DISCUSSION OF THE PAPERS ON INVITATION

G. van OORTMERSSEN - Netherlands Ship Model Basin, Wageningen, the Netherlands

There are two brief remarks that I would like to make with regard to wave groups.

First, Dr. Johnson has mentioned three methods to characterize the wave groups, but I think there is at least a fourth one, which is used at NSMB and also at other institutes. This method is similar to the SIVEH method, and uses the spectrum of the envelope of the rectified wave train.

The other point is the following. Wave grouping is a crucial factor in the low frequency response of moored structures, and in a model test we have to ensure that the wave groups are realistic. But this is not enough. Connected to the wave groups is the so-called wave set-down. This is a low frequency wave that travels with the same velocity as the groups and can be described by a second order wave potential. This wave set-down can have a significant amplitude, in particular in shallow water. The set-down affects the low frequency horizontal excitation of a moored structure to a large extent and is also very important when investigating vertical ship motions in shallow water, because the vertical response amplitude operator at these low frequencies equals I.

When performing model tests on systems with a significant low frequency response it is therefore very important that we pay attention to the low frequency wave connected to the wave groups, and that we ensure that the low frequency wave, generated in the basin, is realistic.

M. SCHMIECHEN - Versuchsanstalt für Wasserbau und Schiffbau, West Berlin

As a colleague of Prof. Johnson on the Information Committee I would like to make a few comments on the semantic problems, which he referred to right at the beginning of his presentation. These problems must with certainty arise, when terms as e.g. non-stationary, non-predictable, non-deterministic, stochastic, ergodic etc are used without reference to coherent explicit models. As a matter of fact the terms in question are precisely defined today in an adequate fashion in text-books and standards. Consequently it is suggested that these technical terms are consistently used in this way in order to avoid unnecessary confusion.

S. OHMATSU - Ship Research Institute, Tokyo, Japan

A SIMPLE METHOD TO GENERATE ARBITRARY WAVES IN MODEL BASIN

A simple method to generate arbitrary wave elevations at an arbitrary intended position in the model basin is proposed. The numerical experiments confirm the usefulness of this method.

I. GENERATION OF THE CONCENTRATED WAVES

In general, the free surface elevation generated in the model basin by the motion of wave maker can be expressed as

$$\eta(x,t) = \int_{-\infty}^{t} V(t')\,\eta_1(x,t-t')\,dt' \qquad (1)$$

where $V(t')$ is the velocity imposed on the wave maker and $\eta_1(x,t)$ represents a function which coincides with the free surface elevation for the case of wave maker velocity is $\delta(t)$ So the function $\eta_1(x,t)$ can be called also an impulse response function. Fig.I shows an example of the function $\eta_1(x,t)$ calculated for the case of flap type wave maker, where the parameters were non-dimensionalized as follows; (d: length of flap)

$$\frac{\eta}{d}\to\eta\ ,\quad \frac{x}{d}\to x\ ,\quad \frac{t}{\sqrt{\alpha/g}}=\tau \qquad (2)$$

For the general method of calculating $\eta_I(x,t)$ see the references/I/, /2/ and /3/.

Now let us define the function $\eta_c(x,t)$ which is the free surface elevation when one moves the wave maker as its velocity is $\eta_I(x,-t)$. $\eta_c(x,t)$ can be expressed by using (I) as

$$\eta_c(x,t)=\int_{-\infty}^{t}\eta_I(x,-t')\cdot\eta_I(x,t-t')\,dt'=$$

$$=\int_0^{\infty}\eta_I(x,t')\cdot\eta_I(x,t+t')\,dt' \qquad (3)$$

If we take the Fourier transform of $\eta_c(x,t)$, we have

$$\int_{-\infty}^{\infty}\eta_c(x,t)e^{-i\omega t}dt=|\eta_I^*(x,\omega)|e^{i\varphi(\omega)}\cdot|\eta_I^*(x,\omega)|e^{-i\varphi(\omega)}=$$

$$=|\eta_I^*(x,\omega)|^2 \qquad (4)$$

where we define the Fourier transform as

$$\int_{-\infty}^{\infty}\eta_I(x,t)e^{-i\omega t}dt=|\eta_I^*(x,\omega)|\cdot e^{i\varphi(\omega)}.$$

In equation (4), it is clear that the Fourier transform of $\eta_c(x,t)$ has constant phase for all ω , so we can call it as "concentrated waves". For putting the method in practice, it is necessary to truncate the measuring time. If one measures $\eta_I(x,t)$ at position x from t=0 to t=T, and if one imposes the velocity of wave maker as $V(t)=\eta_I(x,T-t)$, one has

$$\eta_c(x,t)=\int_0^t\eta_I(x,T-t')\cdot\eta_I(x,t-t')\,dt'. \qquad (5)$$

Then, at least if T is considerably large , one will have concentrated waves at point x and t=T. Fig. 2 shows an example of numerical calculations for the case of x=3 and T=30, where the broken lines represent the waves before and after the concentration .

2. GENERATION OF ARBITRARY WAVE ELEVATIONS HAVING AN INTENDED TIME HISTORY AT AN INTENDED POSITION

By the consideration of previous section, it is possible to introduce a method to generate the arbitrary wave elevations which have an intended time history at an intended position. If one imposes the velocity on the wave maker as V(t)=f(t) from t=0 to $t=T_I$, one has water surface elevations at x, $\eta_f(x,t)$ as

$$\eta_f(x,t)=\int_0^{T_I}f(t')\cdot\eta_I(x,t-t')\,dt' \qquad (6)$$

And then, if one imposes the velocity on the wave maker as $V(t)=\eta_f(x,-t)$, one has

$$\eta(x,t)=\int_{-\infty}^{t}dt'\int_0^{T_I}f(t'')\cdot\eta_I(x,-t-t'')\cdot\eta_I(x,t-t')\,dt'',$$

by using the definition of $\eta_c(x,t)$ equation (3),

$$=\int_0^{T_I}f(t'')\cdot\eta_c(x,t+t'')\,dt''. \qquad (7)$$

As it is obvious in Fig. 2, function $\eta_c(x,t)$ has a feature of δ function of Dirac approximately, then one has

$$\eta(x,t)\propto f(-t) \qquad (8)$$

Now, the procedures of our method to generate the wave elevations whose time history is given by f(t), (t=0 T_I) at position x are as follows;

(a) Wave maker is so controlled that its velocity time history is $f(T_I-t)$, (t=0 T_I).

(b) Wave elevation $\eta_f(x,t)$ is measured at the position x from t=0 to t=T.

(c) After that, wave maker is so controlled that its velocity is $\eta_f(x,T-t)$

Then the wave elevation at the position x is the same approximately as the intended time history f(t).

Fig.3(a) shows an example of numerical experiment where the function $f(\tau)$ was given by $f(\tau)=\sin(2\tau), (\tau=0-\pi)$. For the case of $\tau=0\sim2\pi, 3\pi\cdots,$ we had same results. Fig. 3(b) makes clear the difference between the obtained time history and the intended one.

3. GENERATION OF THE ARBITRARY WAVE ELEVATIONS HAVING AN INTENDED POSITION AT AN INTENDED INSTANT t

By the analogous method to that mentioned in the previous section, we can introduce a method to generate the arbitrary wave elevations which have an intended profile at an intended instant t. We put the intended profile as $g(x)$ between the two points A and B.

(a) Firstly we record the wave elevations $\eta_I(x,t)$ at several points x_j between A and B from t=0 to t=T. The wave elevation $\eta_I(x,t)$ will be generated by the step function motion of wave maker.

(b) We sum up the measured records by multiplying $g(x_j)$ as

$$\eta_g(t)=\sum_j g(x_j)\cdot\eta_I(x_j,t), \quad t=0\sim T \quad (9)$$

(c) After that we control the wave maker so that its velocity is $\eta_g(T-t)$ Then the wave profile at the instant t=T will be nearly proportional to $g(x)$ between A and B.

Fig. 4(a) shows an example of numerical experiment where the function $\eta_I(X,t)$ was calculated at 9 points, i.e. x_j=3.I, 3.2...3.9 and the function $\eta_I(x_j,t)$ was multiplied by sin(0.2$\pi \times j$). Fig.4(b) makes clear the difference between the intended and obtained profiles.

4. CONCLUSION

In Figs. 3(b) and 4(b), we can see a little difference between the intended and the obtained waves. If we use more precise and rather complicated manner, we will get more precise results. However, our method is very simple to apply and it has a great advantage that it does not need any numerical calculation and any complicated control of wave maker.

REFERENCES

/I/ Ohmatsu, S. "On the Transitional Wave Making Phenomena by Wave Maker", Trans. of West Japan Soc. of N.A., Vol. 55, (I978)

/2/ Ohmatsu, S. "On the Transitional Wave Making Phenomena by Wave Maker - for the case of finite depth-", Trans. of West Japan Soc. of N.A.,Vol.57,(I979)

/3/ Ohmatsu, S. "Une Methode Simple Pour Generer Une Houle Arbitraire Dans un Bassin d'Essais", Papers of Ship Research Institute, No. 65 (to be published), (I98I)

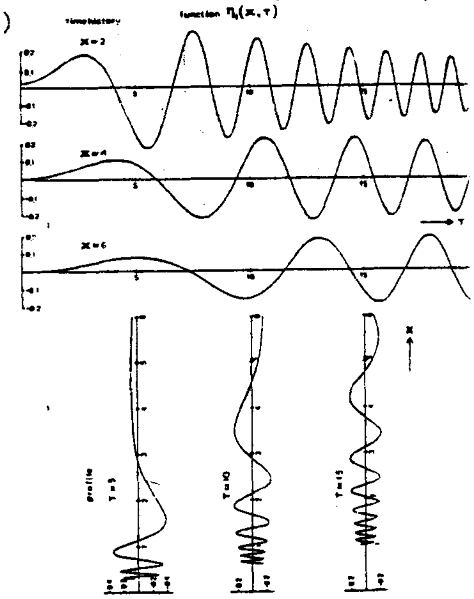

Fig. 1 Timehistory and profile of the function (x,t)

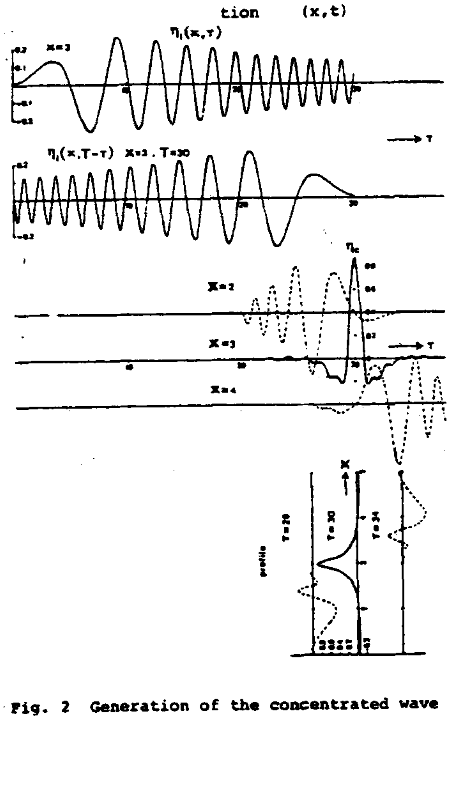

Fig. 2 Generation of the concentrated wave

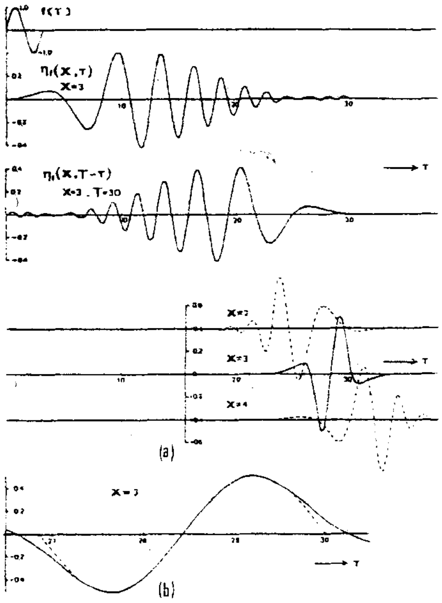

Fig. 3 Generation of the wave having an intended timehistory

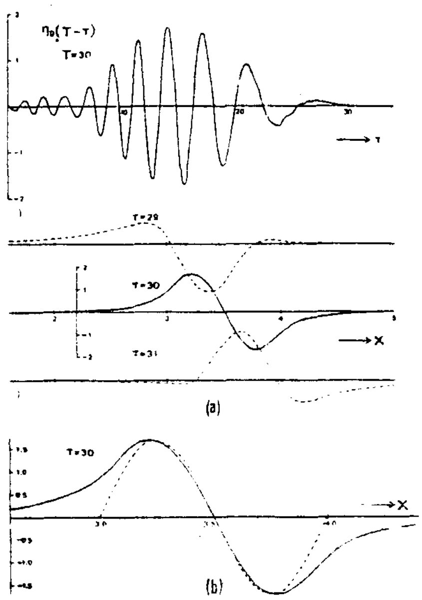

Fig. 4 Generation of the wave having an intended profile

J.V.Wehausen - University of California, Berkeley, USA

I should like to point out that the technique for obtaining a desired wave record at the carriage by first using the desired record to control the wave maker, then measuring the resulting waves at the carriage, and finally reversing the record in controlling the wave maker has been used at the University of California,Berkeley for over twenty years and was described at an ATTC many years ago (perhaps I959). I don't wish to deprecate the contribution of Prof.Takezawa, but only to call attention to this earlier work and perhaps to note that he confirms the observation that there is approximately a 20-year period for rediscovery.

Hun Chol Kim - Ship Research Station, KIMM,Daeduk Science Town, South Korea

Irregular wave generation assumes an applicability of linear superposition. There would be non-linearity arising from wave decay along the length of a towing tank, decay being dependent not only on each wave component but on the whole system of waves.

Particularly once the wave or the wave system breaks there would occur, it would seem, almost certain reduction in amplitude(s) as well as phase shifts in certain components.

I wonder if such has been noted, and if so how serious it is and how should one go about in compensating.

S.J.ROWE - National Maritime Institute,
Feltham, Middlesex, United Kingdom

Firstly, I am concerned about the concept of the generation of waves using the amplitude madulation of the component sine waves,and the confusion this introduces. It seems to me that all this achieves is the extension of the time series before repetition, (the length of the wave sequence becomes a complex function of the modulation frequencies). If one were to record such a time series and perform a Fourier transformation and obtain the coefficients, one could in principle set up a multi-component sine wave synthesizer or a shift register synthesizer in amplitude and phase to produce exactly the same time series.The amplitude modulation therefore is effectively simply inserting additional lines into the spectrum, and one will of course have to analyse long runs in the tank to make use of the finer spectral resolution that has been thus obtained.

If one looks at the time history of such a long time series (however produced) it will 'appear non-stationary'. Physically, this is because adjacent lines, or groups of lines in the spectrum are coming to anti-phase, and thus cancelling out the energy for this frequency band for a period of time.

Finally, I would like to emphasize that in my view there is absolutely no point in averaging the analysis results from two or more repeating sequences of waves. All this will tell you is the repeatability of your wavemaker and instrumentation. (You may prefer not to know this!). Worse still, if you transform as one block two or more sequences, your analysis resolution will be closer than the 'wet lines' in the tank and you will over-resolve the spectrum. It is essentatial therefore that one should generate long sequences of waves that are as long as, or longer than, the total length of run record that you wish to analyse.

REPLY TO THE DISCUSSION

B.JOHNSON - U.S.Naval Academy,
Annapolis, Maryland, U.S.A.

Mr. Rowe has raised two very interesting points which I have had to research after returning home from the ITTC. With regard to the first point, it is not my understanding that any time series can be reproduced by use of a Fourier tranform and a multi-component sine wave synthesizer or shift register synthesizer. Linear wave phenomena represented by a periodic time series (however long the repetition period so long as it is finite) can be reproduced by the sum of sinusoids technique. Transient phenomena which begin and end with zero amplitude will have a valid Fourier transform, but the frequency resolution will be infinitesimal and these time series require an infinite number of component waves to be reproduced exactly. All other time series cannot be reproduced exactly - only an approximation to the original series can be produced. If the wave generation system is a linear system (true for small amplitudes) this approximation will be quite good. Since the discussion concerned large amplitude waves which may be quite non-linear, the reproduction of the original time series will not be possible using Fourier transform techniques.

Amplitude modulation of the individual

components does more than "effectively inserting additional lines into the spectrum". In recent attempts to generate extreme waves, I have been unable to prevent premature breaking when using the sum of sinusoids technique with constant component amplitudes to try to obtain phase convergence at a particular location in the tank. Using the sweep frequency method (transient wave method) in which the component amplitudes vary from zero to whatever amplitude is generated at a particular frequency during the sweep, very large plunging breakers can be produced in deep water. Neither of these generation techniques approximate a real storm sea, which must contain time varying component amplitudes to realize observed extreme waves. I also question whether the extreme values predicted for a stationary Gaussian random process are adequate for predicting the occurrence of extreme waves in non-stationary storm seas. Incidently, I am not aware of how one tells whether or not a time series "appears non-stationary" just by looking at the time history.

With regard to the second point, I agree that averaging the analysis results from two or more repeating sequences of waves has no point if the system is linear. If, however, the system has a non-linear response shich may involve transient decay or amplification, the analysis of more than one repeating sequence will establish whether or not a steady state response has been established.

I also discovered another reference (1) to random testing techniques which should have been included in the original paper. Although the reference addresses the testing of automotive structures, its conclusions are also applicable to the testing of marine structures. The authors of this paper state that pseudo random techniques involving sufficiently long repetition periods to insure adequate spectral resolution of the phenomena being observed are the most efficient for linear systems. However, pure random testing is considered to be better for non-linear systems since "it gives the best linear approximation of a non-linear system." Impact testing (transient method) gave good results for linear systems, but is less effective for non-linear systems, unless only a "quick look" estimate is desired.

Dr. Schmiechen has raised valid point about the use of mathematically defined time series analysis terms. Since there are semantic difficulties arising from the use of these terms to describe and categorize wave time histories, the Information Committee should consider the inclusion of operational definitions of time series analysis terms in the updated Dictionary of Ship Hydrodynamics.

Dr. Kim discussed the influence of wave breaking on the wave system at various locatins in the tank. This problem was mentioned in the footnote on the fourth page of the paper, but the author is not aware of any means of compensating for the wave breaking once it has occured.

REFERENCE (1)
BROWN, D., CARBON, G., AND RAMSEY, K., "Survey of Excitation Techniques Applicable to the Testing of Automotive Structures", Paper No. 770029, Proceedings of the International Automotive Engineering Congress and Exposition, Detroit, Michigan, Society of Automotive Engineers, March, 1977.