

4010

## WIND WAVES - AN INTRODUCTION

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In this lecture I will present to you an introduction on wind waves observed on sea surface. If you are interested more in wind waves than what I will present here, then you please read the first chapter in Kinsman and proceed further.

The sea always contains some sort of waves of different characteristics all throughout water column. Waves at sea surface are called surface waves and those within the water column are called internal waves. I will be talking (there are a number of slides also) only on surface waves generated by wind at the sea surface.

If you look casually at the sea surface, you would always find some waves, either small ripples or big boat-tossing giants. It is an interesting aspect of wind waves that as they propagate over sea surface the water particles involved in the motion execute only circular motions. If you watch a floating bottle or tin, you can easily see that the float remains almost at the same point after it is crossed by a wave; this is true only far out in the sea away from beaches.

Another simple observation about wind waves is its obvious relationship with wind. The stronger the wind the higher or rougher the sea. Other factors which influence the development of waves are 'duration' and 'fetch' of wind. The effects of these two parameters could be basically understood from different types of waves generated by blowing air in 'bursts' and 'flows' into a tea cup and a much larger plate or vessel.

Waves can be classified into various categories on different bases like nature of generating force (free or forced waves), nature of restoring force (capillary or gravity waves), nature of sub-stratum (surface or internal waves), nature of movement of the wave profile (progressive or standing waves), nature of surface profile (sinusoidal or trochoidal waves), nature of particle movement (longitudinal, transverse or orbital), nature of water depth in relation to wave length (deep, shallow or intermediate) and nature of wave periods (short or long waves).

Physical Processes of Wave Generation: When you stand on a seashore and watch the sea surface you can observe waves of different dimensions and patterns depending upon depth of water, water currents and wind force and direction. Very near to the beach, waves would always be breaking due to bottom effects. Out in the coastal sea, waves would be influenced by coastal currents, steepening and breaking them or flattening them out. Local wind also has a similar effect on waves arriving from far distant areas in the open ocean. This does not mean that waves always come from the open ocean. They are generated in shallow coastal seas and very near to beaches by winds; but their dimensions (height and length) and visual patterns would be different due to boundary effects from bottom and shores. For basically understanding the generation processes, it would be ideal to go out into the open ocean

where you get mathematically infinite depths and horizontal sea surface (fetches) over which winds can blow unobstructed for various durations. Let us see the starting of the generation process. A very mild wind starts blowing; the sea surface becomes ruffled in patches. The wavelets are now called capillary waves. The wind becomes stronger 'hitting' the surface with varying forces and periods (impulses or sustained pulses) forming small waves and their groups of different properties travelling in different directions. These waves and their groups go on interacting as they travel out of the windy area. As the wind further strengthens, the energy input onto the sea surface grows stronger and the wave dimensions increase. Simultaneously, the initial ordered pattern or appearance of the sea surface changes into more and more disordered. Finally, the sea surface becomes a chaotic sea of huge waves with large forces which can cause damage to ships and marine installations. Thus a wind generated random sea surface is formed as a result of interaction (both linear and nonlinear) between different types of waves and their groups.

Now, let us see the processes of energy input by wind onto the sea surface. The wind field is always turbulent. This turbulence gives rise to varying energy inputs (in impulses and sustained pulses of various durations) at the same place as the wind blows. These different types of inputs would have both vertical and horizontal components. The relative importance of vertical and horizontal forces depend on the wind force and stage of sea state. Another important feature is the sheltered nature of forward side of the wave crest as the wind hits the rear side. Also, the tangential wind gives rise to a skin flow at the sea surface which would give rise to a 'slipping' effect to the wind-force pulses. All these processes would have different levels of effectiveness at different stages of wave generation and growth. At the very initial phases the normal pressure fluctuations are most significant. Afterwards, the tangential stress becomes more effective. When the waves are of considerable dimensions, 'sheltering' would have significant effects. During faster stages (nonlinear) of growth, wind shear (a net effect of wind velocity changes with height over the sea surface) plays a dominant role.

**Wave Generation Theories:** There are many wave generation (by wind) theories currently available in literature. None is complete. Each one stresses some particular features and fails in some other aspects. The main theories are listed below:-

1. Jeffrey's sheltering theory: accounts for initial generation well, further processes are not represented sufficiently.
2. Sverdrup-Munk theory: assumes turbulent air flow, sheltering is taken into account.
3. Eckart's theory: fully turbulent air flow, neglects sheltering, predicted heights are low.
4. Phillip's theory: turbulent air flow, random normal pressures generate initial wavelets, a resonance mechanism makes the wavelets grow, sea surface feedbacks onto the wind field.
5. Miles theory: assumes initially disturbed sea surface, the sea surface

feedbacks onto the wind profile, waves are greatly affected by a wind layer whose velocity equals the phase velocity of waves.

#### 6. Combined Phillip-Miles model.

**Different Analytical Wave Models:** The sea surface as seen in a generating area is short crested, irregular (or random) and wide banded and is called sea. These waves as they propagate out of the generating wind field become more orderly and narrow banded due to dispersion and are called swell. Waves which are affected by sea bottom over a shoaling coast become more sharp-crested and unstable leading to breaking waves. At the different phases of generation, propagation, shoaling and dissipation the waves look different and their characteristics differ. Hence, different analytical wave theories or models are developed to simulate the different types of waves. It is to be emphasized that even these characteristically different wave theories do not model the complete spectrum of waves at any time or place, but only the dominant or mean waves. Below listed are the main analytical theories:-

1. Airy wave theory or linear wave theory.
2. Stoke's wave theory (non-linear).
3. Cnoidal (Kdv) wave theory (non-linear).
4. Stream function (Dean & Monkmeier) theory (non-linear).
5. Crapper's theory (for capillary waves).

**Wave Measurement and Analysis:** There are many techniques of measuring or recording waves at sea. Using satellite sensors wave height and wind speed can be measured. Also, there are a number of methods of analysing the recorded data from simple, quick and manual to complex, time consuming and computer based. In the widely used Fourier analysis, the sea state is considered to be constituted by an infinite number of sinusoidal component waves which get superimposed randomly. This technique computes energy spectrum of the sea state for further applications.

#### LITERATURE

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