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Annual Sea State Occurrences around the Korean Peninsula

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Abstract

A table of annual sea state occurrences is prepared based on the significant wave heights and modal periods, two parameters representing a Bretschneider wave spectrum. Measurements of them were done by the Korean Ocean Research and Development Institute (KORDI) at 67 points around the Korean peninsula for 22 years. Also the average values of parameters over 4 regions and 4 seasons were derived.

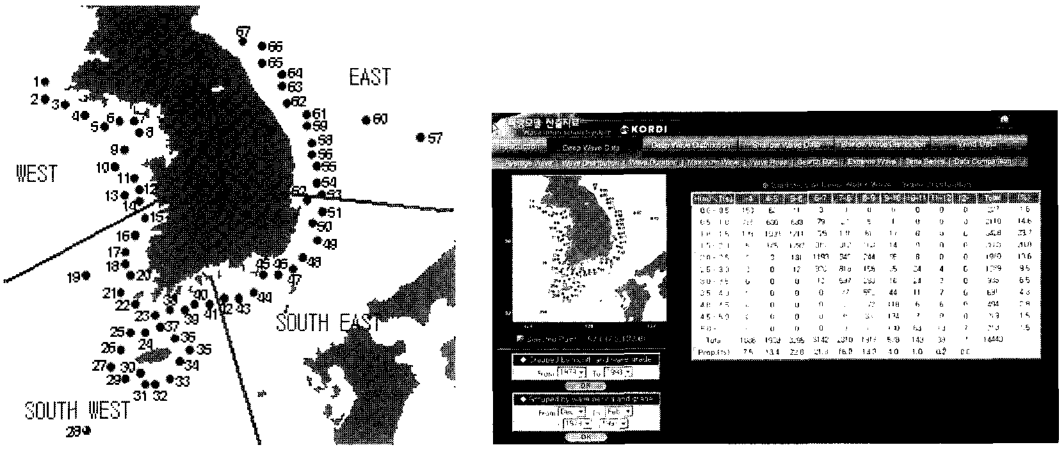
Comparative seakeeping calculations using wave parameters prevalent around Korea and those of the North Pacific at sea state numbers 3, 4, and 5 respectively, show some differences in the assessed seakeeping performance.

Keywords : Bretschneider spectrum , wave parameters around Korea, seakeeping performance assessment

1 Introductoin

The assessment of the seakeeping performance of a ship at a specific region during a specific period involves three-step calculation. At first,it is required to establish a set of statistical values for waves at the region where the ship is to be operated during the period when she navigates. Two parameters, the significant wave height and the modal period are the most popular among various statistical values and the Bretschneider spectrum represented with them is recommended by the IMO as the standard method for representing harshness of sea. When a set of these values is determined, distribution and the total amount of energy of seaway are to be calculated.

A reliable ship motion program to calculate the 6 degrees of freedom ship motion in regular waves is required at the second step of assessment. The linear potential theory is regarded to be most appropriate for this purpose except for the roll motion calculation. Various methods to explain the nonlinear behaviour of roll are suggested and implemented in various ship motion programs. The last step is to combine the information on the seaway and the characteristics of ship motions in regular waves to obtain the characteristics of the motion of the ship in that seaway. The paradigm of linear ship motion theory that there's no interference between the motions of different frequencies, which are excited by disturbances of corresponding frequencies, is still being applied in this last step even though some non-linearities in roll motion are being considered in part. If it is accepted that the development of the ship motion programs have grown to maturity and



(a) Measurement Locations (b) 'http://wave.kordi.re.kr'

Figure 1: Map of measurement locations and a wave scatter diagram

the validity of the linear theory is guaranteed, it can be said that the accuracy of predicting the seakeeping performance of a ship in a irregular seaway now totally depends on the validity of the description of the seaway in which the ship is to be operated.

The main object of this paper is to provide information on annual sea state occurrences around the Korean peninsula presented through a classification table of the significant wave height and the modal period by the sea state number from wave scatter diagrams provided by KORDI so that these parameters are to be used with ease by naval architects who wish to predict the seakeeping performance of a ship near the Korean peninsula. Wave spectra with parameters prevalent around Korea and with those of North Pacific at various sea state numbers are presented. Also, a table of significant wave height and the modal period averaged over a region in a season is presented. Coastal areas around Korea are divided into 4 regions, namely the West, South-West, South-East, and East regions and the twelve months of the year are categorized into four seasons. Clear differences in the wave parameters, resulting in the difference of the distribution and magnitude of energy of exciting disturbance, is shown to induce significant difference in the results of seakeeping performance prediction.

2 Wave models and measurements

Steady and continuous works around the world have been carried out to build up a database to hindcast the sea waves and those results have been published in diverse media. KORDI also, as a part of the National Wave Climate Monitoring Program of the Ministry of Maritime Affairs and Fisheries of Republic of Korea, has been developing instruments and technologies for the coastal wave monitoring system since 1987 and providing the hindcast data on the deep and shallow wave parameters and the wind around the Korean peninsula by combining previous measurements. Measurements were taken at 67 points around South Korea in every three hour interval and the wave parameters, such as the wave direction, the significant wave height and the significant wave period calculated with the HYPA model are presented in the monthly-averaged value at each point. Since the significant periods are known to be similiar to the modal periods (SNU 1973), the significant periods provided with by KORDI are treated as the modal periods. The HYPA (Hybrid Parametric) model is a Coupled Hybrid model that assumes the shape of the wind spectrum in formulating the governing equation for the wave spectrum. The CH model is, again, categorized as a 2nd generation wave model in which nonlinear energy transfers between frequency component waves are considered more rigorously compared to the 1st generation model (Yoon 1999).

Figure 1(a) shows the location where the measurements had been taken for the periods between 1979 and 1998. The distinction of sea around South Korea into 4 regions was made arbitrarily. Figure 1(b) is a dumped screen showing 'Statistics of Deep Water Wave' from 1979 to 1998 at the point 57 near Tokdo in the East sea during winter. This screen can be accessed through 'http://wave.kordi.re.kr.' But, you will need to register first to access the site. Wave scatter diagrams in Figure 1(b) provided for every 12 months at every 67 points located as shown in Figure 1(a) are processed to give the annual sea state occurrence around the Korean peninsula.

3 Annual sea state occurrences around the Korean peninsula

Describing the harshness of sea as sea state numbers is a popular but rather an ambiguous method in that accurate hindcast of the wave statistics of the sea is still difficult and determining the sea state number in a seaway yet depends almost on decision of an experienced captain. The sea state numbers ranging from 0 to 8 are given on various ranges of the significant wave height in an ascending order.

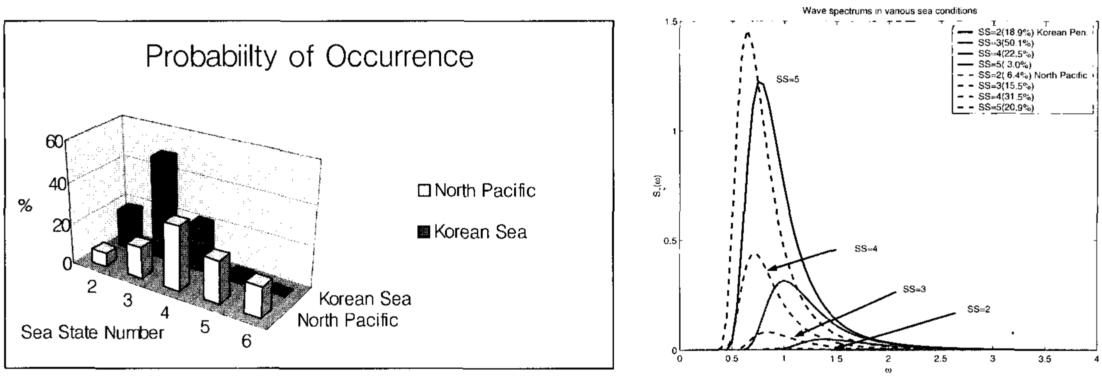
Table 1 shows the annual sea state occurrences around the Korean peninsula and, as a comparative example, those in the North Pacific.

Table 1: Annual seastate occurrence around the Korean Peninsula and in the North Pacific

Seastate	$H_{1/3}$		T_m (Korean Pen.)			T_m (North Pacific)		
	Range	Mean	Probability	Range	Most Probable	Probability	Range	Most Probable
2	0.1-0.5	0.3	18.94	≤ 7.9	3.4	6.40	5.1-14.9	6.3
3	0.5-1.25	0.88	50.08	≤ 8.6	4.5	15.50	5.3-16.1	7.5
4	1.25-2.5	1.88	22.54	≤ 9.7	6.3	31.60	6.1-17.2	8.8
5	2.5-4	3.25	3.00	5.7-11.2	8.2	20.94	7.7-17.8	9.7

The most distinct difference between the statistics of the two sea is the distribution of occurrence of each sea states. Figure 2(a) clearly shows that the most frequent sea state number expected around the Korean peninsula is 3 with the probability of occurrence of up to 50 %, whereas that in the North Pacific is 4 with the probability of 31.6 %. Around the Korean peninsula, a sea condition severer than the sea state number 5 is hardly expected as well, whereas more than 35 % of sea condition in the North Pacific is expected to be equivalent or severer than sea state number 5.

At each sea state, the most probable modal periods of the two seas are also different: those around the Korean peninsula are always shorter than those in the North Pacific, respectively, at each sea state. At sea state 3, you may expect that the most probable modal period in the North Pacific will be 7.5 *sec* whereas, in Korean sea it is 4.5 *sec*. Shorter modal period implies that, even when ranges of the significant wave heights of both seas are the same, the waves of relatively



(a) Probability of occurrence of sea States around the Korean peninsula and in the Noth Pacific

(b) Wave spectra around the Korean peninsula and in the North Pacific

Figure 2: Probability of occurrences and wave spectra of sea states

smaller wave heights are dominant around the Korean peninsula. Wave spectra of sea states 2, 3, 4 and 5 are plotted in Figure 2(b). Although the significant wave heights of two wave systems are the same at each sea state, it is shown that the peak of the wave spectrum at seas around Korea is smaller. This situation reminds us that wave system around Korea has its energy are concentrated in smaller yet steeper waves and, as a result, the ship motion in this wave system will show different characterisitcs from that expected in the North Pacific. In Section 5, what kinds of effect of the difference of sea statistics may bring in is shown based on a sample ship motion calculation.

4 Averaged wave heights and modal periods

Detailed data such as those presented in Table 1 must be preferable but, when some crude information on the sea is only available, the average values is also sufficient. Figures from 3(a) to 3(d) show the contour of the probability of occurrence of the significant wave height and the modal period for each season and region and Table 2 shows the average modal periods and the average significant wave heights for each region and season. Taking the average values over all seasons and regions, the significant wave height of 0.95 m and the modal period of 5.42 sec are obtained.

Table 2: Average significant wave heights and modal periods near the Korean peninsula

$H_{1/3}/T_m$	Winter	Spring	Summer	Autumn	Avg.
West	1.06 / 5.11	0.74 / 5.14	0.78 / 5.88	0.73 / 4.85	0.83 / 5.25
Sout West	1.38 / 5.67	0.99 / 5.43	1.04 / 6.03	1.05 / 5.48	1.12 / 5.65
South East	0.87 / 5.42	0.86 / 5.51	1.04 / 6.05	0.89 / 5.49	0.92 / 5.62
East	1.17 / 5.21	0.84 / 5.02	0.81 / 5.25	0.97 / 5.17	0.95 / 5.16
Avg.	1.12 / 5.35	0.86 / 5.28	0.92 / 5.80	0.91 / 5.25	0.95 / 5.42

5 Comparative seakeeping performance assessment

Sample seakeeping performance assessments of a ship of principal dimensions, as shown in Table 3, are made on two seaways of various wave spectra, which are that of North Pacific and that around the Korean Peninsula. Ship Motion Program (SMP) developed by SNU was used for conducting assessments. This program is based on the Salvesen-Tuck-Faltinsen method and has been validated through repeated comparisons of the outputs of the program with those from various benchmark results.

Table 3: Principal Dimensions

Diaplacement (Ton)	980
LBP (M)	73
Breadth (M)	9.81
Draft (M)	2.75
LCG from Midship (M)	-2.45
Natural Period of Roll	7.5 sec

Speed polar plots for roll and pitch displacements, and vertical acceleration on each seaway are shown in Figures 4 to 6. 6 responses in two sets of sea state numbers 3, 4, and 5, the one set of which had been obtained around the Korean peninsula (KP) while the other set in the North Pacific (NP) are drawn in each figure. Unit for angular displacement is the degree and that for acceleration is the gravitational constant, 'g'. The encounter angle 0 in the figures represents the situation whereby the wave is coming from ahead of ship.

Responses at the same sea state number are shown to have comparable magnitudes and they can be discerned from those at different sea state numbers. Significant differences between responses around the Korean peninsular and in the North Pacific are shown in the roll response when $V = 0$ kts, the pitch response when $V = 21$ kts, and the vertical acceleration when $V =$ 21 kts in sea state 3. Responses around Korea are observed to be significantly smaller in these results. These differences are thought to be due to the differences from modal periods of the exciting disturbance and the natural period of each motion. Especially the modal period of waves in the North Pacific in the sea state number 3 is located near the natural period of roll when $V = 0$ so that, considering the difference of the peak energy from that of sea state 4, the roll response looks to be amplified significantly. In sea state number 5, although significant difference is not shown, responses around Korea show larger motions, which is an opposite trend to that in sea state number 3. An interesting result is that the vertical accelrations around Korea in sea state 4 are of closer magnitude to those in the North Pacific in sea state 5.

6 Conclusions

A table of annual sea state occurrence for waves around the Korean peninsula was derived from wave scatter diagrams provided with by KORDI and can be accessed through 'http://wave.kordi.re.kr'. Also, suggested are seasonal and regional average wave parameters, which are the significant wave height and the modal period, of the wave spectrum around Korea.

Wave spectra described by wave parameters around the Korean peninsula show a tendency that the peaks of the wave spectra at each sea state numbers are shifted toward high frequency domain compared to those in the North Pacific. Sea states of 2, 3, and 4 are prevalent around Korea: the probabilities of their occurrences are shown to be 19 %, 51 %, and 23 %, respectively, the sum of which is slightly larger than 90 % whereas that in the North Pacific is nearly 50 %. These observations tell us that the waves around Korea have smaller wave height and relatively steeper crest.

Differences of the modal frequency and the amount of energy of wave spectra around the Korean peninsula from those in the other sea at the same sea state are thought to result in different seakeeping performances and this is shown by sample assessments of a ship around Korea and in the North Pacific in each case of sea state number 3, 4, and 5. The degree of differences may depend on various variables, such as the type of ship, the operation speed, the severeness of the sea, etc still there is the need for more accurate sea wave statistics of seas around the Korean peninsula.

Acknowledgements

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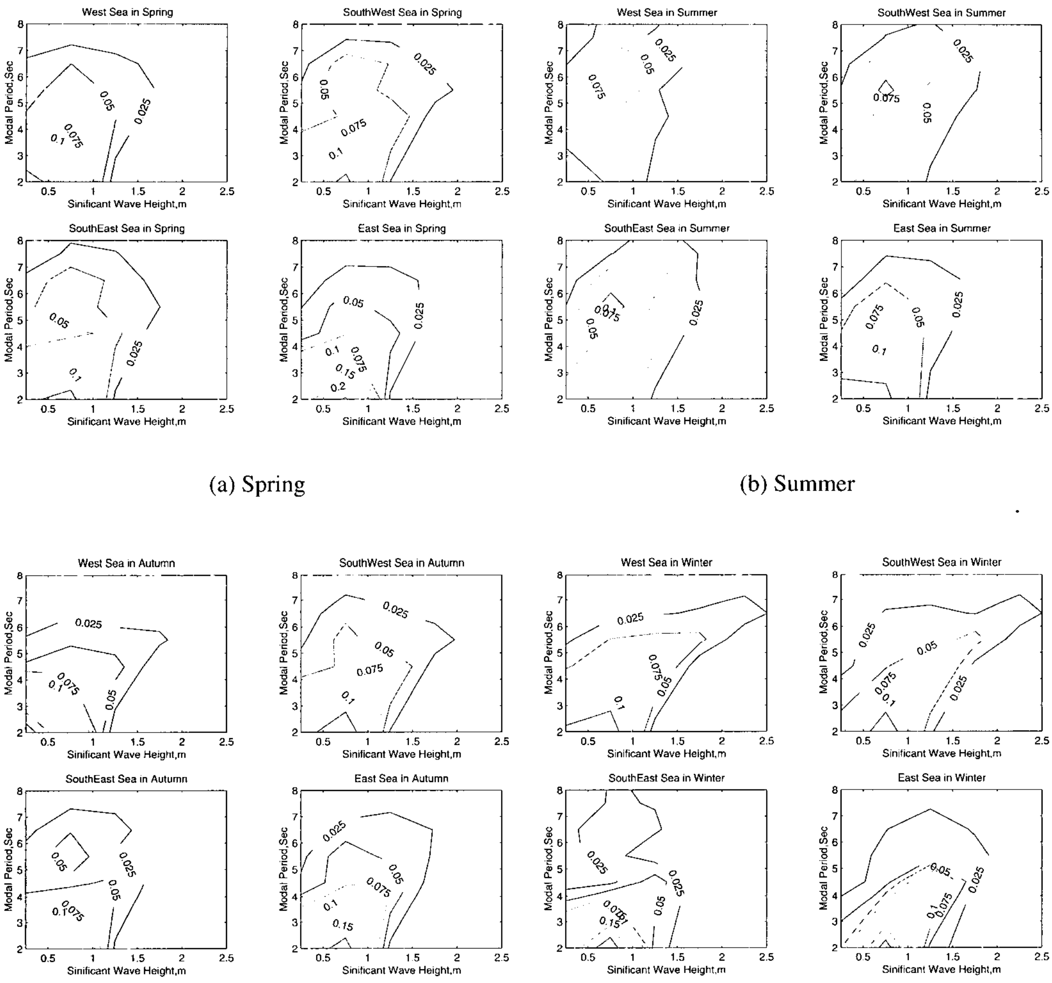


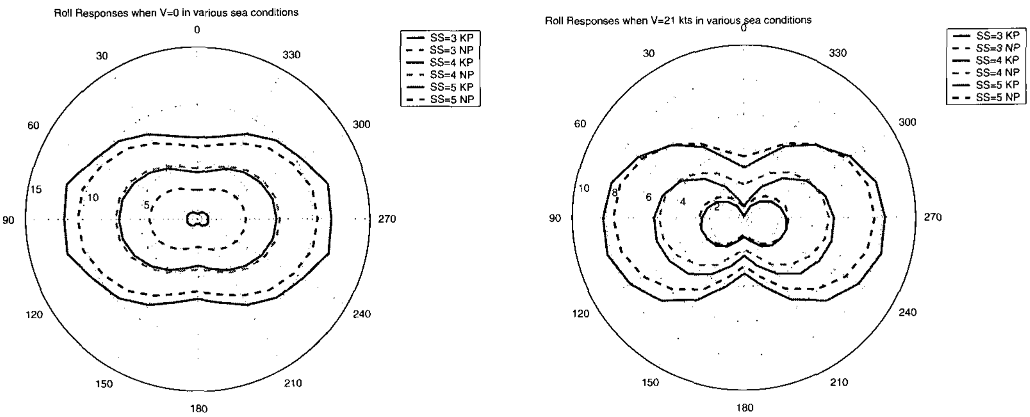
(a) Spring

(b) Summer

(c) Autumn

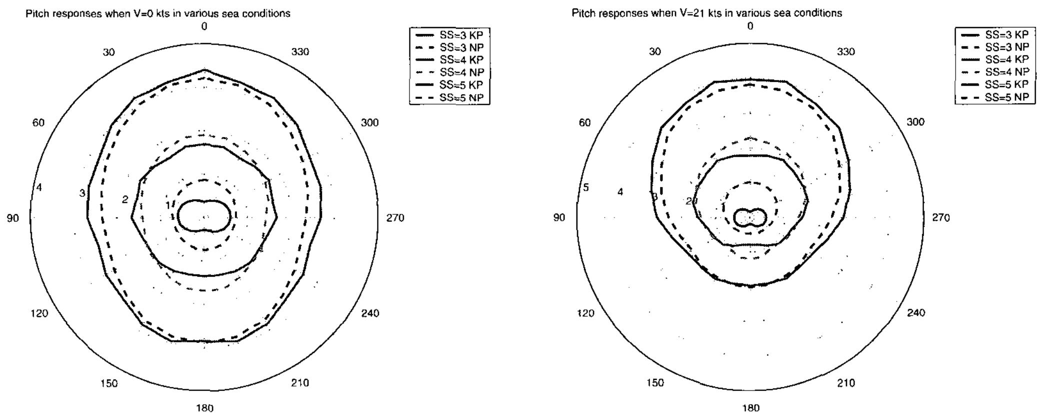
(d) Winter

Figure 3: Contours of probability of occurrence at each season and region



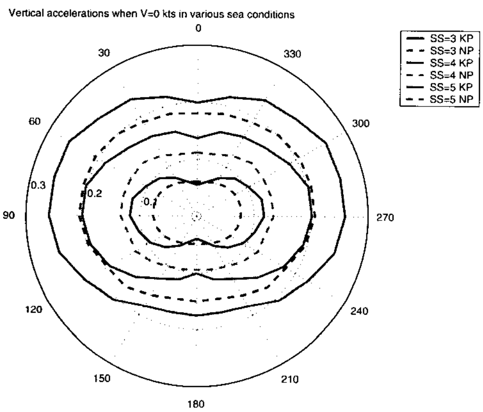
(a) Roll responses when $V = 0kts$ (b) Roll responses when $V = 21kts$

Figure 4: Roll responses

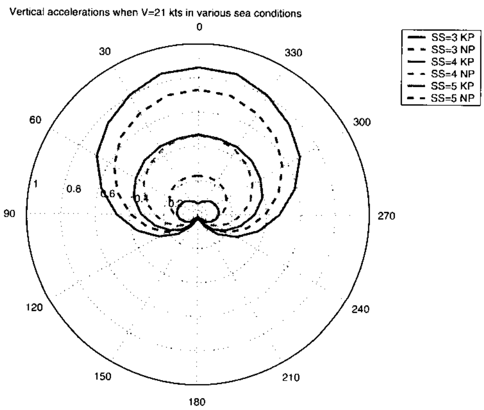


(a) Pitch responses when $V = 0kts$ (b) Pitch responses when $V = 21kts$

Figure 5: Pitch responses



(a) Vertical acclerations when $V = 0kts$



(b) Vertical accelerations when $V = 21kts$

Figure 6: Vertical accelerations