ISSN 0140 3818
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UNIVERSITY OF SOUTHAMPTON

DEPARTMENT OF SHIP SCIENCE

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SORACOS V3.2 : A Suite of Programs for the Simulation of Roll and Capsize of Ships.

Volume 1 USER GUIDE

David G. Jones November 1982

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Overview

The manual is a user guide for the suite of programs SORACOS V3.2.

SORACOS is designed to simulate the non-linear rolling motion of a ship in regular beam waves at zero speed. It can supply the user with a wide variety of tabular and graphical output including the frequency response of the rolling ship, some measure of its stability, and/or a time dependent rolling response.

The user can select the mathematical model he wishes to use. Currently there are two,

(i) 'Model 1' was developed by the University of Southampton by Wright and Fëat. (1).

(ii) 'Model 2' was developed by the University of Newfoundland by Bass. (2).

CONTENTS

CHAPTER 1

OPERATING ENVIRONMENT

1. Operating Environment

The subsequent sections define the hardware and software environment required by the SORACOS suite.

Details of actual channel assignments, file names etc. can be found under the appropriate programs section in the Software Description (chp. 3).

1.1 Software Requirements

The SORACOS suite is written in an extended form of ANSI X3.9 1966 FORTRAN IV, and is not upward compatable with FORTRAN 77. The extensions used are as follows:

(i) Use of END, ERR in a READ statement.
i.e. READ (NIN, 900, END=100, ERR=200) A

(ii) Use of list directed READ statement
i.e. READ (NIN,*) A
This allows free format input.

(iii) Use of quotes in format statements
i.e. 905 FORMAT (1H, 2X,'**** ERROR 10')

SORACOS also uses the GIND-F graphics software library MK2.6.

1.2 Hardware Requirements

SORACOS was designed to be used on a PRIME 550 computer system. However, it is relatively machine independent and can be executed on any comparible system capable of the software support outlined in the previous section and the hardware support outlined in this section.

In addition to the computer, a lineprinter is required for the printing of results. Some form of file storage, usually disk is also needed.

The user interacts with the program via a tektronix type graphics terminal and perhaps a CALCOMP 81 flatbed plotter. Alternatively the user could interact with SORACOS via a normal VDU and CALCOMP 81 plotter.

CHAPTER 2

THEORY

2. Theory

To be able to use the suite of programs, one must be familiar with the theory that SORACOS employs in modelling the system.

MODEL 1 (UNIVERSITY OF SOUTHAMPTON)

Roll in a Beam Sea

Consider a ship rolling in a long crested wave system, incident on the beam. The basic frame of reference is a fixed, right hand coordinate system (x,y,z), origin on the still water surface, with the ship moving forwards along the x-axis, with the y-axis positive to starboard. Suppose for simplicity that the centre of gravity lies on the load waterplane. Let the angle of roll be donated by ϕ. Suppose the waves are long in comparison to the ships beam so that the waveslope as experienced by the ship is approximately that on the x-axis. If we assume that $\theta = \phi-\alpha$ and given that the waves are periodic with a maximum slope of α_M and frequency ω then the relative roll equation can be stated thus -

$$\alpha(t) = \alpha_M \cos(\omega t+\delta)$$

$$\ddot{\theta} + D(\dot{\theta},\theta) + R(\theta,t) = B + f\cos(\omega t+\delta)$$

It must be noted that for comparison with experimental results it is necessary to predict absolute response even though the equation solved is relative. This is achieved via a transformation which assumes that the harmonics of the solution are small compared to the fundamental.

B represents a static bias which introduces assymetry into the system. Possible source of such a heeling moment could be the wind.

$R(\theta,t)$ is a restoring moment and relates to the GZ curve.

$D(\dot{\theta},\theta)$ are the damping terms.

$f\cos(\omega t + \delta)$ is the forcing function and relates to the wave system.

Restoring Moment $(R(\theta,t))$

The form of the restoring moment is given by

$$R(\theta,t) = (1 - p\cos(\omega t + \delta p))(r_1\theta + r_2\theta^3 + r_3\theta^5 \ldots r_{\frac{n+1}{2}}\theta^n) \left(\frac{\omega_o^2}{r_1}\right)$$

Each of these terms is now discussed in more detail.

GZ Curve

For the mathematical analysis of the system, a method whereby the GZ curve can be accurately represented is needed. This is done by fitting the GZ curve with an odd order polynomial, and using this polynomial for the GZ curve.

The order of the polynomial is selected by the user, depending on the accuracy of solution required, between third and fifteenth order. The coefficients $r_1, r_2 \ldots r_{\frac{n+1}{2}}$ are available to the user once he has defined the shape of his curve.

The term ω_o is introduced via

$$r_1 = GM$$

$$\omega_o^2 = \frac{\Delta}{I + \delta I} GM$$

Parametric Excitation

The quantity

$$1 - p\cos(\omega t + \delta p)$$

takes into account the effects of ship position on a wave, and if required heave coupling.

Now δp is given by

$$\delta p = \delta + \delta r$$

If the forcing function has zero phase shift then:-

$$R(\theta,t) = (1 - p\cos(\omega t + \delta p))\ R^{(o)}(\theta)$$

It can be shown (1) that when position on a wave is included:

$$R(\theta,t) = (1 + \alpha_M \sin \omega t)\ R^{(o)}(\theta)$$

where

$$1 - p\cos(\omega t + \delta p) = 1 + \alpha_M \sin \omega t$$

hence

$$\delta p = \frac{\pi}{2}$$

$$p = \alpha_M$$

In addition to position as a wave effect for a time dependent restoring function, the displacement volume of a ship can vary such that

$$\nabla^1 = (1 + p_Z \sin(\omega t + \delta_Z))\nabla$$

If pressure and heave effects are combined we have

$$R(\theta,t) = (1 - p\cos(\omega t + \delta p))\ R^{(o)}(\theta)$$

with

$$p\cos\delta_r = -p_Z \sin\delta_Z$$

$$p\sin\delta_r = \alpha_M + p_Z \cos\delta_Z$$

The user must therefore select the effect he requires to include and calculate the appropriate values of p and δ_r.

It is obvious that the values of p and δ_r depend on frequency ω as well as ship geometry etc. An option is therefore provided to enable the user to either have a fixed value of p and δ_r, or the define p and δ_r as a function of frequency.

Damping Coefficients

The roll damping is given by

$$D(\theta,\dot{\theta}) = k_1\dot{\theta} + \tilde{k}_1\dot{\theta}\theta + k_3\dot{\theta}^3$$

where k_1 and k_3 are found from roll decay experiments. A more detailed discussion of roll decay experiments and how to obtain those parameters can be found in (5). At present, the angle dependent damping term $\tilde{k}_1$ is set to zero, however, should reliable estimates be available then, they can of course be used.

Forcing Function

The forcing function can be expressed as

$$B + f\cos(\omega t + \delta) = B + \frac{I}{I+\delta I}\,\alpha_m\omega^2\cos\,(\omega t+\delta)$$

where B is a constant heeling moment due to wind (input to the program as a still water bias angle) and δI represents the added mass in roll.

The computer program uses a quantity α_e, which represents the 'effective wave slope' to give

$$f\cos\,(\omega t + \delta) = \alpha_e\omega^2\cos\,(\omega t + \delta)$$

In the development of this program and in the example, the figure is

$$\alpha_e = 0.8\alpha_M$$

Inclusion of Sway

A more complete discussion on the inclusion of sway can be found in (4), but briefly -

Assume sway motion involves a known drift velocity term and a periodic component of frequency ω, phase δy

$$y(t) = y_d^{(t)} + y \sin(\omega t + \delta y)$$

where $y_d^{(t)} = v_d t$

where v_d = drift velocity

the roll equation takes on the additional terms:-

$$\ddot{\theta} + D(\dot{\theta}) + R(\theta) + S_1\dot{y} + S_2\ddot{y} = B - \ddot{\alpha}_e$$

n.b. S_1, S_2 include term $\frac{1}{I + \delta I}$

The extra terms that are required by the program to include sway is

S_1, S_2, v_d, y_o and δy

all of which are functions of frequency.

Time Domain Solution

The theory outlined from the basic differential equation describes the behaviour of the ship, rolling in the time domain.

The program 'TIMEPHASE' solves this equation (without sway) using either the Runga-Kutta-Mertson method, or the trapezoidal method (with error control). The difference between the two techniques is that RKM is much faster for the same error margin but TEC can supply a more accurate solution when the system is close to its limit of stability.

Pertubation Series Solution

To obtain the frequency response, a pertubation scheme was applied to the original differential equations (with/without sway) to form an equation which defines the system in the frequency domain. This is solved at different values of wave frequency to obtain the amplitude and phase of the roll motion together with the harmonics.

Stability Parameter

If the frequency response can be determined then a value for the stability 'GAMMA', can also be obtained.

Gamma gives an indication of what happens to the solution in the time domain, if it were perturbed.

The way this parameter is determined and how it is found theoretically can be found in (3). However it is sufficient to say that should gamma be positive, with no other alternate values, then the equation is considered unstable. Conversly, should gamma be negative with no alternate values, then the ship is considered to be stable.

MODEL 2 (UNIVERSITY OF NEWFOUNDLAND)

Roll in a Beam Sea

Consider a ship rolling in a long crested wave system, incident on the beam. The basic frame of reference is a fixed, right hand coordinate system (x,y,z), origin on the still water surface, with the ship moving forwards along the x-axis, with the y-axis positive to starboard. Suppose for simplicity that the centre of gravity lies on the load waterplane. Let the angle of roll be denoted by ϕ. Suppose the waves are long in comparison to the ships beam so that the waveslope as experienced by the ship is approximately that on the x-axis. If we assume that $\theta = \phi - \alpha$ and given that the waves are periodic with a maximum slope of α_M and frequency then the relative roll equation can be stated thus -

$$\alpha(t) = \alpha_M \cos(\omega t + \delta)$$

$$\ddot{\theta} + D(\dot{\theta}) + R(\theta, t, \beta) = f\cos(\omega t + \delta)$$

It must be noted that for comparison with experimental results it is necessary to predict absolute response even though the equation solved is relative. This is achieved via a transformation which assumes that the harmonics of the solution are small compared to the fundamental.

β represents a static bias due to shift in cargo, flooding etc. which introduces assymetry into the system.

$R(\theta,t,\beta)$ is a restoring moment and relates to the GZ curve.

$D(\dot{\theta})$ are the damping terms.

$f\cos(\omega t + \delta)$ is the forcing function and relates to the wave system.

Restoring Moment $(R(\theta,t,\beta))$

The form of the restoring moment is given by

$$R(\theta,t,\beta) = (1 - p\cos(\omega t + \delta p))\left(F(\theta) - F(\theta_S) - Z_O H(\theta)\sin(\omega t + \delta_Z)\right)$$

where

$$F(\theta) = \frac{\omega_o^2}{r_1} (r_1\theta + r_2\theta^3 + r_3\theta^5 \ldots r_{\frac{n+1}{2}}\theta^n)$$

and $$H(\theta) = \frac{\omega_o^2}{h_1} (h_1\theta + h_2\theta^3 + h_3\theta^5 \ldots h_{\frac{n+1}{2}}\theta^n)$$

Each of these terms is now discussed in more detail.

GZ Curve

For the mathematical analysis of the system, a method whereby the GZ curve can be accurately represented is needed. This is done by fitting the GZ curve with an odd order polynomial, and using this polynomial for the GZ curve.

The order of the polynomial is selected by the user, depending on the accuracy of solution required, between third and fifteenth order. The coefficients of $F(\theta)$ (and $H(\theta)$) are available once he has defined the shape of his curve(s).

The term $Z_o H(\theta) \sin(\omega t + \delta_Z)$ represents the time and angle dependent changes in righting lever, GZ associated with changes in displacement. The parameters Z_o and δ_Z represent the amplitude and phase of the relative heave motion. $H(\theta)$ is an odd order polynomial of a GZ 'type' curve derived from the cross curves of stability for the ship. Its derivation is given (2).

We note here that the bias term is included in the left hand side of the equation, within the time dependent parametric factor. See (2) for a detailed explanation of this and for the derivation of $H(\theta)$.

Parametric Excitation

The quantity

$$1 - p\cos(\omega t + \delta p)$$

takes into account the effects of ship position on a wave, and if required heave coupling.

Now δp is given by

$$\delta p = \delta + \delta_r$$

If the forcing function has zero phase shift then:-

$$R(\theta,t,\beta) = (1 - p\cos(\omega t + \delta p))\, R^{(o)}(\theta,t,\beta)$$

It can be shown (1) that when position on a wave is included:

$$R(\theta,t,\beta) = (1 + \alpha_M \sin\omega t)\, R^{(o)}(\theta,t,\beta)$$

where

$$1 - p\cos(\omega t + \delta p) = 1 + \alpha_M \sin\omega t$$

hence

$$\delta p = \frac{\pi}{2}$$

$$p = \alpha_M$$

In addition to position on a wave effect for a time dependent restoring function, the displacement volume of a ship can vary such that

$$\nabla^1 = (1 + p_Z \sin(\omega t + \delta_Z))\nabla$$

If pressure and heave effects are combined we have

$$R(\theta,t,\beta) = (1 - p\cos(\omega t + \delta_r))R^{(o)}(\theta,t,\beta)$$

with

$$p\cos\delta_r = - p_Z \sin\delta_Z$$

$$p\sin\delta_r = \alpha_M + p_Z \cos\delta_Z$$

The user must therefore select the effect he requires to include and calculate the appropriate values of p and δ_r. It is obvious that the values of p and δ_r depend on frequency ω as well as ship geometry etc. An option therefore is provided to enable the user to either have a fixed value of p and δ_r, or to define p and δ_r as functions of frequency.

Damping Coefficients

The roll damping is given by

$$D(\theta) = K_1\dot{\theta} + K_3\dot{\theta}^3$$

where K_1 and K_3 are found from roll decay experiments. A more detailed discussion of roll decay experiments and how to obtain these parameters can be found in (5).

Forcing Function

The forcing function can be expressed as

$$f\cos(\omega t + \delta) = \frac{I}{I+\delta I}\,\alpha_M\omega^2 \cos(\omega t + \delta)$$

where δI represents added mass in roll.

The computer programs uses a quantity α_e, which represents the 'effective wave slope' to give

$$f\cos(\omega t + \delta) = \alpha_e\omega^2\cos(\omega t + \delta)$$

In the development of this program and in the examples the relationship is

$$\alpha_e = 0.8\alpha_m$$

Time Domain Solution

The theory outlined from the basic differential equation describes the behaviour of the ship, rolling in the time domain.

The program 'TIMEPHASE' solves this equation using either the Runga-Kutta-Mertson method, or the trapezoidal method (with error control). The difference between the two techniques is that RKM is much faster for the same error margin, but TEC can supply a more accurate solution when the system is close to its limit of stability.

Pertubation Series Solution

To obtain the frequency response, a pertubation scheme was applied to the original differential equations to form a set of equations that define the system in the frequency domain. This is solved at different values of wave frequency to obtain the amplitude and phase of the roll motion together with the harmonics.

Stability Parameter

If the frequency response can be determined then a value for the stability 'GAMMA' can also be obtained.

Gamma, gives an indication of what happens to be the solution in the time domain, if it were perturbed.

The way this parameter is determined and how it is found theoretically can be found in (3). However it is sufficient to say that should gamma be positive, with no other alternative values, then the equation is considered unstable. Conversly, should gamma be negative with no alternate values then the ship is considered to be stable.

CHAPTER 3

SOFTWARE DESCRIPTION

AND USE

3. SOFTWARE DESCRIPTION AND USE.

The following sections describe how to execute programs from the SORACOS suite. The descriptions relate to use on a PRIME 550 computer, but the principles involved would apply to any system.

The SORACOS suite consists of four programs viz. GZPHASE, PERTPHASE, TIMEPHASE, GLOBALS. Briefly

(i) GZPHASE : Defines the GZ curve by generating odd order coefficients for a polynomial that fits the curve specified by the user. Alternatly the program can be used to plot curves for which the polynomial coefficients are already available.

(ii) PERTPHASE: This program will produce a frequency response and stability response for the ship using one of the selected mathematical models.

(iii) TIMEPHASE : This program produces a time domain response using one of the mathematical models previously described.

(iv) GLOBALS : Globals contain routines used by (i), (ii) and (iii) and must therefore be executed in conjunction with the appropriate program.

3.1 GZPHASE

Purpose

The purpose of this program is to take points that represent the users GZ curve, and, depending on the weighting and order, produce the polynomial coefficients.

Output consists of a list of coefficients and a choice of plots.

If the user already has the coefficients then those can be input and the program will produce a plot of the fitted curve.

Data

The first stage in the execution of this program is the creation of a data file. In the examples used the name of this data file is 'GZDATA'.

The format of this file will depend on what the user wishes the program to perform. The choices are

(i) calculate polynomial coefficients from GZ curve.
(ii) input polynomial coefficients for plotting.

The details now follow.

Input Data

All units are metric and data is input in free format.

line 1 (80 alphanumerics)

title

line 2 (2 integers, 1 real, 1 integer)

GZWGHT	specifies the weight required for curve fitting. GZWGHT=1 accurate at small angles of heel GZWGHT=2 accurate at large angles of heel
GZORDR	specifies order of polynomial that fits the GZ curve. Must be odd and in the range 3...15.
GZVNSH	Vanishing angle of GZ curve (rads)
IOPT	Flag for option IOPT=0 ; requires program to calculate odd order polynomial coefficients that best fit the GZcurve IOPT=1 ; user supplies GZ coefficients for subsequent plotting.

line 3 (1 integer) IF IOPT = 1 IGNORE THIS LINE

GZNPNT	number of pairs of points that describe the users GZ curve.

line 4 (2 reals) IF IOPT=1 IGNORE THIS LINE

GZANG(I)	the x-coordinate (heel angle)of the Ith point of the users GZ curve that is to be fitted with a polynomial	(rads)
GZAMP(I)	the y-coordinate (GZ) of the Ith point of the users GZ curve that is to be fitted with a polynomial	(metres)

Note 1. There are GZNPNT lines as I = 1, GZNPNT

2. There is one line for each pair of points.

line 5 (1 real) IF IOPT ≠ O IGNORE THIS LINE

GZCOEF(I) coefficients of the odd order polynomial that define the GZ curve that is to be plotted such that

$$r_1\theta + r_3\theta^3 \ldots r_{GZORDR}\theta^{GZORDR}$$

where GZCOEF(I) = r_I

Note 1. There are (GZORDR + 1)/2 lines as I = 1, GZORDR, 2

2. There is one line for each coefficient.

File Usage

Having created the data file, the next stage is to ensure the files required by the program are accessible. (i.e. have been 'OPENED'). The file usage of GZPHASE (and GLOBALS) is as follows-

FORTRAN CHANNEL NUMBER	PRIMOS FUNIT NUMBER	FILE NAME	COMMENTS
1	-	-	The users terminal. This must be either- (i) Tektronix type graphic terminal (TTGT) (ii) TTGT + Calcomp plotter (CC81) (iii) VDU + Calcomp plotter (CC81)
8	4	GZDATA	Data file that has just been created.
9	5	GZLIST	Contains results after run is complete (in FORTRAN format control)

On the PRIME, these can now be assigned by typing in, in response to a system prompt:-

```
OPEN GZDATA  4   3
OPEN GZLIST  5   3
```

Execution

The execution of GZPHASE (having created the data file and 'OPENED' the other channels) is now completed in two stages. The first is the creation of an object module file, which contains the necessary GINO routines. Then running this object module.

(i) Creation of Object Module

If the file ' GZPHASE' already exists, then proceed to (ii).

The object module is created, by inputting the following PRIMOS commands in response to appropriate system responses:-

```
FTN   GZPHASE -64V
...
...
FTN   GLOBALS -64V
...
...
SEG
...
LOAD
.....#GZPHASE
LO  B_GZPHASE
LO  B_GLOBALS
LO  CALCMP>B_CC81V
LI  VGRALIB
LI  VGINLIB
LI
....
SA
QU
```

(ii) Execution of GZPHASE

The program is now run by typing in response to a system prompt

```
SEG #GZPHASE
```

Graphic Output

After a few moments, the users terminal should respond by presenting the user with options for plotting.

The responses required are self-explanatory and the user should examine/produce the plots he requires.

The program execution is terminated upon request, by the user.

Listing Results

When execution of the program is terminated and control returns to the system, the file GZLIST contains the results for printing on a lineprinter (with FORTRAN format effecters).

This is now 'SPOOLED' to the lineprinter by typing in response to a system prompt:

```
SPOOL GZLIST -F
```

and later collected.

Errors

Should any errors occur, then the user is notified at his terminal and execution is terminated.

A list of errors is given in appendix I.

The user is encouraged to change the data file so as to deliberately cause errors, to see how the program responds.

Example

The following example shows the output that is obtained from one of the test data files on a PRIME 550 (PRIMOS).

SIMULATION OF ROLL AND CAPSIZE OF SHIPS

SORACOS V3.2

--INPUT DATA--

```
TEST OF GZ (TGZ1) FORM1 GZ CURVE
1  11  0.942  0
12
0.0  0.0
0.0856   0.0034
0.1713  0.0069
0.2569  0.0104
0.3425  0.0134
0.4282  0.0152
0.5138  0.0153
0.5994  0.0139
0.6851  0.0113
0.7707  0.0080
0.8564  0.0042
0.942  0.0
```

--POINTS FOR GZ CURVE SUPPLIED BY USER--

NO OF POINTS = 12

VANISHING ANGLE = 0.9420 RADS

ANGLE (RADIANS)	GZ (METRES)
0.0000	0.0000
0.0856	0.0034
0.1713	0.0069
0.2569	0.0104
0.3425	0.0134
0.4282	0.0152
0.5138	0.0153
0.5994	0.0139
0.6851	0.0113
0.7707	0.0080
0.8564	0.0042
0.9420	0.0000

--ODD ORDER COEFFICIENTS FOR GZ CURVE--

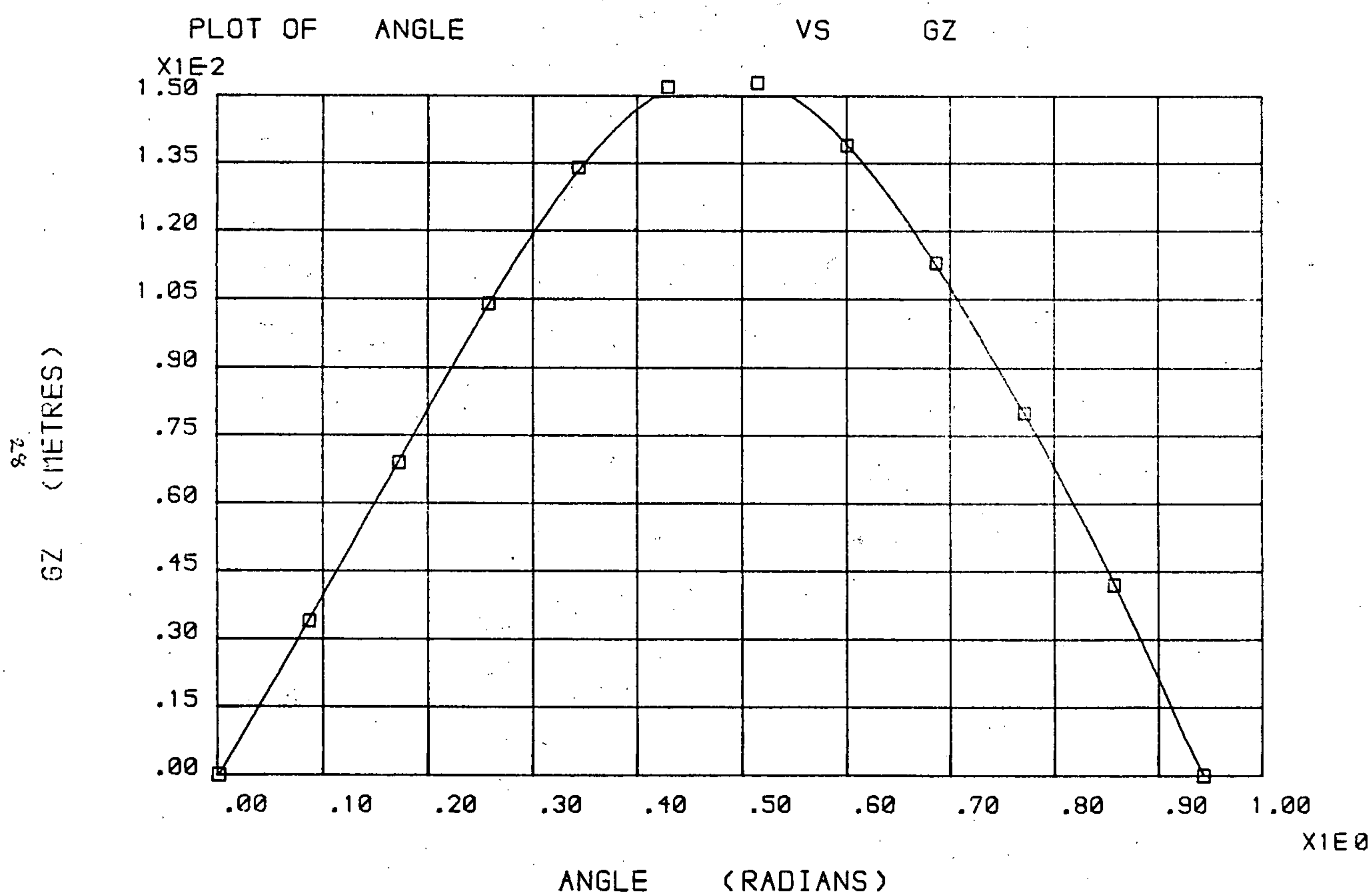
ORDER OF POLYNOMIAL = 11

WEIGHT FUNCTION SELECTED:-

1. MORE ACCURATE AT SMALL ROLL ANGLES

NO OF COEFFICIENT	COEFFICIENT
1	0.03972
3	0.04134
5	-0.52015
7	1.07454
9	-0.95860
11	0.32112

TEST OF GZ (TGZ1) FORM1 GZ CURVE



3.2 PERTPHASE

Purpose

The purpose of this program is to produce a frequency response of a ship rolling in beam seas with zero forward speed.

Basically, two mathematical models are available and effects such as heave and sway can be included if so desired.

Output is in tabular form and the user can select between a very large selection of plots.

-- WARNING --

To fully understand the terminology and definitions of some of the variables required by the program, the user must be conversant with the theoretical approach of the mathematical model he wishes to use.

Data

The first stage in the execution of this program is the creation of a data file. In the examples used the name of this data file is 'PERTDATA'.

The format of this file will depend on what the user wishes the program to perform. The choices are

(i) Model 1 + fixed parametric
(ii) Model 1 + fixed parametric and sway
(iii) Model 1 + parametric as $F(\omega)$
(iv) Model 1 + parametric as $F(\omega)$ + sway
(v) Model 2 + fixed parametric.

The details now follow.

Input Data

All units are metric and free format.

line 1 (80 alphanumerics)

Title

line 2 (1 integer)

IEQTN specifies the mathematical model to use

IEQTN = 1 Wright and Feát

IEQTN = 2 Bass

line 3 (5 reals)

K1	linear damping coefficient
K3	non-linear (cubic) damping coefficient
OMEGAO	natural roll frequency ω_o (rads/sec)
ALPHAM	maximum waveslope α_m (rads)
ALPHAE	effective waveslope α_e (rads)

line 4 (2 reals, 2 integers)

OMGMIN	Minimum frequency for frequency (rads/sec) response
OMGMAX	maximum frequency for frequency (rads/sec) response
NOSTEP	Approximate number of steps for frequency response
NOPAPZ	Number of points defining the parametric in the frequency domain

Note 1. OMGMIN>0 ; typically OMGMIN $\approx 0.5\omega_o$.

2. OMGMAX typically OMGMAX $\approx 2\omega_o$.

3. If NOPAPZ=0 the parametric is defined by two fixed values p and δ_r

4. If IEQTN=2 then NOPAPZ must equal zero.

line 5 (2 reals) IF NOPAPZ≠O IGNORE THIS LINE

PEE Parametric amplitude p

DELTAR Parametric phase δ_r (rads)

line 6 (3 reals) IF NOPAPZ=O IGNORE THIS LINE

PAFREQ(I) frequency of this point (rads/sec)

PAPZ (I) parametric term p_Z

PADZ (I) parametric phase δ_Z (rads)

Note 1. There is one line for each set of three points (see example)

2. NOPAPZ lines are needed as I=1, NOPAPZ

line 7 (1 integer)

NOSWAY Number of points defining sway coefficients in frequency domain

Note 1. If IEQTN = 2 then NOSWAY must equal O

line 8 (6 reals) IF NOSWAY = O IGNORE THIS LINE

SWFREQ(I) frequency of this point (Rad/sec)

PASI(I) sway coupling S1 at this frequency

PAS2(I) sway coupling S2 at this frequency

PAVD(I) sway drift velocity at this frequency (metres/sec)

PAYD(I) amplitude of sway motion at this frequency (metres)

PADY(I) sway motion phase at this frequency (rads)

Note 1. There is one line for each set of five points

Note 2. NOSWAY lines are needed as I=1, NOSWAY.

line 9 (1 integer)

GZORDR specifies order of polynomial that fits the GZ curve

Note 1. Must be odd and in the range 3...15.

line 10 (1 real)

GZCOEF(I) coefficients of the odd order polynomial that define the GZ curve such that

$$r_1\theta + r_3\theta^3 \ldots r_{GZORDR}\theta^{GZORDR}$$

where

GZCOEF(I) = r_I

Note 1. There are (GZORDR + 1)/2 lines as I=1, GZORDR,2

2. There is one line for each point.

line 11 (2 reals) IF IEQTN=1 IGNORE THIS LINE

ZO parametric amplitude for second displaced GZ curve.

ZO = Z_O

DELTAY phase term for second displaced GZ curve (rads) such that

$$\delta_Z = \delta + \text{DELTAY}$$

line 12 (1 reals) IF IEQTN = 1 IGNORE THIS LINE

GZCOEG(I) coefficients of the odd order polynomial that define the displaced GZ curve such that

$$h_1\theta + h_3\theta^3 \ldots h_{GZORDR}\theta^{GZORDR}$$

where

GZCOEG(I) = h_I

Note 1. There are (GZORDR + 1)/2 lines as I = 1, GZORDR,2

2. There is one line for each point.

line 13 (2 reals, 1 integer, 2 reals)

ASTRT — represents the minimum roll amplitude (rads)
to use in the frequency response.
Typically 0.15.

AFIN — represents the maximum roll amplitude (rads)
in the frequency response.
Typically 0.7.

ANPLCS — specifies accuracy of solution required in
number of decimal places.
Typically 5

THETAS — still water bias (heel) angle θ_S. (rads)
can be positive or negative.
If IEQTN=1 ; $+\theta_S$ = heel away from waves (starboard)
If IEQTN=2 ; $+\theta_S$ = heel toward waves (port)

BARK1 — angle dependant damping . (If IEQTN=2 then
BARK1 must equal 0.0).

line 14 (3 integers)

NOEXP — number of experimental points to plot on one of the
graphs.

IXOPT — x-axis option for the experimental points must be in
range 1-20 and corresponds to the same options the
user is presented with for graphic output. i.e.
if IXOPT=1 it means that XEXP(I) contains frequencies
in rad/sec.

IYOPT — As for IXOPT only for the y-axis i.e. if IYOPT=3
then YEXP(I) contains absolute roll amplitudes
(rads).

Note 1 — Experimental points are only plotted onto a user
selected graph when the following conditions are
satisfied.

1) $0<\mathrm{NOEXP}<=25$
2) The user selected choice for the x-axis and y-axis
from the plot menu corresponds with IXOPT and IYOPT.

line 15 (2 reals) IF NOEXP=O IGNORE THIS LINE

XEXP(I) x-coordinate of the users Ith data point in users data units. i.e. Hertz.

YEXP(I) y-coordinate of the users Ith data point in users data units i.e. rads.

Note 1 There are NOEXP lines as I=1, NOEXP

2 There is one line for each pair of points.

File Usage

Having created the data file, the next stage is to ensure the files required by the program are accessible. (i.e. have been 'OPENED'). The file usage of PERTPHASE (and GLOBALS) is as follows.

FORTRAN CHANNEL NUMBER	PRIMOS FUNIT NUMBER	FILE NAME	COMMENTS
1	-	-	The users terminal. This must be either (i) Tektronix type graphic terminal (TTGT) (ii) TTGT + Calcomp plotter (CC81) (iii) VDU + Calcomp plotter (CC81)
8	4	PERTDATA	Data file that has just been created
9	5	PERTLIST	Contains results after run is complete (a FORTRAN format control)
11	7	SCRATCH	Scratch file - contains no useful information at end of run

On the PRIME, these can now be assigned by typing in, in response to a system prompt:-

```
OPEN    PERTDATA    4    3
OPEN    PERTLIST    5    3
OPEN    SCRATCH     7    3
```

Execution

The execution of PERTPHASE (having created the data file and 'OPENED' the other channels), is now completed in two stages. The first is the creation of an object module file, which contains the necessary GINO routines.
Then running this object module.

(i) Creation of object module

If the file PERTPHASE already exists, then proceed to (ii).

The object module is created, by imputting the following PRIMOS commands in response to the appropriate system responses:-

```
FTN   PERTPHASE   -64V
...
...
FTN   GLOBALS     -64V
...
...
SEG
...
LOAD
..... #PERTPHASE
LO  B_PERTPHASE
LO B_GLOBALS
LO CALCMP>B_CC81V
LI VGRALIB
LI VGINLIB
....
SA
QU
```

(ii) Execution of PERTPHASE

The program is now run by typing in response to a system prompt

```
SEG #PERTPHASE
```

Graphic Output

After a few moments the users terminal should respond by presenting the user with options for plotting.

The responses required are self-explanatory and the user should examine/produce the plots he requires.

The program execution is terminated upon request, by the user.

Listing Results

When execution of the program is terminated and control returns to the system, the file PERTLIST contains the results for printing on a line printer (with FORTRAN format effectors).

This is now 'SPOOLED' to the lineprinter by typing, in response to a system prompt:-

```
SPOOL PERTLIST  -F
```

and later collected.

Errors

Should any errors occur, then the user is notified at his terminal and execution is terminated.

A list of errors is given in Appendix I.

The user is encouraged to change the data file so as to deliberatly cause errors, to see how the program responds.

Example

The following example shows the output obtained from the test data file on a PRIME 550 (PRIMOS).

SIMULATION OF ROLL AND CAPSIZE OF SHIPS

SORACOS V3.2

--INPUT DATA--

```
COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS)  5-AUGUST-1982
1
0.157  0.114  5.23  0.15  0.12
3.0  10.0  50  0
0.22  1.571
0
15
0.03926
0.05246
-0.57788
1.05101
-0.14243
-1.80662
2.1857
-0.808
0.2  0.55  5  0.105  0.0
12  2  3
0.617   0.258
0.582   0.220
0.656   0.310
0.622   0.263
0.709   0.553
0.661   0.331
0.807   0.424
0.752   0.454
0.858   0.387
0.800   0.409
0.756   0.482
0.705   0.490
```

--PERTUBATION SERIES ANALYSIS TABLE OF COEFFICIENTS--

LINEAR DAMPING COEFFICIENT	K1	=	0.15700	
NON-LINEAR DAMPING COEFFICIENT	K3	=	0.11400	
ANGLE DEPENDANT DAMPING	K1BAR	=	0.00000	
NATURAL FREQUENCY	WO	=	5.23000	RAD/SEC
MAXIMUM WAVE SLOPE	ALPHAM	=	0.15000	RAD
EFFICITIVE WAVE SLOPE	ALPHAE	=	0.12000	RAD
STILL WATER BIAS	THETAS	=	0.10500	RAD
PARAMETRIC AMPLITUDE	P	=	0.22000	
PARAMETRIC PHASE	DELTAR	=	1.57100	RAD

--MODEL USED--

1: UNIVERSITY OF SOUTHAMPTON (WRIGHT AND FEAT)

--PERTUBATION SERIES ANALYSIS EXPERIMENTAL POINTS--

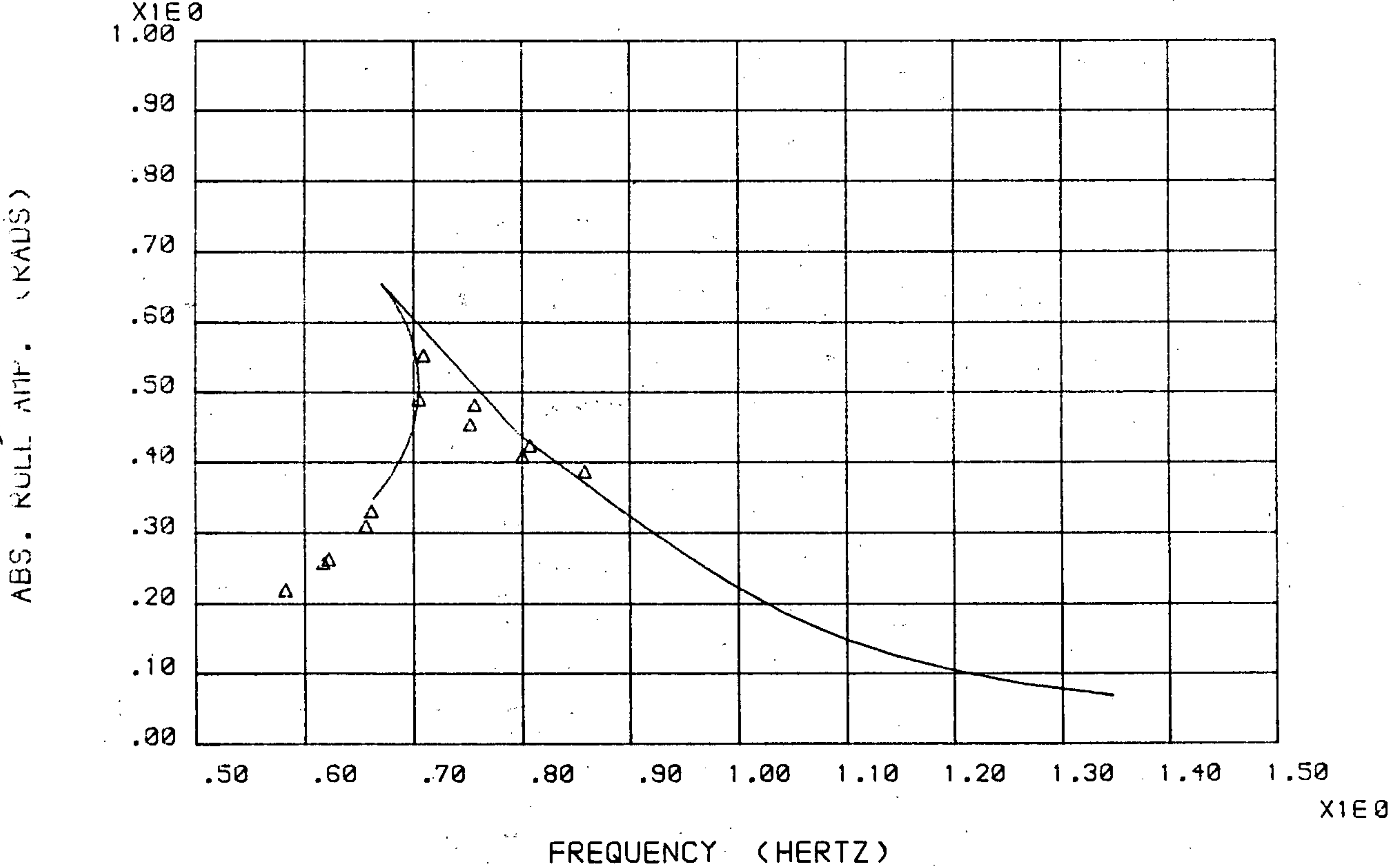
X	Y
0.6170E 00	0.2580E 00
0.5820E 00	0.2200E 00
0.6560E 00	0.3100E 00
0.6220E 00	0.2630E 00
0.7090E 00	0.5530E 00
0.6610E 00	0.3310E 00
0.8070E 00	0.4240E 00
0.7520E 00	0.4540E 00
0.8580E 00	0.3870E 00
0.8000E 00	0.4090E 00
0.7560E 00	0.4820E 00
0.7050E 00	0.4900E 00

COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982 --SORACOS V3.2--

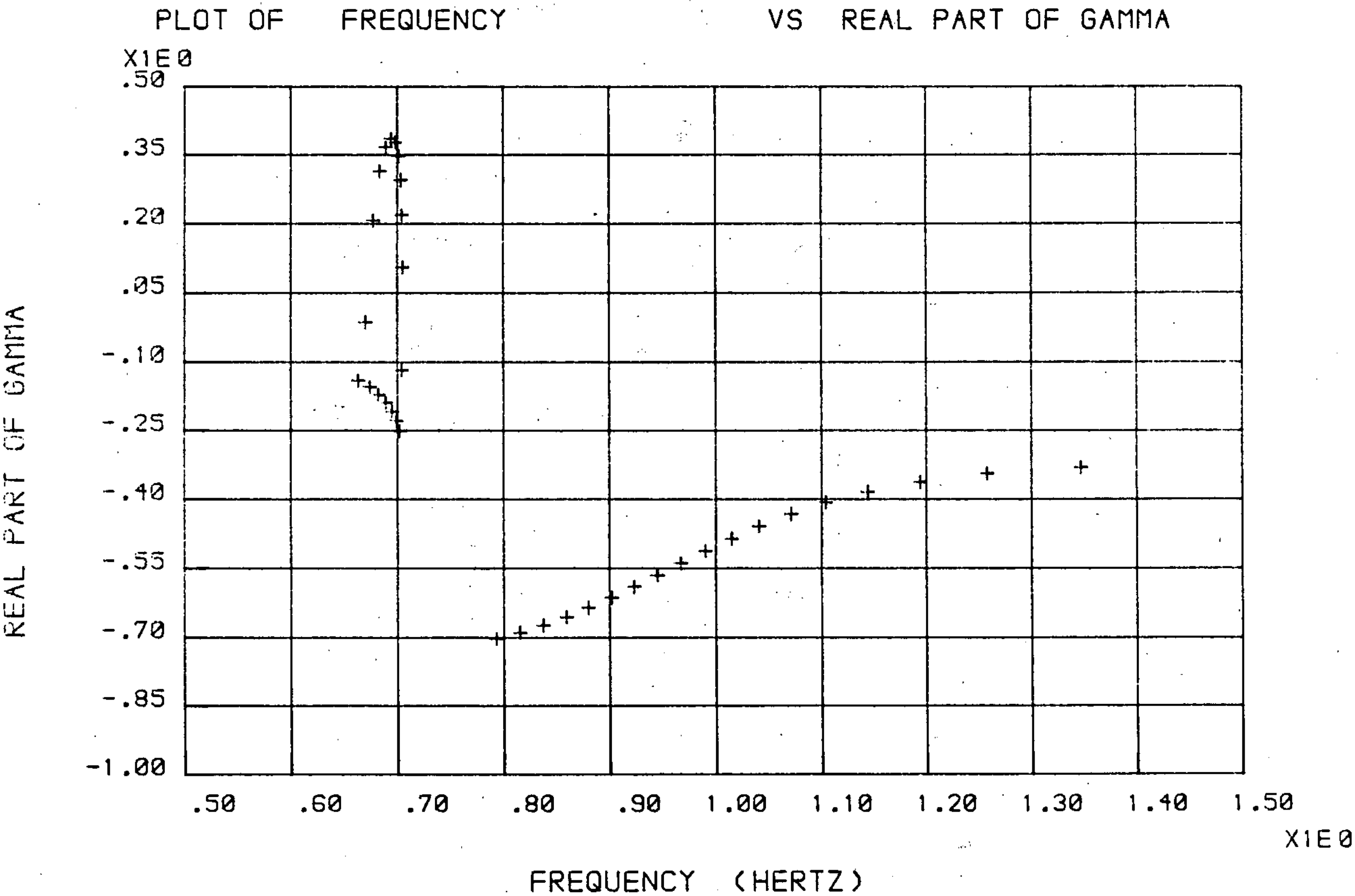
FREQUENCY (RAD/SEC)	(HERTZ)	ABSOLUTE AMPLTD. (RADS)	ROLL PHASE (DEGS)	RELATIVE AMPLTD. (RADS)	ROLL PHASE (DEGS)	SECOND HARMONIC AMPLTD. (RADS)	PHASE (DEGS)	THIRD HARMONIC AMPLTD. (RADS)	PHASE (DEGS)	ABSOLUTE AO (RADS)	RELATIVE AO (RADS)	REAL PART GAMMA
4.168	0.663	0.3493	-93.69	0.2000	-96.46	0.0076	175.19	0.0003	34.82	0.1052	0.1051	-0.140E 00
8.462	1.347	0.0681	38.74	0.2000	74.54	0.0074	-15.75	0.0002	76.96	0.1059	0.0985	-0.331E 00
4.233	0.674	0.3689	-93.39	0.2196	-95.70	0.0084	172.54	0.0004	30.15	0.1054	0.1058	-0.155E 00
7.903	1.258	0.0865	44.33	0.2196	73.58	0.0081	-15.77	0.0003	72.18	0.1055	0.0977	-0.344E 00
4.286	0.682	0.3865	-92.96	0.2392	-94.82	0.0092	169.44	0.0005	26.05	0.1057	0.1068	-0.171E 00
7.500	1.194	0.1058	47.37	0.2392	72.50	0.0088	-15.41	0.0004	67.32	0.1049	0.0969	-0.362E 00
4.329	0.689	0.4080	-92.42	0.2588	-93.83	0.0100	165.95	0.0006	22.52	0.1062	0.1081	-0.159E 00
7.190	1.144	0.1257	48.93	0.2588	71.31	0.0094	-14.64	0.0005	62.54	0.1044	0.0963	-0.384E 00
4.364	0.695	0.4275	-91.75	0.2784	-92.70	0.0109	162.11	0.0009	19.50	0.1068	0.1098	-0.208E 00
6.939	1.104	0.1461	49.53	0.2784	69.99	0.0099	-13.43	0.0007	57.95	0.1040	0.0959	-0.407E 00
4.391	0.699	0.4470	-90.94	0.2980	-91.42	0.0119	158.03	0.0011	16.95	0.1076	0.1119	-0.229E 00
6.729	1.071	0.1668	49.46	0.2980	68.55	0.0105	-11.73	0.0008	53.61	0.1037	0.0957	-0.432E 00
4.416	0.702	0.4663	-89.99	0.3176	-89.99	0.0131	153.78	0.0014	14.80	0.1086	0.1144	-0.251E 00
6.543	1.041	0.1879	48.89	0.3176	66.98	0.0109	-9.50	0.0011	49.56	0.1036	0.0958	-0.459E 00
4.422	0.704	0.4854	-88.88	0.3373	-88.33	0.0143	149.47	0.0018	12.98	0.1098	0.1173	-0.117E 00
6.377	1.015	0.2093	47.93	0.3373	65.27	0.0113	-6.65	0.0013	45.81	0.1037	0.0962	-0.485E 00
4.427	0.705	0.5044	-87.61	0.3569	-86.60	0.0157	145.17	0.0023	11.44	0.1112	0.1207	0.105E 00
6.223	0.990	0.2310	46.65	0.3569	63.42	0.0116	-3.12	0.0017	42.36	0.1040	0.0970	-0.512E 00
4.425	0.704	0.5232	-86.15	0.3765	-84.62	0.0173	140.95	0.0028	10.14	0.1129	0.1245	0.219E 00
6.077	0.967	0.2530	45.08	0.3765	61.42	0.0120	1.18	0.0021	39.18	0.1046	0.0983	-0.539E 00
4.417	0.703	0.5416	-84.52	0.3961	-82.44	0.0190	136.86	0.0035	9.04	0.1149	0.1288	0.296E 00
5.938	0.945	0.2754	43.25	0.3961	59.26	0.0123	6.31	0.0026	36.25	0.1054	0.1001	-0.565E 00
4.404	0.701	0.5598	-82.68	0.4157	-80.04	0.0209	132.94	0.0043	8.11	0.1171	0.1337	0.345E 00
5.801	0.923	0.2982	41.20	0.4157	56.95	0.0127	12.31	0.0032	33.55	0.1066	0.1024	-0.590E 00
4.384	0.698	0.5775	-80.62	0.4353	-77.41	0.0230	129.17	0.0052	7.34	0.1197	0.1391	0.378E 00
5.666	0.902	0.3214	38.93	0.4353	54.48	0.0132	19.17	0.0038	31.06	0.1082	0.1055	-0.613E 00
4.358	0.694	0.5946	-78.34	0.4549	-74.52	0.0253	125.58	0.0062	6.69	0.1227	0.1450	0.385E 00
5.532	0.880	0.3451	36.44	0.4549	51.82	0.0139	26.77	0.0046	28.73	0.1102	0.1092	-0.635E 00
4.328	0.689	0.6112	-75.81	0.4745	-71.36	0.0277	122.13	0.0073	6.17	0.1260	0.1515	0.367E 00
5.397	0.859	0.3692	33.74	0.4745	48.98	0.0149	34.87	0.0056	26.56	0.1127	0.1139	-0.656E 00
4.292	0.683	0.6271	-73.00	0.4941	-67.91	0.0304	118.81	0.0087	5.75	0.1298	0.1596	0.314E 00
5.261	0.837	0.3939	30.83	0.4941	45.94	0.0163	43.12	0.0067	24.52	0.1158	0.1195	-0.674E 00
4.252	0.677	0.6420	-69.88	0.5137	-64.12	0.0333	115.59	0.0102	5.43	0.1341	0.1664	0.207E 00
5.124	0.815	0.4193	27.68	0.5137	42.66	0.0182	51.17	0.0079	22.59	0.1196	0.1262	-0.689E 00
4.208	0.670	0.6559	-66.41	0.5333	-59.95	0.0364	112.46	0.0118	5.21	0.1391	0.1750	-0.134E-01
4.984	0.793	0.4453	24.26	0.5333	39.11	0.0207	58.71	0.0094	20.74	0.1242	0.1342	-0.703E 00

COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982

PLOT OF FREQUENCY VS ABS. ROLL AMP.



COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982



SIMULATION OF ROLL AND CAPSIZE OF SHIPS

SORACOS V3.2

--INPUT DATA--

```
COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS)  5-AUGUST-1982
1
0.157  0.114  5.23  0.15  0.12
3.0  10.0  50  0
0.22  1.571
11
1.0   1.5   1.6   0.0002  0.15   -1.571
3.603  1.005  1.576  0.0003  0.109  -1.575
3.808  1.274  1.577  0.0004  0.097  -1.574
4.054  1.646  1.572  0.0003  0.085  -1.575
4.355  2.166  1.548  0.0004  0.072  -1.572
4.734  2.899  1.497  0.0005  0.060  -1.571
5.234  3.904  1.386  0.0004  0.047  -1.570
5.935  5.477  1.23   0.0006  0.034  -1.565
7.022  6.158  0.855  0.0005  0.021  -1.565
9.066  5.751  0.5223 0.0003  0.008  -1.550
15.7   2.806  0.701  0.0002  0.0001 1.60
15
0.03926
0.05246
-0.57788
1.05101
-0.14243
-1.80662
2.1857
-0.808
0.2  0.55  5  0.105  0.0
12  2  3
0.617  0.258
0.582  0.220
0.656  0.310
0.622  0.263
0.709  0.553
0.661  0.331
0.807  0.424
0.752  0.454
0.858  0.387
0.800  0.409
0.756  0.482
0.705  0.490
```

--PERTUBATION SERIES ANALYSIS TABLE OF COEFFICIENTS--

LINEAR DAMPING COEFFICIENT	K1	=	0.15700
NON-LINEAR DAMPING COEFFICIENT	K3	=	0.11400
ANGLE DEPENDANT DAMPING	K1BAR	=	0.00000
NATURAL FREQUENCY	WO	=	5.23000 RAD/SEC
MAXIMUM WAVE SLOPE	ALPHAM	=	0.15000 RAD
EFFICITIVE WAVE SLOPE	ALPHAE	=	0.12000 RAD
STILL WATER BIAS	THETAS	=	0.10500 RAD
PARAMETRIC AMPLITUDE	P	=	0.22000
PARAMETRIC PHASE	DELTAR	=	1.57100 RAD

--SWAY COEFFICIENTS]--

FREQUENCY	SWAY COUPLING		DRIFT VELOCITY	SWAY MOTION	
(RAD/SEC)	S1	S2	(METRE/SEC)	YO (METRES)	DY (RADS)
1.000	1.5000	1.6000	0.0002	0.150	-1.571
3.603	1.0050	1.5760	0.0003	0.109	-1.575
3.808	1.2740	1.5770	0.0004	0.097	-1.574
4.054	1.6460	1.5720	0.0003	0.085	-1.575
4.355	2.1660	1.5480	0.0004	0.072	-1.572
4.734	2.8990	1.4970	0.0005	0.060	-1.571
5.234	3.9040	1.3860	0.0004	0.047	-1.570
5.935	5.4770	1.2300	0.0006	0.034	-1.565
7.022	6.1580	0.8550	0.0005	0.021	-1.565
9.066	5.7510	0.5223	0.0003	0.008	-1.550
15.700	2.8060	0.7010	0.0002	0.000	1.600

COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982 --SORACOS V3.2--

--PERTURBATION SERIES ANALYSIS EXPERIMENTAL POINTS--

X	Y
0.6170E 00	0.2580E 00
0.5820E 00	0.2200E 00
0.6560E 00	0.3100E 00
0.6220E 00	0.2630E 00
0.7090E 00	0.5530E 00
0.6610E 00	0.3310E 00
0.8070E 00	0.4240E 00
0.7520E 00	0.4540E 00
0.8580E 00	0.3870E 00
0.8000E 00	0.4090E 00
0.7560E 00	0.4820E 00
0.7050E 00	0.4900E 00

COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982 --SORACOS V3.2--

FREQUENCY (RAD/SEC)	(HERTZ)	ABSOLUTE ROLL AMPLTD. (RADS)	PHASE (DEGS)	RELATIVE ROLL AMPLTD. (RADS)	PHASE (DEGS)	SECOND HARMONIC AMPLTD. (RADS)	PHASE (DEGS)	THIRD HARMONIC AMPLTD. (RADS)	PHASE (DEGS)	ABSOLUTE AO (RADS)	RELATIVE AO (RADS)	REAL PART GAMMA
4.223	0.672	0.3467	278.75	0.2000	285.29	0.0035	159.87	0.0003	34.78	0.0947	0.0966	-0.141E 00
8.098	1.289	0.0499	89.82	0.2000	89.95	0.0139	0.21	0.0002	75.37	0.1044	0.1043	-0.314E 00
4.288	0.682	0.3659	279.40	0.2196	285.80	0.0042	157.52	0.0004	29.65	0.0942	0.0967	-0.157E 00
7.607	1.211	0.0696	85.50	0.2196	88.57	0.0152	-0.77	0.0003	70.75	0.1057	0.1039	-0.328E 00
4.342	0.691	0.3849	280.14	0.2392	286.47	0.0050	154.37	0.0005	25.39	0.0939	0.0970	-0.173E 00
7.250	1.154	0.0895	82.36	0.2392	87.14	0.0163	-1.53	0.0004	66.14	0.1067	0.1035	-0.348E 00
4.385	0.698	0.4038	280.98	0.2588	287.31	0.0059	150.69	0.0007	21.89	0.0937	0.0976	-0.192E 00
6.974	1.110	0.1095	79.67	0.2586	85.64	0.0171	-2.18	0.0005	61.62	0.1075	0.1033	-0.370E 00
4.419	0.703	0.4226	281.92	0.2784	288.31	0.0070	146.73	0.0009	19.00	0.0937	0.0987	-0.211E 00
6.750	1.074	0.1297	77.19	0.2784	84.05	0.0179	-2.63	0.0006	57.29	0.1083	0.1033	-0.394E 00
4.446	0.708	0.4411	282.98	0.2980	289.47	0.0082	142.69	0.0012	16.63	0.0939	0.1002	-0.233E 00
6.561	1.044	0.1500	74.80	0.2980	82.32	0.0186	-2.83	0.0008	53.21	0.1091	0.1034	-0.419E 00
4.466	0.711	0.4595	284.15	0.3176	290.77	0.0096	138.72	0.0015	14.68	0.0943	0.1021	-0.255E 00
6.396	1.018	0.1705	72.40	0.3176	80.61	0.0191	-2.72	0.0010	49.41	0.1101	0.1038	-0.446E 00
4.479	0.713	0.4776	285.43	0.3373	292.23	0.0111	134.94	0.0019	13.08	0.0950	0.1045	-0.279E 00
6.249	0.995	0.1912	69.94	0.3373	78.71	0.0196	-2.29	0.0013	45.90	0.1112	0.1046	-0.473E 00
4.487	0.714	0.4954	286.85	0.3569	293.85	0.0129	131.41	0.0024	11.77	0.0960	0.1075	0.412E-01
6.113	0.973	0.2121	67.36	0.3569	76.67	0.0199	-1.52	0.0017	42.67	0.1125	0.1056	-0.501E 00
4.489	0.714	0.5129	288.41	0.3765	295.64	0.0148	128.16	0.0030	10.69	0.0974	0.1109	0.156E 00
5.986	0.953	0.2334	64.64	0.3765	74.47	0.0201	-0.36	0.0021	39.69	0.1139	0.1070	-0.529E 00
4.486	0.714	0.5300	290.13	0.3961	297.61	0.0170	125.19	0.0036	9.81	0.0990	0.1150	0.228E 00
5.865	0.933	0.2550	61.75	0.3961	72.08	0.0202	1.24	0.0025	36.95	0.1156	0.1088	-0.557E 00
4.479	0.713	0.5467	292.01	0.4157	299.78	0.0193	122.49	0.0044	9.10	0.1011	0.1195	0.269E 00
5.747	0.915	0.2770	58.68	0.4157	69.49	0.0202	3.36	0.0031	34.43	0.1174	0.1111	-0.584E 00
4.467	0.711	0.5628	294.08	0.4353	302.16	0.0218	120.03	0.0053	8.54	0.1035	0.1247	0.282E 00
5.631	0.896	0.2996	55.40	0.4353	66.68	0.0200	6.13	0.0038	32.09	0.1195	0.1138	-0.610E 00
4.451	0.708	0.5784	296.36	0.4549	304.78	0.0244	117.78	0.0063	8.10	0.1063	0.1303	0.262E 00
5.516	0.878	0.3226	51.68	0.4549	63.62	0.0196	9.72	0.0046	29.91	0.1218	0.1171	-0.635E 00
4.432	0.705	0.5933	298.88	0.4745	307.67	0.0272	115.72	0.0074	7.79	0.1096	0.1365	0.200E 00
5.401	0.860	0.3468	48.08	0.4745	60.28	0.0192	14.39	0.0055	27.86	0.1243	0.1210	-0.658E 00
4.410	0.702	0.6073	301.69	0.4941	310.86	0.0300	113.80	0.0086	7.58	0.1134	0.1433	0.668E-01
5.285	0.841	0.3716	43.98	0.4941	56.60	0.0187	20.47	0.0065	25.93	0.1271	0.1256	-0.680E 00
4.385	0.698	0.6203	304.83	0.5137	314.43	0.0329	111.98	0.0100	7.48	0.1177	0.1506	-0.252E 00
5.168	0.822	0.3976	39.52	0.5137	52.54	0.0183	28.35	0.0077	24.08	0.1301	0.1309	-0.700E 00
4.358	0.694	0.6321	308.39	0.5333	318.45	0.0358	110.23	0.0115	7.49	0.1226	0.1583	-0.561E 00
5.048	0.803	0.4251	34.58	0.5333	47.97	0.0183	38.34	0.0091	22.28	0.1334	0.1371	-0.718E 00

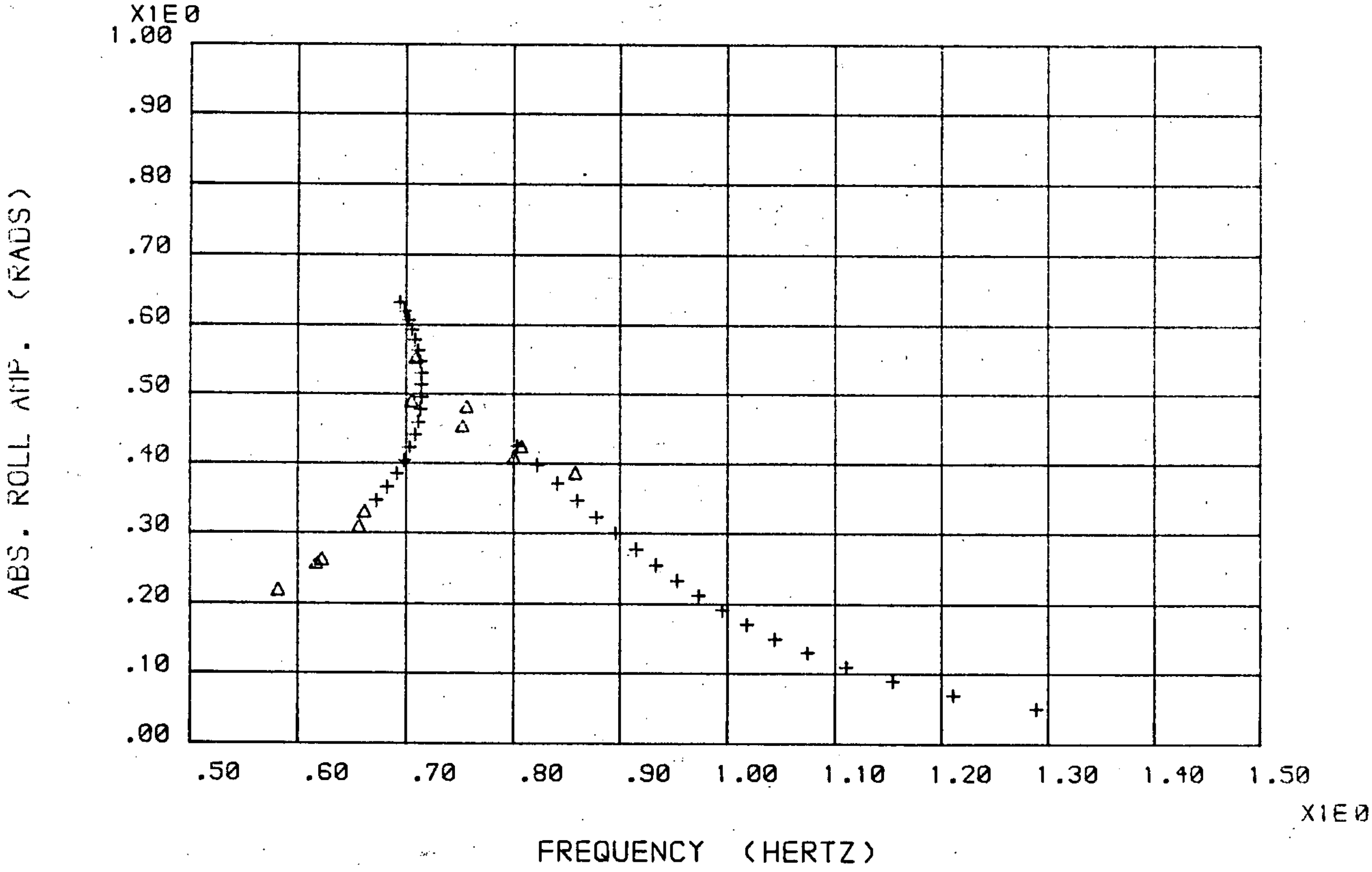
COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982 --SORACOS V3.2--

S W A Y

FREQUENCY		PARAMETRIC		SWAY COUPLING		DRIFT VELOCITY	SWAY MOTION	
(RAD/SEC)	(HERTZ)	P	DELTAR (DEGS)	S1	S2	(METRE/SEC)	YO (METRES)	DY (DEGS)
4.223	0.672	0.220	90.010	1.9290	1.5610	0.0003	0.077	-90.160
8.098	1.289	0.220	90.010	6.0260	0.6145	0.0003	0.013	-91.060
4.288	0.682	0.220	90.010	2.0440	1.5550	0.0004	0.075	-90.110
7.607	1.211	0.220	90.010	6.1160	0.7004	0.0004	0.016	-90.510
4.342	0.691	0.220	90.010	2.1410	1.5490	0.0004	0.073	-90.080
7.250	1.154	0.220	90.010	6.1510	0.7868	0.0005	0.019	-89.950
4.385	0.698	0.220	90.010	2.2210	1.5450	0.0004	0.071	-90.050
6.974	1.110	0.220	90.010	6.1580	0.8706	0.0005	0.021	-89.620
4.419	0.703	0.220	90.010	2.2860	1.5410	0.0004	0.070	-90.040
6.750	1.074	0.220	90.010	6.1400	0.9490	0.0006	0.024	-89.490
4.446	0.708	0.220	90.010	2.3370	1.5380	0.0004	0.069	-90.030
6.561	1.044	0.220	90.010	6.0900	1.0190	0.0006	0.026	-89.460
4.466	0.711	0.220	90.010	2.3750	1.5360	0.0005	0.068	-90.030
6.396	1.018	0.220	90.010	6.0060	1.0790	0.0006	0.028	-89.480
4.479	0.713	0.220	90.010	2.4010	1.5340	0.0005	0.068	-90.020
6.249	0.995	0.220	90.010	5.8900	1.1310	0.0006	0.030	-89.530
4.487	0.714	0.220	90.010	2.4160	1.5330	0.0005	0.067	-90.020
6.113	0.973	0.220	90.010	5.7430	1.1770	0.0006	0.031	-89.580
4.489	0.714	0.220	90.010	2.4200	1.5330	0.0005	0.067	-90.020
5.986	0.953	0.220	90.010	5.5620	1.2160	0.0006	0.033	-89.640
4.486	0.714	0.220	90.010	2.4150	1.5340	0.0005	0.067	-90.020
5.865	0.933	0.220	90.010	5.3480	1.2490	0.0006	0.035	-89.700
4.479	0.713	0.220	90.010	2.4000	1.5340	0.0005	0.068	-90.020
5.747	0.915	0.220	90.010	5.1050	1.2770	0.0005	0.037	-89.760
4.467	0.711	0.220	90.010	2.3780	1.5360	0.0005	0.068	-90.030
5.631	0.896	0.220	90.010	4.8430	1.3030	0.0005	0.039	-89.810
4.451	0.708	0.220	90.010	2.3480	1.5380	0.0004	0.069	-90.030
5.516	0.878	0.220	90.010	4.5690	1.3270	0.0004	0.041	-89.860
4.432	0.705	0.220	90.010	2.3110	1.5400	0.0004	0.069	-90.040
5.401	0.860	0.220	90.010	4.2920	1.3500	0.0004	0.043	-89.900
4.410	0.702	0.220	90.010	2.2690	1.5420	0.0004	0.070	-90.040
5.285	0.841	0.220	90.010	4.0200	1.3750	0.0004	0.046	-89.940
4.385	0.698	0.220	90.010	2.2220	1.5450	0.0004	0.071	-90.050
5.168	0.822	0.220	90.010	3.7590	1.4010	0.0004	0.049	-89.970
4.358	0.694	0.220	90.010	2.1720	1.5480	0.0004	0.072	-90.070
5.048	0.803	0.220	90.010	3.5110	1.4290	0.0004	0.052	-89.990

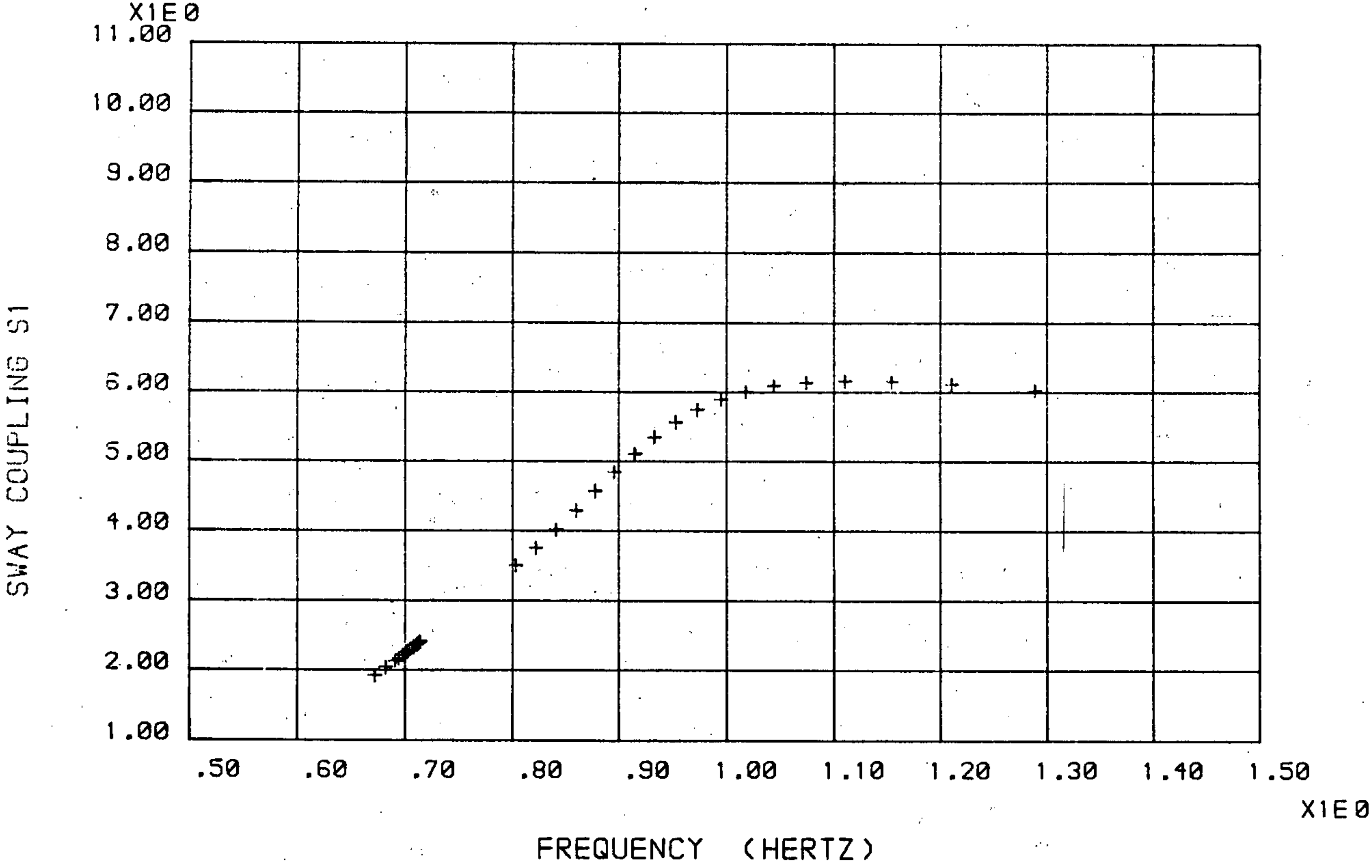
COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982

PLOT OF FREQUENCY VS ABS. ROLL AMP.



COPY OF RUN 5.7 (VOL2 COMPUTED RESULTS) 5-AUGUST-1982

PLOT OF FREQUENCY VS SWAY COUPLING S1



3.3 TIMEPHASE

Purpose

The purpose of this program is to produce a time domain response of a ship rolling in beam waves with zero forward speed.

Basically two mathematical models are available and effects such as heave can be included if so desired.

Solution are calculated using one of two numerical integration techniques, depending on the accuracy required, and how close the system is to its limit of stability.

Output is in tabular form and the user can select between a very large selection of plots.

--WARNING--

To fully understand the terminology and definitive of some of the variables required by the program, the user must be conversant with the theoretical approach of the mathematical model he wishes to use.

Data

The first stage in the execution of this program is the creation of a data file. In the examples used, the name of the file is 'TIMEDATA'.

The format of this file depends on what the user wishes the program to perform.

This is now detailed.

Input Data

All units are metric and free format.

line 1 (80 Alphanumerics)

Title

line 2 (1 integer)

IEQN Specifies the mathematical model to use

IEQN = 1 Wright and Feat

IEQN = 2 Bass

Line 3 (4 reals)

k1	linear damping coefficient
k3	non-linear (cubic damping)
BARK1	angle-dependent damping. If IEQN = 2, BARK1 must equal 0.0
OMEGAO	natural roll frequency ω_0 (rad/sec)

line 4 (1 integer, 4 real)

NOSTEP	number of steps to take between t=0.0 and t=TSTOP	
PEE	parametric amplitude p If NOWVS≠0, then PEE must equal 0.0	
DELTAR	parametric phase δp	(rads)
OMEGA	frequency of beam waves ω If NOWVS≠0 then OMEGA must equal 0.0	(rads/sec)
TSTOP	duration of solution	(secs)

<u>line 5</u> (1 real, 1 integer, 2 real, 2 integer)

DELTA	phase of waves δ	(rads)
NDPLCS	accuracy of solution in number of decimal places	
ROLL(1)	initial roll angle at t=O can be positive or negative, convention is same as THETAS	(rads)
ROLL(2)	initial roll velocity at t = O	(rads/sec)
ISOLN	solution method required ISOLN = O ; Runga-Kutta-Mertson (RKM) ISOLN = 1 ; Trapezoidal with error control (TEC) For normal use RKM is recommended. However TEC can supply a more accurate solution when the system is close to its limit of stability.	
NOWVS	if the user requires to specify his own forcing function, then NOWVS specifies the number of points describing the function. Use this option with care.	

<u>line 6</u> (3 real) IF NOWVS=O THEN IGNORE THIS LINE

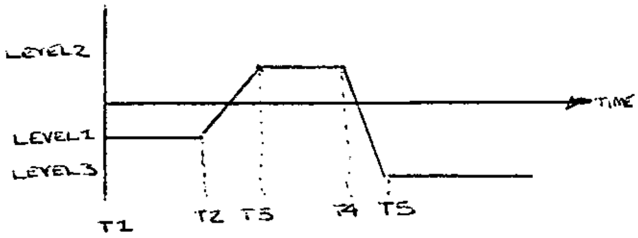
SWVST(I)	the time of the I^{th} point that defines the forcing function	(secs)
SWVS(I)	waveslope α of the forcing function at the I^{th} point	(rads)
SPT(I)	forcing function at the I^{th} point User calculated from $\ddot{\alpha}+\beta$ where β is the value of the static heeling <u>moment</u> at t = SWVST(I).	

Note 1. There are NOWVS lines as I=1, NOWVS

2. There are one set of points per line.

line 7 (8 real) IF NOWVS ≠ O THENNIGNORE THIS LINE

The maximum waveslope α_M can be defined in the time domain to produce the following function



where

AM(1)	LEVEL 1	(rads)
AM(2)	LEVEL 2	(rads)
AM(3)	LEVEL 3	(rads)
AM(4)	T1	(secs)
AM(5)	T2	(secs)
AM(6)	T3	(secs)
AM(7)	T4	(secs)
AM(8)	T5	(secs)

line 8 (8 real) IF NOWVS ≠ O THEN IGNORE THIS LINE

The effective wave slope α_e can be defined in the time domain in the same way as α_M. (see above) using similar convention

AE(1)	LEVEL 1	(rads)
AE(2)	LEVEL 2	(rads)
AE(3)	LEVEL 3	(rads)
AE(4)	T1	(secs)
AE(5)	T2	(secs)
AE(6)	T3	(secs)
AE(7)	T4	(secs)
AE(8)	T5	(secs)

line 9 (8 reals)

The static bias angle θ_s can be defined in the time domain in the same way as α_m (see above) using similar convention -

TS(1)	LEVEL1	(rads)
TS(2)	LEVEL2	(rads)
TS(3)	LEVEL3	(rads)
TS(4)	T1	(secs)
TS(5)	T2	(secs)
TS(6)	T3	(secs)
TS(7)	T4	(secs)
TS(8)	T5	(secs)

The convention used is

If IEQN = 1 (Wright and Feat) then

$+\theta_s$ = heel to starboard (away from wave maker)

$-\theta_s$ = heel to port (towards wave maker)

If IEQN = 2 (Bass) then

$+\theta_s$ = heel to port (towards wavemaker)

$-\theta_s$ = heel to starboard (away from wavemaker)

line 10 (1 real)

GZORDR Specifies order of polynomial that fits the GZ curve.

note 1. Must be odd and in the range 3...15.

line 11 (1 real)

GZCOEF(I) coefficients of the odd order polynomial that define the GZ curve such that

$$r_1\theta + r_3\theta^3 \ldots r_{GZORDR}\theta^{GZORDR}$$

where

$$GZCOEF(I) = r_I$$

Note 1. There are (GZORDR + 1)/2 lines as I = 1, GZORDR, 2.

2. There is one line for each point.

line 12 (2 reals) IF IEQN = 1 IGNORE THIS LINE

ZO para metric amplitude for second displaced GZ curve.
$ZO = Z_o$

DELTAY phase term for second displaced GZ curve such that
$\delta_Z = \delta + DELTAY$

line 13 (1 real) IF IEQN=1 IGNORE THIS LINE

GZCOEG(I) coefficients of the odd order polynomial that defines the displaced GZ curve such that

$$h_1\theta + h_3\theta^3 \ldots h_{GZORDR}\theta^{GZORDR}$$

where

$GZCOEF(I) = h_I$

Note 1. There are (GZORDR + 1)/2 lines as
I = 1, GZORDR, 2

2. There is one line for each point.

line 14 (3 integers)

NOEXP number of experimental points to plot one of the graphs.

IXOPT x-axis option for the experimental points.
Must be in range 1...10 and corresponds to the same options the user is presented with for graphic output. i.e. If IXOPT = 1 it means that XEXP(I) contains times in seconds.

IYOPT As for IXOPT only for y-axis. i.e. If IYOPT = 6 then YEXP(I) contains relative roll angles in rads.

Note 1. Experimental points are only plotted onto a user selected graph when the following conditions are satisfied:-

1) 0 < NOEXP< = 250
2) The user selected choice for the x-axis and y-axis from the plot menu corresponds with IXOPT and IYOPT.

line 15 (2 reals) IF NOEXP=O IGNORE THIS LINE

XEXP(I) x-coordinate of the users I^{th} data point in the users data units i.e. seconds.

YEXP(I) y-coordinate of the users I^{th} data point in users data units i.e. rads.

File Usage

Having created the data file, the next stage is to ensure the files required by the program are accessible. (i.e. have been 'OPENED'). The file usage of the TIMEPHASE (and GLOBALS) is as follows;

FORTRAN CHANNEL NUMBER	PRIMOS FUNIT NUMBER	FILE NAME	COMMENTS
1	-	-	The users terminal. This must be either- (i) Tektronix type graphic terminal (TTGT) (ii) TTGT + calcomp plotter (CC81) (iii) VDU + calcomp plotter (CC81)
8	4	TIMEDATA	Data file that has just been created.
9	5	TIMELIST	Contain results after run is complete. (using FORTRAN format control).
11	7	SCRATCH	Scratch file - contains no useful information at end of run.

On the PRIME, these can now be assigned by typing in, in response to a system prompt:-

```
OPEN TIMEDATA  4  3
OPEN TIMELIST  5  3
OPEN SCRATCH   7  3
```

Execution

The execution of TIMEPHASE (having created the data file and 'OPENED' the other channels), is now completed in two stages. The first is the creation of an object module file, which contains the necessary GINO routines. The running this object module.

(i) Creation of object module

If the file TIMEPHASE already exists, then proceed to (ii).

The object module is created, by inputting the following PRIMOS commands in response to the appropriate system responses:-

```
FTN    TIMEPHASE         -64V
...
...
FTN    GLOBALS           -64V
...
...
SEG
...
LOAD
.....#TIMEPHASE
LO B_ TIMEPHASE
LO B_ GLOBALS
LO CALCMP B_CC81V
LI  VGRALIB
LI  VGINLIB
LI
....
SA
QU
```

(ii) Execution of TIMEPHASE

The program is now run by typing in response to a system prompt:

```
SEG #TIMEPHASE
```

Graphic Output

After a few moments the users terminal should respond by presenting the user with options for plotting.

The responses required are self-explanatory and the user should examine/produce the plots he requires.

The program execution is terminated upon request, by the user.

Listing Results

When execution of the program is terminated and control returns to the system, the file TIMELIST contains the results for printing on a lineprinter (with FORTRAN format effectors).

This is now 'SPOOLED' to the linesprinter by typing, in response to a system prompt:-

```
SPOOL TIMELIST   -F
```

and later collected.

Errors

Should any errors occur, then the user is notified at his terminal and execution terminated.

A list of errors is given in appendix I.

The user is encouraged to change the data file so as to deliberately cause errors, to see how the program responds.

Example

The following example shows the output obtained from the test data files on the PRIME 550 (Primos).

SIMULATION OF ROLL AND CAPSIZE OF SHIPS

SORACOS V3.2

--INPUT DATA--

```
TEST DATA FOR TIMEPHASE (FILE3/SYSTEM2)
2
0.249   0.102   0.0   5.539
80  0.1   1.571   4.40   2.450
0.0  5  0.3  0.0  0  0
0.174  0.174  0.174  0.0  10.0  10.0  10.0  10.0
0.214  0.214  0.214  0.0  10.0  10.0  10.0  10.0
0.105  0.105  0.105  0.0  10.0  10.0  10.0  10.0
5
0.04928
-0.03549
0.00359
1.2  0.0
0.04728
-0.03
0.005
0  0  0
```

TEST DATA FOR TIMEPHASE (FILE3/SYSTEM2) --SORACOS V3.2--

--TIME DOMAIN SOLUTION TABLE OF COEFFICIENTS--

--CONSTANT COEFFICIENTS--

LINEAR DAMPING COEFFICIENT	K1	=	0.24900
NONLINEAR DAMPING COEFFICIENT	K3	=	0.10200
ANGLE DEPENDANT DAMPING	K1BAR	=	0.00000
NATURAL FREQUENCY	WO	=	5.53900 RADS/SEC
FREQUENCY	W	=	4.40000 RADS/SEC
PARAMETRIC AMPLITUDE	P	=	0.10000
PARAMETRIC PHASE	DELTAR	=	1.57100 RAD
INPUT PHASE	DELTA	=	0.00000 RAD
INITIAL ROLL ANGLE		=	0.30000 RAD
INITIAL ROLL VELOCITY		=	0.00000 RADS/SEC
TIME OF SOLUTION		=	2.45000 SEC
HEAVE AMPLITUDE FACTOR	ZO	=	1.20000
HEAVE AMPLITUDE PHASE	DELTAY	=	0.00000 RAD

--DEFINABLE WAVEFORMS--

EFFECTIVE WAVE SLOPE :		WAVE SLOPE :		STILL WATER BIAS :	
L1 =	0.2140 RAD	L1 =	0.1740 RAD	L1 =	0.1050 RAD
L2 =	0.2140 RAD	L2 =	0.1740 RAD	L2 =	0.1050 RAD
L3 =	0.2140 RAD	L3 =	0.1740 RAD	L3 =	0.1050 RAD
T1 =	0.0000 SEC	T1 =	0.0000 SEC	T1 =	0.0000 SEC
T2 =	10.0000 SEC	T2 =	10.0000 SEC	T2 =	10.0000 SEC
T3 =	10.0000 SEC	T3 =	10.0000 SEC	T3 =	10.0000 SEC
T4 =	10.0000 SEC	T4 =	10.0000 SEC	T4 =	10.0000 SEC
T5 =	10.0000 SEC	T5 =	10.0000 SEC	T5 =	10.0000 SEC

--SOLUTION METHOD--

0 : RUNGA KUTTA MERTSON

-- MODEL USED --

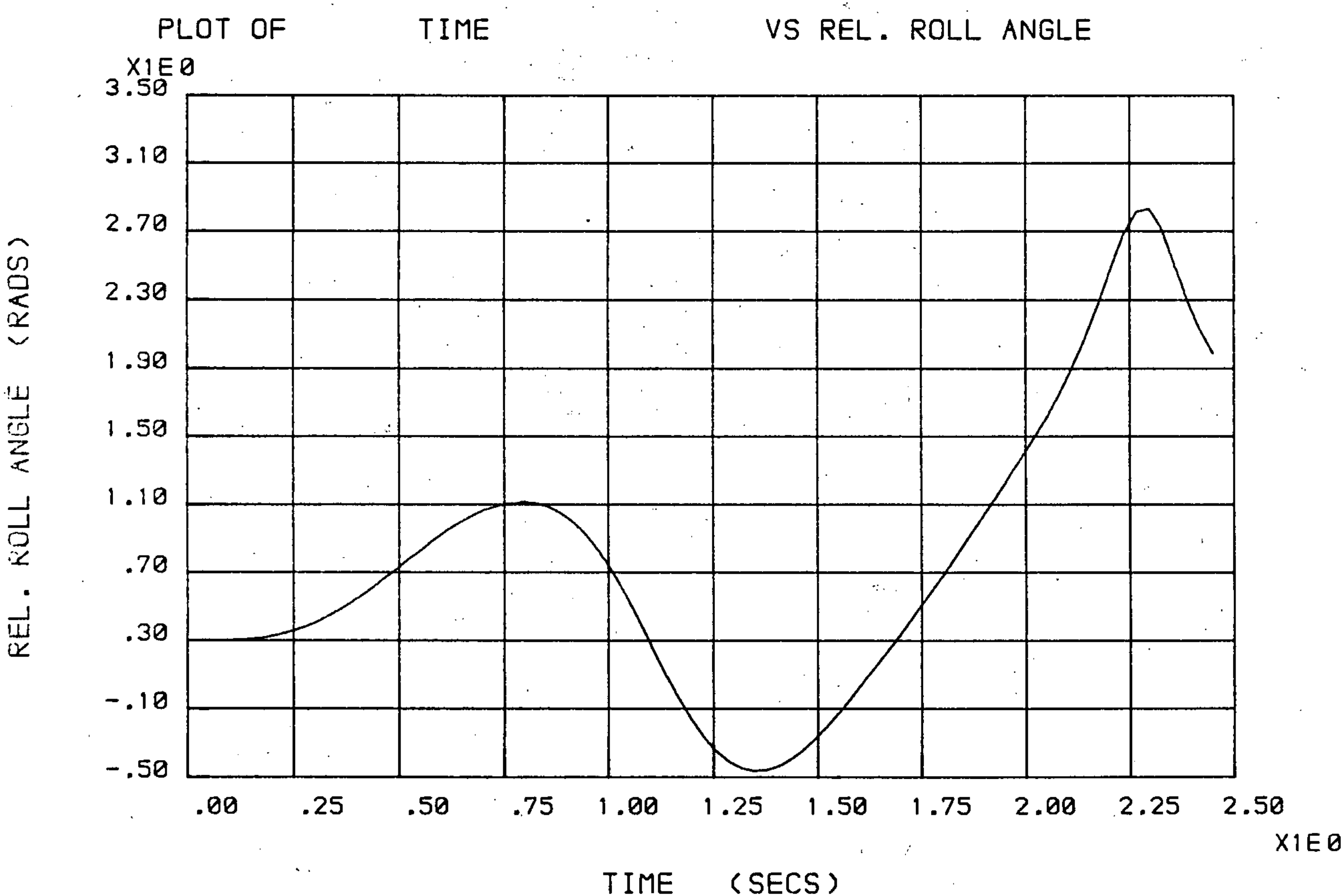
2: UNIVERSITY OF NEWFOUNDLAND (BASS)

TEST DATA FOR TIMEPHASE (FILE3/SYSTEM2) --SORACOS V3.2--

TIME (SECS)	FREQUENCY (RAD/SEC)	MAXIMUM WAVE SLOPE (RADS)	EFFECTIVE WAVE SLOPE (RADS)	STILL WATER BIAS (RADS)	RELATIVE ROLL ANGLE (RADS)	RELATIVE ROLL VELOCITY (RAD/SEC)	INST. WAVE SLOPE (RADS)	ABSOLUTE ROLL ANGLE (RADS)	FORCING FUNCTION
0.0306	4.4000	0.1740	0.2140	0.1050	0.2996	-0.0187	0.1724	0.4720	4.1055
0.0612	4.4000	0.1740	0.2140	0.1050	0.2993	0.0021	0.1677	0.4670	3.9935
0.0919	4.4000	0.1740	0.2140	0.1050	0.3001	0.0594	0.1600	0.4601	3.8091
0.1225	4.4000	0.1740	0.2140	0.1050	0.3032	0.1492	0.1493	0.4526	3.5556
0.1531	4.4000	0.1740	0.2140	0.1050	0.3095	0.2672	0.1360	0.4455	3.2377
0.1837	4.4000	0.1740	0.2140	0.1050	0.3198	0.4091	0.1202	0.4400	2.8611
0.2144	4.4000	0.1740	0.2140	0.1050	0.3348	0.5704	0.1022	0.4370	2.4326
0.2450	4.4000	0.1740	0.2140	0.1050	0.3549	0.7470	0.0823	0.4372	1.9600
0.2756	4.4000	0.1740	0.2140	0.1050	0.3807	0.9344	0.0610	0.4416	1.4519
0.3062	4.4000	0.1740	0.2140	0.1050	0.4122	1.1273	0.0385	0.4507	0.9175
0.3369	4.4000	0.1740	0.2140	0.1050	0.4497	1.3198	0.0154	0.4651	0.3664
0.3675	4.4000	0.1740	0.2140	0.1050	0.4930	1.5041	-0.0080	0.4849	-0.1914
0.3981	4.4000	0.1740	0.2140	0.1050	0.5417	1.6717	-0.0313	0.5103	-0.7456
0.4287	4.4000	0.1740	0.2140	0.1050	0.5951	1.8127	-0.0540	0.5411	-1.2863
0.4594	4.4000	0.1740	0.2140	0.1050	0.6523	1.9173	-0.0758	0.5766	-1.8038
0.4900	4.4000	0.1740	0.2140	0.1050	0.7121	1.9768	-0.0961	0.6160	-2.2885
0.5206	4.4000	0.1740	0.2140	0.1050	0.7729	1.9847	-0.1147	0.6581	-2.7317
0.5512	4.4000	0.1740	0.2140	0.1050	0.8331	1.9380	-0.1313	0.7018	-3.1254
0.5819	4.4000	0.1740	0.2140	0.1050	0.8910	1.8369	-0.1454	0.7456	-3.4624
0.6125	4.4000	0.1740	0.2140	0.1050	0.9451	1.6848	-0.1569	0.7881	-3.7367
0.6431	4.4000	0.1740	0.2140	0.1050	0.9937	1.4869	-0.1656	0.8281	-3.9432
0.6737	4.4000	0.1740	0.2140	0.1050	1.0357	1.2487	-0.1713	0.8644	-4.0782
0.7044	4.4000	0.1740	0.2140	0.1050	1.0699	0.9744	-0.1738	0.8960	-4.1393
0.7350	4.4000	0.1740	0.2140	0.1050	1.0951	0.6661	-0.1733	0.9218	-4.1254
0.7656	4.4000	0.1740	0.2140	0.1050	1.1103	0.3227	-0.1695	0.9408	-4.0366
0.7962	4.4000	0.1740	0.2140	0.1050	1.1144	-0.0601	-0.1627	0.9517	-3.8747
0.8269	4.4000	0.1740	0.2140	0.1050	1.1061	-0.4898	-0.1530	0.9532	-3.6425
0.8575	4.4000	0.1740	0.2140	0.1050	1.0839	-0.9750	-0.1405	0.9434	-3.3443
0.8881	4.4000	0.1740	0.2140	0.1050	1.0458	-1.5231	-0.1254	0.9204	-2.9854
0.9187	4.4000	0.1740	0.2140	0.1050	0.9899	-2.1350	-0.1080	0.8819	-2.5724
0.9494	4.4000	0.1740	0.2140	0.1050	0.9145	-2.7975	-0.0887	0.8257	-2.1128
0.9800	4.4000	0.1740	0.2140	0.1050	0.8184	-3.4755	-0.0678	0.7506	-1.6149
1.0106	4.4000	0.1740	0.2140	0.1050	0.7021	-4.1080	-0.0457	0.6564	-1.0877
1.0412	4.4000	0.1740	0.2140	0.1050	0.5680	-4.6163	-0.0227	0.5453	-0.5408
1.0719	4.4000	0.1740	0.2140	0.1050	0.4213	-4.9264	0.0007	0.4220	0.0159
1.1025	4.4000	0.1740	0.2140	0.1050	0.2688	-4.9936	0.0240	0.2928	0.5724
1.1331	4.4000	0.1740	0.2140	0.1050	0.1180	-4.8145	0.0470	0.1650	1.1184
1.1637	4.4000	0.1740	0.2140	0.1050	-0.0239	-4.4203	0.0691	0.0452	1.6442
1.1944	4.4000	0.1740	0.2140	0.1050	-0.1511	-3.8614	0.0899	-0.0612	2.1402
1.2250	4.4000	0.1740	0.2140	0.1050	-0.2593	-3.1905	0.1091	-0.1502	2.5974
1.2556	4.4000	0.1740	0.2140	0.1050	-0.3458	-2.4542	0.1263	-0.2195	3.0074
1.2862	4.4000	0.1740	0.2140	0.1050	-0.4093	-1.6889	0.1412	-0.2680	3.3630
1.3169	4.4000	0.1740	0.2140	0.1050	-0.4492	-0.9229	0.1536	-0.2956	3.6576
1.3475	4.4000	0.1740	0.2140	0.1050	-0.4660	-0.1791	0.1632	-0.3028	3.8858
1.3781	4.4000	0.1740	0.2140	0.1050	-0.4607	0.5211	0.1698	-0.2908	4.0437
1.4087	4.4000	0.1740	0.2140	0.1050	-0.4348	1.1571	0.1734	-0.2614	4.1282
1.4394	4.4000	0.1740	0.2140	0.1050	-0.3906	1.7095	0.1738	-0.2169	4.1379
1.4700	4.4000	0.1740	0.2140	0.1050	-0.3311	2.1643	0.1710	-0.1600	4.0725
1.5006	4.4000	0.1740	0.2140	0.1050	-0.2591	2.5159	0.1652	-0.0939	3.9333
1.5312	4.4000	0.1740	0.2140	0.1050	-0.1780	2.7696	0.1563	-0.0216	3.7228
1.5619	4.4000	0.1740	0.2140	0.1050	-0.0903	2.9407	0.1447	0.0543	3.4448
1.5925	4.4000	0.1740	0.2140	0.1050	0.0015	3.0506	0.1304	0.1319	3.1044
1.6231	4.4000	0.1740	0.2140	0.1050	0.0961	3.1227	0.1137	0.2098	2.7077
1.6537	4.4000	0.1740	0.2140	0.1050	0.1926	3.1778	0.0950	0.2876	2.2618
1.6844	4.4000	0.1740	0.2140	0.1050	0.2907	3.2319	0.0745	0.3653	1.7750
1.7150	4.4000	0.1740	0.2140	0.1050	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.7456	4.4000	0.1740	0.2140	0.1050	0.4926	3.3649	0.0300	0.5226	0.7142
1.7762	4.4000	0.1740	0.2140	0.1050	0.5968	3.4417	0.0067	0.6035	0.1595
1.8069	4.4000	0.1740	0.2140	0.1050	0.7034	3.5160	-0.0167	0.6866	-0.3981
1.8375	4.4000	0.1740	0.2140	0.1050	0.8120	3.5792	-0.0398	0.7722	-0.9485
1.8681	4.4000	0.1740	0.2140	0.1050	0.9224	3.6259	-0.0622	0.8602	-1.4817
1.8987	4.4000	0.1740	0.2140	0.1050	1.0340	3.6571	-0.0835	0.9505	-1.9881
1.9294	4.4000	0.1740	0.2140	0.1050	1.1464	3.6833	-0.1033	1.0431	-2.4583
1.9600	4.4000	0.1740	0.2140	0.1050	1.2597	3.7249	-0.1211	1.1386	-2.8841
1.9906	4.4000	0.1740	0.2140	0.1050	1.3750	3.8122	-0.1368	1.2382	-3.2575
2.0212	4.4000	0.1740	0.2140	0.1050	1.4941	3.9827	-0.1500	1.3441	-3.5719
2.0519	4.4000	0.1740	0.2140	0.1050	1.6202	4.2766	-0.1605	1.4597	-3.8215
2.0825	4.4000	0.1740	0.2140	0.1050	1.7576	4.7273	-0.1681	1.5896	-4.0018
2.1131	4.4000	0.1740	0.2140	0.1050	1.9114	5.3399	-0.1726	1.7388	-4.1096
2.1437	4.4000	0.1740	0.2140	0.1050	2.0857	6.0494	-0.1740	1.9117	-4.1429
2.1744	4.4000	0.1740	0.2140	0.1050	2.2809	6.6538	-0.1722	2.1087	-4.1011
2.2050	4.4000	0.1740	0.2140	0.1050	2.4881	6.7443	-0.1674	2.3207	-3.9849
2.2356	4.4000	0.1740	0.2140	0.1050	2.6824	5.6916	-0.1595	2.5229	-3.7965
2.2662	4.4000	0.1740	0.2140	0.1050	2.8179	2.8153	-0.1486	2.6693	-3.5393
2.2969	4.4000	0.1740	0.2140	0.1050	2.8360	-1.8169	-0.1351	2.7008	-3.2178
2.3275	4.4000	0.1740	0.2140	0.1050	2.7121	-5.8920	-0.1192	2.5929	-2.8381
2.3581	4.4000	0.1740	0.2140	0.1050	2.5062	-7.0819	-0.1011	2.4051	-2.4069
2.3887	4.4000	0.1740	0.2140	0.1050	2.2979	-6.3490	-0.0811	2.2167	-1.9321
2.4194	4.4000	0.1740	0.2140	0.1050	2.1224	-5.0865	-0.0597	2.0626	-1.4222
2.4500	4.4000	0.1740	0.2140	0.1050	1.9859	-3.8446	-0.0372	1.9486	-0.8865

TEST DATA FOR TIMEPHASE (FILE3/SYSTEM2)



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Appendix I

Error Messages

The following is a list of errors that are trapped by SORACOS. The page number referenced details the variable concerned.

ERROR NUMBER	MESSAGE	PAGE NUMBER
2	GZ CURVE NOT DEFINED	
5	GZ CURVE FROM COEFFICIENTS ONLY	
6	GZWGHT NOT IN RANGE	
7	GZORDR NOT IN RANGE	
8	GZNPNT NOT IN RANGE	
10	ERROR ON DATA INPUT	
12	NOEXP OUT OF RANGE	
14	NOSTEP NOT IN RANGE	
16	NOPAPZ NOT IN RANGE	
18	NOSWAY NOT IN RANGE	
20	NDPLCS NOT IN RANGE	
22	TSTOP NOT IN RANGE	
24	ISOLN NOT IN RANGE	
26	NOWVS NOT IN RANGE	
27	IEQN NOT IN RANGE	

AMENDMENT LIST

SECTION NUMBER	TITLE	DATE OF ISSUE	ISSUED BY

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