HYDRAN-XR

Hydrodynamic Response Analysis
with
Integrated Structural Finite Element Analysis

Version 25.1

Introduction

NumSoft Technologies

1. Overview

1.1. General Description

HYDRAN-XR combines structural finite element analysis and hydrodynamic analysis for the integrated three-dimensional HYDroelastic Response ANalysis of floating or fixed structures. Of course, it will also carry out purely structural finite element analysis as well as purely hydrodynamic analysis of rigid structures. However, it has been designed from the 'ground-up' to analyze the integrated fluid-structure analysis problem, more specifically the wave-induced response (motions, displacements, and structural forces and stresses) of flexible (deformable) structures. The hydrodynamic motion response of a single rigid body and of multiple rigid bodies are treated as subsets of the more general formulation for flexible structures.

HYDRAN-XR includes an extensive numerical infrastructure, as well as input/output, scripting, and finite element capabilities.

The theory underlying HYDRAN-XR includes:

- Linear hydroelasticity
  - Linear hydrodynamics
  - 3-D linear potential theory
  - Green function method
  - Constant panel formulation
  - Complete structure-fluid-structure interaction
    - Infinite or finite water depth
- Linear structural dynamics
  - Finite element or analytical model
  - 'Direct' or 'reduced-basis' (assumed modes) approaches
  - Linear mooring stiffness
- Frequency domain solution
  - Transfer functions for responses

Response quantities that can be obtained include:

- Structural displacements at any point
- Structural forces and stresses (depends on structural model)
- Fluid potential/velocity on the wetted surface
- Fluid pressures on the wetted surface

Key features of HYDRAN-XR include:

- Number of fluid panels only limited by computer memory
- Double, single, or no structural symmetry options
  - For large structures, double symmetry can reduce the memory and computational requirements to 1/16 of that for no symmetry
- Response of multiple flexible and/or rigid bodies
- Detailed control over solution process

- Extensive set of commands to manipulate response data
- Scripting language
- Integrated structural finite element capability
- On-line user manual
- Windows and Macintosh versions available: Linux version available upon request
- Any consistent unit system can be used.

1.2. Theoretical Foundation

HYDRAN-XR is based on general, linear, three-dimensional hydroelasticity theory as developed in [1-4], and on finite element structural theory as found in any of many textbooks. Applications of the theory and approach used in HYDRAN-XR are found in [5-8]. For flexible bodies, HYDRAN-XR can accept a 'structural' model that has been determined separately, or it can be modeled in HYDRAN-XR directly. Based on the structural model, HYDRAN-XR then determines the hydrodynamic loading and structural response. To determine the hydrodynamics, the three-dimensional Green function method, and specifically the well-known constant panel method, is used.

1.3. Contact Information

Send email to support@hydran-xr.com for bug reports or program support, or send to info@hydran-xr.com for general questions.

1.4. Document Organization

This **Introduction** is organized as follows. Section 2.0 contains a brief introduction to using HYDRAN-XR as well as an example of the input. Section 3.0 provides a summary of the HYDRAN-XR commands that are specifically for hydroelastic analysis. Detailed information on all commands are in the separate document **HYDRAN-XR Command Reference**. Section 4.0 contains the references cited. Appendix A contains the input for several examples involving systems of multiple rigid bodies.

2. Getting Started for Hydroelastic Analysis

2.1. Notation and Terminology

It is necessary for the user to understand the notation and terminology used in HYDRAN-XR. As an example, consider the multi-body system, or structure, shown schematically in plan view in Fig. 1. The structure is one which might occur, for example, for a mobile offshore base, where each of the 5 bodies (modules) is a fairly ‘conventional’ semi-submersible. A possible body numbering system is indicated in the figure, where the body with the largest x_1 coordinate is numbered 1. For the following discussion only, we will assume that each body is modeled as rigid. They may be flexibly connected or unconnected. The structure has 30 independent displacement degrees-of-freedom. One set of degrees-of-freedom would be the 6 rigid body modes (surge, sway, heave, roll, pitch, and yaw) of each body.

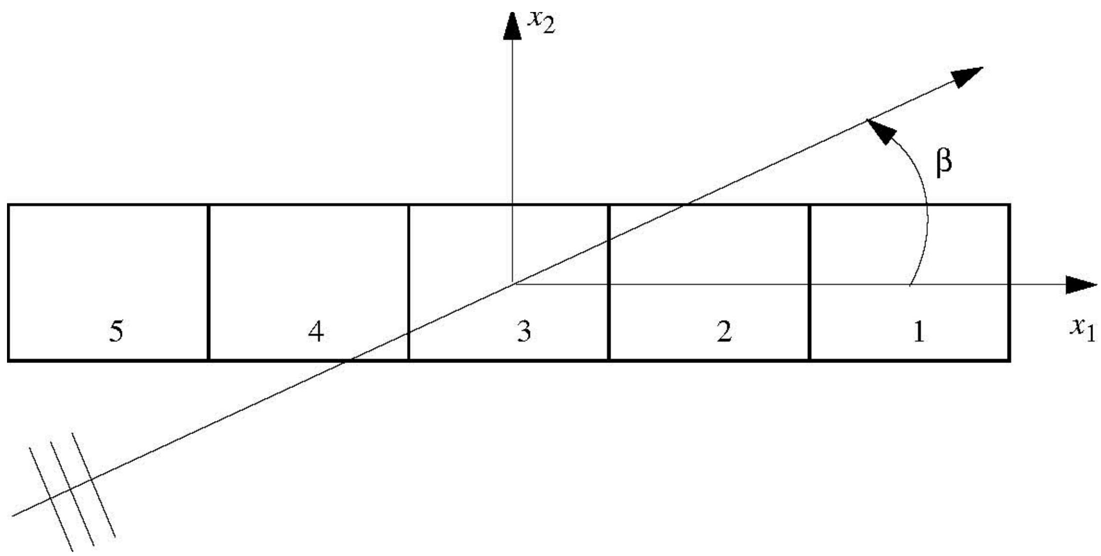

Figure 1 Schematic of a 5-body system

2.2. Coordinate Systems

There are three types of coordinate systems referenced in HYDRAN-XR. All are right-hand, Cartesian coordinate systems. There is one inertial coordinate system, which is indicated in Fig. 1. The origin of the inertial coordinate system is always on the still-water level, and the x_3 axis is positive up. The wave heading is indicated by the angle β. In Fig. 1, the inertial coordinate system has been placed at the center of the body (in plan view); although this may be convenient, it is not required. The regular wave has a unit amplitude, a harmonic variation of $e^{i\omega t}$, and a wave crest at the origin at time $t = 0$.

If desired, the user can specify a separate body-fixed coordinate system for each body. A convenient choice might be to have a body’s body-fixed coordinate system at its center of gravity. The body-fixed coordinate system can be located arbitrarily with respect to the inertial coordinate system. However, if the program is to generate the rigid body modes of surge, sway, heave, roll, pitch, and yaw for a given body, and the corresponding hydrostatic stiffness (hydrostatic restoring coefficients), then the body-fixed coordinate system for that body must: 1) be on the same vertical line as the body's center of gravity; and 2) have the same orientation as the inertial coordinate system (i.e., not rotated with respect to the inertial system).

A third type of coordinate system is the input coordinate system, which is the coordinate system in which the nodal coordinates are specified. The nodes are used to define the panel meshes for the bodies. It can be oriented arbitrarily with respect to the inertial coordinate system, and a separate input coordinate system can be specified for each body.

In some parts of the manual and on-line help, the alternative notation (x, y, z) may be used instead of (x_1, x_2, x_3).

2.3. Panel Mesh

The panel mesh refers principally to the mesh of constant-source panels that describe the wetted surface of the structure. The wetted surface of the structure is the surface with global coordinates $x_3 \leq 0$ in the initial, static equilibrium position. Panels above the still-water level are allowed, but they are not included in the hydrodynamic calculations.

2.4. Symmetry

An important feature of HYDRAN-XR is its ability to exploit symmetry of the structure. Symmetry, as used in HYDRAN-XR, refers to symmetry of the hydrodynamic panel mesh, relative to the inertial coordinate system, and to the displacement patterns, or 'modes,' used to represent the motion of the wetted surface (see Section 2.5). It does not refer to symmetric loading conditions, and it does not necessarily imply actual structural symmetry. Specifically, symmetry of the hydrodynamic panel mesh can be exploited for both oblique waves, in which the hydrodynamic exciting forces are neither symmetric nor antisymmetric, and for unsymmetric structures. For example, for the structure in Fig. 1, it may be that the topside of the bodies are such that they are not structurally symmetric, or the bodies may be unsymmetrically connected. Again, the only requirements are that the hydrodynamic panel mesh is symmetric and that the motion can be decomposed into symmetric and antisymmetric modes. For a system composed of individual, connected or unconnected, multiple bodies, symmetry refers to the entire structure (i.e, the system), not to each body individually.

Single symmetry refers to symmetry with respect to the inertial $x_1 - x_3$ plane. Double symmetry refers to additional symmetry with respect to the inertial $x_2 - x_3$ plane. In the above example, if each body is symmetric with respect to $x_1 - x_3$, then single symmetry can be exploited. If the bodies are such that the system is also symmetric with respect to $x_2 - x_3$, then double symmetry can be exploited. A typical example of the latter is when all bodies are identical and themselves doubly-symmetric.

The primary advantage of exploiting symmetry is a large decrease in the computations and the memory required to determine the response. As compared to no symmetry, single and double symmetry can reduce the memory requirements by 1/4 and 1/16, respectively.

When single symmetry is used, the hydrodynamic panel mesh with coordinates $x_2 \geq 0$is specified. When double symmetry is used, the hydrodynamic panel mesh with coordinates $x_1 \geq 0$ and $x_2 \geq 0$ is specified. For the structure in Fig. 1, single symmetry would mean that 1/2 of the wetted surface of all five bodies would be discretized. Double symmetry would require that 1/2 of the wetted surface of bodies 1 and 2, and 1/4 of the wetted surface of body 3, would be discretized. Bodies 4 and 5 would not be discretized explicitly.

Regardless of whether the structure is symmetric or not, the equations of motion for the entire structure are formed and solved. This means that the structure matrices, i.e., mass, damping, and stiffness, for the entire structure must be provided. With reference to Fig. 1, 30 equations of motion are formed, and the mass matrices of bodies 4 and 5 must be specified even if double symmetry is used.

2.5. Assumed Modes and Generalized Displacements

HYDRAN-XR formulates the equations of motion of the structure based on a finite number of displacement patterns, or assumed-modes. The corresponding magnitudes of these assumed-modes are the so-called generalized displacements (or generalized coordinates). This is a very common approach in structural mechanics and structural dynamics, and it is designed to reduce the number of displacement degrees-of-freedom. Even the traditional formulation for a single rigid body, in which the displacements are represented by the surge, sway, heave, roll, pitch, and yaw at, say, the center of gravity, can be viewed as an application of this approach. For example, the ‘unit’ surge motion is the assumed mode, and the actual value of surge, which is of course calculated, is the corresponding generalized displacement. In the field of hydrodynamics and hydroelasticity, these assumed modes are sometimes erroneously referred to as ‘generalized’ modes. Historically, a subset of the normal modes of vibration of the structure in air (‘dry modes’) have often been used. However, it is not required that the normal modes be used; any system of independent patterns of displacement can be used to form an alternative vector basis in which to represent the displacements. Because of this generalized displacement approach, the term forces is used herein to mean generalized forces. For a given displacement pattern, the corresponding generalized force can be an actual force, a moment, or some combination of forces and moments that has no direct physical meaning. In addition, the structural mass, stiffness, and damping matrices and the hydrodynamic matrices (added mass and hydrodynamic damping) are also expressed in terms of these assumed modes. (For example, the added mass matrix that is calculated by HYDRAN-XR is the generalized added mass matrix.)

For the system shown in Fig. 1, the assumed modes can be the 6 rigid body modes of each body if either no symmetry or single symmetry is used. However, if double symmetry is used, a transformation from the traditional rigid body modes must be carried out. To exploit double symmetry, the displacements must be represented in doubly symmetric/antisymmetric modes, and the equations of motion must be expressed in this alternative vector basis. Consider, for example, surge of body 1. This motion is symmetric about the plane $x_1 - x_3$ but it is neither symmetric nor antisymmetric about the plane $x_2 - x_3$. However, surge motion of body 1 can also be represented as a combination of a mode of motion involving symmetric surge of bodies 1 and 5 (+surge for body 1 and –surge for body 5) and a mode involving antisymmetric surge (+surge for both bodies) [4]. Bodies 2, 3 and 4 have no motion in these two modes. All motions of each body can be represented similarly in terms of symmetric and antisymmetric modes. For the 5-body, 30 degree-of-freedom structure, there are 30 symmetric/ antisymmetric modes.

HYDRAN-XR requires the user to provide the real structural mass, viscous damping, and stiffness matrices. (Hysteretic damping is also possible.) It is important to note that the generalized matrices must be provided, i.e., the matrices consistent with the assumed modes.

For systems of multiple rigid bodies, the **hyd_rigid_modes** command is a convenient way to define the traditional surge, sway, heave, roll, pitch and yaw modes for each body. For doubly-symmetric systems, the command **hyd_genmodes** is a convenient way to transform these modes to the doubly-symmetric modes discussed above. This command will transform all the matrices (including structural mass and stiffness) that have been defined relative to the traditional modes.

2.6. Structural Response

The HYDRAN-XR command **hyd_analysis** determines the added mass and hydrodynamic damping as a result of radiated waves, as well as the incoming and diffraction forces from incoming waves. The command **hyd_analysis_response** uses these quantities to form and solve the generalized equations of motion for wave-induced response per unit wave amplitude. The command **hyd_analysis_response_P** uses the added mass and damping to form and solve the generalized equations of motion for user-defined harmonically-varying loads. In either case, complex generalized displacements are written to file *project_name*.cor (where *project_name* is the name of the project specified by the user). If the generalized displacements are not physically meaningful, or if other response components are desired (such as connector forces), a convenient means to determine these response quantities is provided. The user can specify a 'modal' matrix. This matrix should have one row for each response component desired. The number of columns is equal to the number of assumed modes. Each row contains the value of the component in the corresponding mode. For example, element (4,6) would contain the value of the 4th response component (whatever quantity the user wants to recover) when the 6th mode has a generalized displacement magnitude of 1. The command **hyd_tf** multiplies this matrix with the vector of generalized displacements to obtain the transfer functions of the response components. An additional advantage of using the command **hyd_tf** is that the transfer functions generated in this way are in a more convenient form than they are in *project_name*.cor.

2.7. Infinite vs. Finite Water Depth

HYDRAN-XR will handle either infinite or finite water depths. A large degree of control is provided the user to specify under what circumstances the more efficient infinite depth calculations are used. In the **hyd_parameters** command, the water depth is specified (parameter h). The optional parameter kh is the limiting value for the product of k, the wave number (i.e., 2π/wave length) and the water depth. If for a given wave frequency, the actual value of kh is greater than the specified value, then the infinite depth routines are used. If the value is less, then the finite depth routines are used. The default value of kh is 10, which is very conservative. A smaller number can often be specified without significant loss of accuracy. If one wants just infinite depth, one should give a water depth and value of kh which ensures that the calculated kh is always greater than the limiting value for all frequencies considered in the analysis.

2.8. Output Files

A number of files are created by running HYDRAN-XR. Some may or may not be created, depending on the output options specified. The files are text files unless indicated otherwise. Files are given the same basic name as the project name, specified by the user when HYDRAN-XR is started, with an extension. (In the following, * represents the project name.) Files that can be created are:

*.pan	panel data
*.adm	added mass coefficients
*.adp	hydrodynamic damping coefficients
*.exf	generalized wave excitation forces
*.hhr	wave exciting forces based on the Haskind-Hanaoka relations
*.cor	generalized coordinates
*.ot2	additional output
*.kf	hydrostatic stiffness
*.dis	nodal displacements (formatted)
*.res	nodal displacements (unformatted)
*.pot	velocity potentials at panel centers
*.prs	hydrodynamic pressures at panel centers
*.hpr	change in hydrostatic pressures at panel centers
*.tf	transfer functions (see the command hyd_tf)

2.9. Running HYDRAN-XR

HYDRAN-XR is a command-driven program. It runs as a separate thread within a graphical user interface (UI), which is also referred to as HYDRAN-XR. It can also be run directly from a command-line interface, such as Terminal in MacOSX or Windows PowerShell in Windows. Two special features are its database of arrays, which are either input or generated by the program, and its command language. Unparalleled access to the internal data through the commands allows the user significant power in adapting the solution flow to solve unique problems, as well as in post-processing output data according to his or her needs. A large number of commands are provided to facilitate such manipulation. Second, the command language allows fairly powerful scripts to be almost ‘mini-programs.’ Every command has an on-line help. Indeed, command descriptions provided in this document and the companion **HYDRAN-XR Command Reference** are ‘hard copy’ output of the on-line help facility.

A large number of commands are provided to facilitate describing the problem and for manipulation of the data for scripting. The vast majority of commands support the general data manipulation and the structural finite element analysis. The hydrodynamic-only commands all start with ‘hyd_’ or ‘phyd_’.

When a user starts a HYDRAN-XR session using the GUI, the first input is a project name. The user is then presented with the following screen:

```
 * * * * * * * * * * * * H Y D R A N - X R  v. 25.1* * * * * * * * * * * * *
*                                                                           *
 *                   Hydrodynamic Response Analysis                          *
 *                                with                                       *
 *             Integrated Structural Finite Element Analysis                 *
 *                                                                           *
 *                              April 2025                                   *
 *                                                                           *
 *                         Copyright 2016-2025                               *
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 *                      Software is provided AS IS.                          *
 *                         Use at your own risk.                             *
 *                                                                           *
 * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

 Enter project name:
```

If running from the command line, the project name is expected at this point. The project name is used to create the text files *project_name.out* and *project_name.log*. The former file contains output of the session, while the latter contains a log of all commands issued during the session. The log file allows a session to be recreated exactly at a later date.

In interactive mode, commands are entered in the command input box in the UI, or directly at the command prompt (`hydran-xr>`) in a command-line interface. The list of HYDRAN-XR-specific commands is given in Section 3.0. See the companion document **HYDRAN-XR Command Reference** for detailed information on all commands. Even when run from a UI, most commands will have been created in a text input file that is read during program execution. It simply is not practical to type the commands interactively. This is discussed in more detail in Section 2.11.

There is some flexibility as to the sequence in which commands are specified. Basically, if the ‘output’ of a command is required as ‘input’ for another command, the former must be specified before the latter. The detailed help on a command provides information on which commands must be specified before it.

2.10. HYDRAN-XR Command Syntax and Database

The command **help hydran-xr** prints the following brief description of the program.

```
HYDRAN-XR determines the linear, hydroelastic, wave-induced response of
offshore structures. Prior to 2016, HYDRAN was developed by OffCoast, Inc.,
and was available for licensing. Starting in 2016, Dr. H.R. Riggs, the
primary developer of HYDRAN with OffCoast, now develops HYDRAN-XR, the
successor to HYDRAN. HYDRAN-XR may be used without charge. Contact Dr.
Riggs, at support@hydran-xr.com, for program support and/or purchase of the
source code.

Significant effort has been devoted to verifying the accuracy of HYDRAN-XR;
```

however, no claims or guarantees as to its accuracy are made and absolutely no liability for damages, either direct or consequential, is accepted by the developer or any other party.

HYDRAN-XR uses the MANOA "kernel". As a result, HYDRAN-XR inherits all the capabilities of MANOA, an open development environment for Matrix And Numerical-Oriented Analysis. MANOA was originally developed in the Department of Civil and Environmental Engineering at the University of Hawaii at Manoa. The source code that was developed at UHM is in the public domain.

HYDRAN-XR inherits a fundamental and unique feature of MANOA: a database that manages all data and that allows the user to manipulate it directly by basic, "Unix-like" commands. HYDRAN-XR has many commands that support character, integer, real, and complex matrices. These commands are based on 1-byte character, 4-byte integers, 8-byte reals, and 16-byte complex values. Limited support for 4-byte reals and 8-byte complex is also provided. Specialized commands are available to aid in linear and non-linear structural analysis. (The finite element library is limited, but the addition of elements is quite simple.) All commands are described in on-line help messages, available with the "help" command, and an index of commands is available via the "index" command. HYDRAN-XR supports both interactive and batch modes.

The command format is

```
command  arg1 ... argN  parameter1 ... parameterN
```

The arguments (arg1, etc.) are names of arrays in the database (or that will be created and added to the database). The parameters control the operation of the command. Arguments (i.e., names of arrays in the database) can be of arbitrary length and can contain almost any character. However, they cannot begin with a "-" or a "~", and they cannot contain an "=" or a blank. In general, parameters either have a leading "-" or contain an "="; the former is used for "toggle" type parameters, while the latter is used for parameters whose value is specified. Arguments and parameters may be intermixed on the command line. The command format is illustrated by the on-line help for the help command, which is reproduced below:

```
Command Syntax
  help (h) command [-f] [l=?]
    On-line help for command. For an index of available commands use the
    command index.
      If -f is given, then output is written to the output file; otherwise
      output is to the screen only. If l is specified, then l lines will be
      scrolled at a time.

      Optional parameters are indicated as such by being enclosed in [].
      The [] are not part of the command.
```

Both arguments and the values of parameters can be specified by "variables", that is, by names of arrays in the database that contain the appropriate information. For arguments, the array must contain the name of the actual argument, while for parameters the array must contain the appropriate numerical values. In both cases, the variable name must be preceded by a "~". With reference to the above example, we could get help on a command with

```
help ~NAME l=~lines
```

```
Array NAME should be a character array with the actual command name. (This
array should be "null-terminated"; see the commands setch and inputch.)
Similarly, the first value in the integer array lines will be used to
control the scrolling.

An input "record" in HYDRAN-XR can span a number of actual "lines;" a
record of input is continued to the next line if the & character is the
last nonwhite character on the line. There is no direct limitation on the
number of continuations, but a record cannot be longer than 2048 bytes.
Finally, anything following the two-character sequence /* on a line is
treated as a comment. Clearly, lines with comments cannot be continued.
Blank lines also can be used to separate text, enhancing the readability of
the input and output.

Both fixed and scientific notation can be used to input real and complex
values; however, the Fortran convention of using a "d" or "D" for the
exponent is not supported. Only the mathematical convention of "e" or "E"
is supported.
```

2.11. Example

As a simple example, consider the motion analysis of a single rigid body. The body is a rectangular box with dimensions 90 m x 90 m and a draft of 40 m [9]. It is freely-floating in deep water. The inertial coordinate system is located at the center of the box on the still-water level. The body is doubly-symmetric, and some example files will exploit this. For no symmetry, all four sides and the bottom must be meshed. For single symmetry, only the +y side, half the fore and aft ends, and half the bottom need be meshed. For double symmetry, only one quadrant need be meshed. The input files that use this box are in the folder Testing/Examples.

As an example, box2.txt uses double symmetry, and it reads the file box2-gen.txt for the mesh definition. This mesh uses 16 rectangular panels, 4 on each surface (note that this is a coarse mesh for demonstration purposes only). There are 12 panels below the surface and 4 panels above the surface. The 4 ‘dry’ panels serve no purpose except for visualization if the mesh is plotted. The wave-induced response at 8 wave periods and 2 wave angles is determined. The response is expressed in terms of surge, sway, heave, roll, pitch, and yaw about the body-fixed coordinate system, which coincides with the inertial coordinate system.

Normally, the commands will not be input in interactive mode, but rather an input file would be created with a text editor. The command **filein** can be used to read and execute such an input file. If the file has the same name as the project name, then the **filein** command does not need any arguments. If the file has a different name, then the file name must be given as the argument to the **filein** command. The command **return** in an input file returns to interactive mode. Input files can be documented with comments by the character sequence /*; anything following /* on a line is a comment.

The **save** command saves the database in a file called *project_name*.db. Now assume, for example, that the response of the same body, but with different rotational inertia properties, is desired. Then, a new project, with a different name, could be run, with the following commands, obviating the hydrodynamic calculations:

```
readdb project_name              /* read the existing database, where project_name
                                 /* is the name of the previous project
hyd_rmass
         (Define the new mass matrix here)
hyd_analysis_response            /* carry out the new analysis
hyd_tf                           /* generate the new transfer functions
```

Additional examples are discussed in Appendix A.

2.12. Fundamental Commands

Besides the specialized commands for hydroelastic analysis, there are many general commands that can be used. Many users may not need many of these. However, some basic commands that any user may need are:

Command	**Purpose**
`dir or ls`	short listing of arrays in database
`input`	input a real matrix
`mv or rename`	rename an array
`print`	print a matrix
`quit`	quit HYDRAN-XR
`rm or del`	remove an array from the database

3. List of HYDRAN-XR Commands

The following is an alphabetical listing of HYDRAN-XR commands that are directly related to hydroelastic analysis. The listing is available on-line via the command `index hydrodynamics`.

```
hyd_analysis                  added mass, hydrodynamic damping, exciting forces
hyd_analysis_response         wave-induced hydroelastic response
hyd_analysis_response_drag    wave-induced hydroelastic response
hyd_analysis_response_P       external force hydroelastic response
hyd_assign_mooring            assign mooring stiffness to a body
hyd_body_check                check body data
hyd_close_files               close HYDRAN-XR output files
hyd_convert_fea_mesh          convert FEA mesh to hydrodynamic panel mesh
hyd_coordaxs                  specify coordinate axes
hyd_coord_trans               transform input coordinates to inertial coordinates
hyd_export_graphics           export hydro. panel mesh to graphics program
hyd_export_graphics_th        export time history motion to graphics program
hyd_flex_modes                input flexible modes
hyd_genmodes                  transform to generalized coordinates
hyd_irregular                 short-term extreme response
hyd_modal_pressure            print exciting and modal pressures
hyd_mooring_line              input mooring line data
phyd_mooring_line             print mooring line data
hyd_mooring_stiffness         input mooring stiffness
phyd_mooring_stiffness        print mooring stiffness
hyd_nodes                     input nodal coordinates
phyd_nodes                    print nodal coordinates
hyd_node_gen                  node generation
hyd_node_tolerance            check nodes for still water and symmetry planes
hyd_panel                     define 4-node (or 3-node) panel elements
phyd_panel                    print panel elements
hyd_panel_rmap                create reverse mapping of panel numbers
hyd_parameters                input global control parameters
hyd_postresponse              obtain some post-processed responses
hyd_postresponse_P            obtain some post-processed responses
hyd_rigid_modes               generate rigid body modes
hyd_rmass                     input mass matrix for user modes
hyd_surf_elevation            determine the "free" surface elevation
hyd_surf_nodes                input surface nodal coordinates
phyd_surf_nodes               print surface nodal coordinates
hyd_surf_node_gen             surface node generation
hyd_surf_node_tolerance       check surface nodes
hyd_surf_panel                define 4-node (or 3-node) surface elements
phyd_surf_panel               print surface elements
hyd_tf                        calculate transfer functions
hyd_velocity                  calculate fluid velocity at user-specified points
hyd_velocity_nodes            define velocity point coordinates
phyd_velocity_nodes           print coordinates
hyd_velocity_node_gen         generate velocity point coordinates
hyd_velocity_node_tolerance check velocity nodes
hyd_wave                      input wave frequencies and incidence angles
hyd_wave_dispersion           solve for wave length, wave number
hyd_wave_spectra              input wave spectra
phyd_wave_spectra             print wave spectra
hyd_wet                       estimate "wet" natural frequencies
```

4. References

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Appendix A: Examples

The input files can be downloaded from the website. The can be found in Testing/Examples.

A.1 Two-Body Example – Single Symmetry

Refer to input file box1_2mod.txt. This example has two 2 unconnected bodies. Each body is identical to the box in the example described in Section 2.11. Single symmetry is used. The boxes are arranged serially along the inertial *x*-axis, and the origin of the inertial coordinate system is located at the center of body 1. The center-to-center spacing is 1000 m.

A.2 Three-Body Example – No Symmetry

Refer to input file box0_3mod.txt. This problem deals with a system of 3 unconnected bodies. Each body is identical to the box in the example described in Section 2.11. No symmetry is used. The boxes are arranged serially along the inertial *x*-axis, and the origin of the inertial coordinate system is located at the center of body 2. The center-to-center spacing is 1000 m. The entire mesh for each box is specified. The input defines each box centered at the origin of the inertial coordinate system. HYDRAN-XR is then used to shift boxes 1 and 3 +1000 m and –1000 m, respectively.

A.3 Three-Body Example – Single Symmetry

Refer to input file box1_3mod.txt. This is a system of 3 unconnected bodies. Each body is identical to the box in the example described in Section 2.11. Single symmetry is used. The boxes are arranged serially along the inertial *x*–axis, and the origin of the inertial coordinate system is located at the center of body 2. The center-to-center spacing is 1000 m. One-half of the boxes are specified. As input, all boxes are centered at the origin of the inertial coordinate system. HYDRAN-XR is then used to shift boxes 1 and 3 +1000 m and –1000 m, respectively.

A.4 Three-Body Example – Double Symmetry

Refer to input file box2_3mod.txt. This is a system of 3 unconnected bodies. Each body is identical to the box in the example described in Section 2.11. Double symmetry is used. The boxes are arranged serially along the inertial x-axis, and the origin of the inertial coordinate system is located at the center of body 2. The center-to-center spacing is 1000 m. One-half of box 1 is specified, and 1/4 of box 2 is specified. As input, both boxes are centered at the origin of the inertial coordinate system. HYDRAN-XR is used to shift box 1 +1000 m.