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Theoretical Overview of Metacentric Height (GM) & its Vindicative Propounding of a Floating Body

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Abstract — Floating body is generally assumed to have its negligible own effects of the portions above the fluid line on which it floats on maintaining the stability. Towards attaining the conditional stability remains always at its objectives. When on voyaging and/or in stationery state of condition, the body keeps struggling with several of its disturbing factors being conditioned by its governing solving and/or remissive mitigations. Eradication from out of any dangers is of its prime attitudes. In general, movement in angular direction always tries to be become oscillatory towards the unstable prevailing, keeping the smaller displacements aside negligibly. The equilibrium is to be stayed more stable, even if the body is subjected to a given minute angular displacement to cautious directions, particularly when the meta-centre does coincide at its point of centre of gravity. The wedge of the body, so formed, does then keep varying with its prevalent nature by quantified moments & it depends on the body's configuration & dimension. Mathematics & also of its advanced outlets contributes to finding out the various physical natures of the body. The wetted wedge-shaped parts of the body are, nonetheless, imparting the ruling factor upon the reigning principle of the buoyancy. The water-wedge (volume) displaced by the weight of the floating body has been wholesomely considered to examine the absolute magnitude of couple, so generated by, as well as the inter-related varying metacentric heights, as well; it also, although, with at par the suitability of the above assumption like as that of the negligible effects of atmospheric air pressure & alike, indeed. Scope of this literature resides on explaining behaviours of this wetted surface's attributive forces in conjunction with the wave manoeuvring (both of on its rolling & pitching endeavours), in addition to the planes of its acting & its related statistics.

Here in this article a theoretical approach has, thereby, been layered down to inspect & to have an attempt visualize & subsequently formulate the resultant meta-centric height for which the title is so meant by. The pertaining required establishment of dimensional similarity (similitude justification) has also been extracted thereon to justify on the subject matter so concerned to as far as its purposes get met by the values to the corresponding maximum & minimum. In gist, these are always with subject to its subsequent proper justifications, keeping the stable equilibrium in vision.

Keywords: Metacentric Height(GM), Centre of Buoyancy, Neutral Equilibrium, Buoyant Force, Floating Body, Dimensional Similarity, Correlation Coefficient, Wave Manoeuvring, Desired Rise of GM, Acting Plane of GM, Angle of Tilt.

Index: **Here is the list of the notations used in this article in the following tabulation. Others that are not enlisted do signify in the cases as applied to in the subjective articles.**

Sl. No.	Notation(s) used	Feature
1	¥	Volume of the Liquid displaced by floating body
2	$d_n i_{Lbd}$	biswas constant
3	M	Metacenter
4	$d_n i_b$	biswas ½ value constant
5	G	Center of Gravity
6	θ	Angle of Tilt

I. INTRODUCTION

Negligibility necessitates to parcel of human-life & its biosphere. It comes in picture only when the not-so-unusual overburden is not to be granted. Consideration, to some degrees always, is then a regular function of the weight-less lesser physical quantities, automatically. This tendency of neglecting the apparently invaluable matters is everywhere in every field of our regular access to this biosphere. Propounding vindications are therefore required to be on its 'consideration' over the considerations to safeguard on its bigger spaces. This theoretical views show the different aspects of its applications & several of its other useful end of need of human-life.

Sailing across any natural liquid body of resources needs of such not-so-unconventional contributory forces, but it's within its permissible ranges of flexibility itself. Flexibility depends on the potentially positional suitability of its cardinal governing factors. Sometimes, the cardinal points are visible clearly & physically; sometime it's not, but only to the theoretical perspectives followed by its application through chips & its machines. Then only, it is well-perceived about its locational presences.

Wind's direction with its magnitudinally directed significant effects governs most of such forces on and around the sailing equipment & its accessories activate. These physical forces generate inside the floating body & act upon the controlling cardinals (fig. 1) into moulding towards the instability. Other hydrodynamic forces that often cause huge expansion of ocean as well as sea-way waves, includes different atmospheric calamities such as earthquake, flashflood, ice-melt etc. All these when & so exist in either or together with stronger energy & expansive maneuvers results into forming of none other than the so-called mishaps that lead to count lives as well as various costly natural resources of ocean-life inhabitances[article *K 1.1* (i)]. Untimely grasps of domination, in many fields, over these forces are still beyond scope of the mankind to those extents of some factorial non-implications of capability to where its willingness has been hounding since times immemorial.

Years had then went away having glided upon by these cardinal points for the necessary purposes with loads of happenings, experiences & laziness of comforts together with its utilities, since the generation in its conventional form. Many more things still need to be revised to give the human-life a better, rather broader, fragrance of engineering. The utilization of floating body is such an aspect to think on. This literature tells that how utilization of floating bodies is still left to go by of to be arriving to… by that magnitude… & it could have been to more of its present value than by efficiency for increasing improvements to its transport maneuverings & the humankind as well.

Here, as far as the subject of the theoretical matter is concerned, the demerits of going higher are, nonetheless, none. It's because of its self-explanatory features of fields of applications, scientifically. The only object to keep it under vision of its driving whiles is whether the statutory governing condition (GM>PG) is to be getting satisfied in all the time of the sailing [1]. Depending on the capacity required & the loads to be transferred the configurations of the floating body should have to be set-up accordingly. In this matter, the equation (3.0) can be viewed over for the conception to get adjusted with, subsequently.

With the vision of the objective, different expressions have been derived of several conditions in this paper for the stability of body; both analytically & graphically. Also, statistically the newly 'GM' height has been analyzed herein to get the impact of the derived essential statistical parameters. All these analyses are ultimately towards the objective of betterment – betterment for the science & technology – betterment in loading, unloading of cargo & sailing's more spaces together with the better effective quality on its one-way driving, costs of voyaging etc, quantitatively. Betterment is also on getting the advancement over the earth's future ages by the anticipation like 'better late than never'. Fully, it's worth-full, at last. Mankind will be supposedly becoming ahead of the present paces of living.

Irrespective of discrimination between the theoretical propagation & its establishment and its ultimate dominative form to become activated into its fruitful practical guise, there should always be the legacy in every forerunner of dreaming one-self of it to be plunged into the ocean of hopes. This is a continuous process.

Repetitive rise & fall, ups & downs, undulation & plains in behind of that process, before its full-form stabilization, has prepared one Country, one being & one World to become so prosperous & so enchanting by it's the then passing-by times of the processing. With these cascative developments this literature can be said to be as an "overview" over a conventional concept of metacentric height, theoretically. Some vindicative findings have hereby also been delineated exclusively by both graphically & stochastically.

Since the formation of the conventional expression of metacentric height, i.e. GM = [(I/¥) – PG]; where, I = Second Moment of area of the plan of the body at the free-liquid surface about the axis concerned & ¥ = volume of displaced liquid (i.e. volume of the submerged portion of vessel), it has become a tradition to follow up on it [3]. That is why, this equation of metacentric height is hereby regarded as 'conventional' expression of the same.

Till date, no such modification and/or furtherance over this conventional state of GM has hardly brought down into the picture of engineering & become a new face by the successive establishment. Here, in this literature an approach is given to bring out the modified expression of GM. Therefore, this literature is thereby termed as an 'overview' over the existing conventional expression of GM. Here, the overviews & the related propounding have been given with the detailing as for it is intended to, theoretically, along with its subjective practical propagation by dimension by dimension – physique by physique – tilt by tilts.

Background Upliftment-

Upliftment, in any field, be it smaller or large enough or of mediocre magnitude, is always granted with the corresponding scientific fulfillments. The concern about the other side of its vantages is, although, always to be kept in while implementing this for great causes of the progression of the mankind. Improvement over the sea-way is thus necessary to bring one country up towards the uprising time-bound benefits.

Water is incompressible fluid. Water is a liquid form out of the three physical forms of substance on the earth. Each form of it is stronger than the remaining about its own range & the zone of existence. It is just a medium. It has the power of resistance to get through one's (i.e. of aquatic lives) breathing capability for not to get reigned over by else, on the underwater whiles.

Spending the Ocean lives is well-known to those objects which experience it for at least once or on frequent basis for commencing their various own purposes, especially on those severe whiles of stormy times of voyaging. Actually safe travelling means to be to what provisions of safety should be meant to be. In sailing, apart from all of the prevailing forces responsible for such horrible mishaps & collision, as such, of vessel, ship etc., the disturbances over the control line (i.e. M-G-P) by any means (it may however be due to machinery faults, also, even while running through quiescent condition of the sea-ways) will endanger the stability of ships.

'Water water everywhere…not a single drop to drink' – this poetic verse would often be compared & might be rhymed as pathetically as 'Land land everywhere…the wavy lands…not a single one to land'. This type of dying moments may strike into one's head through spines coldly, seeing no possible land's existence everywhere surrounding to alight on; land's vision is then seemed like the relieving thrusting object to quench the thirst-like wishing to become stable with relief gasps. Getting Lands in views gives comforts for the long-time voyagers. May be the nearby land is beckoning with its minute shades, but it's also too far from them to solve dreary, then. – This is just a glimpse always being experienced by a voyager standing on its deck and/or may be for a long time after having been lost the actual tracks of voyaging, hugely. This may also be the pathetic picture of the travelers swimming on a pool of streaming water after their ship (or alike) has devastatingly destroyed during their prosperous journey in the middle of sea, surrounding of which no land comes to seeing ever to anybody else. So, this unprecedentedly dreary and/or boring situation often happened with vessel, ship etc. due to various causes like atmospheric, climatic & functional disputes etc. And, when it happens reader should not even dream of such unwanted fateful events – God's sake; that's…that's very very severe, indeed.

In short, every voyaging takes place to carry its various loads such as commercial, industrial, domestic & etc. All loads are either for export or import & depending on that the importance also varies on the voyaging. These varying loads are called as 'surcharge load'. Their positions also govern the stability & vice-versa, which is in general expressed by our well-known relationship & i.e, $GM = N\ W_1/W \tan\theta$; where, W_1 = surcharge load, N = distance of the surcharge load from the specified & concerned control-line, θ=angle of inclination (i.e., tilt) & W=weight of the body acting through centre of gravity [3]. More or less, sea-life also has different fragrance of travelling as the other modes of conveyances such as train, airplane, on-land vehicular activity & etc., have.

"All goes well that ends well" – this is the most common talk in every travel. The significance of metacentric height comes to views or become important while the matter of instability beckons. Say for an example, during thunderstorm the vessel is in the middle of sea, then every inhabitant, starting from its driver to the general traveler, starts realizing graspingly the instability of or the horrible-beckoning of deaths. This is due to the outburst of oscillation of the metacentric height or the travel of the point 'M' along the so-called control-line of M-G-P downwards (fig.1). In fact, then only the plays of the points (M, G & P) are seen to be displayed by nature or the waves so created in the body of sea-ways [2].

Mechanics responsible for generating these contributory governing forces have been of a long-time matter of the discussions in the related fields & is required to de delineated with numerous approaches elaborately along with its perspicuous subjective presentation. Some new excavations are shown here on the same. Response is, thereby, always expected from anybody else to make its purpose become more advancing.

Till so far whatever is the progress about the metacentric height, the values are getting implemented varyingly for different vessels, depending on the type & nature of loading & the pattern of shipping (particularly, the length of voyaging) to be offered. In general, the conventional 'GM' value for most of the floating body is in the range from 0.3m to 1.2m. For warships, it is of 1m to 1.5m [2]. Despite the effect of GM's capability & out of lots of reasons of breakage and/or the unbalanced 'GM' height due to mechanical disturbances also, there is also having the formation of lesser free-board with respect to the bodily (i.e. physicality on safety) control point (i.e., centre of gravity) - this is also another reason for the body of being plungered into such disruption. So on this needful but simultaneously so dreadful juncture to become freed out of the congestion so created in the control-line or simply to relieve the

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point of metacentre (M) to go & get to its greater length from the centre of gravity of the vessel, this theoretical expression [eq (3)] of GM height is the best one to be followed on for bearing with more & relaxingly established in giving the comforts simultaneously to its spines (i.e. GM height) of vessel. The values of such metacentric heights are exemplarily given later in this article. Summarily, the GM height as propounded by this theoretical article reckons the counting, as like its traveler, of bringing troubled ship to become stable state. Henceforth here on this particular aspect, in addition to those other various advantages, this article holds good on many facets of sailing advantages, at its utmost.

The much-known general conventional self-explanatory expression of the GM height is given by: GM = (I/¥) – PG, where the main governing control point(M) which is so fixed upon the well-known control line M-G-P that it has lesser distance of free-board to movement freely. Although, so far none has had any improvement over the conventional expression of GM height [i.e. GM = (I/¥) – PG] - the application of this thrusting literature is thereon worthwhile; subject to its further accomplishments as required to on its needful basis. Therefore, the floating bodies like vessels, ships etc remain suspending based on this conventional equation so far, till it doesn't get affected & altered by any fateful accidents, or of alike. Here, this study will depict whether the GM height can be increased or not with subject to its stability; even to its higher degrees of stability. Its comparison has also been made with respect to earlier one to have the vision of this (nearly!) advantageous GM (i.e. GM*) height for lending more comforts to its passengers, as well.

It is axiomatic & expected that all these discussions will be able to open more emphasization by this theoretical overview, of the purposes concerned in broader purviews of its application. In view of this, certain mitigatory measures required to be listed are also given thereon in here which must exfoliate the pages of useful aspects of thoughts for its correct implementation & the purposes of its utility. The formulae, which have been formulated so, have multi-directional effects. So, it is hereby propounded that much more thoughts could now be thrown on these peculiarity, subjectively, from every of its possibilities to see & show its 'those' unseen, unearthed & unwoven embodiments to flourishing. The expression of GM, as given by this article for amendment over the past conventional one when applied to, will evolve out the actual evolution of the life of voyaging.

II. METHODOLOGY

A. Description of the Theoretical Overview

Buoyant force attains to be stronger proportionately by the amount of the body subsiding into the flowing liquid & with relatively less oscillatory motions. Subsequent travel of the metacentre (M) about the point 'G' governs the controlling power of stability of a floating body & reverse is also the same, i.e. for continuous come-and- go of 'M' with respect to 'G'. In connection with this to be achieved for safety & stability, the corresponding velocity & the wave resistances do enter to be its pertinent part into the controlling factor against instability. Oscillation is caused in any running floating body and/or to the body about to be landing near the shore-line, but this may become as a damaging factor to the floating body with the position of 'M' and/or the varying magnitudes of the metacentric height (GM). Buoyancy, after all, is the resultant phenomenon which the body & its upholding cardinals always experiences.

In this article, an approach has here been postulated theoretically by mechanics where the variation of this buoyant force has been detailed picturesquely with various angle of tilts on its harmonic motion (Fig.1). Formulation of metacentric height (GM) is the main basis in order to rely upon the approach. In this vindication, the defined kinetics related to force mechanism has been deployed to bring out the related expressions of the same to be served. Regarding its application, the metacentric height comes out as higher than the previous as-usual-long-time conventional value of itself. Here on this particular ground of higher capacitative aspect of floating body, this article may now be termed as 'theoretical' subject to the satisfaction of its necessary parameters, more rationally. The correlation coefficient for PM* (i.e. modified PM) versus θ° comes as 0.983 (Table1). This indicates the correlation in between them to be 'good' so far as its significance is meant to stochastically (Fig.2 & Table1).

As said earlier, the expression of conventional metacentric height = GM = PM – PG, where, PM = I/¥. The newly GM height is now going to be expressed in the following article *B*. Let's this be termed as GM* & PM* [i.e. GM and/or PM along with asterisk (*) mark define their corresponding modified values, as well] for GM & PM respectively for this newly altitudes for the floating body. This conventional 'GM' height, as being applied & manufactured for so long to various floating bodies, now by the application of this provisionary theoretical article is hereby laid down below.

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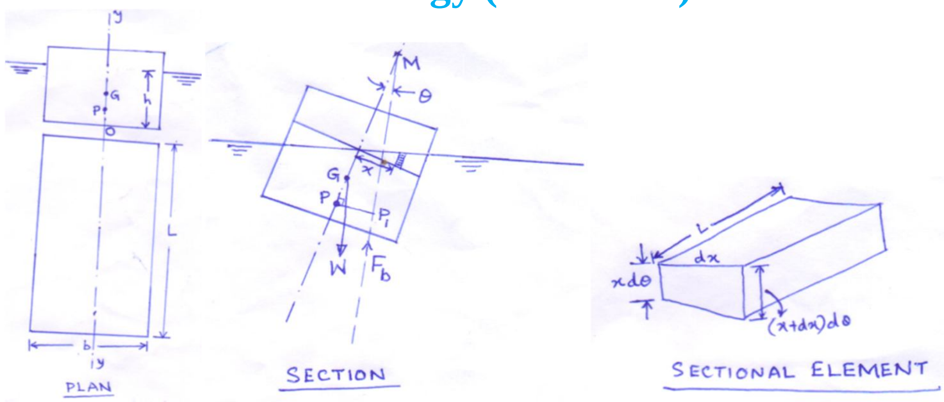

Figure1. Conventional Metacentric Height of a Floating Body

B. On the Path towards the Theoretical Overview over the Derivation of 'Metacentric Height (GM)*

Let, b = width of floating body at the liquid line (in Plan View); L = length of floating body at the liquid line (in Plan View); h = depth of submergence of floating body with respect to the liquid line.

Considering a small strip of thickness 'dx' at a distance 'x' from centre-line of a floating body as shown in the figure1, the derivation is as follows:-

Area = $(1/2)[xd\theta+(x+dx)d\theta]dx = (1/2)[2xd\theta+(dx)d\theta]dx$

Volume of the strip = V = $(1/2)[2xd\theta+(dx)d\theta]Ldx = (1/2)[2x\tan\theta+(dx)\tan\theta]Ldx$;

where, $d\theta=\tan\theta=dx/x$ & also, $\sin\theta=L.dx$

Weight of the strip, W = (specific weight)(volume) = $(\rho g)V$

Moment caused by the weight of the strip, $Mw = (W\cos\theta)(x+x) = (\rho g)(V\cos\theta)2x$

Therefore, $Mw = (\rho g)(\cos\theta)(x)[2x\tan\theta+(dx)\tan\theta]Ldx$ …(1)

Again, Moment evolved out due to the metacentre as well as the centre of gravity of vessel is given by

$Mm = (F_b)(PM)_x \tan\theta$ …(2)

where, F_b = Force due to buoyancy = $W\sec\theta$ & PM_x = Metacentric Height at the section(X-X) considered.

On equating equation(1) & (2) for equilibrium,

$F_b(PM)_x(\tan\theta) = (\rho g)(\cos\theta)(x)[2x\tan\theta+(dx)\tan\theta]Ldx$

$(W\sec\theta)(PM)_x(\tan\theta) = (\rho g)[2x^2\sin\theta + (xdx)\sin\theta]Ldx$

$(\rho g ¥)(PM)_x \sec^2\theta = (\rho g)[2x^2Ldx + (xdx)Ldx]$

Where, ¥ = volume of displaced liquid = volume of the submerged portion of vessel

= (ρg)weight of the displaced liquid = (ρg)weight of the submerged portion of vessel

Thereby, $(PM)_x = (\cos^2\theta/¥)[2x^2Ldx + (xdx)Ldx]$

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Integrating to obtain the Total BM of the above expression,

Total PM = PM* =$\int \sum$ [PM_x] = $\int$ [($\cos^2\theta$/¥){$2x^2$Ldx + (xdx)Ldx }] = [($\cos^2\theta$/¥){ $\int 2x^2$Ldx + $\int$ (xdx)Ldx}]

Thereby, Total PM = PM* = $\int$ $(PM)_x$ = ($\cos^2\theta$)[$\int 2\, x^2$dA + $Ab^2/8$](1/¥) = ($\cos^2\theta$)[I + $Ab^2/8$](1/¥)

where, I = $\int 2\, x^2 dA$ = Second Moment of area of the plan of the body at the free-liquid surface about the y-y axis.

Elemental area at the free-liquid surface = dA = Ldx; $\int$ Ldx = A = Total area

&, $\int\int$ (xdx)Ldx is given by(fig.1):-

$$\int_0^X \int_0^{Ldx} (dy)(dx) = A \int_0^{b/2} x\, dx = A\, [(x^2/2)]_0^{b/2} = Ab^2/8$$

Now, the Total PM's expression is given by:-
PM* = ($\cos^2\theta$/¥)[I + $Ab^2/8$] = ($\cos^2\theta$)[(I/¥) + (Ab^2/8¥)] = ($\cos^2\theta$)(I/¥)[1 + (Ab^2/8I)]
Finally, PM*= (I/¥)($d_n i_{Lbd}$) …(3)
where, biswas constant = $d_n i_{Lbd}$ = Dimensional Multiplying Factor

Therefore, biswas constant = $d_n i_{Lbd}$ = [1 + (Ab^2/8I)]($\cos^2\theta$) … (3.0a)

This 'biswas constant' ($d_n i_{Lbd}$) is the function of the particular dimensional parameters of the configuration concerned for a floating body of the desired 'GM' (i.e. GM*) height.
Therefore it's hereby concluded as it is clearly seen from Eq.3,
Newly PM = PM* = (*biswas constant*)(Conventional value of PM) = ($d_n i_{Lbd}$)(I/¥)
The variation of PM* with the angle of tilt (θ) is shown in the figure2, keeping the dimensional parameters (such as L, b, h & I) of the floating body to constant genre, except the varying values of 'θ' obviously.
Here in the fig.2, the pictorial delineation has been shown on both for polynomial as well as for linear trend-line basis. The pertinent defining equations have come out to be of the same for both types of curve and that is expressed as, y = (-) 0.039x + 1.136 & its profile is self-explanatory.

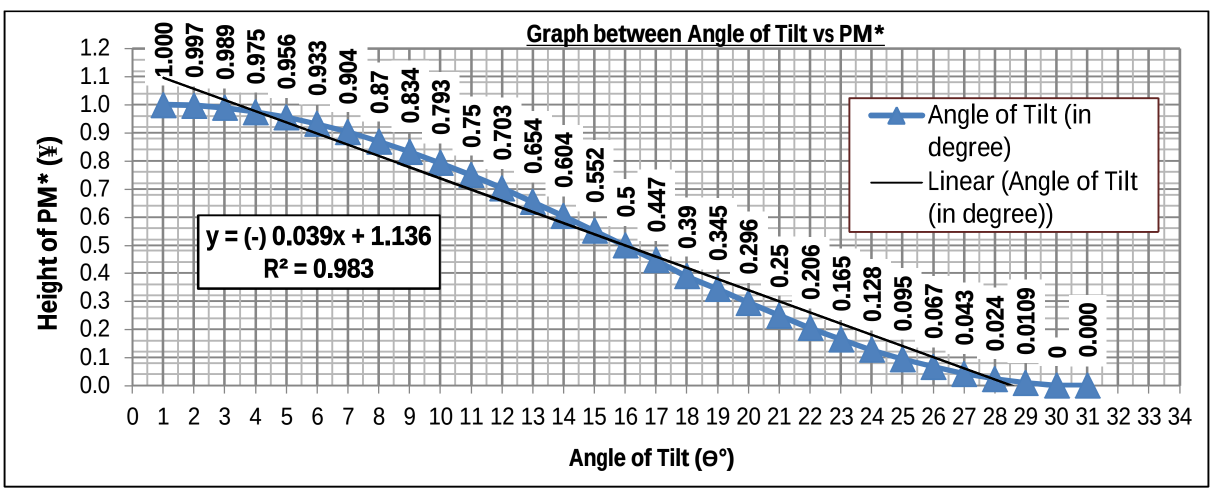

Figure2. Schematic Profile of the Variation of Governing Height (PM*) of Metacenre by Tilt (θ). (see Table 1)

Therefore, from the fig.1 we have for the floating body,

GM* = PM* – PG = PM* – PG = (I/¥)($d_n i_{Lbd}$) – PG …(3.0b)

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where, GM* = Newly obtained Metacentric Height ; &, its Modified PM = PM* = (I/¥)($d_n i_{Lbd}$).

PG = Height of center of gravity from the center of buoyancy = (OG – OP).

OG = Height of center of gravity from the lowest point (O) of the body.

OP = Height of center of buoyancy from the lowest point (O) of the body.

$d_n i_{Lbd}$ = biswas constant

This above expression (3.0b) is self-explanatory & it has later been shown in its field of use & it is the basic desired expression of the newly metacentric height for GM* of the floating body.

Mathematically, the equation of the newly metacentric height is hereby expressed as the multiplication of the function of angle of tilt (θ) & the corresponding configurational dimensions, i.e. GM* = f(θ)f(L,b,h) …(3.0c)

The eq.(3.0c) has been discussed later in the succeeding articles, as it goes on, for developing it into its furtherance.

Table1. Value of PM* vs Angle of Tilt (θ)

Sample No. (m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Parameters	θ	0°	3°	6°	9°	12°	15°	18°	21°	24°	27°	30°	33°	36°	39°	42°	45°
	PM*#	1.000	0.997	0.989	0.975	0.956	0.933	0.904	0.870	0.834	0.793	0.750	0.703	0.654	0.604	0.552	0.500

Sample No. (m)		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Parameters	θ	48°	51°	54°	57°	60°	63°	66°	69°	72°	75°	78°	81°	84°	87°	90°
	PM*#	0.447	0.390	0.345	0.296	0.250	0.206	0.165	0.128	0.095	0.067	0.043	0.024	0.011	$2.73*10^{-3}$	0.000

indicates that it gets lowered by 0.05 units in each subsequent interval.

C. Evaluation of Equilibrium Stability

For obtaining maximum tilt at its critical state,

d(PM*)/dθ = 0

1) $d[\cos^2\theta\,(I/¥+Ab^2/8¥)] = 0$
2) $-2\cos\theta\sin\theta = 0$
3) $\cos^2\theta + \sin^2\theta - 2\cos\theta\sin\theta = 1$
4) $(\sin\theta - \cos\theta)^2 = 1$
5) $\sin\theta = \cos\theta + 1$
6) $2\sin(\theta/2)\cos(\theta/2) = 2\cos^2(\theta/2)$
7) $\sin(\theta/2) = \cos(\theta/2)$
8) $\tan(\theta/2) = 1 = \tan 45°$
9) $\theta/2 = 45° = \Pi/4$
10) $\theta_c = \theta_{critical} = 90°$

Hence, the value of the $\theta_{critical}$ will be either 90° or 180° on the either side of its rotating axis (i.e about y-y axis).

So, $(\theta)_{critical} = \Pi$ or $\Pi/2$, subject to the provisionary changes in dimensional configuration of the body in particular. (Fig.2 & Table1 may be suggested in for this).

D. Condition for Maximum value of GM Evaluation*

Let's assume, a = Total height of the floating body in Sectional View (fig.1).

By %age distribution, maximum value of this newly GM, i.e. GM* can be obtained with respect to the conventional GM value, functionally (Article *G & H.*).

Mathematically, with the help of the derivation mechanism, the maximum value of GM* is as follows, subject to the configurational dimensions (discussed in article *J.*) as adopted in it. This (similitude analysis) may be varying as the case may be, depending on its vector independency.

Therefore, from fig.1we have, GM* = PM* – PG = PM* – (OG - OP) = PM* – (a/2 – h/2)

$GM^* = (\cos^2\theta)[(I/¥) + (Ab^2/8¥)] – (a/2 – h/2)$

For the maximum of GM*, d(GM*)/dh = 0

$d[(\cos^2\theta)\{(I/¥) + (Ab^2/8¥)\} – (a/2 – h/2)]/dh = 0$

$\{ \cos^2\theta \}d(I/¥)/dh + \{ \cos^2\theta \}d(Ab^2/8¥)/dh – d(a/2)/dh + d(h/2)/dh = 0$

$\{\cos^2\theta\}d(I/¥)/dh + \{ \cos^2\theta \}d(Ab^2/8¥)/dh + 1/2 = 0$

where, $d[(\cos^2\theta)Ab^2/8¥]/dh = (\cos^2\theta)d[Ab^2/(8bLh)]/dh = (-)(\cos^2\theta)[Ab^2/(8bLh^2)]$

$= (-)(\cos^2\theta)[Ab^2/(8bLh^2)]$

Thereby, $d[(\cos^2\theta)(I/¥)]/dh - (\cos^2\theta)[Ab^2/(8bLh^2)] + 1/2 = 0$

Multiplying 'h' on both sides,

$\cos^2\theta(I/¥)dh/dh - (\cos^2\theta)[Ab^2h/(8bLh^2)] +h/2 = 0$

$(\cos^2\theta)(I/¥) = (\cos^2\theta)[Ab^2h/(8bLh^2)] - h/2$

$(I/¥) = [Ab^2h/(8bLh^2)] - h/(2\cos^2\theta) = [Ab^2/(8bLh)] - h/(2\cos^2\theta)$

Thereby, $(I/¥) = [Ab^2/(8¥)] - h/(2\cos^2\theta)$; where, ¥ = Volume at the free liquid surface = (bL)h

Finally, $(I/¥) = [Ab^2/(8¥)] - h/(2\cos^2\theta))$ …(4)

The equation(4) is the required expression for governing criteria of the maximum metacentric height (GM*).

Simplifying the Eq. 4,

$(I/¥) = [Ab^2/(8¥)] - h/(2 \cos^2\theta) = [Ab^2/(8¥)] - h/(1+ \cos2\theta) = [Ab^2/(8¥)] – h(1- \cos2\theta)/(1- \cos^22\theta)$ ...(4.a)

$(I/¥) = [Ab^2/(8¥)] – h(1- \cos2\theta)/\sin^22\theta) = [Ab^2/(8¥)] – h(1- \cos2\theta)/\sin^22\theta)$ ...(4.b)

Again, $(I/¥) = [Ab^2/(8¥)] – (h/2)\sec^2\theta = [Ab^2/(8¥)] – h[1+ \tan^2\theta]/2$ …(4.c)

The equation (4) will be the condition for acquiring the max. of the metacentric height (GM*), as well.

E. Simplification of the Expression of GM by some Exemplary Dimensional Configuration of floating body*

E.1) Square Floating Body:-

As per the equation (3.0), $PM^* = (I/¥)(d_n i_{Lbd})$

For the case of a body of square plan area bxb keeping the others are same,

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The *biswas constant* is given by, $d_n i_{Lbd} = [1 + (Ab^2/8I)](\cos^2\theta)$.

From the fig.1, Area, $A = (b)(b) = b^2$, $I_{y-y} = b(b^3/12)$

Therefore, $(\textit{biswas constant})_{square} = (d_n i_{Lbd})_{square} = (\cos^2\theta)[1 + (b^2b^2)/(8bb^3/12)] = 2.5\cos^2\theta$

Let, $d_n i_b$ = biswas ½ value constant = $(2.5)\cos^2\theta$;

Therefore, $(PM^*)_{square} = (I/¥)(d_n i_b) = (I/¥)(2.5\cos^2\theta)$ ...(E.1)

Further, $(PM^*)_{square} = (b^4/4.8¥)\cos^2\theta$ …(E.1a)

E.2) Rectangular Floating Body:-

For rectangular plan area Lxb keeping other parameters are same,

$(PM^*)_{rectangular} = (\cos^2\theta)(I/¥)[1 + (bL)(b^2)/(8Lb^3/12)] = (2.5)\cos^2\theta(I/¥)$ …(E.2)

As, biswas ½ value constant (as obtained earlier) = $(2.5)\cos^2\theta$

So, $(PM^*)_{rectangular}$ = (I/¥)(biswas ½ value constant) ; Therefore, $(PM^*)_{rectangular} = (PM^*)_{square}$

Further, $(PM^*)_{rectangular} = (bL^3/4.8¥)\cos^2\theta$ …(E.2a)

It is clearly thereby obtained that the equation of BM* is same for both of square & rectangular floating body.

Thereforth, PM* = (biswas ½ value constant)$_{rectangular\ or\ square}$ (I/¥)

Conversely, $PM^* = (I/¥)(d_n i_b)_{rectangular\ or\ square}$ ...(E.2b)

where, $d_n i_b$ = biswas ½ value constant = $(2.5)\cos^2\theta$

The biswas ½ value constant ($d_n i_b$) is the dimensional factor of the '*biswas constant*' ($d_n i_{Lbd}$) of the particular configuration of the floating body which is same for both of the article (E.1) & (E.2) just described above.

Functionally & Generally, the same expression of PM* is hereby given as:

PM* = (biswas ½ value constant)(I/¥) – it is valid for both configuration of square & rectangular body.

This above expression (E.1 & E.2) is, therefore, self-explanatory & it has later been shown in its various fields of use.

E.3) Straight Floating Body with Spherical Ends:-

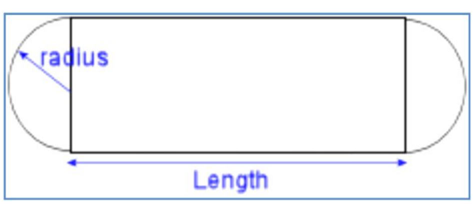

Figure 3. Plan view of Floating body with spherical ends

Considering a floating body having straight length 'L' with its spherical ends of radius 'b/2' as shown in the fig.3,

Total Area, $A = (\Pi/4)b^2(1/2)2 + Lb = (\Pi b^2/4) + bL$

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Moment of Inertia, $I = (\Pi/64)b^4(1/2)2 + Lb^3/12 = (\Pi b^4/64) + Lb^3/12$

Now, biswas constant is given by: $(d_n i_{Lbd}) = [1 + Ab^2/8I](\cos^2\theta)$

where, $Ab^2/8I = [\{(\Pi b^2/4) + bL\}b^2]/[\{(\Pi b^4/64) + Lb^3/12\}]8$

$(1 + Ab^2/8I) = (9\Pi b + 80L) / (3\Pi b + 32L) = (9P1 + 80L)/(3P1 + 32L) = (9P1 + 80A1)/(3P1 + 32A1)$ …(5)

where, P1 = perimeter of the spherical surface (for each of both the ends) = Πb

A1 = surface area of the straight portion of the body per unit width = (A/b) = L

From Eq.(5), we get, $[1 + Ab^2/8I] = (9P1 + 80A1) / (3P1 + 32A1)$

$= [9(P1/ A1) + 80] / [3(P1/A1) + 32]$

$= [(9+80P_h)/(3 + 32P_h)]$

where, P_h = ratio of surface area to surface perimeter = A1/P1 = biswas ratio of hydraulic depth

By the equation (3.0a),

biswas constant = $(d_n i_{Lbd}) = [1 + Ab^2/8I](\cos^2\theta) = (\cos^2\theta)[(9+80P_h)/(3 + 32P_h)]$

As per the *equation* (3.0), $PM^* = (I/¥)(d_n i_{Lbd})$

Further, $PM^* = (\cos^2\theta)(I/¥)[(9+80P_h)/(3 + 32P_h)] = (\cos^2\theta)(I/¥)i_{p.h}$

where, $i_{p.h}$ = biswas progressive value (integer value>1) of the particular configuration concerned

$i_{p.h} = [(9+80P_h)/(3 + 32P_h)]$

*The 'biswas progressive value' ($i_{p.h}$) is the dimensional modification of biswas constant ($d_n i_{Lbd}$) of the particular configuration of floating body which is found to be slightly greater than both of the values given in the article (*E.1*) & (*E.2*).*

Therefore, PM = ($\cos^2\theta$)(biswas progressive value)(I/¥)*

$PM^* = (\cos^2\theta)\ (i_{p.h})\ (I/¥)$ ...(6)

So, it is evidently shown that for a straight floating body with spherical ends the GM* value will be higher than the previous floating body of square & the rectangular one. The 'biswas progression constant' ($i_{p.h}$) will be having the effect cause increase in the value of GM*, so obtained.

It should hereby be noted that the corresponding dimensional similitude should have to be performed, as described in the succeeding article (i.e., article *J*), for each of the configurations stated above.

*F. An exemplary subjective form of the expression of PM** - The newly expression of PM* has several applications of use, as many of its well-known regards as applied by the conventional one. Here is an approach of a pattern of a body, rectangular in plan, has been shown (fig.1) to find out the not-so-different but useful the expression of PM*.

The expression of PM* as obtained (from eq.1), $PM^* = \cos^2\theta\ (I/¥+Ab^2/8¥)$

For the rectangular plan (bxL) of a floating body, it can also take the following functional form as -

$PM^* = [\{2Lb^3 + 3Ab^2\}/24(hbL)] = A[b^2 + 1.5b^2]/[12(hA)] = 2.5\ b^2/(12h) = b^2/(4.8h)$

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Thereby, PM* is further expressed by: $PM^* = f(\theta)[b^2/(4.8h)]$

$$PM^* = Cos^2\theta\ [b^2/(4.8h)] \qquad \text{…(F.1)}$$

So, the equation (3.3) is a ready-made equation to use by its dimensions.

Similarly, owing to the fact of the differently configured floating body, the above particular expression (eq.F.1) can also be suitably used & the lineal length (L), here by its property itself, should be so provided that the value of b/h ratio is properly satisfied by the conditional equilibrium, i.e. GM* >PG.

It should hereby also be noted that the lineal dimensions can also get selected through the subsequent scale ratios as derived by the dimensional analysis later as it to be implemented for the entire particularities as the case may be.

Mathematically,
$PM^* = f(\theta)f(L,b,h)$; where, $f(L,b,h) = (I/¥+Ab^2/8¥)$ & $f(\theta) = Cos^2\theta$.

From fig.1, it shows that L, b & h corresponds to its length, width & its liquid-depth of submergence respectively.
Thereby, $f(L,b,h) = (I/¥+Ab^2/8¥) = [\{Lb^3/(12)hbL)\}+\{Ab^2/8(hbL)\}]$

*G. Exemplary glimpses of a Comparison between the Conventional 'GM' & the newly 'GM', i.e. GM**

An example is sufficient to propagate ideas about how the newly propounded 'GM' (i.e. GM*) is more advantageous. Based on this exemplary instance the Table2 & Table3 have been determined. Here is given that.

Suppose, a wooden block in the form of a rectangular prism floats with its shortest axis vertical. The block 40 cm long, 20cm wide & 15cm deep with a depth of immersion of 12cm. Let's calculate the position of the metacentre & make some comment on the stability of the block. Here is its solution.

Weight of 1cm^3 of liquid (let's it be water) = $(9.79)10^{-3}$ N

Weight of the floating body = Weight of the displaced volume of water = $(12)(20)(40)(9.79)10^{-3}$ N = 93.98 N

Now the two cases will arise as to make it happen by the anticipatory objective of this theoretical paper.

G.1. Case-1) By Conventional Metacentric Height (GM) Formula

OP = Height of Centre of Buoyancy above the base of the block = 12/2 = 6 cm

OG = Height of Centre of Gravity of the block above O = 15/2 = 7.5 cm

If 'M' is the metacentre, PM = I/¥

Where, I = Moment of Inertia of the water line area about OO' (i.e. about y-y axis) = $(40)20^3/12 = 26666.67\ cm^4$
¥ = Volume of fluid displaced by the body = (12)(20)40) cm^3 = 9600 cm^3

Hence, PM = I/¥ = $(40)20^3/\{(12)(20)(40)(12)\}$ = 26666.67/9600 = 2.778 cm

The conventional GM = PM - PG = PM – (OG-OP) = 2.778 - (7.5 - 6.0) cm = 1.277 cm

Since, M is above G, the body is in stable equilibrium.

G.2. Case-2) By the Newly Metacentric Height (GM*) Formula

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If 'M' is the metacentre, PM* can be written as, $PM^* = Cos^2\theta\ (I/¥+Ab^2/8¥)$

Thereby, $PM^* = f(\theta)f(p)$ …(G.2)

where, p = Factor of $GM^*=(I/¥+Ab^2/8¥)$

Now, Area (Lineal) = A = 20 x 40 cm^2 & width, b = 20cm.

Thereby, $p = [(2.778) + (40)\ (20)(20^2)/(8)(9600)]cm = 6.944$ cm

From Eq.(G.2), we have, $PM^* = 6.944f(\theta)$ …(G.3)

Now by eq. (G.3) & from fig.2, PM* can easily determined once & for every time of the oscillation of the floating body & also is its corresponding values of GM*.

Now, let's check out the variation in the subsequent value of GM for each of the above cases on the basis of angle of tilt. The article *'C'* may hereby be kept aside for its delineation purposes.

G.2.1. When θ = 0° (i.e, at stationary and/or when the body is not tilting on its either sides aside)

Applying eq.3 & Table1, we get, PM* = 1(6.944) = 6.944 cm; GM* = 6.944 – 1.5 = 5.444 cm

Now, let's calculate the percentage change with respect to its Conventional parameters & have a look on its variations correspondingly (Table2 & Table3).

Let the %age change for PM & GM be designated by PM'' & GM'' respectively.

It has been found by that the %age change in the value of PM (i.e. from PM to PM*) = PM''= 149 % (increase) & %age change in GM (from GM to GM*) = GM''= 326% (increase).

G.2.2. When θ = 45° (i.e, when the body is tilting on its either sides aside by 45°)

Applying eq.3 & Table1,

we get, PM* = 0.5(6.944) = 3.472 cm (based on the critical equilibrium/stability of the body)

Subsequently, GM* = 1.972 cm. Similarly, %age change in PM* = 25%; & %age change in GM* = 54.35%

Likewise, the other alike features also exist with their full prevalence over PM* & GM* by several of its magnitudes on the basis of the Table1 & Table2. That discussion is little later described in the article *H.* And, the above comparative depiction is so self-explanatory that the changes, for which this journal paper is concerned, can well then be perceived. Table2 & Table3 show its completeness.

H. Slope of the 'GM' plane

Now, the gradients of the planes consisting of the metacentre (M), G, P and its corresponding connecting lineal surfaces are forming the active cone-shaped planes. This acting planar surface of the gradient(s) is hereby termed as '***biswas plane(s)***'. Nonetheless to proclaim that these planes are of numerous by number by its own nature of act. Values of one of such kind of ***biswas plane(s)*** of alike genre are also hereby shown in the Col.(9) of the same tabular format of Table2 below, in order to have some knowledge about it.

The Table2 implies the schematic idealization of the active planes of PM as well as PM* along the lineal width, length & depth of the body (fig.1). Its corresponding percentage changes in the value of GM* for the different lineal directions are also depicted in the Table3 below.

Table2. Planar Gradient in the Value of GM*

Sl. No.	Dimensional Elemental Parameter	Lineal Value (cm)	Case	Name of Comparative Element(s) for Metacentric Height	Original Comparative Respective Elemental value (cm) of Metacentric Height	Name of Rate of Metacentric Height (i.e. Elemental Rate per Lineal Dimension)	Value of Rate of Height = Original value divided by its Lineal value [Col.(5)/ Col.(3)]	Comparative value of Slope, θ, on the acting plane of Metacentric Height (degree)	
Col.(1)	Col.(2)	Col.(3)	Col.(4)	Col.(5)	Col.(6)	Col.(7)	Col.(8)	Col.(9)	
1	Width	20	Art.*G.1.* (Case- I)	Conventional GM	1.277	GM/unit width	0.0639	1 in 15.65	3.65°
						GM/unit length	0.0319	1 in 31.30	1.82°
2	Length	40				GM/unit depth	0.1064	1 in 9.39	6.05°
			Art.G.*2.* (Case-II)	Newly GM i.e., GM*	1.972	GM*/unit width	0.0986	1 in 10.14	5.63°
3	Depth	12				GM*/unit length	0.0493	1 in 20.28	2.82°
						GM*/unit depth	0.1643	1 in 6.08	9.31°

The Table.3 expresses the lineal variation (GM") in the value of metacentric height in relation to the Conventional GM & the modified GM (i.e. GM*) at one glance. Its corresponding values of PM are justly nonetheless.

Table3. Percentage Variation in the Value of Comparative Value of GM

Sl. No.	Lineal Direction	Value of Rate of Metacentric Height		%age increase in GM (i.e. GM")
		Initial GM (i.e. Conventional GM)	Newly GM (i.e. GM*)	
1	Width-wise	0.064	0.099	54.42
2	Length-wise	0.032	0.049	54.42
3	Depth-wise	0.106	0.164	54.42

J. Dimensional Synthesis

Obviously, mainly & certainly the Geometrical parameters govern in formulating the 'GM' entirely. It may be useful & having the targets in relation of breaking this independency of scalars within the region of itself for some cases of the field concerned in except of this. Because, the expression of the total resistance (sum of the either case as described above) is required as a function of 'GM' height and/or velocity, in order to do so. This is also a matter of concern to be decided on to go on to its subjective furtherance. As for the information, there is also kinematic & dynamic similarity – it's now out of scope of this present scenario of this literature, although it may appear to become of its next steps of furtherance. On the basis of the methodology established by the prominent scientist William Froude, the resistances (the wave resistance & the frictional resistance) offered by the floating body can be best expressed & determined as well. Reynold's equation is also needed in this regard to go to its useful extents using the expression of 'GM' height as obtained by this literature.

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Behavior of this newly 'GM' height (i.e. GM*) can hereby also be implemented examiningly to have numerical values of the resistances. Thus, the entire scenario will definitely get a new (revised) outlook simultaneously alongwith the unfolding of the other governing elements. Therefore, the theoretical expression of 'GM" height is henceforth in most utility of diversive dimensions to evaluate its effect on its entire regions and/or domains with regards to the total resistance of floating body such as ship, vessel & alike bodies is as followed in article *J.1* below, with respect to the similarity required as per the equation (3) as it expresses to.

J.1. Geometric Similitude

Here, the expression of similitude for a prototype & its corresponding model has been evaluated.

The dimensional synthesis is done to determine the dimensions (given by scale) applicable to obtain the desired feasibility of the object concerned (fig.1).

J.1.1. Dimensional Similarity

The Geometrical similarity has been found to be acting as per the modified equation of metacentric height (eq.3) & is hereby described on the basis of its geometrical dimensions for getting its potential similarity subsequently.

Geometrical Similitude -

We have the governing expression of Metacentric height(GM) as,

$PM^* = (\cos^2\theta)[(I/¥) + (Ab^2/8¥)] = (\cos^2\theta)[(bd^3/12¥) + (bd)b^2/8¥)]$

$= (\cos^2\theta)(bd^3/12¥)[1+ (1/d^2)(12b^2/8)] = (\cos^2\theta)(I/¥)[1+ (3/2)(b/d)^2]$

$= (\cos^2\theta)(I/¥)[1+ f^2]$; where, f = Geometrical Similitude Factor =(3/2)*(b/d)

Therefore, $PM^* = (\cos^2\theta)(I/¥)[1+ f^2]$ ...(J.1)

Now, as per law of geometrical similitude the following scale ratios are obtained:-

Let model & its prototype be designated as by the subscript of the letter 'm' & 'p' respectively. And, Scale ratio is being termed by the subscript of the letter 'r', correspondingly.

Thereby,

Scale ratio for length (i.e., simply, Scale ratio) = $L_r = L_p/L_m$;

Scale ratio for area (i.e. Area ratio) = $A_r = A_p/A_m$;

and, Scale ratio for volume (i.e. Volume ratio) = $¥_r = ¥_p/¥_m$

Moreover, Scale ratio for Geometrical Similitude Factor = $f_r = f_p/f_m$

Now, for the expression to be said with respect to geometrical similitude,

the scale ratio for the geometric height is given by the eq.(J.1),

$(PM^*)_r = (PM^*)_p/(PM^*)_m$

$= (\cos^2\theta r)(I_r/¥_r)[1+ f_p^2]/[1+ f_m^2]$

$= (\cos^2\theta_r)(I_r/¥_r)[1+ f_m^2 + f_p^2- f_m^2]/[1+ f_m^2]$

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$= (\cos^2\theta_r)(I_r/¥_r)[\ 1+ (f_p^{\ 2}\text{-}f_m^{\ 2})/(\ 1+ f_m^{\ 2})]$

$= (\cos^2\theta_r)(I_r/¥_r)[\ 1+ \{(f_r^{\ 2}\text{-}1)/\{(1/f_m)^2\text{+}1)]$

$= (\cos^2\theta_r)(I_r/¥_r)[\ 1+ \{(f_r^{\ 2}\text{-}1)/(1/f_m^{\ 2}\text{+}1\}]$

Assuming, $(1/f_m)^2$ ~ negligible & considered to be as 1.

Hence, $(PM^*)_r = (\cos^2\theta_r)(I_r/¥_r)\ [\ 1+ (f_r^{\ 2}\text{-}1)/2] = (\cos^2\theta_r)(I_r/¥_r)(\ 1+ f_r^{\ 2})/2$ …(J.2)

The expression (J.2) is self-explanatory & is the required expression for its further analysis for getting its corresponding modeling structures of the desired prototypes as well, in order to get desired results as the case may be.

$PM^* = (\cos^2\theta)[(\ I/¥) + (Ab^2/8¥)] = (\ p)\ Cos^2\theta$; where, $p = [(\ I/¥) + (Ab^2/8¥)]$

The factor 'p' is the Factor of GM which is nothing but the function of the biswas constant ($d_n i_{Lbd}$).*

By considering the 'p' factor as constant, values of the governing parameter PM* have been obtained for various values of angle of tilt(θ°) & it is shown in the above Table1 which has earlier already been depicted in a graphical format in the fig.1 which is self-explanatory on its basic application ground & also on its several of other aspects.

K. Major Findings

K.1 ***Application (& Future Scopes)*** **-** The following applications of this theoretical article are hereby expressed on the basis of its utmost utility. The related statistical extractions are in article *K.2* below. The foregoing comparative discussions show the objectives of this literature more clearly.

K.1.1 Application of Statistical Approach

i)The graph (Fig.1) shows that the behavior of the curve follows by the rule of the following governing equation, i.e. y = (-) 0.039x+1.136. Apart from the graph (Fig. 2) based on the equation (3) as depicted in the article *A*, the other useful ones should be –

1) PM_r vs f_r for various values of θ_r (for different fixed values of $I_r/¥_r$ on each graph).
2) PM_r vs θ_r for various values of f_r (for different fixed values of Ir/¥r on each graph).
3) PM_r vs θ_r for various values of $I_r/¥_r$ (for different fixed values of f_r on each graph).
4) PM_r vs f_r for various values of $I_r/¥_r$ (for different fixed values of θ_r on each graph).
5) PM_r vs $I_r/¥_r$ for various values of θ_r (for different fixed values of f_r on each graph).
6) PM_r vs $I_r/¥_r$ for various values of f_r (for different fixed values of θ_r on each graph).

All these graphs along with its curves & their numerical equations, once established, will be able to clearly describe their explanatory features & thereby the corresponding purposes of the objectives of this literature will be met subsequently.

ii) It is clear from Table1 that the Statistical analysis shows the value of standard deviation belongs to 0.459 (about 0.46) which indicates that the modal position of the frequency distribution curve of the equation (3) will lie slightly skewed to the left.

iii) There is better positioning with respect to standard deviation (article *K.2*) to improve the entire analysis by simplifying its modal position to the location of the standard mean of the normal distribution curve; thereby the metacentric height as well as the full governing stability can also be able to be attained more safely by the corresponding adjustments.

iv)The probability distribution curve, after shifting & adjusting properly by the transference of modal to the standard mean position, should be satisfying the criteria, i.e $\int f(x)dx = 1$ & will be more of firm basis for its exact analysis & its corresponding useful derivations.

v) The correlation coefficient (R^2) has been found to be 0.983 which is expressing a 'good' correlation amongst the parameters of the equation3.0, with regards to the statistical approach (fig.2).

vi) The equation of the linear variation is also having the same equation as that obtained by the curve & i,e. y= -0.039x+1.136(as obtained from Fig.1). It is also very useful in the purposes being aimed on.

K.2 Statistical Analysis

The thirty one (31) samples have been tested & analyzed statistically. The equation (3) is the governing one in doing that. Also the equation (3.0c *& F.1*) should be consulted herein with for its pursuitous results as by those so obtained & shown in the Table 1. This table is one of the most usefulness that describes the exact significance of the theoretical evidences of this literature, as well (Fig.2).

K.2.1 Statistical Derivations

The extractions of the values given in Table1 have been obtained as per the general synthesis of fundamental mathematical equation explained in article *B* & it's also a self-explanatory one.

The following statistical elements for the samples have been obtained as follows:-

Mean = m' = (1/31) $\sum m_i$ = 0.895; where, i be the sample number.

Standard Deviation (σ) is found to be as,

$\sigma = \sqrt{[\{\sum (m_i - m')^2\}1/(m-1)]} = 0.459$

Variance = σ^2 = 0.211

These statistical elements are having the correlation with the governing parameters of metacentric height & shown in Table1 & Fig.2.

L. Prohibition & Precautionary Measures

a) The Liquid medium through which the floating body will keep moving should be within the permissible limit of its relative density particularly as specified by the equation (3) for maintaining stability, in addition to the other criteria of safely floats. Let this medium be Water as for this literature's consideration.

b) The 'p' factor should always be checked & correctly implemented on order to avoid any unavoidable discrimination which is far of stability.

c) Angle of tilt (θ) should never be allowed to go further beyond its permissible stats also.

d) They configuration should be justified with at par the value of standard deviations & its variances, indeed.

f) The Correlation Coefficient [as propounded & extracted by Fig.2] as defined in various graphs of different features of the floating body should also be such imparted along with its body itself that the entire mass becomes accustomed with its readily stable mechanics over the dynamic maneuvering on the waves of fluids.

g) As 'GM*' is inversely proportional to '¥', therefore, the metacentric height depends on the fluid's unit weight. This implies not to neglect the several aspects of the flowing liquid such as its salinity, hardness, oil-smeared, afresh, etc., while deriving the dimensional configuration of floating body. It's giving the advantageous tunes on its (GM*'s) widenesses.

h) The various unrestraint terrestrial (both latitudinal & longitudinal) considerations should be properly ascertained into selecting the governing parameters like θ, rolling speed & etc. for combating against the atmospheric calamities so caused to.

i) In furnishing point no.(h) above, the newly height of GM should be chosen corresponding to the nature of courses of the floating body. In regards of this to be on safety, the several configuration of floating body will have to be separately designed. In addition, some courses that are unavoidable but also at the same time risky, should be marked as '*warding off zone*' which should be abided as long as the special zones persist of.

j) Some zones on the floating body like that of the flowing courses should also have to be demarcated by the guidelines of 'special zone'. These zones will be at the locations of its possible dangers on the floating body. Say, a vessel is so longer enough that its middle portion needs to be protected from any overburdening & other criterion to be within the permissible features; so it's to be left empty on its few yards of protective distances. Thereby, some precautionary message can be deputed thereon by providing sign-board serving the message of 'special zone'. Moreover, no such extra load and/or staying of anybody much longer there should be prohibited & totally stopped for its safety purposes. Although for safety, these special zones may be different (by magnitudes and orientations) for differently configured floating body.

j) 'Always to be in use of remote sensing techniques' – this should be maintained as much as possible in every floating body in circumstances of needy extrusions.

k) With a view of equation 3.0b for GM* height, some auxiliary units all along the surface (along inside as well as outside perimeter) of floating body can be attached to easily. So, these will also have to be provided & designed with a purview of its easy winding up by mechanical system while it necessitates. Such folding & unfolding methodology & its required machinery parts can be provided simultaneously, as the states come by, to enjoy the extra widths as provided by the eq. (*J.1*) of the newly derived metacentric height.

l) Architectural-like arrangements may also be on its floating body to mould over it as a guise of the floating body. Apart from abiding the bodily mechanics considering it as an extra load, it should always pertain & conform to the guidelines as followed by the above point no. (k) & (b), especially regarding its use on folding and/or unfolding aspects, by safety.

III. CONCLUSION (INCLUDING FUTURE SCOPE)

Following conclusions are hereby given along with some more views of future scope of work –

A. Velocity plays the governing role in maintaining the stability with regards to the metacentric height. Also, the classified velocities along the rolling & pitching component of a floating body are the main matter of concern, although. So, equation of velocity, if expressed rationally as a function of GM* height [eq. (3)], becomes dimensionally essential to its further synthesis by dynamic similarity also.

B. Dimensional analysis of dynamic similarity (esp. by Reynold's model law, most appropriately) of the floating body in connection with the above-said expression of velocity is then required to be examined for the same purpose of as required by, on reaching the purview of this article also.

C. From the Geometric similitude analysis (article *J*), the scale ratio required for the GM* height for prototype & its corresponding model has been devised & expressed by equation (*J.1*) to establish the certain methodology for its ultimate propagations.

D. Detailed atmospheric parameters are also required to be necessitated, controlled & implemented to have the overall balance on voyaging, else. In this connection, remote sensing appurtenances shall have to be applied as a must basis.

E. As per equation (3.0b), it is nonetheless that the modified GM height (i.e. GM*) has been found to be higher that its previous conventional measure of the height, irrespective of the region (i.e., range) of its variety of values in the metacentric height as it be applied to different floating bodies.

F. This GM* value is nonetheless, advantageous with its several aspects of needs, passion & compliments by now-a-days lives.

G. The additive term "$Ab^2/8$" corresponds to the bodily and/or geometric dimension of floating body. This means that it pertains to more stability of the body by deriving more spaces ontowards.

H. In the final form of equation (3), the angle of tilt (θ) is in the form of "$Cos^2\theta$". It implies the purview of delineations of the oscillating floating body with advancement over its stability. Also, the extended maneuver to which the floating vessel will be able to go at the considerations of its ranging capabilities is also obviously another utility of the simultaneous advantages.

I. The combined effective utilization of concluding point no. (g) & (h) above will ultimately forgo to & enhance the simultaneous benefits, i.e., the provision of more & more spaces (including auxiliaries) and the stability with more accuracy in itself, indeed.

J. Lastly but not the least, the expression as published by this article has multi-facets of deliverance of the dimensionally diversified features (as on the 'I' value, technically & most appropriately) by of its applications, as well, for undergoing experiences over the several geometrical floating bodies.

K. Moreover, the precautionary measure should be properly maintained almost at dangerous locations all through of a floating body. Because, any incremental effect of loading's placing may create causation of danger incrementally on that courses of the floating body.

L. Also, the application including mechanical as well as physical should be transformed to digitization by operating system (so-called 'App' system) of modern advanced technology, as on the present mobile-age fast-life 21st Century the pace of transport facility goes on rising not only on day-by-day, but it's by hours-to-hours. It'll then be so speedily efficient.

IV. RECOMMENDATIONS

In addition to the findings described above, the following recommendations are just an incremental increase over the prior ones as having been… – that is perhaps the unending versions. Let's have a glimpse on that –

A. Additionally, keeping in views of all the aspects of the general & its technological applications in making the entire maneuverings completely & perfectly, the governing system of a floating body should run under the guidance of some system-generated software which will satisfyingly be able to assure the complete & entire system's safe run, both on physical ground & its technological fields, with respect to this newly metacentric height, GM*, particularly.

B. Besides several future aspects of the GM* height, there should obviously be able to have the correlations amongst the various shaped floating bodies like rectangular, circular, spherical, hemispherical, trapezoidal etc., in their plan-view dimensions subsequently which should further not be having any such present deficits & the turbulences as it so having been got causing to onto the floating bodies since…

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REFERENCES

[1] K Subramanya, 1000 Solved Problems in Fluid Mechanics (includes Hydraulic Machines), Tata McGraw Hill Publishing Company Limited, 2006 Edition.
[2] Dr. P.N.MODI & Dr. S.M.SETH, Hydraulic And Fluid Mechanics including Hydraulic Machines, Standard Book House, 18th Edition, 2011.
[3] Dr. R.K.Bansal, A Text Book of Fluid Mechanics and Hydraulic Machines (S.I. units), Laxmi Publication (P) Ltd., New Delhi, March 2002 Edition.