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Hydrological Determination of Turbomachinery Potential in Current

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***Abstract*— Electrical energy production from ocean current needs more computational research where we can easily determine the capacity about wave currents by numerical analysis. This is the reason why we have compared different computational methods to have one similar methodology about the determination of process control.**

Extracting electrical energy from ocean currents could yield in excess of 10 TWh/year (0.4 EJ/year) if major estuaries with large tidal fluctuations could be tapped. Because the density of water is more than 830 times that of air, an ocean current of just 2.3 m/s can produce electricity at a rate equivalent to a mean annual wind speed of 62 m/s. The best sites in the world with currents about 10 m/s are located mainly off of the west coasts.

***Keywords*— Hydrology, potential, turbomachinery, technology of current measurements, partial differential equations**

I. Introduction

Electrical energy production from ocean current needs more computational research where we can easily determine the capacity about wave currents by numerical analysis. This is the reason why we have compared different computational methods to have one similar methodology about the determination of process control.

Extracting electrical energy from ocean currents could yield in excess of 10 TWh/year (0.4 EJ/year) if major estuaries with large tidal fluctuations could be tapped. Because the density of water is more than 830 times that of air, an ocean current of just 2.3 m/s can produce electricity at a rate equivalent to a mean annual wind speed of 62 m/s. The best sites in the world with currents about 10 m/s are located mainly off of the west coasts.

II. Introduction To PDEs

An easy way to comply with the conference paper for1. Introduction to PDEs

A partial differential equation is simply an equation that involves both a function and its partial derivatives. In these lectures, we are mainly concerned with techniques to find a solution to a given partial differential equation, and to ensure good properties to that solution.

That is, we are interested in the mathematical theory of the existence, uniqueness, and stability of solutions to certain PDEs, in particular the wave equation in its various guises. Most of the equations of interest arise from physics, and we will use x, y, z as the usual spatial variables, and t for the the time variable. Various physical quantities will be measured by some function u = u(x, y, z, t) which could depend on all three spatial variable and time, or some subset. The partial derivatives of u will be denoted with the following condensed notationmatting requirements is to use this document as a template and simply type your text into it.

$$u_x = \frac{\partial u}{\partial x},\ u_{xx} = \frac{\partial^2 u}{\partial^2 x},\quad u_t = \frac{\partial u}{\partial t},\ u_{xt} = \frac{\partial^2 u}{\partial x \partial t}$$

The Laplace operator is the most physically important differential operator, which is given by margins must be set as follows:

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

2.1 Equations From Physics

Some typical partial differential equations that arise in physics are as follows. Laplace's

$$\nabla^2 u = 0$$

which is satisfied by the temperature u = u(x, y, z) in a solid body that is in thermal equilibrium, or by the electrostatic potential u = u(x, y, z) in a region without electric charges. The heat equation

$$u_t = k\nabla^2 u$$

which is satisfied by the temperature u = u(x, y, z, t) of a physical object which conducts heat, where k is a parameter depending on the conductivity of the object. The wave equation

$$u_{tt} = c^2 \nabla^2 u$$

which models the vibrations of a string in one dimension u = u(x, t), the vibrations of a thin membrane in two dimensions u = u(x, y, t) or the pressure vibrations of an acoustic wave in air u = u(x, y, z, t). The constant c gives the speed of propagation for the vibrations. Closely related to the 1D wave equation is the fourth order PDE for a vibrating beam,

$$u_{tt} = -c^2 u_{xxxx}$$

where here the constant c2 is the ratio of the rigidity to density of the beam. An interesting nonlinear version of the wave equation is the Korteweg-de Vries equation

$$u_t + cuu_x + u_{xxx} = 0$$

which is a third order equation, and represents the motion of waves in shallow water, as well as solitons in fibre optic cables.

There are many more examples. It is worthwhile pointing out that while these equations can be derived from a careful understanding of the physics of each problem, some intuitive ideas can help guide us. For instance, the Laplacian.

$$\nabla^2 u = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}$$

can be understood as a measure of how much a function u = u (x, y, z) differs at one point (x, y, z) from its neighbouring points. So, if ∇2u is zero at some point (x, y, z), then u(x, y, z) is equal to the average value of u at the neighbouring points, say in a small disk around (x, y, z). If ∇2u is positive at that point (x, y, z), then u(x, y, z) is smaller than the average value of u at the neighbouring points. And if ∇2u(x, y, z) is negative, then u(x, y, z) is larger that the average value of u at the neighbouring points.

Thus, Laplace's equation

$$\nabla^2 u = 0$$

represents temperature equilibrium, because if the temperature u = u(x, y, z) at a particular point (x, y, z) is equal to the average temperature of the neighbouring points, no heat will flow. The heat equation

$$u_t = k\nabla^2 u$$

is simply a statement of Newton's law of cooling, that the rate of change of temperature is proportional to the temperature difference (in this case, the difference between temperature at point (x, y, z) and the average of its neighbours). The wave equation

$$u_{tt} = c^2 \nabla^2$$

is simply Newton's second law (F = ma) and Hooke's law (F = kΔx) combined, so that acceleration utt is proportional to the relative displacement of u(x, y, z) compared to its neighbours. The constant c2 comes from mass density and elasticity, as expected in Newton's and Hooke's laws [7].

2.2 Finite String And Separation Of Variables

Consider a finite piece of string, of length L, fixed at the two ends [7].

$$\frac{\partial^2 u}{\partial t^2} = c^2 \frac{\partial^2 u}{\partial x^2} \quad \text{for } x \in (0, L)$$

with boundary conditions

$$u(0,t) = u(L,t) = 0$$

Initial conditions are still,

$$u(x,0) = R(x), \qquad \frac{\partial u}{\partial t}(x,0) = S(x)$$

Could solve using d'Alembert's formula but it is diffucult to include the boundary conditions using this approach.

Better to try a, separation of variables

$$u(x,t) = X(x)\, T(t)$$

Important: T should not be confused with the earlier tension [7].

$$\frac{\partial^2 u}{\partial x^2} = X''T, \qquad \frac{\partial^2 u}{\partial t^2} = XT''$$

Hence the wave equation becomes [7]

$$XT'' = c^2 X'' T$$

Dividing by XTc^2 gives

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$$\frac{T''}{Tc^2} = \frac{X''}{X} = -\alpha^2$$

where α is a constant. The solution of

$X'' = -\alpha^2 X$ is

$$X = a.\cos(\alpha x) + b.\sin(\alpha x)$$

and the boundary condition [7] ,

$X(0) = X(L) = 0$ give $a = 0$ and $\alpha L = n\pi$

Where n is a positive integer. Similarly the solution of

$T''' = -\alpha^2 c^2 T$ is

$$T = \tilde{a}\cos(\alpha ct) + \tilde{b}\sin(\alpha ct)$$

giving the solution for u as

$$u = \sin\left(\frac{n\pi x}{L}\right)\left(A\cos\left(\frac{n\pi ct}{L}\right) + B\sin\left(\frac{n\pi ct}{L}\right)\right)$$

where and this is a solution for any positive integer and as the equation is linear then any linear combination of such solutions is also a solution. This gives the final form of the solution [7]

$$u(x,t) = \sum_{n=1}^{\infty} \sin\left(\frac{n\pi x}{L}\right)\left(A_n.\cos\left(\frac{n\pi ct}{L}\right) + B_n.\sin\left(\frac{n\pi ct}{L}\right)\right)$$

The set of constants and are determined by initial conditions [7].

$$u(x,0) = R(x) = \sum_{n=1}^{\infty} A_n .\sin\left(\frac{n\pi x}{L}\right)$$

$$\frac{\partial u}{\partial t}(x,0) = S(x) = \sum_{n=1}^{\infty} B_n .\frac{n\pi c}{L}\sin\left(\frac{n\pi x}{L}\right)$$

An expansion of the form

$$R(x) = \sum_{n=1}^{\infty} A_n .\sin\left(\frac{n\pi x}{L}\right)$$

is called a half-sine Fourier series, and there is an integral formula for the coefficients L

$$A_n = \frac{2}{L}\int_0^L R(x)\sin\left(\frac{n\pi x}{L}\right)dx$$

Proof: It is easy to prove that for positive integers m and n

$$\frac{2}{L}\int_0^L \sin\left(\frac{n\pi x}{L}\right)\sin\left(\frac{m\pi x}{L}\right)\,dx = \partial_{nm}$$

Where ∂_{nm} equals 1 if n =m and zero otherwise.

Multiplying both sides of (*) by $\frac{2}{L}\sin\left(\frac{m\pi x}{L}\right)$ and integrating gives

$$\frac{2}{L}\int_0^L R(x)\sin\left(\frac{m\pi x}{L}\right)dx = \sum_{n=1}^{\infty} A_n \frac{2}{L}\int_0^L \sin\left(\frac{n\pi x}{L}\right)\sin\left(\frac{m\pi x}{L}\right)dx = \sum_{n=1}^{\infty} A_n\partial_{nm} = A_m$$

Similarly, $B_n\frac{n\pi c}{L}$ are the coefficient of $S(x)$ hence

$$B_n\frac{n\pi c}{L} = \frac{2}{L}\int_0^L S(x)\sin\left(\frac{m\pi x}{L}\right)dx = \frac{2}{n\pi}\left\{-2\cos\left(\frac{n\pi}{2}\right) + 1 + \cos(n\pi)\right\}$$
$$= \frac{2}{n\pi}\left\{1 + (-1)^n - 2\cos\left(\frac{n\pi}{2}\right)\right\}$$

Now $\cos\left(\frac{n\pi}{2}\right)$ equals 0 if n is odd and equals $(-1)^{\frac{n}{2}}$ if n is even , henc

$A_{2r-1} = 0$

$A_{4r} = 0$

$$A_{4r-2} = \frac{8}{(4r-2)\pi} = \frac{4}{(2r-1)\pi}$$

Finally,

$$u(x,t) = \sum_{r=1}^{\infty} \sin\left(\frac{(4r-2)\pi x}{L}\right).\frac{4}{(2r-1)\pi}\cos\left(\frac{(4r-2)\pi ct}{L}\right)$$
$$= \frac{4}{\pi}\left\{\sin\left(\frac{2\pi x}{L}\right)\cos\left(\frac{2\pi ct}{L}\right) + \frac{1}{3}\sin\left(\frac{6\pi x}{L}\right)\cos\left(\frac{6\pi ct}{L}\right) + \frac{1}{5}\sin\left(\frac{10\pi x}{L}\right)\cos\left(\frac{10\pi ct}{L}\right) + \cdots\right\}$$

Eg. A string is pulled aside and realised from rest so that $u(x,0) = \sin\left(\frac{2\pi x}{L}\right), u_t(x,0) = 0$

Find the series solution.

Now, as before $B_n = 0$ and $R(x) = \sum_{n=1}^{\infty} A_n\sin\left(\frac{n\pi x}{L}\right)$

However, as

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$R(x) = \sin\left(\frac{2\pi x}{L}\right)$

We see that only $A_1 \neq 0$, and is, in fact, 1 so the series consists of only one term and we have,

$u(x,t) = \sin\left(\frac{2\pi x}{L}\right)\cos\left(\frac{2\pi ct}{L}\right)$

We can also consider α string that is pulled aside and released from rest so that

$u(x,0) = kx(L-x)$ and $u_t(x,0) = 0$

In such a case we have to work harder. We note the symmetry of $u(x,0)kx(L-x)$ about $x = \frac{L}{2}$. Hence $A_{even} = 0$.

Also for $n =$ odd:

$$A_n = \frac{2k}{L}\int_0^L x(L-x)\sin\left(\frac{n\pi x}{L}\right)dx = \frac{4k}{L}\int_0^{\frac{L}{2}} x(L-x)\sin\left(\frac{n\pi x}{L}\right)dx = \frac{8kL}{(n\pi)^3}$$

Thus

$$u(x,t) = \frac{8kL}{\pi^3}\sum_{r=0}^{\infty}\frac{1}{(2r+1)^3}\sin\left(\frac{2r+1}{L}\pi x\right)\cos\left(\frac{2r+1}{L}\pi ct\right)$$

III. A. Classical Method Of Wave Theory

The sea wave is a motion of wave tops and wave bottoms on the sea surface in unregular series. In engineering practice for calculate of the wave influence on the structure used one extremum wave. Therefore, may use different wave theory. There are three main wave theory: Airy, Stokes and knoidal theory.

The Airy wave theory is avery approximately theory. This theory may be used for wave with small height as compared with wave length and deep of water. For more detailed calculate may be used Stokes theory, if wave length equally to 0.1 of the deep water. For long wave may be used knoidal theory. In the fig.1 may to see application different wave theory in dependence deep of water –H, wave length -□ and deep of water –h.

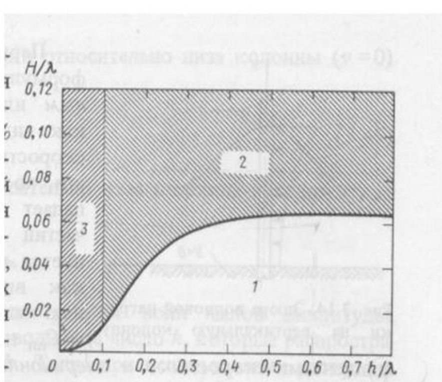

Fig.1. Diagram of the wave theory application: 1-Airy theory; 2 –Stokes theory; 3 –knoidal theory.

IV. Airy Wave Theory

This theory was investigate in 1842 by G.B.Airy1. This theory based on the sinusoidal profile of wave and small height of wave –H as compared with length -□ and deepth of sea –h (Fig.1).

If ordinates x,y have dimension as on the fig.1, then deflection wave surface from sea level may be to write in view:

$$\eta = \left(\frac{H}{2}\right)\cos(kx - \omega t) \qquad (1)$$

Then the horizontal and vertical components may be find:

$$\begin{cases} v_x = \frac{\omega H}{2}\frac{\cosh ky}{\sinh kh}\cos(kx-\omega t) \\ v_y = \frac{\omega H}{2}\frac{\sinh ky}{\sinh kh} \end{cases} \qquad (2)$$

Where k –wave number; ω -cyrcular frequency

$$k = \frac{2\pi}{\lambda} \qquad \omega = \frac{2\pi}{T} \qquad (3)$$

From Airy theory we have that

$$\omega^2 = gk\tanh kh \qquad (4)$$

Where g –gravity acceleration.

So as

$$kx - \omega t = k(x+\Delta x) - \omega(t+\Delta t) \qquad (5)$$

From here

$$c = \frac{\omega}{k} = \frac{\lambda}{T} \qquad (6)$$

Then we have formula for velocity of the Airy wave

$$c = \left(\frac{g}{k}\tanh kh\right)^{\frac{1}{2}} \qquad (7)$$

The Airy waves are waves with small height. Therefore, the acceleration of water particles will be:

$$\begin{cases} a_x = \frac{\omega^2 H}{2}\frac{\cosh ky}{\sinh kh}\sin(kx-\omega t) \\ a_y = \frac{\omega^2 H}{2}\frac{\sinh ky}{\sinh kh}\cos(kx-\omega t) \end{cases} \qquad (8)$$

The superfluous pressure as difference between pressure in force and atmospheric pressure in the poin with coordinates (x,y) in moment of time –*t*, according to Airy theory is:

$$p = \rho g\frac{H}{2}\frac{\cosh ky}{\cosh kh}\cos(kx-\omega t) + \rho g(h-y) \qquad (9)$$

Where ρ -density of water.

Stokes theory

The theory of wave with finish amplitude was investigate in 1847 by G.G.Stokes[1]. The main idea of the Stokes method is distribution of the wave equation in series and define coefficients of distributions. In according fifth order Stocks theory the deflection of sea surface from sea level is:

$$\eta = \frac{1}{k}\sum_{n=1}^{5}F_n\cos n(kx-\omega t) \qquad (10)$$

Where

$$\left.\begin{array}{l} F_1 = a; \\ F_2 = a^2 F_{22} + a^4 F_{24}; \\ F_3 = a^3 F_{33} + a^5 F_{35}; \\ F_4 = a^4 F_{44}; \\ F_{55} = a^5 F_{55} \end{array}\right\} \qquad (11)$$

Moreover parameters F_{22}, F_{24}... had dependence from kh and a may be find from relation:

$$kH = 2\left[a + a^3 F_{33} + a^5 (F_{35} + F_{35})\right] \qquad (12)$$

The horizontal and vertical components of velocity with x,y coordinates in t –time moment may be find:

$$\left\{\begin{array}{l} v_x = \dfrac{\omega}{k} \sum\limits_{n=1}^{5} G_n \dfrac{\cosh nky}{\sinh nkh} \cos n(kx - \omega t) \\ v_y = \dfrac{\omega}{k} \sum\limits_{n=1}^{5} G_n \dfrac{\sinh nky}{\sinh nky} \sin n(kx - \omega t) \end{array}\right. \qquad (13)$$

Where

$$\left.\begin{array}{l} G_1 = aG_{11} + a^3 G_{13} + a^5 G_{15}; \\ G_2 = 2\left(a^2 G_{22} + a^4 G_{24}\right); \\ G_3 = 3\left(a^3 G_{33} + a^5 G_{35}\right); \\ G_4 = 4a^4 G_{44}; \\ G_5 = 5a^5 G_{55} \end{array}\right\} \qquad (14)$$

In this G_{11}, G_{13}... –wave velocity parameters have dependence from kh. The approximately values of parameters in table 1 and 2.

Table 1

Таблица 3.5. Значения параметров профиля волны [40]

h/λ	F_{22}	F_{24}	F_{33}	F_{35}	F_{44}	F_{55}
0,10	3,892	−28,61	13,09	−138,6	44,99	163,8
0,15	1,539	1,344	2,381	6,935	4,147	7,935
0,20	0,927	1,398	0,996	3,679	1,259	1,734
0,25	0,699	1,064	0,630	2,244	0,676	0,797
0,30	0,599	0,893	0,495	1,685	0,484	0,525
0,35	0,551	0,804	0,435	1,438	0,407	0,420
0,40	0,527	0,759	0,410	1,330	0,371	0,373
0,50	0,507	0,722	0,384	1,230	0,344	0,339
0,60	0,502	0,712	0,377	1,205	0,337	0,329

Table 2

аблица 3.6. Значения параметров

h/λ	G_{11}	G_{13}	G_{15}	G_{22}	G_{24}
0,10	1,000	−7,394	−12,73	2,996	−48,14
0,15	1,000	−2,320	−4,864	0,860	−0,907
0,20	1,000	−1,263	−2,266	0,326	0,680
0,25	1,000	−0,911	−1,415	0,154	0,673
0,30	1,000	−0,765	1,077	0,076	0,601
0,35	1,000	−0,696	−0,925	0,038	0,556
0,40	1,000	−0,662	−0,850	0,020	0,528
0,50	1,000	−0,635	−0,790	0,006	0,503
0,60	1,000	−0,628	−0,777	0,002	0,502

h/λ	G_{33}	G_{35}	G_{44}	G_{55}
0,10	5,942	−121,7	7,671	0,892
0,15	0,310	2,843	−0,167	−0,257
0,20	−0,017	1,093	−0,044	0,006
0,25	−0,030	0,440	−0,005	0,005
0,30	−0,020	0,231	0,002	0,001
0,35	−0,012	0,152	0,002	0,000
0,40	−0,006	0,117	0,001	0,000
0,50	−0,002	0,092	0,000	0,000
0,60	−0,001	0,086	0,000	0,000

The relation between cyrcular frequency and wave number have view:

$$\omega^2 = gk\left(1 + a^2 C_1 + a^4 C_2\right) \tanh kh \qquad (15)$$

Where C_1 and C_2 –wave frequency parameters. The values of their parameters in table 3.

Table 3

Таблица 3.7. Значения параметров частоты волны и давления [40]

h/λ	C_1	C_2	C_3	C_4
0,10	8,791	383,7	−0,310	−0,060
0,15	2,646	19,82	−0,155	0,257
0,20	1,549	5,044	−0,082	0,077
0,25	1,229	2,568	−0,043	0,028
0,30	1,107	1,833	−0,023	0,010
0,35	1,055	1,532	−0,012	0,004
0,40	1,027	1,393	−0,007	0,002
0,50	1,008	1,283	−0,001	~0
0,60	1,002	1,240	−0,001	~0

The velocity of distributed wave c in fifth order Stocks theory find from equation:

$$c = \left[\frac{g}{k}\left(1 + a^2 C_1 + a^4 C_2\right) \tanh kh\right]^{\frac{1}{2}} \qquad (16)$$

After definition of the velocity componets parameters v_x and v_y may be find acceleration components:

$$\left.\begin{array}{l} a_x = \dfrac{\partial v_x}{\partial t} + u\dfrac{\partial v_x}{\partial x} + v\dfrac{\partial v_x}{\partial y}; \\ a_y = \dfrac{\partial v_y}{\partial t} + u\dfrac{\partial v_y}{\partial x} + v\dfrac{\partial v_y}{\partial y} \end{array}\right\} \qquad (17)$$

The superfluous pressure as difference between pressure in force and atmospheric pressure in the poin with coordinates (x,y) in moment of time –t, according to Stokes theory is:

$$p = \rho\frac{\omega}{k}u - \frac{1}{2}\rho\left(v_x^2 + v_y^2\right) - \frac{\rho g}{k}\left(a^2 C_3 + a^4 C_4 + ky'\right) \qquad (18)$$

Where $y' = y - h$, and C_3 and C_4 –pressure parameters, which had dependence from kh or h/λ. The value of their parameters in table 4.

Knoidal wave theory

The Stokes theory give satisfactory results then h/λ -depth of aquatorium is more then 0.1. For shallow water may to applied knoidal theory of wave. This method was investigate by Korteweg and de Vries in 1895. The parameters in knoidal wave theory writing over eleptic function. The knoidal waves are periodic and their profile may to write as:

$$\eta = \eta_{\min} + Hcn^2(kx - \omega t, m) \qquad (19)$$

Where η –deflection of wave surface from sea level in the point with x –coordinates in t –time moment; η_{min} –deflection corresponding to wave bottom ; H –height of wave; cn –Jacobi eleptic function with m –modulus $(0 \leq m \leq 1)$. The modul –m have relation with wave height –H, wave length -λ and deep of water –h:

$$mK^2 = \frac{3}{16}\frac{H\lambda^2}{h^3} \qquad (20)$$

Where K –parameterwhich have dependence from m (full eleptic integral). The values m,K and $H\lambda^2/h^3$ in table 4.

Tablo 4. Parameters in Knoidal Wave Theory

m	$H\lambda^2/h^3$	K	E
0	0	1.571	1.571
0.100	1.38	1.612	1.531
0.200	2.94	1.660	1.489
0.300	4.71	1.714	1.445
0.400	6.74	1.778	1.399
0.500	9.16	1.854	1.351
0.600	12.17	1.950	1.298
0.700	16.09	2.075	1.242
0.800	21.74	2.257	1.178
0.900	31.90	2.578	1.105
0.950	42.85	2.908	1.060
0.990	72.13	3.696	1.016
1.000	∞	∞	∞

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The wave number k, cyrcular frequency ω have relations with wave length λ and period T in following form:

$$k = \frac{2K}{\lambda}; \qquad \omega = \frac{2K}{T}; \qquad (21)$$

Moreover, the frequency have relation with wave number, as:

$$\omega^2 = ghk^2\left[1 + \frac{H}{mh}\left(\frac{1}{2} - \frac{E}{K}\right)\right]^2 \qquad (22)$$

Where g –gravity acceleration; E –second order full elleptic integral, which have dependence from modulus m. The values of E in table 4, too. The value η_{min} may to write over wave height

$$\frac{\eta_{\min}}{H} = \frac{K(1-m)-E}{mK} \qquad (23)$$

From (20) equation we have

$$\frac{\eta - \eta_{\min}}{H} = cn^2(\theta, m) \qquad (24)$$

Where $\theta = kx - \omega t$. The numerical of this correlation for different θ and min table 5.

Tablo 5. $\frac{(\eta - \eta_{\min})}{H}$ büyüklüğünün yaklaşık sonuçları

θ	m=0	m=0.2	m=0.4	m=0.6	m=0.8	m=1.0
0	1.000	1.000	1.000	1.000	1.000	1.000
0.2	0.960	0.960	0.960	0.960	0.960	0.960
0.4	0.848	0.850	0.852	0.852	0.854	0.856
0.6	0.681	0.687	0.694	0.699	0.706	0.712
0.8	0.487	0.500	0.516	0.530	0.545	0.560
1.0	0.292	0.317	0.342	0.368	0.394	0.420
1.2	0.131	0.162	0.194	0.229	0.266	0.305
1.4	0.029	0.053	0.085	0.123	0.166	0.216
1.6	0.001	0.003	0.019	0.049	0.094	0.151
1.8	0.052	0.016	0.000	0.009	0.044	0.104
2.0	0.175	0.062	0.028	0.001	0.013	0.071

For shallow water, whe may to used knoidal theory the horizontal velocity components is:

$$v_x = \left(\frac{g}{h}\right)^{\frac{1}{2}} \eta \qquad (25)$$

Then the acceleration components for shallow water will to:

$$a_x = \frac{\partial v_x}{\partial t} + v_x \frac{\partial v_x}{\partial x} \Rightarrow a_x = \pm 2kH(c - v_x)\left(\frac{g}{h}\right)^{\frac{1}{2}} A \qquad (26)$$

Where $c = \frac{\omega}{k}$ is velocity of wave circulation and A find over following formula:

$$A = \left[\frac{\eta - \eta_{\min}}{H}\left(1 - \frac{\eta - \eta_{\min}}{H}\right)\left(1 - m + m\frac{\eta - \eta_{\min}}{H}\right)\right]^{\frac{1}{2}}$$

The positive a_x may to used by $0 \le \theta \le K$ and negative in the $K < \theta \le 2K$ case.

The pressure on the y –level from bottom may to find from formula:

$$p = \rho g(h + \eta - y)$$

At the $m=1$ time we have $cn(\theta) = sch\theta$ and profile of wave will to unperiodic and in full above sea level. This wave is called a solitary wave.

V. B.Comparison of Dynamical Wave Theory with Classical Method

$$\begin{cases} v_x = \dfrac{\omega}{k}\sum\limits_{n-1}^{5} G_n \dfrac{\cosh nky}{\sinh nkh}\cos n(kx - \omega t) \\ v_y = \dfrac{\omega}{k}\sum\limits_{n-1}^{5} G_n \dfrac{\sinh nky}{\sinh nky}\sin n(kx - \omega t) \end{cases}$$

We will compare the classical method of longitudinal wave equation

$V_x = u(x,t)$ with the dynamical non-linear wave equation

A. Example Solution for Dynamical Method

With Computation

$L = 50\ m$
$c = 100$
$x = 20\ m$
$k = 80$
$r = 1$
$t = 10\ s$

$$u(x,t) = \frac{8kL}{\pi^3}\sum_{r=0}^{\infty}\frac{1}{(2r+1)^3}\sin\left(\frac{2r+1}{L}\pi x\right)\cos\left(\frac{2r+1}{L}\pi ct\right)$$

$$\frac{h}{\lambda} = 0,5 \qquad \frac{H}{\lambda} = 0,02$$

$$y = h \qquad x = \lambda$$

$$k = \frac{2\pi}{\lambda} \qquad \omega = \frac{2\pi}{T}$$

$$v_x = \frac{\omega H}{2}\frac{\cos h\, ky}{\sin h\, kh}\cos(kx - \omega t)$$

$$v_x = \frac{2\pi\, 0,02\lambda}{2T}\frac{\cos h\, {}^{2\pi}/_{\lambda}\, 0,5\lambda}{\sin h\, {}^{2\pi}/_{\lambda}\, 0,5\lambda}\cos\left(\frac{2\pi}{\lambda}\lambda - \frac{2\pi}{T}t\right)$$

$$u(x,t) = \frac{\pi 0,02\lambda}{T}$$

V. RESULT

The different two methods about the determination of current energy as renewable energy source is compared in scope with sensitivity analysis. As a result two different conclusions can be seen from determination of horizontal current propagation. It means that the dynamical and claasical wave theory methods have different conditions in scope of current energy potential determination.

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