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RISERDYN 4.0.2

GM-33054-0800-37063

August 7, 2000

DOCUMENT DETAILS AND ISSUE RECORD

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Rev	Date	Details	Author	Checked	Approved
0	04/08/00	Issued for Version 4.0.2	JFR	NSW	NSW

This document was produced using the HelpBreeze Document Wizard.

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RISERDYN General

RISERDYN

RISERDYN is a PC-based frequency domain static/dynamic rigid riser analysis program. It is based on RASM (Riser Analysis using Stochastic Method), developed in 1988 by Earl & Wright. RISERDYN analyses riser performance with accuracy comparable to time-domain analyses, as demonstrated in various test cases and comparisons. Its input structure is specifically tailored to modelling marine drilling risers, but it can also be used for analysis of tension leg platform (TLP) tethers, single anchor leg moorings or any other vertical, narrow offshore structure. A significant advance over RASM is that RISERDYN is windows-based, with greatly simplified input/output user-interfaces. The present version runs on Windows NT , and running time for most riser configurations is minimal.

The program uses finite element methods, as described by Krolikowski & Gay (Ref. 1), to calculate the riser response to forces created by combined random seas and current. RISERDYN's linearisations, as verified against available test cases and data, achieve accurate dynamic analyses for all parameter ranges of practical interest. Wave spectra are represented by Pierson-Moskowitz or JONSWAP forms. Two-dimensional current profiles are as piece-wise linear shears. Vessel surge and heave motions are input at the riser top as RAO's. Amplitude and phase are required for each input frequency. The program calculates the riser's distributed hydrodynamic drag and inertia loads and moments.

The program can perform iterations on ranges of riser tension, mud density and vessel offset for static and/or dynamic analyses in one run. The iterative feature allows efficient assessment of required tension vs. offset and mud density. RISERDYN also performs static analysis and calculates natural resonant frequencies and mode shapes of risers. Mode shapes are useful in assessing vortex-induced vibrations (VIV). Disconnected risers — i.e., riser hung-off — can be accurately modelled for static and lateral dynamic analysis.

As typical of finite element analyses, concise riser models are easily prepared. The riser model is subdivided into zones with constant properties. Finite element size, riser properties and hydrodynamic coefficients can be changed from zone to zone. Flex joints are modelled by a special element located at the desired position on the riser. Any number of them can be specified anywhere on the riser. Tapered segments, such as the column terminator on a production riser, are modelled by tapered tubular elements. The BOP is modelled by a single element assigned weight and bending stiffness (very large), and for riser hang-off, hydrodynamic coefficients, area and volume. The internal/external pressure influence on "effective tension" is rationally handled in RISERDYN. Internal pressure above the internal fluid (mud) column can be input to simulate backpressure in a blowing diverter line, or shut-in pressure at the top of a production riser. Lost circulation is modelled by specifying the top of the mud column below the riser top. The riser model can be extended below the BOP to include the casing and the approximate linear lateral soil support stiffness.

Output detail is user specified either a one sheet summary and/or all the response details. RISERDYN selects a frequency increment based on the input, which can be overridden by the user to obtain frequencies at specific values.

Possible output parameters include:

- Static, dynamic and combines values of response
- Axial, bending and hoop stresses

- Von Mises equivalent stress including hoop loading
- Stress utilisation factors using API interaction equations
- Slopes and deflections
- Reactions at riser supports
- Flex joint rotations
- Slip joint stroke

RISERDYN Background

Static vs. Dynamic Analysis For Exploratory Drilling Risers

Static analysis is generally sufficient for exploratory drilling riser operating conditions. All preliminary riser design analysis and analysis to define normal drilling limits can typically be performed statically.

The limiting response is typically the lower flex joint angle, and much less frequently, top flex joint angle or stress. API RP 2Q (Ref. 2) recommends that the lower flex joint angle be limited to 2^o for the “normal drilling condition”. The flex joint angle limitation is mainly to prevent excessive equipment wear by the continuously rotating drill string. The angle limits are thus constraints on the average (or static) angle.

Riser analysis for response to large waves should be performed dynamically. Some programs have included a static wave loading feature that generally give overly conservative results. The conservatism stems from the fact that the relative motion between riser and water is typically less than the absolute water motion. This is partly because the riser top velocity is often in phase with the water particle horizontal velocity, thus reducing local loadings below those from static calculations. Consequently, RISERDYN calculates wave loads and responses dynamically and does not include a static analysis feature.

Since a random sea spectrum is the best way to represent a realistic sea state, irregular seas are used in the dynamic analysis.

Mathematical Model

RISERDYN generates a mathematical riser model based on user specified input information. In addition to the model nodes dictated by the riser section and soil/ casing input, the model adds nodal points at the mean waterline, at the inner fluid surface elevation, and at all positions for which boundary conditions are defined. In some cases, it adds a few (up to 5) nodes to catch the wave kinematics decay. To avoid numerical problems, RISERDYN treats any two nodes within 2 inches as one. It creates two nodes with the same elevation for the special flex/ball joint element.

Figure 1 shows a typical exploratory drilling riser comprising of the following components, all of which can be modelled with RISERDYN:

- Conductor and surface casing laterally supported by simplified elastic soil springs
- Blowout preventor (BOP) supported by the surface casing
- Lower flex joint with arbitrary rotational stiffness
- Riser running up to a telescopic slip joint. An intermediate flex joint(s) may be inserted anywhere along the string.
- A slip joint with a tensioner ring applying constant tension. The top of the slip joint connects to the drilling unit with a flex joint (typically a ball joint modelled with zero rotational stiffness).

Other riser configurations can also be modelled with RISERDYN. For example, Figure 2 shows a disconnected exploratory drilling riser freely hanging from a floating unit. Production riser systems, TLP tethers and Single Anchor Leg Moorings can also be modelled.

The co-ordinate system origin is located at the mudline for connected and disconnected cases. The y-axis is positive upwards and the x-axis is positive to the right (see Figure 3). Vertical y co-ordinates below the mudline are negative. The analysis takes place in this x-y plane with positive x being the direction in which the environment is progressing—not the direction from which it is coming. Counterclockwise rotations, slopes and moments are positive.

The riser is typically modelled in sections with constant riser joint properties and constant element length. Tapered elements are also available to model tapered column terminators on production risers. If riser properties or the desired element length changes, a new section should be introduced. Element length can be large where lateral load gradients are small, such as in regions below the wave zone where current loads predominate, Element lengths of as much as 50 or even 100 feet are reasonable if lateral load gradients are low. However, it should be noted that the analytical results are available only at nodal points, so the coarser the mathematical mesh, the fewer results are computed.

If there are no changes in riser properties and the loadings are uniform, long elements on the order of 25 to 75 feet are reasonable. To check whether a model has small enough elements: a typical problem twice with two different element sizes. If the results compare well, the model with fewer elements is satisfactory, and the model with the most elements has an unnecessarily long run time.

For dynamic analysis, element length should be reduced in the wave zone to capture the wave force gradients. The water particle motion decay factor equals (for elevation in feet):

$$e^{\{-1.223(\text{depth below surface in feet})/(\text{wave period}^2)\}}$$

This factor equals 0.46 for a depth of 10 feet and the short wave period of 4 seconds, suggesting a 2 to 5 foot element length just below the waterline to capture short period wave forces. Element length for dynamic analysis can be rapidly increased with increasing depth below the mean waterline.

Using linear wave theory means that the loaded riser length cannot vary with wave height (e.g., there are no free-surface effects). The program does not account for wave forces above the mean water line. The hydrodynamic load reference diameter is used to calculate drag and inertia forces. It is typically equal to the riser pipe OD (outside diameter) for un-buoyed risers and the buoyancy OD for buoyed risers. The program sets this diameter to zero in the region that hydrodynamic loading is allowed.

RISERDYN ignores any soil/casing input for a freely hanging riser.

Governing Equations

The program uses the finite element method to formulate the riser’s equations of motion equating the inertia, damping and stiffness forces to the applied loading as shown below:

Inertia + Damping + Stiffness Forces = Applied Forces

$$M\ddot{x} + C\dot{x} + Kx = F$$

M in the inertial term includes the mass of the riser, the riser buoyancy, the riser contents and the added mass.

Damping is incorporated into the stiffness formulation by means of a complex system matrix. The real part of the complex stiffness is represented by the system stiffness

($K - \omega^2 M$, where ω is the circular wave frequency in rad/sec), while the imaginary part of the system stiffness is represented by the damping (ωC) based upon the relative velocity.

The stiffness term (Kx) models all the lateral and rotational forces proportional to riser displacement. These include:

Bending stiffness terms (*EI* terms): These are the conventional beam bending stiffness terms proportional to the riser moment of inertia (I) and Young's modulus (E). These bending stiffness terms are typically very small in comparison to the tension and pressure stiffening terms.

Real tension stiffening terms: The real tension in the riser steel (which causes axial stress) stiffens the riser and resists curvature similar to tension in a guitar strings.

Fictitious tension stiffening terms: The fictitious tension performs the same function as real tension in resisting riser curvature—but unlike real tension it does not produce any axial stress. The sum of real and fictitious tension is called "effective tension" and is discussed in more detail in Section 2.5

Weight/Buoyancy stiffening terms: The net riser weight in water introduces a weak lateral restoring force proportional to riser slope which restrains the free hanging riser against lateral movement (refer to Figure 7). This is the force that stabilises and restores a pendulum consisting of a stiff bar hinged at the top to its original vertical position, and so is one of the restoring forces for the disconnected riser.

Riser constraint stiffness: Lateral or rotational springs can be added at the top or bottom of the riser.
The right side of the equation represents the applied riser lateral loadings, including hydrodynamic drag, inertia loads and user input concentrated loads at specific elevations.

Real Riser Tension

The real riser tension causes axial stress in the pipe wall, and contributes to the effective tension discussed in Section 3.5. Real riser tension is calculated at the top and bottom ends of each finite element for a connected riser by starting with the input tension at the top (element 1) and working down the model, element by element, using static's. Real tension is calculated the same way in a disconnected riser by first using static's to calculate the top tension.

For riser elements above the mean waterline (there is always a node at the waterline) the real tension at node $i+1$ is calculated as follows:

$$T_{i+1} = T_i - \text{[weight in air of riser element } i\text{]}$$

The weight of element i in air is the weight per unit length (obtained by dividing the joint weight in air by the joint length) multiplied by the length of element i.

For riser elements below the mean waterline real tension in element i at node $i+1$ is given by:

$T_{i+1} = T_i -$ [weight in water of riser element i + buoyant force on the riser pipe steel in element i].

The buoyant force on the steel pipe is not distributed along the riser length. It is applied at the riser base at the BOP top.

If there is a change in riser pipe wall thickness, external hydrostatic pressure contributes to the real tension as illustrated in Figure 4. This effect is important for the analysis of tapered column terminators found on production risers. The program calculates an applied vertical nodal force as shown in Figure 4, and includes it in the calculation of real riser tension. The program also calculates a vertical force due to change in inside diameter similar to a change in outside diameter.

User has an option to input real tension distribution, which overwrites the default calculations.

Effective Riser Tension

Riser curvature is resisted by the riser's conventional beam bending stiffness which is proportional to EI. Curvature and "effective" tension also act together to produce a lateral load that restores the riser to its un-deformed position. The effective tension at any riser elevation is the sum of the real tension and "fictitious" tension. The real tension produces axial stress in the riser pipe body but the fictitious tension does not. Any riser analysis must model the effective tension to obtain correct lateral and bending response.

The lateral load proportional to real tension and curvature is derived on Figure 5. This lateral load acts with the rate of change of shear to react the static applied lateral loads.

Lateral load is introduced by real tension acting across a slope change (i.e., a concentrated curvature) at a flex joint in a similar fashion.

The program calculates the fictitious tension with the following formula (derived on Figure 6) and adds it to the real tension to obtain the effective tension at each analytical riser node.

$$T_{fictitious} = P_{outer} \times A_{outer} - P_{inner} \times A_{inner}$$

Internal bursting pressure subtracts from the fictitious (and effective) tension to destabilise the riser. External crushing pressure adds to the effective tension stabilising and straightening the riser.

Internal pressure is the sum of hydrostatic pressure due to the mud column and any additional pressure input above the mud column. Seawater hydrostatic head to the mean waterline causes external pressure.

To check that the effective tension distribution is correct for a typical exploratory drilling riser, the user can spot check it at one or two elevations. The effective tension at any elevation should equal the top tension minus the weight in air or water (depending on whether the element is above or below the mean waterline) of the riser and its contents above that elevation.

Large curvatures result from low effective tension at the riser base. If the effective tension is negative over enough riser length (on the order of 100 to 300 feet), the riser base will be unstable.

User has the option to input effective tension distribution, which overwrites the default calculations.

The tension calculations are different for a freely hanging riser and a connected riser. For the connected riser, RISERDYN uses the user specified top tension as the starting point, then works its way down the riser to the bottom. For the freely hanging case, RISERDYN ignores any user input top tension, and calculates the top tension by summing up the actual riser weight less buoyancy. Then it proceeds with tension calculations as for the connected riser.

For complex situations, the profile of real and effective tension can be input directly, overriding any values calculated internally. RISERDYN cannot check for input errors in the overriding tension distribution, so user must be very careful when using this option. If the tension is too low to prevent the riser buckling, an unstable stiffness will be created and the program will not be able to solve problems.

RISERDYN interpolates the overriding tension distribution from the input points. If any part is not covered by the input range, the values at the ends of the range will be used.

The positive curvature shown stretches the pipe on the negative X side and compresses the pipe on the positive X side. This changes the areas over which the pressures act, creating lateral loads.

The radial force on the differential slice with area equal to $[r_i d\alpha][dy(1 - \text{bending strain})]$ due to internal pressure is given by:

$$(P_i\, r_i\, d\alpha)\; dy\; (1 - (\delta^2 x/\delta y^2)\; r_i \cos\alpha)$$

The external pressure acts in the opposite direction.

Factoring by $\cos\alpha$ to get the component in the riser analysis plane (the orthogonal components cancel each other) and integrating around the pipe circumference gives:

$$dH_i \;=\; 2 \int_o^{\pi} P_i\, r_i\, d\alpha\; dy\; (1 - (\delta^2 x/\delta y^2)\; r_i \cos\alpha)\; \cos\alpha$$

$$dH_i/dy \;=\; 2\, P_i\, r_i \int_o^{\pi} (\cos\alpha - (\delta^2 x/\delta y^2)\; r_i \cos^2\alpha)\; d\alpha$$

$$dH_i/dy \;=\; -P_i\; (\pi\, r_i^2)\; (\delta^2 x/\delta y^2)$$

$dH_i/dy \;=\; -P_i\, A_i\, (\delta^2 x/\delta y^2)$, where $A_i \;=\; \pi\, r_i^2$.

Performing a similar operation on the outside pressure gives:

$$dH/dy \;=\; dH_o/dy + dH_i/dy$$

$$dH/dy \;=\; (P_o\, A_o \;-\; P_i\, A_i)(\delta^2 x/\delta y^2)$$

This expression for differential horizontal load has the same form as the expression derived for horizontal load due to tension acting with curvature. Since the term $(P_o\, A_o - P_i\, A_i)$ performs the same function as real riser tension in determining the riser’s lateral response, it is called the fictitious tension.

Casing And Soil Models

Soil springs and casing models are interconnected in RISERDYN. The user must define both. If either soil or casing is not specified, RISERDYN will ignore the other input, and assume no soil/casing in the model.

The casing string supporting the BOP is the first portion of the riser model defined. The next portion is the BOP (modelled by the program as a single and especially stiff finite element), followed by the riser itself input by distinct sections (or zones). The slip joint is modelled with one or two separate riser sections at the riser top.

Enough casing length should be modelled to capture the decay of the mudline moment with depth. Soft soils require on the order of 100 to 200 feet of casing model length. stiff soils require only 50 to 100 feet to be modelled. Check the modelled length adequacy by making sure that the bending moment decays out to a negligible value near the end.

An efficient model will have smaller casing finite elements near the mudline to capture the locally large curvatures. Lower portions can be modelled with larger elements. An element length of 5 to 10 feet should suffice near the mudline.

The program calculates the real tension (or compression) at the top of the casing model and linearly varies it to zero at the bottom of the model. Since the external pressure below the mudline is not well defined, pressure contributions to the effective tension are ignored. The effective tension is set equal to the real tension.

A typical casing model will consist of the 30“ conductor and 20” surface casing. The program algebraically adds the bending stiffness of all strings of casing, thus neglecting any shear transmitted through the cement. This is conservative and results in overestimates of casing slope, deflection and bending stress. If the user doesn’t want to use this assumption, he must calculate an equivalent single casing OD and wall thickness and input it as a single string of casing.

The soil stiffness is introduced as lateral force per unit length of 30“ conductor per unit of lateral deflection, as is conventional for pile analysis. The units are lbs/ft/ft. The program distributes the elastic foundation to the casing model nodes automatically. Scour or slotting under the BOP can be modelled by specifying zero soil stiffness for the first few feet below the mudline defined by the zero y co-ordinate. It is also possible to model the mud line above the BOP and casing connection.

Since casing string lateral accelerations are negligible, the mass modeling is not crucial. Soil added mass and the mass of the casing string contents are ignored.

Riser Model

The riser is modelled in sections with constant riser joint properties and constant element length. If the riser properties or the desired element length changes, a new section should be introduced.

Elements length can be large where lateral load gradients are small, such as in regions below the wave zone where current loads predominate. Element lengths of as much as 50 or even 100 feet are reasonable if lateral load gradients are low.

Element length should be reduced in the wave zone to capture the wave force gradients. The water particle motion decay factor equals:

$$e^{\{-1.223(\text{depth below surface in feet})/(\text{wave period}^2)\}}$$

This factor equals 0.46 for a depth of 10 feet and the short wave period of 4 seconds, suggesting a 2 to 5 foot element length locally just below the waterline to capture short period wave forces. Element length for dynamic analysis can be rapidly increased with increasing depth below the mean waterline. If there are no changes in riser properties and the loadings are uniform, long elements on the order of 25 to 75 feet are reasonable.

The way to check whether a model has small enough elements is to run a typical problem twice with two different element sizes. If the results compare well, the model with fewer elements is satisfactory, and the model with more elements is unnecessarily costly in computer storage and run time.

Using linear wave theory means that loaded riser length cannot vary with wave height (e.g., there are no free-surface effects). The program does not account for wave forces above the mean water line.

The hydrodynamic load reference diameter is used to calculate drag and inertia forces. It is typically equal to the riser pipe OD for buoyed risers. The suggested drag coefficients for typical un-buoyed risers with kill and choke lines is 1.3, based on wind tunnel test results. For buoyed risers it is 1.0 due to the lack of adjacent peripheral lines.

Flex Joint Models

Lower, upper and possibly intermediate flex joints must be added to the riser model (Refer to Figure 1 for nomenclature). Any number of flex joints can be modelled.

Figure 3 compares a typical riser element to a flex joint element. The riser element is commonly found in the literature and derives its stiffness from beam bending stiffness (EI), effective tension (T) and lateral gravity force stiffening.

The flex joint ”finite element“ was developed for this application. Two nodes occupy the same co-ordinates to provide two separate degrees of rotational freedom, modeling the top and bottom halves of the joint. The flex joint’s rotational stiffness (zero for a ball joint) is input by the user. Stiffness terms producing a lateral force proportional to both the change in slope and the real tension across the joint are calculated by the program and included in the riser model.

Slip Joint Modeling And Stroke Calculations

The slip joint outer and inner barrels are typically modelled as two separate riser zones. The lower zone models the outer barrel. The upper zone models the inner barrel. The tensioner ring is placed at the top of the outer barrel. Any riser zone above the tensioner ring is assigned a zero real tension.

There are two contributors to slip joint stroke:

Riser slope

Vessel heave

Riser slope causes the slip joint to extend. The amount of slip joint stroke is contributed by each riser element's slope using the Pythagorean theorem. Total maximum stroke is calculated by adding each element's maximum contribution to stroke (from the top of the BOP to the top of the riser) to maximum vessel heave.

Each element's mean (static) slope is added to its maximum dynamic slope (using statistical assumptions commonly used for sea states, the maximum dynamic slope is approximated as 1.86 times significant dynamic slope) to obtain the maximum total slope. The maximum total slope is used in the total slip joint stroke calculation.

It is necessary to add element slope first before calculating each element's contribution to total stroke because of the sum of the squares in the formula on Figure 8.

Dynamic stroke can be assumed equal to the maximum total stroke minus the mean stroke.

Each element's maximum dynamic slope amplitude is assumed to occur simultaneously. In fact, riser element dynamic slopes are not exactly in phase and the true dynamic stroke component will be somewhat less than calculated. Also, vessel heave is added to the dynamic stroke assuming that maximum heave occurs at the same instant as maximum dynamic stroke due to riser element slope.

Stress Calculations

The program prints out a number of stress values as follows:

Axial stress (f_a) equal to the real tension divided by the pipe cross sectional area.

Bending stress (f_b) equal to the absolute value of the bending moment divided by the section modulus.

Total stress (f_t) equal to the axial stress plus or minus the bending stress depending on which gives the highest absolute value. The total stress is given the sign of the axial stress.

Hoop stress (f_h) equal to the differential pressure across the riser multiplied by the outside radius and divided by the wall thickness.

Equivalent stress (f_e) given by: $f_e = \sqrt{(f_t^2 + f_h^2 - f_t \times f_h)}$.
This is the Von Mises equivalent (or "distortional energy") stress for bi-axial stress state. Yield is said to occur when the equivalent stress equals the tensile yield stress.

The equivalent stress is calculated twice — for $f_t = f_a + f_b$ and for $f_t = f_a - f_b$. The larger of the two is output. This is done because a small negative total stress combined with a positive (bursting) hoop stress makes the sign of the third term (i.e., $- f_t \times f_h$) positive and often maximises the equivalent stress.

API RP 2A (Ref. 3, section 2.5.4) recommends an equation for stress utilisation when tension (or compression) and hydrostatic collapse occur simultaneously. Hydrostatic collapse pressures will occur in a drilling riser if the hole looses circulation. when RISERDYN calculates differential crushing pressure across the riser wall, it will calculate the upstream and downstream total of axial and bending stress.

If both of these total stresses are tensile (as is usual), RISERDYN will use the highest of the two to calculate the collapse/tension utilisation.

If both are compressive, it will use the total stress with the highest absolute value (i.e., the most negative) to calculate the collapse/tension utilisation.

If the total stresses on the upstream and downstream side of the riser have opposite signs, RISERDYN will calculate both utilisation's and select the highest for output.
All alternatives use safety factors appropriate to situations where the 1/3-increase is allowed.

Boundary Conditions

Concentrated forces, moments and springs can be added at any riser elevation to allow modeling unusual situations. For instance, the lateral stiffness imparted to the free hanging BOP by the tensioned guidelines can be modelled with a concentrated spring and a force. Another example could be that a guyed tower's guylines could have their linearised stiffness modelled as a concentrated spring and dashpot at the point of guyline attachment to the "riser" model of the tower.

For the ease in modeling a typical drilling riser, RISERDYN assumes a pinned connection between the vessel and the riser top. To override this assumption, the user must specify an additional boundary condition at the riser top with zero force or moment.

If a disconnected, freely hanging riser is modelled, RISERDYN will ignore the user input displacement constraints at the bottom to ensure a free node at the model's base.

If a casing string is not modelled, the riser bottom will be free at the base unless springs or displacements are specified.

For a dynamic analysis, the riser top is forced to move laterally with the vessel. The program defines surge as horizontal motion of the riser top in the direction of the environment. This differs from the naval architect's definition of surge, which is usually referenced to the ballasted vessel's centre of gravity, far below the drill floor. The conventional surge definition also refers only to forward/aft motion rather than motion in the direction of the environment, as used here. Roll and pitch referenced to the vessel centre of gravity contribute significantly to the horizontal motion at the drill floor elevation.

Heave is used only in the calculation of slip joint stroke.

Surge and heave are input with response amplitude operators (RAO's) at specific wave periods. Enough points should be input to characterise the RAO curves. The program uses a straight line interpolation between the input points to obtain values at the analysis frequencies. Be sure to define the RAO curves over the analysis frequency range, typically from zero frequency (very large period) to about 1.5 to 2.0 rad/sec (approximately 3 to 4 second periods). At frequencies above the highest specified, the RAO is assumed equal to the value at that highest specified frequency. Also be sure to enter a point at each break point in the heave and surge RAO amplitude and phase.

The program assumes that RAO's are cosine functions with a positive phase (ϕ) indicating a lag in response with respect to wave crest:

$$\text{RAO} = \text{Amplitude} \times \cos(\omega t - \phi)$$

Vessel motion RAO's are input at any number of discrete frequencies which do not have to coincide with the analytical wave frequencies. The surge RAO's are used as the dynamic riser top boundary conditions. The heave RAO's are used only for the slip joint stroke calculations. RISERDYN obtains the vessel surge RAO's and phase angles at the desired frequencies by interpolating between the input points. If an analysis frequency lies outside the input range, RISERDYN will select the boundary value on the appropriate side of the spectrum — i.e., vessel RAO's are extended at both ends of the spectrum.

Wave Model

Seastates are specified in RISERDYN by two parameters: H_S, the significant wave height (i.e., average of the 1/3 highest waves), and T_Z, the mean zero-crossing period. Either of two wave spectral shapes may be specified:

A modified Pierson-Moskowitz (PM) formulation (also known as a Bretschneider spectrum), developed for fully developed seas where the wind duration and fetch are both large, or

A JONSWAP formulation, developed for the North Sea conditions where storm duration and fetch are both too short to produce fully developed seas:

Both are commonly used in a variety of engineering applications outside their original objectives.

The modified PM formulation is:

$$S(\omega) = [5 H_S^2/\{16 T_P^4\}]\ \omega^{-5} \exp\{-1.25/(T_P^4\omega^4)\}$$

where T_P is the peak spectral period. For a PM spectrum, T_z and T_P are related by

$$T_Z = T_P/1.408$$

The JONSWAP formulation is the PM multiplied by a peakedness factor, γ^a:

$$S(\omega) = [\ 5 H_S^2/\{16T_P^4\}]\ \omega^{-5} \exp\{-1.25/(T_P^4\omega^4)\}\ \gamma^a$$

$$\text{where } a = \exp\ [-\{\omega - 2\pi/T_P\}^2/\{2\ \sigma^2\ (2\pi/T_P)^2\}$$

$$\sigma = 0.07 \text{ for } \omega < 2\pi/T_P\text{, and } 0.09 \text{ for } \omega \geq 2\pi/T_P$$

$$\gamma = 3.3$$

If $\gamma = 1.0$, the JONSWAP reduces to the PM. Sometimes the value of γ is modified based on site-specific data, but RISERDYN allows no other values for γ. Wave energy is more concentrated in the JONSWAP spectrum around the peak spectral energy wave period. The relationship between the peak spectral period and the mean zero crossing period is:

$$T_Z = T_P/1.28$$

The dynamic analysis approximates the wave spectrum with a number of frequency bands. The frequency bandwidth (i.e., frequency increment) is specified by the user and defaults to 0.05 rad/second. Typical analysis should use the default frequency increment. Smaller increments will improve accuracy, but add significantly to storage and run time requirements.

RISERDYN selects the first analysis frequency as the first multiple of the frequency increment for which the value of the wave spectral density function equals 1% of the peak value. It then defines the analysis frequency range by selecting the last (the highest) frequency such that the wave spectral density also equals 1% of the peak. An additional analysis frequency is added at the wave spectrum peak for accuracy in the numerical integration's. The program then numerically integrates the wave spectrum and compares the resulting significant wave height to the input value. If the error is more than 1%, another frequency increment is added to the frequency range the comparison is made again. This process is repeated until the error is less than 1%.

The program calculates the total horizontal wave force per unit of riser length as the sum of the inertia force (F_i) and the relative velocity drag force (F_d) where:

$$F_d = ½\ \rho\ C_d D\ (u - \dot{x})\ |u - \dot{x}|$$

$$F_i = \rho (\pi D^2/4) \times (C_m \dot{u} - C_a \ddot{x})$$

where $(\cdot) = d(\ )/dt$

ρ = water mass density

D = hydrodynamic diameter

C_d = drag coefficient

C_m = inertia coefficient

C_a = added mass coefficient, $C_m - 1$

u = water particle velocity

x = riser displacement

The program accounts for the inertia force component proportional to the water particle lateral acceleration on the right side of the equation as an added mass term. The relative velocity damping is accounted for in the imaginary part of the complex system matrix.

Current Model

If current profile is not defined, RISERDYN will analyse the riser without current. to define a current profile, at least two points must be input. The surface current velocity is one of them. RISERDYN calculates the nodal current profile by interpolating between input points. Any region outside the range of defined current is assigned zero current. RISERDYN allows only one value at each depth. To specify a stepped current profile, two current velocities should be defined at two different depths, at least 2 inches apart. RISERDYN will condense any two nodes closer than 2 inches into one node.

Resonant Mode Analysis

Mode shapes (eigenvectors), natural frequencies and period may be obtained for the riser system using the eigenvectors analysis option. The number of modes will be equal to one half of the number of analytical joints but not more than 8 (thus a two node system will produce one mode shape, but all systems of 16 nodes or more will produce 8 mode shapes). However, the user has the option of requesting less than 8 modes.

Any arrangement of mass and restraint modeling may be used, so long as there are no zero mass nodes which could only occur if both the weight of the riser and the density of the water are set equal to zero. It is not necessary that the riser be statically restrained, as the solution algorithm consists of a subspace iteration method. The method uses a QR solution procedure (as described in Dahlquist & Bjorn) to solve all the modes of the reduced system. After several iterations are performed, the system converges to a final solution. The initial trial vectors consist of a scaled vectorised mass for the first trial vector, with the remainder being as described by Bathe & Wilson. The number of trial vectors utilised is equal to twice the number of analytical nodes, or the number of analytical nodes plus four, whichever is less.

Only the results for the number of solved vectors, not the number of trial vectors, are produced. The output consists of a table of eigenvalues, frequencies, periods and model participation factor followed by the eigenvectors or the mode shapes. Each mode shape is scaled so that the maximum translational displacement is equal to 1.0.

Multiple Run Analysis

Static, dynamic and modal parametric analyses can be performed for the following variables: riser top tension, weight density of mud in the riser, and static horizontal offset at the riser top.

RISERDYN stops the parametric analyses when a riser finite element has a compressive axial force larger than the riser's Euler buckling load. Therefore, it is recommended to change the riser top tension from the largest to smallest in parametric analyses.

Both static and dynamic multiple runs can be performed. Multiple dynamic analyses require a significant amount of time, so are often run overnight.

Problem Size And Limitation

The program can be run for a matrix of analysis cases, involving variation in offset, mud weight and top tension. The size of this matrix is not fixed, but is dependent on the complexity of the modelling of the riser, casing and environment. Arrays are stored pseudo dynamically in a single very large array of fixed size. This array has been upsized in line with the capability of present machines. The arrays for modelling the riser, casing and environment occupy the lower reaches of the large array, whilst the remaining space is available for the matrix of analysis cases.

It is unlikely that the user will exceed the current array limits. The program will give a warning at run-time if the limits are exceeded.

Running RISERDYN

Running RISERDYN

Starting RISERDYN

The RISERDYN riser analysis suite is initialised from the Windows Start menu under programs, Global Maritime, RISERDYN 4.0.2. The RISERDYN interface has been designed to be user friendly utilising four drop-down menus, nine tabs and ten buttons.

Drop-down Menus

The drop-down menu provides a series of functions: File, View, Run, and Help.

Buttons Menu

The buttons provide a series of functions ranging from saving to printing. The button function can be displayed by simply holding the mouse arrow over the button for two seconds. The buttons available include:- New Riser Makeup File, Open Riser Makeup File, Save Riser Makeup File, View Output, View Graphics, Calculate Minimum Top Tension, Run Riser Analysis, Comments on Input, Perform Data Check and About RISERDYN.

Tabs Menu

On opening RISERDYN the Location Details tab will be displayed, others include Current Profile, Conductor / Soil Springs, Wellhead / BOP/LMRP, Vessel Parameters, Joint Definition, Riser Make-Up, Run Details and Flex Joint / Tensioner Ring. To edit or view information on a specific tab select the tab with the appropriate name, a data window will then be available for editing.

New Riser Makeup File

This button clears all the information in the tabs and allows the definition of a new Riser Make-Up file. New riser files created will automatically be given the default file extension of *.RSM.

Open Riser Makeup File

This button will display the Windows Open file dialog which will show a list of existing Riser Make-Up files *.RSM. The list will default to the directory of RISERDYN, or to the directory currently in use.

Save Riser Makeup File

This button will save any changes to the Riser Makeup File.

Calculate Minimum Top Tension

This button will open a new window for calculating the minimum top tension requirements according to the procedures laid down in API RP 16Q, "Recommended Practice for Design, Selection, Operation and Maintenance of Marine Drilling Riser Systems", section 3.3.2. The user is also able to compute the limiting heave acceleration beyond which buckling of the riser would occur in the disconnected situation, and compare it to the actual heave for the given conditions and vessel parameters. This window contains information required for calculating the minimum top tension. The submerged riser weight and the net lift of buoyancy material have been calculated from the defined riser configuration. The user is able to alter the various tolerance factors, mud weight, mud column height and tensionner information. The minimum slip ring and top tension are calculated and can be compared to the available top tension.

Buttons are available to produce curves of a) Minimum Slip Ring and Top Tension requirements for a range of mud weights, b) allowable wave height for a range of wave periods below which riser buckling should not occur in the disconnected situation. Further buttons will print results to file and close the window.

Comments on Input

This button allows the user to add comments to the input data. Comments are applicable to the tabs selected.

Perform Data Check

This button will check the program for any invalid data and will inform the user as to its location.

Run Riser Analysis

This button runs the riser analysis. When finished a new window will be displayed informing the user that the calculations were performed and the status of the analysis. The location of the output and plot files will also be given.

Run Existing RSR

This function allows the user to run a riser analysis on an existing *.RSR file. A new window will open with a list of *.RSR files. The list will default to the directory of RISERDYN. Select the required file and select open. The program will then run a riser analysis on this file. On completion of the riser analysis a message box will appear informing the user that the analysis is complete. The results can view in the output. The user should note that *.RSR files cannot be edited in this program.

Location Details

Location Details

Well Name

Enter the well name.

Water Depth, Shielded Depth and Seawater Density

Enter the seawater density and water depth. The depth to the bottom of the shielded zone may also be specified. The units for density are pounds per cubic feet (lbs/cu ft) and the units for both depths are feet (ft), measured from the water surface, positive downward. The user can tick the default box if a seawater density of 64.3 lbs per cubic foot is required.

Wave Conditions and Spectrum

For a dynamic analysis, a wave spectrum must be defined. The spectrum is defined by a significant wave height, a zero crossing period, and a spectrum type.

Significant Wave Height Hs

Wave Period, Tz

Wave Spectrum

Once the user has entered the required details for this window they can progress to the next window for data entry, Current Profile

Significant Wave Height Hs

Enter the significant wave height. The significant wave height is defined as the average of the one-third highest waves in a wave record. The wave height is measured from the bottom of a trough to the succeeding wave crest. The units for wave height are feet, (ft).

Wave Period, Tz

Enter the zero crossing period for the wave spectrum. The zero crossing period is used to locate the frequency of the maximum wave energy. For the Pierson-Moskowitz wave spectrum the peak period is 1.408 times the zero crossing period; for the JONSWAP spectrum the factor is 1.28. The frequency of maximum wave energy is 2π divided by the peak period. The units for zero crossing period are seconds, (sec).

Wave Spectrum

Select the spectrum type. RISERDYN can generate either a Pierson-Moskowitz wave spectrum or a mean JONSWAP wave spectrum.

Current Profile

Current Profile

A current velocity profile may be entered. The current velocities are used to calculate the current drag force for static analyses and to calculate the combined current and wave drag forces for dynamic analyses. RISERDYN linearly interpolates between the entered values when intermediate values are needed. Values for Current speed and depth can be entered directly into the table on this tab but must be entered from the top of the table. The current velocity profile entered in the table is displayed on the graph in this tab.

Once the user has entered the required details for this tab they can progress to the next tab for data entry, Conductor / Soil Springs**.**

Conductor / Soil Springs

Conductor / Soil Springs

The Soil and Conductor information gives the effective stiffness for the downhole casing. All casing sections are assumed to extend from the bottom of the BOP (wellhead) to the lowest elevation for which a soil spring is given, i.e. the soil information must be specified for the casing stiffness to be considered.

Once the user has entered the required details for this tab they can progress to the next tab for data entry, Wellhead / BOP/LMRP.

Conductor Properties

Casing Length

Enter the length of the casing. The units for length are feet, (ft).

Casing OD

Enter the outside diameter of the casing string onto the table provided. The units for diameter are inches, (in).

Wall Thickness

Enter the casing wall thickness onto the table provided for the relevant Casing OD. The units for thickness are inches, (in).

Young's Modulus

Enter the Young's Modulus of the casing material. The units for Young's Modulus are millions of pounds per square inch, (multiples of 10^6 psi).

Soil Properties

Elevation

Enter the elevation for the soil spring constant. The elevations are measured from the mudline, negative downward. The units for elevation are feet, (ft).

Stiffness

Enter the soil stiffness (spring constant) at the given elevation. The units for the stiffness are kips per foot displacement per foot of casing length, (kips/ft/ft).

Wellhead/BOP/LMRP

Wellhead/BOP/LMRP

If the BOP or a portion of the BOP is connected to the riser, the following information should be given. If just the LMRP is disconnected (i.e. hung-off analysis) then enter only the LMRP details.

Once the user has entered the required details for this tab they can progress to the next tab for data entry, Vessel Parameters**.**

Subsea Stack Properties

LMRP Height

Enter the height of the LMRP. The elevation is measured from the mudline, positive upwards. The units for height are feet, (ft).

BOP Height

Enter the height of the BOP. The elevation is measured from the mudline, positive upwards. The units for height are feet, (ft).

Wellhead Height

Enter the height of the Wellhead. The elevation is measured from the mudline, positive upwards. The units for height are feet, (ft).

LMRP Dry Weight

Enter the LMRP dry weight, the weight measured in air. The units for weight are kips, (multiples of 1000lb).

LMRP Wet Weight

Enter the LMRP wet weight, the weight measured in water. The units for weight are kips, (multiples of 1000lb).

BOP Dry Weight

Enter the BOP dry weight, the weight measured in air. The units for weight are kips, (multiples of 1000lb).

BOP Wet Weight

Enter the BOP wet weight, the weight measured in water. The units for weight are kips, (multiples of 1000lb).

LMRP Hydrodynamic Properties

LMRP Drag Area

Enter the effective drag area of the LMRP. For calculating the current/wave force on the LMRP, the effective drag area must be specified. The units for area are square feet, (ft^2).

LMRP Drag Coeff (CD)

Enter the drag coefficient. The drag coefficient is also required for calculating the forces on the LMRP. The drag coefficient is non-dimensional.

LMRP Inertia Coeff (Cm)

Enter the hydrodynamic inertia coefficient, (mass coefficient), for the LMRP. The hydrodynamic inertia coefficient is used to calculate the fluid inertia forces on the LMRP. The inertia coefficient is defined as in Section 2.12 (i.e., $C_m = 1.0 + C_a$, the added mass coefficient). The inertia coefficient is non-dimensional.

LMRP Volume

Enter the effective hydrodynamic volume displaced by the LMRP. The effective displaced hydrodynamic volume is required to determine the fluid inertia forces on the LMRP. The units of volume are cubic feet, (ft^3).

Once the user has entered the required details for this tab they can progress to the next tab for data entry, Vessel Parameters.

Vessel Parameters

Vessel Parameters

For a dynamic analysis, the motion at the top of the riser is specified as a set of vessel motion Response Amplitude Operators (RAO's) and their phases. Data for the RAO's can be entered manually or a custom vessel file (with default file extension *.CVF) can be used instead if one exists for this vessel.

Once the user has entered the required details for this tab they can progress to the next tab for data entry, Joint Definition**.**

Vessel Name

Enter the name of the vessel.

Draft

Enter the vessel draft. The units for draft are feet, (ft).

Rotary Table above Keel

Enter the distance between the Rotary Table and the keel. The units for length are feet, (ft).

Diverter below Rotary Table

Enter the distance between the Diverter and the Rotary Table. The units for length are feet, (ft).

Number of Tensioners

Enter the number of Tensioners.

Tensioner Rating

Enter the Tensioner rating. The units for Tensioner rating are kips.

Read Vessel Particulars from File

The vessel data on this tab can be imported from a custom vessel file. This button will open a new window to display a list of existing custom vessel files *.CVF. The list will default to the current directory. Select the required file and the vessel particular information on this tab will be updated.

Period

Enter the regular wave period for the RAO values. The units for wave period are seconds, (sec).

Lateral Motion Amplitude

Enter the lateral RAO for this wave period. The lateral RAO is defined as lateral response, peak-to-peak, divided by regular wave height. The RAO's are non-dimensional.

Lateral Motion Phase

Enter the phase of the peak of the lateral response relative to the wave crest. A positive phase implies a lag between wave crest and peak response. The units for phase are degrees, (deg).

Read RAO Table from File

The vessel RAO data on this tab can be imported from a custom vessel file. This button will open a new window to display a list of existing custom vessel files *.CVF. The list will default to the current directory. Select the required file. The user will be asked for the input wave incident angle onto vessel. The vessel RAO data on this tab will be updated.

Joint Definition

Joint Definition

This tab provides the capacity to view, edit and create a database of joint details. Joint details defined in this tab can then be used in the next tab, the Riser Make-Up tab, to define the make-up of the Riser. Joint properties and details are stored in a Riser Joint database, with filename extension *.RSD, see RISERDYN Data Files. In this tab a new Riser Joint File can be created and an existing Riser Joint database can be edited.

Once the user has entered the required details for this tab they can progress to the next tab for data entry, Riser Make-Up.

Joint Identifier

Enter a name for the joint.

Description

Enter a brief description of the joint.

Yield Stress

Enter the Yield Stress of the joint. The units for the Yield Stress are kips per square inch, (ksi)

Joint Length

Enter the length of the joint. The units for length are feet, (ft).

Top Structural OD

Enter the outside diameter (OD) at the upper end of the riser joint. If the lower and upper outside diameters are not equal, the joint will be considered as a single tapered element. The units for diameter are inches (in).

Bottom Structural OD

Enter the outside diameter (OD) at the lower end of the riser joint. The units for diameter are inches (in).

Top Wall Thickness

Enter the wall thickness at the upper end of the riser joint. If the lower and upper wall thicknesses are not equal, the joint will be considered as a single tapered element. The units for thickness are inches, (in).

Bottom Wall Thickness

Enter the wall thickness at the lower end of the riser joint. The units for thickness are inches, (in).

Choke Line Int. Diameter

Enter the Choke Line Internal Diameter. The units for diameter are inches, (in). This diameter is used in calculating the Choke line cross sectional area for use in the Top Tension calculations.

Kill Line Int. Diameter

Enter the Kill Line Internal Diameter. The units for diameter are inches, (in). This diameter is used in calculating the Kill line cross sectional area for use in the Top Tension calculations.

Auxiliary Line Int. Diameter

Enter the Auxiliary Line Internal Diameter. The units for diameter are inches, (in). This diameter is used in calculating the Auxiliary line cross sectional area for use in the Top Tension calculations.

Joint Dry Weight

Enter the joint dry weight for bare and buoyant cases, the weight measured in air. The units for weight are lbs.

Joint Wet Weight

Enter the joint wet weight for bare and buoyant cases, the weight measured in water. The units for weight are lbs.

Joint Cd

Enter the drag coefficient for the joint for bare and buoyant cases. The drag coefficient is non-dimensional.

Joint Cm

Enter the hydrodynamic inertia coefficient, (mass coefficient), for the joint for bare and buoyant cases. The hydrodynamic inertia coefficient is used to calculate the fluid inertia forces on the joint. The inertia coefficient is defined as in Section 2.12 (i.e., $C_m = 1.0 + C_a$, the added mass coefficient). The inertia coefficient is non-dimensional.

Open (Joint Database)

This button will open a new window to display a list of existing Riser Joint Files *.RJD. The list will default to the directory of RISERDYN.

Save (Joint Database)

This button allows the user to save any changes made to the joints in the database.

Save As (Joint Database)

This button will open a new window, which allows the user to save the joint database to a different name and location.

Add (Joint Database)

This button allows the user to add another joint and it's properties to the database. Enter the joint details as described in Joint Definition and select the Add button. If any invalid data has been entered a message box will appear after the Add button has been selected. The message box will inform the user as to the invalid data's location and nature. Select the OK button on the message box and edit the appropriate data.

Edit (Joint Database)

This button allows the user to edit the properties of a joint that is already defined in the joint database. Select the joint that requires editing, select the Edit button and edit the required joint properties. Once the joint properties have been edited select the End Edit button and the database will be updated. If any invalid data has been entered a message box will appear after the End Edit button has been selected. The message box will inform the user as to the invalid data's location and nature. Select the OK button on the message box and edit the appropriate data.

Delete (Joint Database)

This button allows the user to delete a joint from the database. Select the joint that requires deleting and select the Delete button.

Riser Make-Up

Riser Make-Up

The riser configuration is defined on this tab. The diverter is assumed to be at the top of the riser and the BOP/LMRP at the bottom. Intermediate riser sections are defined by choosing joint types, defined on the Joint Definition tab, and specifying the number of joints in the section, whether or not the joints include buoyancy material and how many subdivisions of the section will be made. Finer element distribution (increased subdivision) is generally made near the bottom of the riser and near the water surface (wave zone), in effect refining the mesh. It may also be desirable to include flex or ball joints. A maximum of eight flex joints from the Flex Joint/Tensioner Ring tab and sixteen riser joints from the Joints database may be input.

The BOP and the Diverter cannot be removed from the riser make-up.

Once the user has entered the required details for this window they can progress to the next window for data entry, Run Details

Required Riser Length

This box indicates the riser length required to satisfy the defined arrangement of water depth, vessel and equipment layout. The user cannot edit this box directly. The units for length are feet, (ft).

Defined Riser Length

This box shows the user the length that has already been defined in the riser make-up table beneath. The user cannot edit this box directly. The units for length are feet, (ft).

Distance to Go

This box shows the user how much more riser length needs to be defined. The distance to go should be within the stroke of whatever slip joint is defined. The user cannot edit this box directly. The units for length are feet, (ft).

Section

The riser is made up of a series of sections. Each section can be made up of one or more joints of the same type. For each section a joint type, number of joints, whether it is buoyant or not and the number of subdivisions need to be defined.

Name

The name specified on the Joint Definition tab in the Description box is automatically entered in this box when the Joint Type is selected. The user cannot edit this box directly.

Joint Type

Select the joint type from the drop-down list in this box. The joint type refers to the Joint Identifier specified on the Joint Definition Tab. Joint properties for the chosen joint type will automatically be entered onto this table. The drop down list also contains the flex joints defined on the Flex Joint/Ring Tensioner tab. These flex joints can be inserted into the riser make-up as required.

No of Joints

Enter the number of this type of joint that is required at this location.

Section Length

This column displays the riser section lengths. The section length is calculated from the joint length and the number of joints. The user cannot edit this box directly. The units for length are feet, (ft).

Top Elevation

This column displays the top elevation for the joints in each section of the riser. Elevations are measured from mudline, positive upwards. The user cannot edit this box directly. The units for elevations are feet, (ft).

Top Depth

This column displays the depth of the top of the joints for each section of the riser. Depths are measured from the top of the joint to the water surface, positive upwards. The user cannot edit this box directly. The units for depths are feet, (ft).

Buoyant

The user can select whether this section of joints take the properties for the Buoyant or Bare condition as define on the Joint Definition tab**.** Select Yes from the drop-down list if the joint is required to be buoyant and No if properties for the bare case are required.

Net Weight

The weight of the joint/joints for each section of the riser is calculated in this column. The user cannot edit this box directly. The units for weight are lbs.

Subdivisions

Enter the number of equal length elements into which subdivide this section of the riser. If this is a tapered section of riser, it must be treated as a single element.

Insert

This button allows the user to insert more sections for the riser make-up. Sections are inserted above a selected row. A maximum of 26 sections are permitted by this program, which should comprise of no more than 16 riser sections and 8 flex or ball joints. The remaining are fixed as the diverter and the BOP/LMRP.

Delete

This button allows the user to delete sections from the riser make-up.

Run Details

Run Details

The Run Details tab defines the operating parameters of the riser top tension, mud weight, offset, bottom condition, mud elevation, mud pressure, water depth, density and shielded depth.

Once the user has entered the required details for this window they can progress to the next window for data entry, Flex Joint / Tensioner Ring

Title

Enter the Report Title in this box.

Sub Title

Enter the Report Sub Title in this box.

Bottom Condition

Select the bottom connection condition: Connected or Hung off. For most riser analyses, the downhole casing, BOP and riser are a continuous member - Connected. A disconnected riser may be analysed by specifying the condition - Hung Off. If the connected option is chosen, then the BOP and the LMRP properties are used within the analysis. If the hung off option is chosen, then only the LMRP properties are used.

Output Detail

The user can specify what type of output is required either a shortened summary or a full detailed report can be produced.

Top Tension: Initial, Unit, Increment and Number

Enter the initial tension at the top of the riser. For multiple analysis (as for a parametric study) a tension increment may be specified, and the number of times to increment the tension may be given. The units for the top tension and tension increment are kips, (multiples of 1000lbs).

Mud Weight: Initial, Unit, Increment and Number

Enter the initial mud weight. An increment for stepping the mud weight may be entered, and the number of increments may be specified. The units for mud weight and weight increment are pounds per gallon, (lbs/gal).

Offset: Initial, Unit, Increment and Number

Enter the initial offset of the top of the riser. For multiple analyses, an offset increment may be specified, and the number of times to increment the offset may be given. The units for the top offset and offset increment are feet, (ft).

Analysis Type

The list box gives the user three options for the analysis, of which only one can be selected.

Static

Dynamic

Vibration Modes

Select the analysis type. Either a static, dynamic, or vibration mode analysis (resonant mode shape/natural frequency (eigen vector) analysis) can be selected. If a vibration mode analysis is selected the number of modes is also required.

Mud Elevation and Surface Pressure

Enter the elevation and surface pressure of the mud column. The units for the elevation are feet, (ft), measured from the mudline positive upwards, and the units for the pressure are pounds per square inch, (psi).

Use Diverter Elevation?

The user may specify the mud column height. If the Use Diverter check box is selected , the program will calculate the mud column height as being from the top of the LMRP to the diverter position as specified in the vessel details.

Flex Joint / Tensioner Ring

Flex Joints Details

Flex Joints Name

Enter the name of the flex joint.

Dry Weight

Enter the dry weight, the weight measured in air, of the flex/ball joint. The units for weight are kips, (multiples of 1000lb).

Wet Weight

Enter the wet weight, the weight measured in water, of the flex/ball joint. The units for weight are kips, (multiples of 1000lb).

Stiffness

Enter the rotational stiffness of the flex joint. The units for rotational stiffness are moment, (kips x feet), per degree of rotation, (kip-ft/deg). Zero, (0.0), may be entered for a ball joint.

Once the user has entered the required details for this window they can progress to the next window for data entry, Tensioner Ring.

Tensioner Ring

The Tensioner Ring property window is not available in this version of RISERDYN.

Getting Results

Viewing & Plotting Outputs

For viewing graphs see Plot Graphs (Graphics).

For viewing output see View Output.

For Minimum Tope Tension see Calculate Minimum Top Tension

View Output

This button launches the RISERDYN Output file viewer. If a riser analysis has just been performed the viewer will display the *.OUT file that has just been created. Otherwise the viewer is empty. *.OUT files may be viewed by either using the file open menu command, or by using the Open RISERDYN Output File button. This prompts the user for the name and location of the *OUT file. The list will default to the directory of RISERDYN and file extensions of .OUT. In addition Minimum Top Tension files can also be viewed with file extension *.TTP. To view a Minimum Top Tension or *.TTP file select the open button in the viewer window and change the Files of Type drop-down menu to Top Tension Print Files *.TTP. Only files with extension *.TTP will be displayed. Locate and select the desired file as before.

The output may be printed and the font displayed may also be altered. The viewer is a MDI (Multiple Document Interface) so any number of *.OUT and *.TTP files may be viewed at once.

The files contain the text results of the simulation, detailed or summarised, according to the choice made in the Run Details tab of RISERDYN.

RISERDYN Viewer has drop down menus to allow the user to print displayed files and to open further files.

Calculate Minimum Top Tension

This button will open a new window for calculating the minimum top tension requirements according to the procedures laid down in API RP 16Q, ”Recommended Practice for Design, Selection, Operation and Maintenance of Marine Drilling Riser Systems“, section 3.3.2. The user is also able to compute the limiting heave acceleration beyond which buckling of the riser would occur in the disconnected situation, and compare it to the actual heave for the given conditions and vessel parameters. This window contains information required for calculating the minimum top tension. The submerged riser weight and the net lift of buoyancy material have been calculated from the defined riser configuration. The user is able to alter the various tolerance factors, mud weight, mud column height and tensionner information. The minimum slip ring and top tension are calculated and can be compared to the available top tension.

Buttons are available to produce curves of a) Minimum Slip Ring and Top Tension requirements for a range of mud weights, b) allowable wave height for a range of wave periods below which riser buckling should not occur in the disconnected situation. Further buttons will print results to file and close the window.

Plot Graphs (View Graphics)

This button activates the Staticplot program. Staticplot is used to display graphs of stress and deflection for the analysis that has been carried out. If a riser analysis has been carried out, Staticplot automatically loads the *.PLT file. Otherwise the user must do so manually.

Open

If a riser analysis has just been run the Riser Plot Selection window will automatically open, if not select the file to be viewed and click the Open button, or double-click the file to be viewed.

A Riser Plot Selection window will be enabled after opening a *.PLT file to allow the user to choose the graph to be plotted.

Go to section on StaticPlot for information on the Graphical Viewer.

Files of type

Only files of type *.PLT may be viewed using this plotter.

Riser Plot Selection

The user can choose the form of the plot from the selections available in the Riser Plot Selection window.

Variation along Riser

Variation with Offset

Mode Number

Mud Weights

Top Tensions

Offsets

Show % offsets as feet

Once the selections have been made the user will progress to the graphical viewer, StaticPlot

StaticPlot

The RISERDYN graphical viewer, StaticPlot, shows a graphical representation of the results with the plot options chosen in the Riser Plot Selection window.

StaticPlot has drop down menus to allow the user to print displayed plots and carry out a series of other tasks.

StaticPlot provides the ability to edit the graphs as desired see Editing Static Plot Graphs.

File

New Plot..

The New Plot selection will enable the Riser Plot Selection window with the current file to enable a new plot.

Open..

The Open selection will enable the Open window to allow the selection of any *.PLT file.

Close

The Close selection allows the user to close the active plot window.

Print..

The Print selection will enable a Print window to allow the user to the print the active plot to a local or network printer using the standard Windows print functions.

Print Preview

The Print Preview selection will enable a window to show a preview of the plot using the standard Windows print preview functions.

Print Setup

The Print Setup selection will enable the Print Setup window as displayed from the Print window to allow the user to change the printer or the printer settings.

Exit

Exits StaticPlot.

Edit

Not available in this version of RISERDYN.

View

Toolbar

This enables or disables the toolbar.

Window

New Window

This will enable a New Window of the active plot window.

Cascade

This will cascade any plots currently open.

Tile

This will tile any single plot open to fill the window. Multiple plots will tile the window depending on the number of plots open.

Arrange Icons

Not available in this version of RISERDYN.

Editing Static Plot Graphs

The horizontal axis, vertical axis, data labels and legend can all be edited within StaticPlot. Simply double click the item that requires editing, for example the x axis, and a small window will then appear containing all the parameters that the user can utilise to edit the graph. These parameters are detailed below: -

Axis Editing Window

The graph’s axis’s can be edited by double click them and using the following functions:-

From

This defines the start value of this axis.

To

This defines the end value of this axis

Step

This defines the numerical gap between each major graticule

Minor Ticks

This defines the number of minor graticules between each pair of major graticules.

Position

The Bottom, Middle and Below or Right, Left and Middle options can be used to specify the position of the graticules in relation to the relevant axis.

Line Attributes

On selecting this button a line parameter window will appear which provides the ability to edit the **colour**, **style** and **width** of the axis line. Select **OK** to accept the changes and **Cancel** to reject them.

Intercept

By editing the intersect point the user can move the relevant axis’s in relation to one another.

Grids

Major and minor grid systems are available. Their relative positions relate to the Step and Minor Ticks respectively. The grid style can be edited by selecting the **Style** buttons and using the **colour**, **style** and **width** functions**.**

Logarithmic

Select the tick box to specify a logarithmic scale.

Axis Labels Editing Window

The axis label in the graph area can be edited by double click them and using the following functions:-

Label Position

The location of the label can be defined by selecting the desired position.

Last Label

The last axis label can be removed or replaced using the **On**, **Off** and **Text** options.

Text Parameters

This button enables a window that allows the user to edit the text font, size, colour and appearance.

Format

This pane allows the user to define the number format and set the required precision by defining the number of decimal places required. StaticPlot allows three formats:- Decimal, Scientific and Engineering.

Text Editing Window

All the text in the graph area can be edited by double click it and using the following function: -

Text Parameters

This window enables the user to edit the text as well as the font, size, colour and appearance.

Output

Summary or Detailed Results

The summary only reports the maximum displacements and stresses and their corresponding location. The full report gives the results at each node.

Modelling Documentation

The riser model is summarised in a concise element property table. It lists element number, top node evaluation, outside diameter, wall thickness, real tension and hydrodynamic reference diameter for all types of elements except the tapered element. Tapered element properties are listed at both the element top and the bottom. In additional, the properties at the bottom of the model are always given.

The hydrodynamic reference diameter is set to zero in the region above the mean water level and below the mudline.

Static Analysis Results

The summary lists the maximum lateral displacement, axial, bending, total, hoop, Von Mises stresses, and API utilisation factor for interaction between hydrostatic collapse pressure and axial load. RISERDYN also outputs the riser model top and bottom reactions, the total upper and lower flex joint angles, and the riser slip joint stroke.

The detailed report gives the nodal results at the top of each element. The results at the model bottom are also given. The results include all items described in the last paragraph.

Dynamic Analysis Results

The mean, the dynamic and the total responses are given for a dynamic analysis. There are two output levels. The static part is exactly the same as the one described in the previous section. The dynamic results at each node are the statistically expected maxima in 1000 oscillations. The detailed output lists the bending stress and displacement. The summary lists the maximum bending stress and lateral displacement with their static and dynamic responses. The major difference in the slip joint stroke calculation is that the expected maximum vessel heave in 1000 oscillations is added to the riser slip joint stroke.

Multiple Run Analysis

A parametric study can be performed with multiple run analysis. A round-robin result matrix for various top tensions, mud weight densities and static offsets is generated. The report summarises the predicted maximum stresses and flex joint angles for each combination. Requesting the detailed output option for a multiple run analysis will produce voluminous data. The summary output option is recommended.

Resonant Mode Analysis Results

The eigen solution prints the first N resonant frequencies, and modal shapes. Lateral displacements are used for defining the modal shapes and are normalised to a maximum amplitude of 1.0.

RISERDYN Viewer has drop down menus to allow the user to print displayed files and to open further files.

File

Open

The Open selection will enable the Open window to allow the selection of any *.TTP, and *.OUT files.

Print

The Print selection will enable a Print window to allow the user to print the active view to a local or networked printer using the standard Windows print functions.

Exit

Exits RISERDYN viewer.

Format

Font

The user can edit the output files using the fonts function.

Window

Tile

This will tile any single view open to fill the window. Multiple views will tile the window depending on the number of views open.

Cascade

This will cascade any views currently open.

Filename

A list of files that are open in this viewer are displayed beneath the cascade function. The user can switch to different files by selecting their name from the list.

Validation

Validations & Graphical Output Specifications

Validation

API Bulletin 2J compared a number of riser programs and methods and included a table giving mean results and the variance. The mean values and RISERDYN results are given in Table 1 where good agreement is shown in general. The static wave results (run by modifying the current profile to include horizontal wave particle velocities up to the still water level using linear wave theory, and denoted by -S in the table case names) differ a little but this is open to interpretation and is not recommended for analysis.

RISERDYN uses the stochastic linearisation method (Krolikowski and Gay OTC 3777 1980) computing the dynamic loads and response in an irregular seastate. The API dynamic comparisons are for regular waves and have not been compared in the data given.

Graphs

Additional graphs are available but are not shown here include:

families of curves of angles (top or bottom) with offset, repeated for each mud weight

mode shapes for up to 8 natural frequencies of riser vibration

disconnected (hung-off) riser examples

Examples of tabular/printed output are available on request

Table 1 Comparison of RASM results with average API results - API BUL 2J 1st Edition Jan 1977

TEST CASE ID	Maximum bending stress (ksi)		Max bending stress location above BOP (ft)		Maximum total stress (ksi)		Lower ball joint angle (degrees)		Upper ball joint angle (degrees)	
	API ave	RASM	API ave	RASM	API ave	RASM	API ave	RASM	API ave	RASM
500-0-1	2.53	2.50	111	110	4.34	4.34	2.94	2.93	0.82	0.83
500-0-2	0.94	0.93	115	100	6.80	6.83	2.20	2.19	1.21	1.21
500-20-1-S	5.86	5.12	461	445	9.51	8.68	3.66	3.54	-0.79	-0.54
500-20-2-S	4.27	3.69	463	450	10.54	9.92	2.51	2.45	0.24	0.39
1500-0-1	5.61	5.53	117	110	9.49	9.61	6.14	6.01	0.48	0.49
1500-0-2	0.6	0.59	111	95	16.57	16.60	2.55	2.55	1.12	1.13
1500-20-1-S	5.87	5.69	117	110	12.25	11.85	6.31	6.18	-0.31	-0.21
1500-20-2-S	2.13	1.83	1467	1455	18.33	18.03	2.61	2.59	0.67	0.73
3000-0-1	8.66	9.24	140	130	11.03	11.53	10.13	10.61	0.24	0.23
3000-0-2	0.38	0.36	125	110	16.58	16.58	2.69	2.69	1.06	1.05
3000-20-1-S	8.71	9.39	145	130	12.43	11.80	10.14	10.79	-0.63	-0.50
3000-20-2-S	2.07	1.78	2968	2955	18.31	17.99	2.73	2.71	0.55	0.63

Figures

Figure 1 - Connected Riser

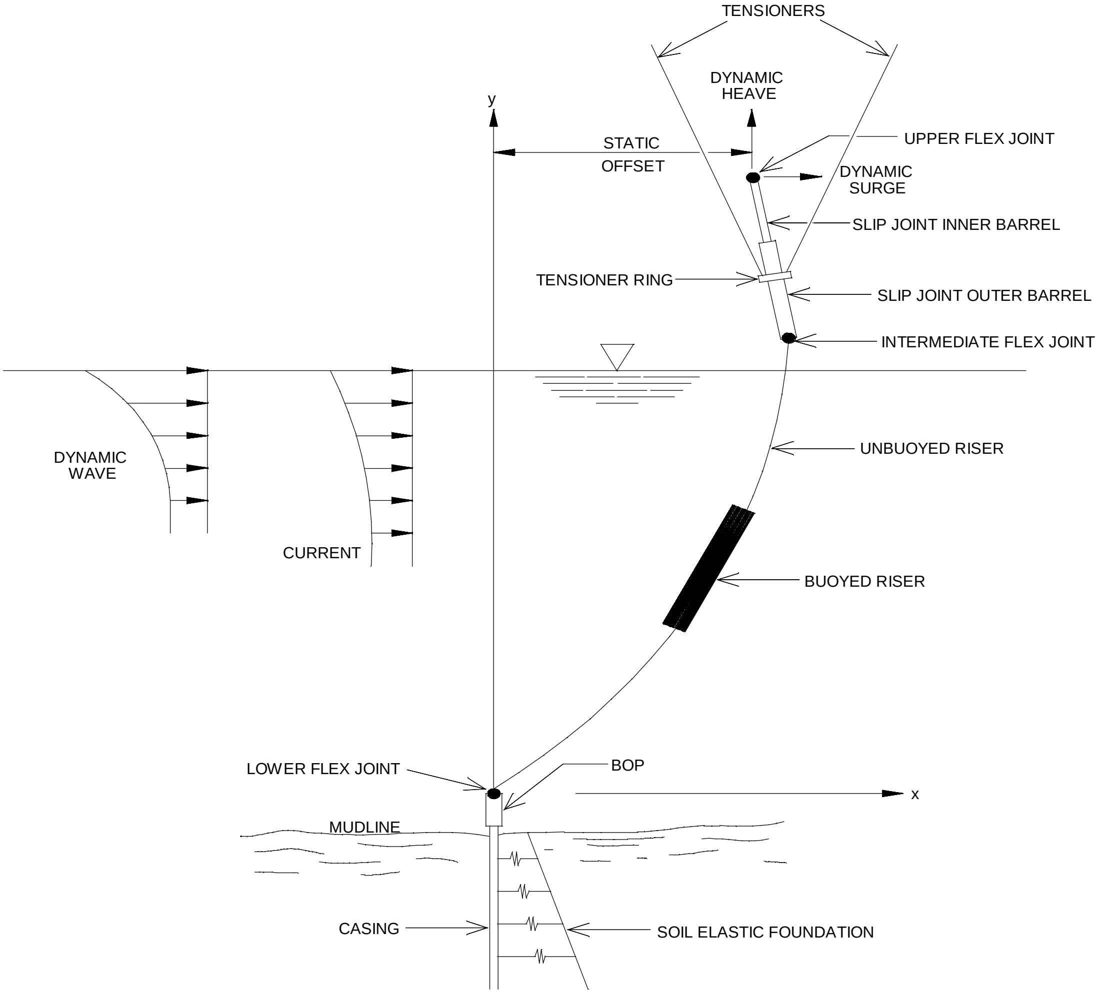


Figure 2 - Disconnected Riser

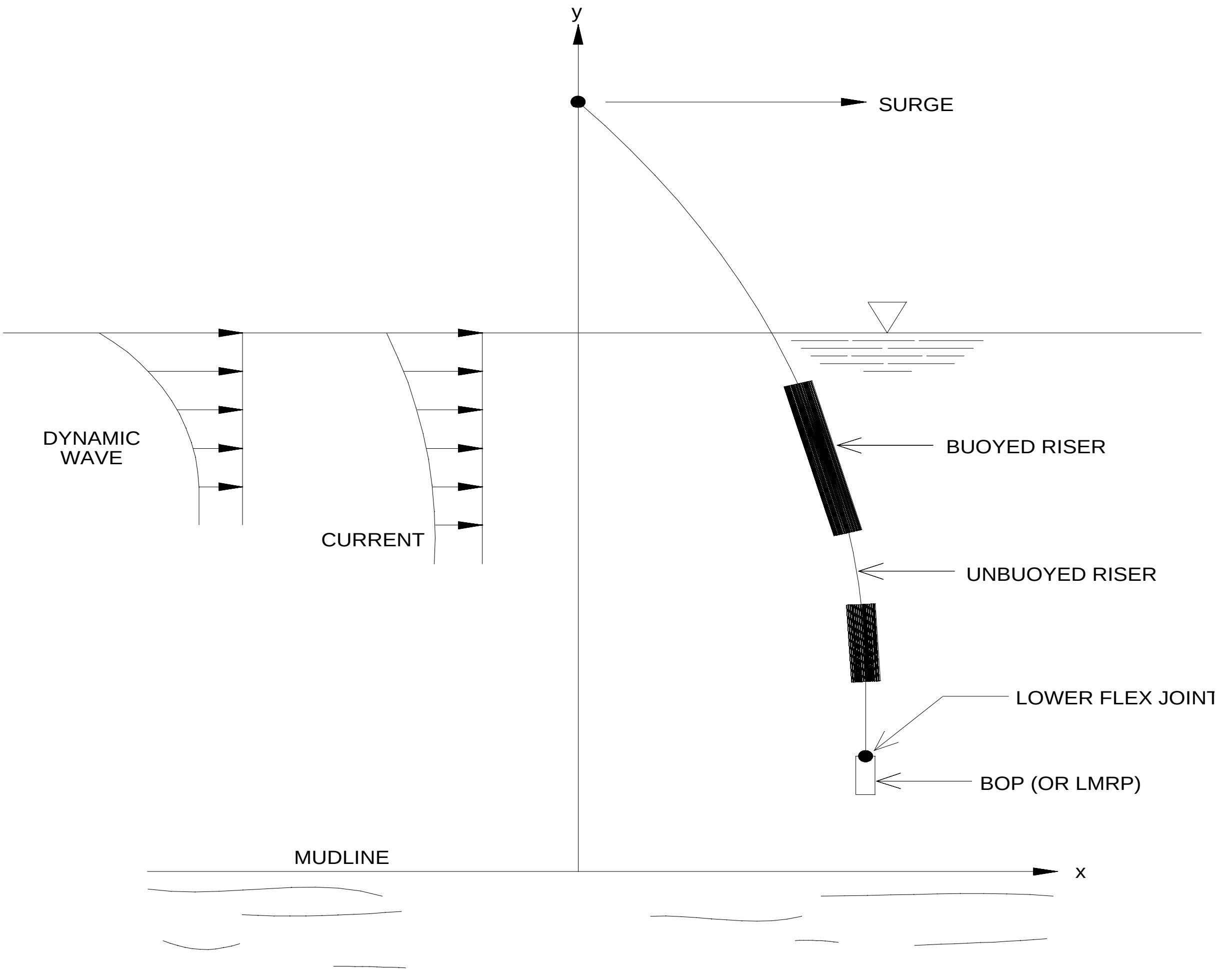


Figure 3 - Finite Element Types and Sign Convention

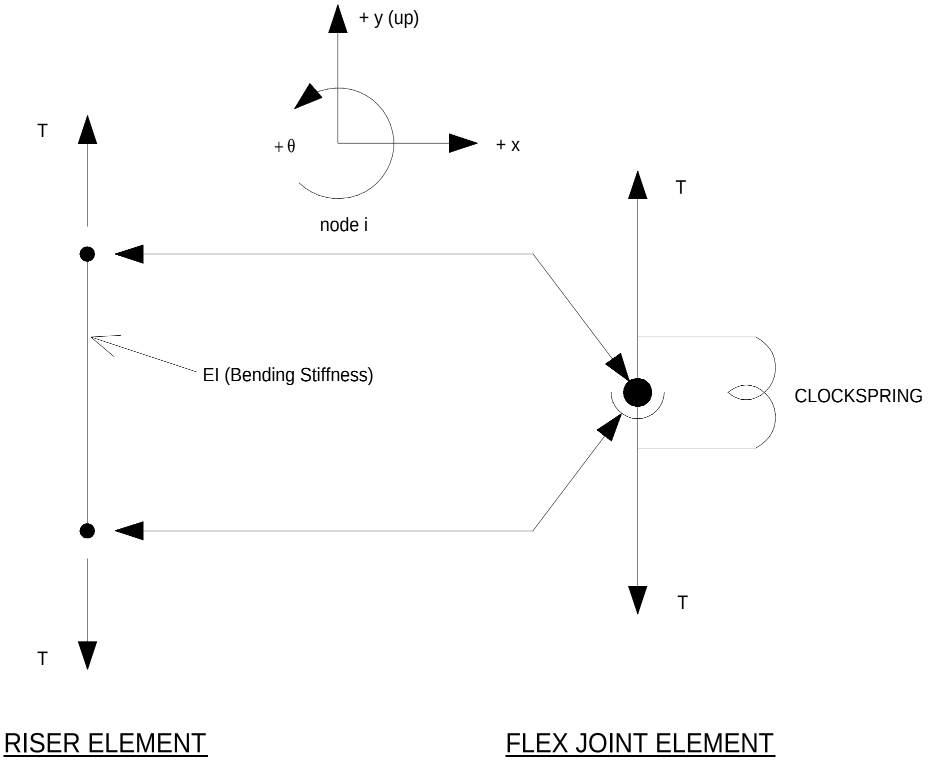
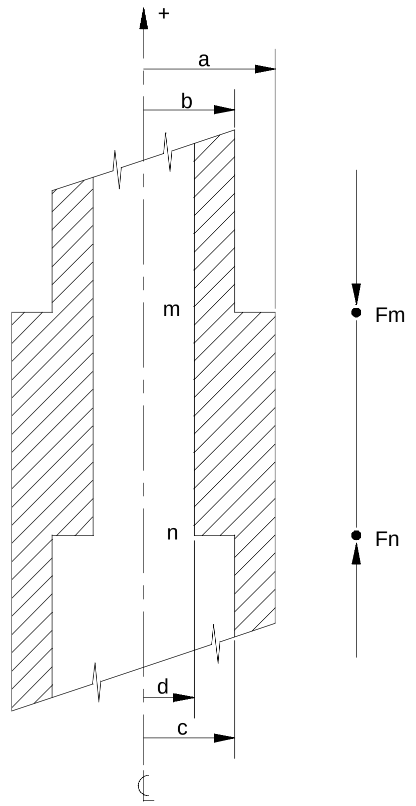


Figure 4 - Axial Force Due to Diameter Change



$F_m = - P_{om} \pi (a^2 - b^2)$

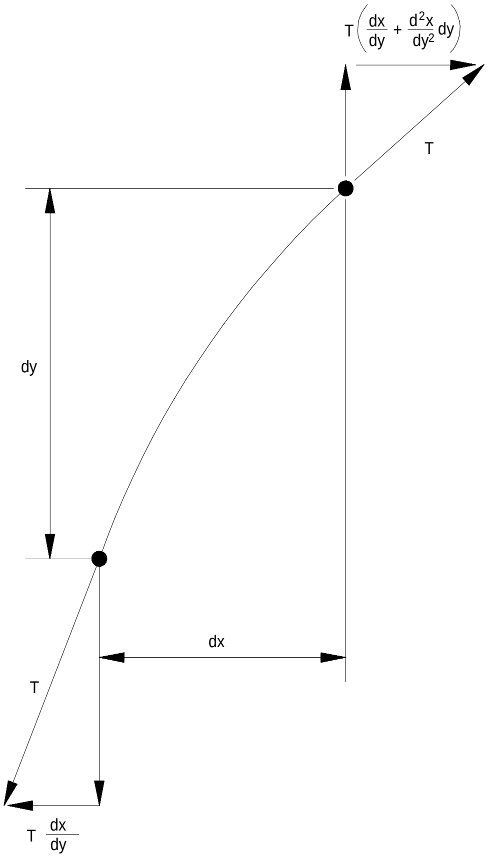
$F_n = + P_{om} \pi (c^2 - d^2)$

Where:

P_{om} = Outside Pressure @ m

P_{in} = Inside Pressure @ n

Figure 5 - Lateral Load Proportional to Tension & Curvature

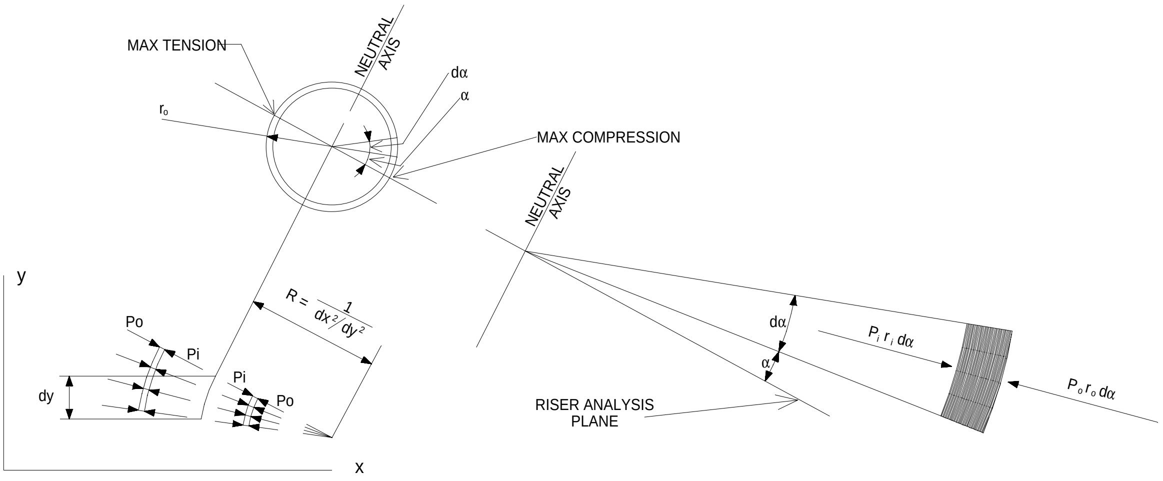


$$dH = -T\,dx/dy + T(dx/dy + d^2x/dy^2\,dy)$$

$$dH = T\,d^2x/dy^2\,dy$$

$$dH/dy = T\,d^2x/dy^2$$

Figure 6 - Fictitious Tension Derivative



The positive curvature shown stretches the pipe on the negative X side and compresses the pipe on the positive X side. This changes the areas over which the pressures act, creating lateral loads.

The radial force on the differential slice with area equal to $[r_i d\alpha][dy\ (1 - \text{Bending Strain})]$ due to internal pressure is given by:

$(P_i\, r_i\, d\alpha)\ dy\ (1 - d^2x/dy^2\ r_i \cos\alpha)$

The external pressure acts in opposite direction.

Factoring by $\cos\alpha$ to get the component in the riser analysis plane (the orthogonal components cancel each other) and integrating around the pipe circumference gives:

π

$dH_i = 2\quad P_i\, r_i\, d\alpha\ dy\ (1 - d^2x/dy^2\ r_i \cos\alpha)\cos\alpha$

o

π

$dH_i/dy = 2\, P_i\, r_i\quad (\cos\alpha - d^2x/dy^2\ r_i \cos^2\alpha)\ d\alpha$

o

$dH_i/dy = -P_i\,(\pi\, r_i^2)\ d^2x/dy^2$

$dH_i/dy = -P_i\, A_i\ d^2x/dy^2$, where $A_i = r_i^2$

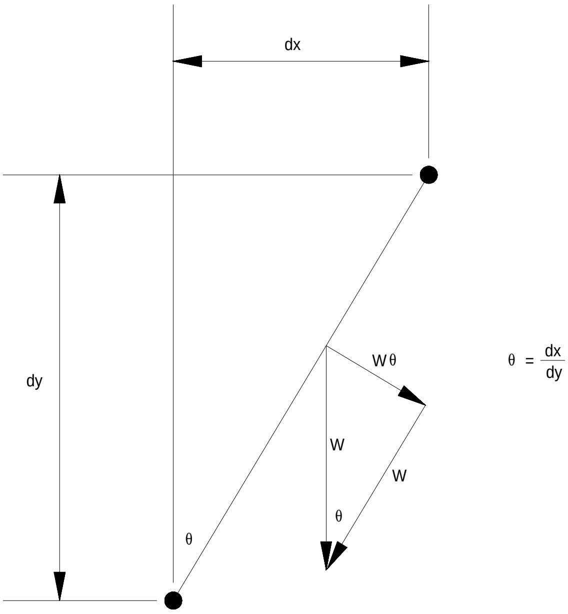
Performing a similar operation on the outside pressure gives:

$dH/dy = dH_o/dy + dH_i/dy$

$dH/dy = (P_o\, A_o - P_i\, A_i)\ d^2x/dy^2$

This expression for differential horizontal load has the same form as the expression derived for horizontal load due to tension acting with curvature on Figure 2.3 since the term $(P_o\, A_o - P_i\, A_i)$ performs the same function as real riser tension in determining the riser’s lateral response, it is called ”fictitious tension“.

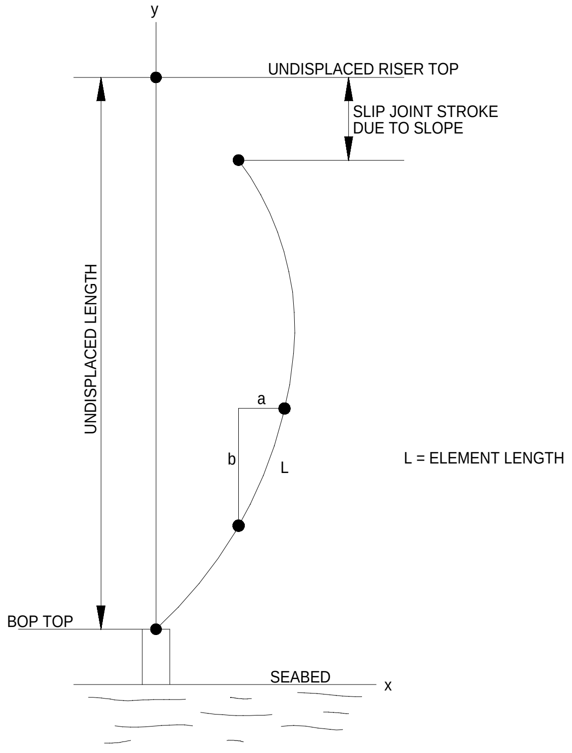
Figure 7 - Lateral Load Proportional to Riser Slope



W is the net buoyed weight of the riser and it’s contents per unit length.

$$W \sin \theta = W\theta = W\,dx/dy$$

Figure 8 - Slip Joint Stroke Due to Riser Slope



L - b = ELEMENT's SLOPE CONTRIBUTION TO SLIP JOINT STROKE

$$L - b = L - \sqrt{(L^2 - a^2)}$$

References

References

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