SEA WAVE PATTERN EVALUATION

SWPE 7.0
SIMPLIFIED USER'S GUIDE

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Summary

In SWPE versions 1.0 and 2.0, Michell's thin-ship theory was implemented to yield the free wave spectrum, far-field wave elevations, velocity components and velocity potential behind monohull vessels moving steadily forward on a calm deep sea. Version 3.0 added the capability to calculate near-field wave elevations, and incorporated eddy-viscosity damping of far-field waves. Version 4.0 further extended capabilities to multihulls and submerged bodies, and finite-depth effects on far-field wave elevations. Version 5.0 increased computational accuracy and speed, and allowed computation of sinkage and trim. Version 6.0 improved the eddy-viscosity procedure. The ability to calculate wave resistance and viscous resistance was added in Version 7.0. This is a simplified guide to use of `SWPE7.0`, with emphasis on input and output structures, assuming availability of a compiled version of

the program. A more detailed User's Manual for the source code, including description of individual units of the program, was provided for `SWPE5.0`.

1 HULL GEOMETRY

The coordinate system and hull parameters are as follows: x is positive astern, y is positive to starboard, and z is positive upwards (hence negative for normal ship sections, since $z = 0$ at the waterline). Hulls are assumed to be symmetric with respect to their own centreplanes, which are parallel to the x-axis, and are specified by offsets consisting of the positive y coordinates on a uniformly-spaced rectangular grid of stations x and waterlines z.

To accommodate multihull arrangements, the program requires specification of the location of every hull in the ensemble. This is effected by specifying the location of the centre of each hull in the horizontal xy-plane. For monohulls, the centre of the ship is most conveniently located at $x = 0$ and $y = 0$, but there is no compulsion to use this convention.

2 INPUT FILE

All input to the program is via the plain text file called "`swpe.in`". It is crucial that only numeric values and the five user-comment lines (lines 5–9 of the input file) be changed in this file. The other lines of text must not be modified in any way because the program confirms the input structure is as expected, in order to eliminate the possibility of the user inadvertently introducing errors by, for example, reordering the contents of the file.

2.1 Preliminary lines

The first four lines of the file serve as a heading for the file which identifies the program version.

The next five lines (all beginning with "`Note:`" in the example files) have been included to allow user comments. These user-comment lines are not used by the program, but the program expects at least one character in each of them. Of all the text lines in the input file, it is only these five which can be modified by the user.

Each variable to be used by the program is preceded by a description of that variable, the units that are assumed, and the type of value expected (integer or decimal). In some cases, suggested upper and lower limits on variables are are also given.

2.2 Physical parameters

The first block of parameters sets values for physical quantities affecting the problem.

The first parameter is the value of the gravitational acceleration g (in ms^{-2}). Normally use 9.81.

Water density ρ (in kg m^{-3}) must be entered as a decimal. Normally use 1025.9.

Water molecular kinematic viscosity ν (in $\mathrm{m}^2\mathrm{s}^{-1}$) must be entered as a decimal. Typical values are 0.000001141 for fresh water, or 0.00000118831 for salt water.

Water kinematic eddy viscosity ν_e (in $\mathrm{m}^2\mathrm{s}^{-1}$) must be entered as a decimal. Zero is allowed, and values larger than 0.01 are not recommended. In the `SWPE6.0` report we studied various choices for ν_e in detail, and for routine use we recommend 0.0001.

Water depth in metres must be entered as a decimal. To simulate infinite depth water, use a negative value. This choice is recommended even if the actual water depth is significantly less, even down to values comparable to the shiplength or lower, noting that true finite-depth near-field results are not computed by this version of the program. Any positive value of depth results in the program computing and combining the far field in a fluid of the depth specified and the near field in a fluid of infinite depth.

The last parameter in this group specifies the vessel's speed U (in ms^{-1}).

2.3 Wave Calculation parameters

The second block of parameters in the input file is concerned with the calculation of the free wave spectrum and the wave elevations.

Limits on the size of the rectangular computational domain are then entered as decimals.

The wave patch x-minimum is the x-ordinate of the fore-most edge of the rectangle, while wave patch x-maximum is the x-ordinate of the aft-most edge. Number of wave patch x nodes is the number of grid points in the x direction, and must be an integer greater than 0 and less than or equal to 300.

Similarly, wave patch y-minimum is the y-ordinate of the port side of the rectangle, while wave patch y-maximum is the y-ordinate of the starboard side of the rectangle. Number of wave patch y nodes is the number of grid points in the y direction, and must be an integer greater than 0 and less than or equal to 300.

If values of 1 are entered for both the number of wave patch x nodes and the number of wave patch y nodes, the program will calculate the wave elevation at the single point (`x-minimum,y-minimum`).

Standard transverse and longitudinal wave cuts are easily effected. For example, if the number of wave patch x nodes is set to 1, and the number of wave patch y nodes is set to 100, the program will calculate wave elevations at 100 equally-spaced points across the track along the line extending from (`x-minimum,y-minimum`) to (`x-minimum,y-maximum`).

On the other hand, if, for example, the number of wave patch x nodes is set to 100, and the number of wave patch y nodes is set to 1, then the program will calculate 100 wave elevations along the longitudinal cut extending from (`x-minimum,y-minimum`) to (`x-maximum,y-minimum`).

The height of evaluation nodes for calculation of the velocity potential, fluid velocities and stream surfaces, must be a decimal value less than or equal to zero. Usually this parameter should be set to zero, so that all computations are performed at the free surface level.

The integration type, which must be an integer equal to either 1,2,3 or 4, determines the method to use for the calculation of wave elevations. If (recommended option) a value of 1 is chosen then wave elevations are calculated using Newman's method for the local field and the method of Tuck, Collins and Wells for the far-field component. A value of 2 employs a speed-up option to eliminate the computation of the local field where its contribution is negligible. A value of 3 instructs `SWPE` to calculate only the far-field integral and its velocity components, for the entire rectangular patch. A value of 4 instructs `SWPE` to calculate wave elevations along the side of the hull at $z = 0$.

The number of θ intervals to be used in the calculations must be entered as an even integer. This is the only user-input parameter directly controlling accuracy in `SWPE7.0`. Higher `ntheta` is more accurate but more time-consuming. Normally use 1000 for monohulls, up to 4000 for multihulls.

2.4 Ship definition

The ship geometry is defined in the remaining blocks of the input file.

The first block contains one parameter only, namely the number of hulls in the ensemble.

In the second block (and any subsequent blocks) of the ship definition section, each hull in the ensemble is specified, in turn. The program will read as many hull definitions as was specified by the number of hulls.

The following discussion applies to each hull specified in the input file.

The first input required is the x-ordinate of the centre of the hull. The second input is the y-ordinate of the centre of the hull. They are used to specify the location of the hull relative to the origin of the coordinate system. For an input file containing a single hull these values would usually both be zero so that the hull was centred on the origin.

Following those, the length, beam, and draft of that hull must be specified. Note that length refers to the desired longitudinal distance from the first station of hull offsets to the last station. Similarly, draft refers to the desired vertical distance from the first (lowest) waterline of hull offsets to the last (highest) waterline, and therefore does not necessarily refer to the amount of the vessel that is submerged beneath the free surface, unless the initial sinkage or depth of submergence is zero.

The next parameter is the initial sinkage or depth of submergence of the vessel, and is positive downwards. It is defined as the distance between the undisturbed waterplane ($z = 0$) and the uppermost waterline (at midships), i.e. the last column of offsets in the table. This value can be positive, zero, or negative. A positive value of depth of submergence indicates that the vessel is fully submerged, as would be the case for a submarine. A negative value of initial sinkage allows the hull offsets to rise above the undisturbed waterplane ($z = 0$), as would be the case if the offsets specified a complete hull rather than just the wetted section.

Trim angle (in degrees) specifies the initial trim of the vessel relative to the specified offsets. A positive value raises the bow. The point about which the hull is rotated is the centre of the uppermost waterline.

The program assumes initially that the hull is in an attitude specified by these input values of sinkage and trim (which may be zero), and takes action to adjust these values depending on the value of the maximum number of squat iterations, which can only be 0 or 1.

If this parameter is set to zero, the program will adjust the input offsets using the specified values of initial sinkage or depth of submergence and trim before performing any flow computations, but will not calculate hydrodynamic forces on the hull, nor in any way change the specified sinkage and trim.

On the other hand, if the user specifies that the maximum number of squat iterations is equal to 1, then (after adjusting the input offsets to take account of the specified input sinkage and trim if any) `SWPE` will calculate the corrected sinkage σ and trim τ. Finally, the hull offsets are rotated by τ and then translated by σ, before any further flow calculations (such as wave elevations or hull wave profiles) are performed.

The number of stations and the number of waterlines describing the hulls must be integers greater than or equal to 3, and less than or equal to 89 in the current compiled version. The actual bow and stern ends are counted as stations, and the resulting total number of stations must be an odd integer. That is, the number of x-wise intervals of length must be an even integer. Similarly, the number of waterlines must also be an odd integer. Stations must be equally spaced, as must be waterlines.

It does not matter whether the offsets describing each hull are in dimensional or non-dimensional form. The program will automatically scale the offsets to the hull beam.

All offsets at the bow (the first row) must be equal to zero (decimal). Stern offsets (the last row) may be all zero (no transom) or some non-zero if there is a transom stern of a shape determined by the non-zero offsets. The number of rows (cross-sections) and columns (waterlines) in the offset data must be the same as the number of stations and waterlines specified earlier.

After the last hull definition block has been read, the program reads the last line of the input file, which contains the text “end of file”.

3 OUTPUT FILES

All output files created by `SWPE` are in plain text format. Those that contain principally numeric data are suitable for plotting in gnuplot without further modification.

3.1 swpe.out

Elevation and flow outputs are normally contained in the file `swpe.out` in text format.

The first two columns in this file contain the x- and y-ordinates of the grid points, followed by the total wave elevation, the velocity potential, and the x, y and z velocity components for each node of the rectangular patch. All of these quantities are calculated at the depth specified by the height of the evaluation nodes. If that depth is not zero, then the third column (total wave elevation) should be interpreted as the stream surface corresponding to that depth far ahead of the hull.

If the integration type is set to 4, i.e. the wave profile only along the hull is requested, this file is not used. Instead, wave elevations are written to the file `hullwave.out` described below.

3.2 hullwave.out

If the integration type is set to 4, the output file is `hullwave.out`. The first column then contains the x-ordinates of the midpoints between stations, the second column contains the y-ordinates at the waterline $z = 0$. The five columns following the x- and y-ordinates contain the wave elevation, velocity potential, and the velocity components, respectively (at $z = 0$) for each panel.

3.3 vessel.out

The *non-zero* offsets are contained in the file `vessel.out` in such a way that plotting in gnuplot produces a wire-mesh representation of the hulls. This provides a convenient method for ensuring that the offsets supplied have been interpreted as expected. Note that because some offsets with a value of zero are in fact valid (for example along the bow or keel), and because such offsets are not contained in the file, there may appear to be discrepancies.

3.4 pq.out

This file contains the values of θ and the computed far-field complex wave amplitude (or "free-wave spectrum") as a function of wave angle θ. This is in the form of Michell P and Q functions for each value of θ, separately for each hull in the ensemble. The first row contains labels for the columns.

3.5 drag.out

Contains the ship speed, followed by the total drag and its components, wave drag, hydrostatic drag and viscous drag.

3.6 squat.out

Geometric details of the final hulls, which may be squatted relative to the input hulls via inputted or computed sinkage and trim, are written to the file `squat.out` in text format.

For each separate hull, this file contains the weight (in Newtons), displacement volume, buoyancy, waterplane area, waterplane moment of inertia, longitudinal centre of floatation, longitudinal centre of buoyancy, vertical centre of buoyancy, draft, and sinkage and trim. Although not all of these parameters are used in `SWPE`, they can provide a useful check against errors in the input specification.

4 EXAMPLE INPUT FILES

To use the example files described below, you must first copy the example file to the file named `swpe.in`. Note that input files from previous versions of `SWPE` must be modified before they will work with `SWPE7.0`.

For most sinkage and trim calculations, `SWPE` requires that the offset table contain waterlines above the undisturbed waterplane $z = 0$. The examples presented below show two ways in which this can be accomplished.

4.1 DDG51 destroyer hull

The file “`ddg51.in`” contains offsets for the “static” DDG51 destroyer hull, as supplied by DTMB.

This example file uses true offsets up to the top of the model, well above the design waterline.

4.2 Wigley catamaran

The file “`wigcat.in`” contains offsets for two Wigley hulls, which in conjunction produce a Wigley-hulled catamaran.

The offset table in the present example comprises 11 stations and 21 waterlines; the uppermost 10 waterlines (i.e the last 10 columns of the offset table) have the same offsets as the 11th waterline, i.e. the “usual” waterline at $z = 0$ for this hull has been extended upward in a wall-sided manner. The draft to the top waterline is 12.5 m. By specifying the initial sinkage for this extended vessel to be -6.25 m (that is, that the uppermost waterline be at height 6.25 m above the undisturbed free surface), the draft of the underwater portion is then also 6.25 m, which is the standard draft for the unsquatted Wigley hull.