MRE Numerical Calculations

Wave Parameter Calculations

Table 1: Wave Parameter calculations

Wave parameter	Unit	Notation	Definition	Deepwater waves	Shallow water waves
Phase Velocity	m/s	C_p	The rate at which the wave propagates in water.	$\frac{g*t}{2\pi}$	$\sqrt{g*z}$
Group Velocity	m/s	C_g	The velocity with which the overall envelope of the wave propagates in water.	$\frac{C_p}{2}$	$\approx C_p$
Wavelength	m	λ	The horizontal distance between two successive crests or troughs of a wave.	$C_p * t$	$C_p * t$
Average energy density	J/m^2	E	The amount of energy stored in a region per unit volume	$\frac{\rho * g * H^2}{16}$	-
Energy flux	kW/m	P	The rate of transfer of energy through a surface	$\eta * E * C_g$	-

Where
- g is the acceleration due to gravity (≈9.81 m/s2).
- z is the ocean depth in meters.
- t is the wave period (in seconds).
- ρ is the ocean water density.
- H is the significant wave height in meters.
- η is the energy conversion efficiency of a device.

Density of surface seawater

The density is defined as mass per unit volume. Ocean water is denser than pure water as density changes with changes in temperature, pressure, and salinity of ocean water. The density of ocean water ranges from 1.020 to 1.070 g/cm3. As the depth increases, temperature decreases, salinity, and pressure increase making water denser. The ocean water density as a function of salinity, temperature, and pressure is given by [1]

$$\rho_{(S,T,p)} = \frac{\rho_{(S,T,0)}}{1 - \frac{P}{K_{(S,T,p)}}}$$

Where,
- S is the seawater salinity in ppt (33-38).
- T is the temperature in °C.
- p is the water pressure in bars (at the surface ≈ air pressure).
- $\rho_{(S,T,0)}$ is the density of seawater at one-atmosphere pressure in kg/m^3.
- $K_{(S,T,p)}$ is the secant bulk modulus (module of seawater compressibility).

Ocean Current Parameters Calculations

Neglecting Salinity and temperature, depending on the latitude, the pressure at a particular depth is given by [2].

Using the Hydrostatic pressure equation, the approximate density can be determined using the following equation.

$$P_w = \frac{(1-C) - \sqrt{(1-C)^2 - (8.84 * 10^{-6} * z)}}{4.42 \ * \ 10^{-5}} \quad bar$$

Using the Hydrostatic pressure equation, the approximate density can be determined using the following equation.

$$\rho = P_w/gz$$

The Energy density is given by [3]

$$E = \frac{1}{2}\rho v^2(v.n)$$

In general, it is written as

$$E = \frac{1}{2}\rho v^3$$

The power density is given by.

$$P = \iint_A E\, dA$$

Or

$$P = \eta * E$$

Where

- z is the depth of the ocean.
- $C = 5.9 * 10^{-3} + D^2 * 5.25 * 10^{-3}$
- $D = sin\left(abs\left(Latitude * \frac{Pi}{180}\right)\right)$
- v is the velocity of the current.
- n is the unit vector normal to area A
- η is the conversion coefficient.

References:

1. Frank J.Millero, Alain Poisson. International one-atmosphere equation of state of seawater. Deep Sea Research Part A. Oceanographic Research Papers. Vol 28, Issue 6, June 1981, Pages 625–629.
2. Saunders, "Practical Conversion of Pressure to Depth", J. Phys. Oceanog., April 1981.
3. Shirasawa, K., Tokunaga, K., Iwashita, H., & Shintake, T. (2016). Experimental verification of a floating ocean-current turbine with a single rotor for use in Kuroshio currents. Renewable Energy, 91, 189-195.