WAVE ENERGY OF THE ROMANIAN COASTWISE

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Considering the actual tendency in using at a large scale of regenerative energies, in the last years a great intense was represented by the energetic wave potential and the capture, conversion and utilization of this kind of energy.

The paper refers first of all to the wave characteristics in the Romanian costal region described by the simple frequency of appearance on height and period ranges of the waves.

Secondly, the potential and total unit energy repartitions on height and period wave intervals in the Romanian costal region were described in the present paper.

Wave characteristic and energy repartition as a function of those characteristics for the Romanian costal region are very important for the selection of the energy collector device type and also for the optimum designing of the component elements for an efficient capturing of the wave energy.

Keywords: wave frequency appearance, wave height, wave period, wave potential energy, wave total energy.

1. Introduction

The more increasing energy crisis has guided the researchers and engineers attention to the regenerative energy sources. One of this is the wave energy. In Romania most of the studies were driven to determine the wave characteristics of the Romanian seashore region and their energetic potential in the Romanian Black Sea Coast area. Also, for designing appropriate wave energy collector devices, several studies were made.

The paper describes in a succinct manner the results obtained by a research team constitute of members from the Hydraulics and Environmental Protection Department of the Technical University of Civil Engineering Bucharest and from the Meteorology and Hydrology Department of the University of Bucharest. The

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purpose of the research was to determine the wave characteristics and their unit energy in the Romanian Black Sea coastal area.

The wave characteristics measurements were made for a five years time period, at three representative measurement stations placed on the entire Romanian coastal region (Sfântu Gheorghe, Constanța and Mangalia). The obtained data were processed using statistical methods and the results were presented as graphs.

2. Wave characteristics in the costal area

The description of the wave regime of the Romanian Black Sea costal area was made based on the primary data concerning the heights and periods of the waves in a five year interval.

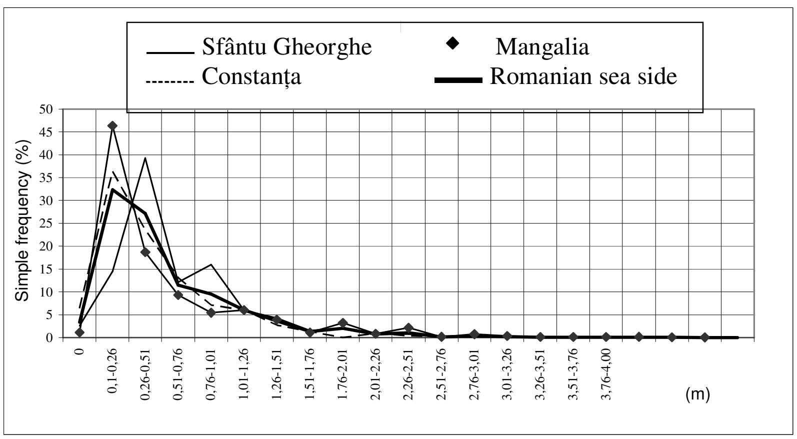

Fig. 1. Simple frequency f_h of wave appearance on different wave height ranges *h.*

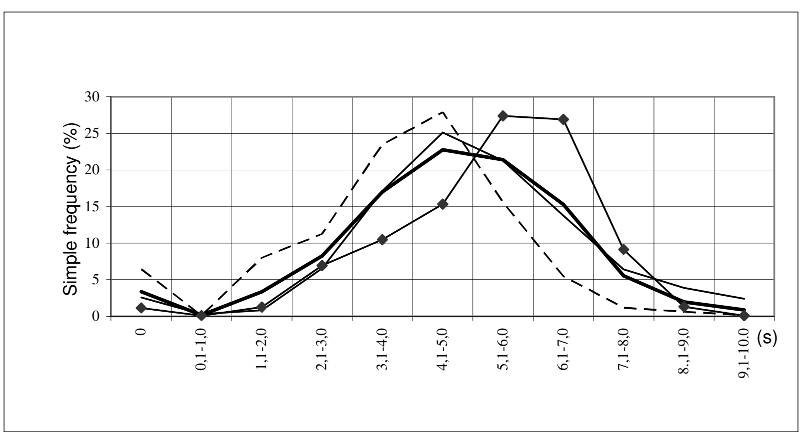

Fig. 2. Simple frequency f_T of wave appearance on wave periods ranges *T.*

The purpose was to compute the simple frequency of appearance of the waves on height and period ranges in the coastal locations Sfântu Gheorghe, Constanța and Mangalia.

To determine the wave's parameters and their energetic characteristics required for designing of the wave energy capture devices was accomplished a statistical ranging of the measured waves after their height and period [1, 9]. The simple frequency values on different height ranges f_h and the wave periods f_T were plotted in the figures 1 and 2 for the stations Sfântu Gheorghe, Constanța and Mangalia.

3. Raw power and energy of the waves

In a wave field, the size of the total unit power and the potential unit power is given by the following expressions:

$$P_t = e \cdot c \text{ and } P_p = e \cdot c_{gr}, \tag{1}$$

were P_t and P_p are the total unit power and the mean potential unit power of the wave field [kgf.m/(m.s)]; e is total mean specific energy of the wave field [kgf.m/(m^2)] and c and c_{gr} are the celerity (the propagation speed) of the individual waves and the mean celerity of an group of waves from the given field [m/s] given as follows [3]:

$$e = \frac{\gamma}{8} h_m^2; \quad c = \frac{gT}{2\pi} th\left(\frac{2\pi}{\lambda}\right); \quad c_{gr} = \frac{c}{2}\left[1 + \frac{4\pi H\lambda}{sh(4\pi H\lambda)}\right], \tag{2}$$

were h_m^2 is the mean values of the square height of the waves of the given field [m^2]; γ is the specific weight of the sea water [1012 kgf/m^3]; λ is the mean length of the waves of the given field [m]; H is the water depth [m]; g is the acceleration of gravity [9.81 m/s^2] and T the mean period of the wave field [s].

For a time period Δt of the wave power the corresponding elementary energy [kgfm/m] can be determined with the following relationship:

$$\Delta E = P \cdot \Delta t. \tag{3}$$

For practical use of the aforesaid formulas in computing the hydrological data processing the daily observed waves elements in the coast region, first of all two problems must be solved: to find out the average square height and the average height value of the waves in the given wave field. To find out the value of the mean square height of the waves it was used an empirical function which expresses the wave height with the F probability in the wave field of the coast area with smaller water depths:

$$\frac{h_F}{\bar{h}} = \left[-\frac{4}{\pi}\left(1+0.4\frac{\bar{h}}{\pi}\right)\ln(F)\right]^{\frac{1-\frac{\bar{h}}{H}}{2}}, \tag{4}$$

were h_F is the wave height of F probability in the given wave field [m]; $\bar{h}$ is the average wave height in the given field [m]; H is the water depth [m]; F is the probability that the height of the waves in the given field will exceed the value h_F.

Using the last equation further the mean square ratio $h/\bar{h}$ for different ratios $\bar{h}/H$ is determined by using the following formula:

$$\left(\frac{h}{\bar{h}}\right)_m^2 = \frac{\sum\left(\frac{h_F}{\bar{h}}\right)^2 \cdot \Delta F}{\sum \Delta F}. \tag{5}$$

For the calculus is considered that $\Delta F = 0.1$ so it can be observed that the mean square ratio $h/\bar{h}$ is linear correlated with the ratio h/H through the following empirical function:

$$\left(\frac{h}{\bar{h}}\right)_m^2 = 1.2315 - 0.2851\frac{\bar{h}}{H}. \tag{6}$$

Thanks to the fact that in every given wave field the average height of the waves h is a constant value, results immediately from the previous function the value of the mean square height of the waves as follows:

$$h_m^2 = \left(1.2315 - 0.2851\frac{\bar{h}}{H}\right)\cdot \overline{h^2}. \tag{7}$$

The second problem is to find out the average height of the waves in the given wave field. The technology for observing and measuring the coast waves consists in the fact that for each observation three heights for big distinct waves will be measured in a time period of about 5 minutes. So the mean value $\overline{h}_F$ and after this by timing the mean period T of the given field will be determined. The probability F of the observed height of the waves in the given wave field with the average height $\overline{h}$ is determined with the following relationship [5]:

$$F[\%] = \frac{n}{N} \cdot 100\,;\ N = \frac{t}{T} \tag{8}$$

were: n is the number of the observed big waves $(n = 3)$; t is the observation time interval about $(t = 300s)$; T is the mean period of the wave field [s].

Considering the aforesaid, results the expression of the probability F in percents:

$$F[\%] = \frac{3T}{300} \cdot 100 = T[s]\,. \tag{9}$$

The relation above shows that the probability in percents of the average height $\overline{h_F}$ of the observed distinct waves in the given field is approximately equal with the mean period T of the waves in the given wave field. Based on this ascertainment and using the empirical statistical correlation function between average height of the wave field $\overline{h}$ and the average height of a given number of wave's $\overline{h_F}$ results the following relationship:

$$\overline{h} = H\left[\frac{\overline{h_F}}{(H \cdot a_F)}\right]^{bF}; a_F = 1.634 - 0.125F^{0.319}; b_F = \left(0.73 + 0.053F^{0.319}\right)^{-1} \tag{10}$$

For obtaining of those results the experimental data obtained from the studies accomplish by B.H. Gluhovschi on wave fields were used [3, 6].

Based on the presented formulas, a computing algorithm and a specific program were elaborated in order to determine the potential and total mean unit energy repartition on height intervals and periods for the 10 m fathom line of the Romanian Black Sea coast waves. The potential and total unit energy cumulated both on height intervals as well as on periods can be also determinate.

Figures 3 and 4 show the average multi annual potential unit energy distributions on distinct height and wave mean period ranges, in the area of the Romanian coastwise of the Black Sea at Sfântu Gheorghe, Constanța and Mangalia, corresponding for the 10 m fathom line.

Figures 5 and 6 show the average multi annual total unit energy distributions on distinct height and wave mean period ranges in the area of the Romanian coastwise of the Black Sea at the same locations, corresponding for the 10 m fathom line.

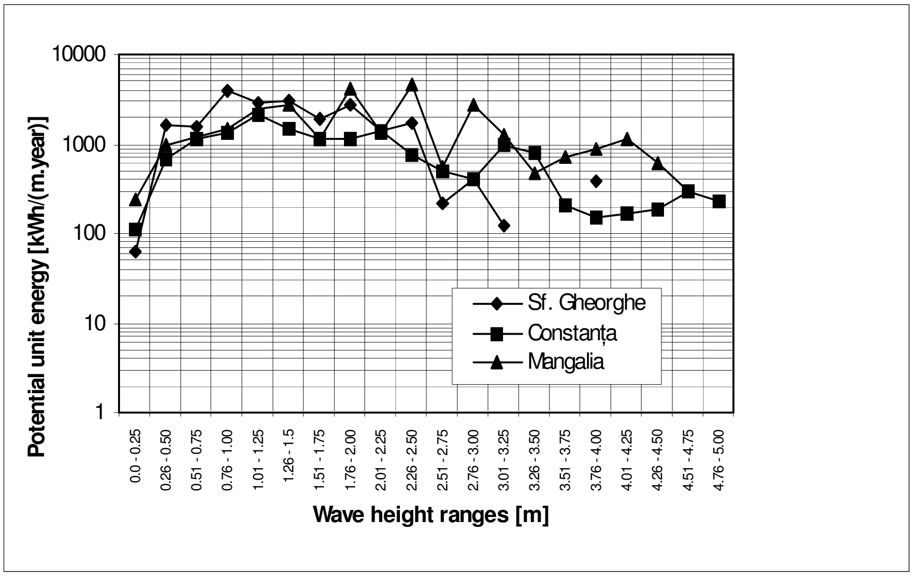

Fig. 3. Potential unit energy distribution on distinct wave height ranges.

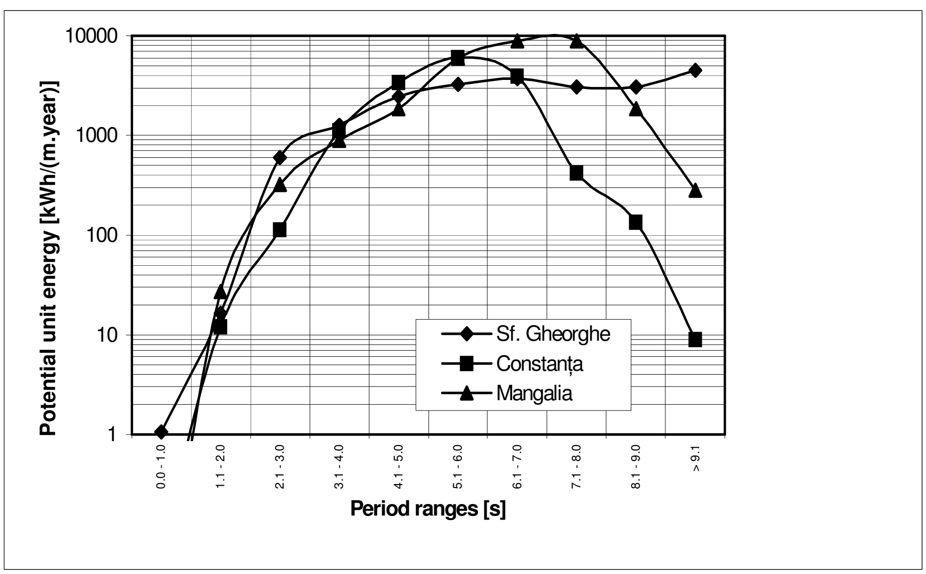

Fig. 4. Potential unit energy distribution on average wave period ranges.

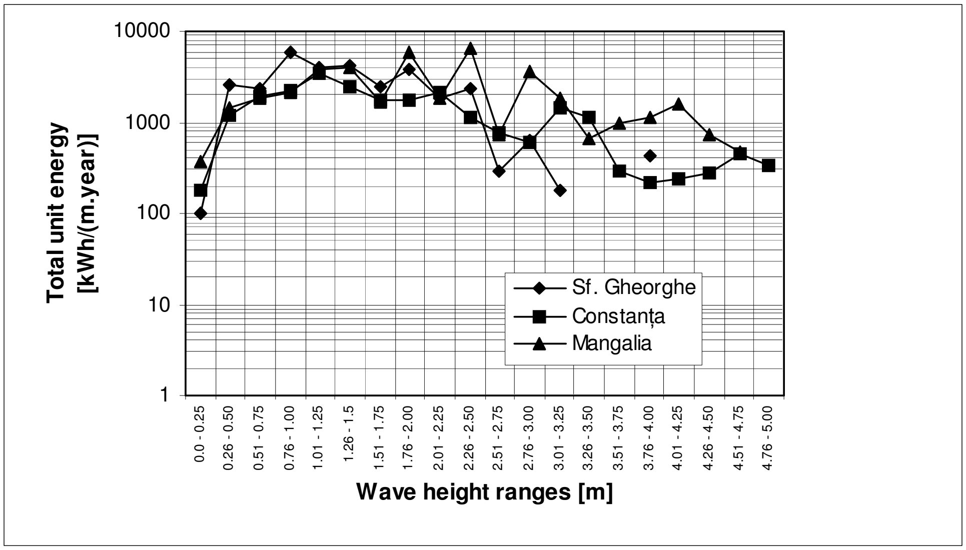

Fig. 5. Total unit energy distribution on distinct wave height ranges.

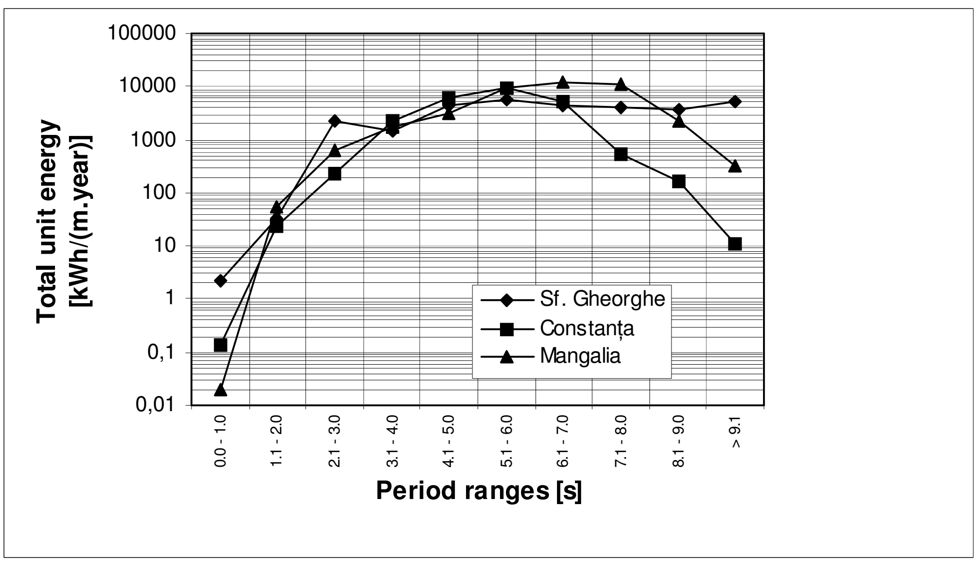

Fig. 6. Total unit energy distribution on average wave period ranges.

Although the highest unit wave power on the Romanian coast at the three analyzed locations has close values, there are still differences between the waves raw energetic potentials in these points. This is explained by the specific physic and geographical particularities of each station.

6. Conclusions

Analyzing the results, it can be observed that simple frequency distributions of appearance on height ranges of the waves have a unique modal shape with a strong left asymmetry, and the values of the peaks in the range of 0.1…0.51 m. The simple wave frequency of appearance distribution on wave period ranges are also one-dimensional with a lightly asymmetry and the peak values in the period ranges of 4.1…6.0 s.

The potential and total energy distribution analysis shows the existence of an important wave energetic potential of the Romanian coast region which must be captured and convert for utilizing this regenerative energy source. Although the values of the potential and total energy distribution on wave height and periods ranges are almost the same for the three studied stations, it can be observed some differences between the waves rough energetic potentials. This can be explained by the particular geographic and physical characteristics of each of the three locations where the stations are placed.

One of the most important parameters for computing the energy is the wave height. However the knowledge of all the wave characteristics and the energy repartition regarding these characteristics is most important for the designing of the wave energy collector devices appropriate for the Romanian Black Sea Coast.

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