigated in this study to evaluate the ride comfort are the body vertical acceleration, the suspension working space, the dynamic tire load and the displacement of the body.
- The ride comfort is greatly affected by driving over humps, especially at high speeds.
- Traveling over humps, whether circular or trapezoidal, has a great impact on the comfort of riding, as well as the stability of the car.
- There is a clear and tangible improvement when a semi-active suspension system is used compared to a passive suspension system. The semi-active suspension system is characterized by the presence of PID controller. The PID goal is to minimize the value of the body vertical acceleration values considering the body vertical acceleration as the controller input and changing the damping coefficient as the controller output.
- These improvements were obtained in the body vertical acceleration, the suspension working space, the displacement of the body, and the dynamic tire load levels.
- With the high speeds, the ride comfort is achieved for all the humps used in this study except for cat-eye hump, whereas the worth ride comfort is achieved at low speeds.
- Therefore, through these results, it can be recommended to use the active or semi-active suspension systems instead of the passive

suspension system to improve ride comfort and maintain the car's stability while the vehicle is traveling on humps.

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Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Engineering Research Paper

Techniques for writing a good quality engineering research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of research engineering then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.
22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.
23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.

- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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