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1 FUNCTION

Ramberg-Osgood Convertor™ is a sub software of OFFPIPE Assistant™ which is developed to transform Ramberg-Osgood equation from stress-strain form to moment-curvature form for offshore pipelines. Users can also apply this software to pipe with any type of materials and dimensions by input custom parameters.

Ramberg-Osgood equation in stress-strain form is:

\[
\frac{\varepsilon}{\varepsilon_y} = \frac{\sigma}{\sigma_y} + \alpha \left( \frac{\sigma}{\sigma_y} \right)^\beta
\]  

(1.1)

in which

\[
\sigma_y = SMYS
\]  

(1.2)

\[
\varepsilon_y = \frac{\sigma_y}{E}
\]  

(1.3)

where

\(\varepsilon\) Strain;

\(\varepsilon_y\) Nominal yield strain;

\(\sigma\) Stress;

\(\sigma_y\) Nominal yield stress;

\(\alpha\) Ramberg-Osgood parameter in stress-strain form;

\(\beta\) Ramberg-Osgood parameter in stress-strain form;

\(SMYS\) Specified minimum yield strength;

\(E\) Elastic modulus.

In some commercial offshore pipeline software, such as OFFPIPE™, it is often required to provide Ramberg-Osgood equation in moment-curvature form:

\[
\frac{K}{K_y} = \frac{M}{M_y} + A \left( \frac{M}{M_y} \right)^\beta
\]  

(1.4)
in which

\[ K_y = \frac{2 \times SMYS}{ED} \]  \hspace{1cm} (1.5)

\[ M_y = \frac{2 \times SMYS \times I}{D} \]  \hspace{1cm} (1.6)

\[ I = \frac{\pi(D^4 - (D - 2t)^4)}{64} \]  \hspace{1cm} (1.7)

where

\( K \) Curvature;

\( K_y \) Nominal yield curvature;

\( M \) Moment;

\( M_y \) Nominal yield moment;

\( A \) Ramberg-Osgood parameter in moment-curvature form;

\( B \) Ramberg-Osgood parameter in moment-curvature form;

\( I \) The area moment of inertia;

\( D \) Outside diameter of the pipeline;

\( t \) Wall thickness of the pipeline.

Ramberg-Osgood Convertor™ outputs \( A, B, K_y, M_y \) with input of \( SMYS, \alpha, \beta, E, D, t \).

Ramberg-Osgood Convertor™ has several features as following:

1. Easy and standard input

A range of offshore pipeline steel types, API standard pipe sizes (OD in inches) and wall thicknesses from API "Specification for Line Pipe" (2000) are provided in the software, which can be input by simply clicking on the down arrow. The relevant yield stresses, Ramberg-Osgood parameters in stress-strain form, elastic modulus and outside diameters then appear in the appropriate boxes. Users can also input custom parameters for special pipelines.

2. Rapid and precise transform

For any input, the transform will be completed in several seconds. \( 2^{12} \) integration points are
adopted to integrate the cross section of pipelines and $2^7$ data points are adopted to fit the Ramberg-Osgood parameters in moment-curvature form.

3. Multiple pipe layers supported

Multiple pipe layers input is supported by Ramberg-Osgood Convertor™. Users can input 5 pipe layers at most.
2 INSTALLATION

To start to use Ramberg-Osgood Convertor™, please:

For dongle edition user:
1. Download software from official website.
2. Replace the original "license.dll" file with the one received.
3. Insert the attached dongle into one of USB ports of your PC.
4. Double click "Ramberg-Osgood Convertor.exe" icon in the folder to start the software.

For soft lock edition user:
1. Download software from official website to licensed PC.
2. Replace the original "license.dll" file with the one received.
3. Double click "Ramberg-Osgood Convertor.exe" icon in the folder to start the software.

Ramberg-Osgood Convertor™ runs on PC with Windows OS.
3 HOW TO USE

Brief procedure of running Ramberg-Osgood Convertor™ is shown as following:

1. Input pipeline parameters

(1) Click on the down arrow of combobox “Pipe Layer Number” in groupbox “Input” to select the number of pipe layer to be input, as shown in Fig. 3.1. At most 5 pipe layers can be specified. Several pipe layer properties input tabsheets will appear below corresponding to the number selected.

![Fig. 3.1 Select pipe layer number](image-url)
(2) Specify maximum strain of the pipeline in “Strain Limit (%))” edit, as shown in Fig. 3.2. Calculation will be conducted below this limit.

(3) Click on the down arrow of combobox “Steel Grade (API)” to select steel grade of pipeline, as shown in Fig. 3.3. Once steel grade specified, values of SMYS, α, β, and E will be specified automatically and shown in edits below. Users can also select “Custom” to input their own parameters in edits below.
(4) Click on the down arrow of combobox “Dimension” to select pipeline dimension
measured by inch, as shown in Fig. 3.4. For example, “OD_56” means the nominal outside diameter of the pipeline is 56 inches, and so on. Once pipeline dimension specified, outside diameter of the pipeline measured by mm will be specified automatically and shown in “Outside Diameter (mm)” edit below. Users can also select “Custom” to input their own outside diameter in “Outside Diameter (mm)” edit below.

(5) Click on the down arrow of combobox “Wall Thickness (mm)” to select pipeline wall thickness, as shown in Fig. 3.5. These thicknesses are automatically generated according to the dimension users specified. Users can also input their own wall thickness in combobox “Wall Thickness (mm)” directly.

Fig. 3.5 Select pipeline wall thickness
(6) Parameters in step (3)~(5) should be input for other pipe layers. Users can input properties of different pipe layers in any sequence.

2. Run the transform

Click button “Run” to execute the transform. The progressbar in the most below of the window will show the progress of transform. When completed, values of $A$, $B$, $K_y$, $M_y$ will show in groupbox “Output – Ramberg-Osgood Parameters”, and Ramberg-Osgood curve will display in the chart in the right side of the window. Click the checkbox below to view $M/M_y$ vs $K/K_y$. 
4 THEORY INSTRUCTION

1. Determination of $A$

As shown in Fig. 3.7, when $M=M_y$, there is

$$A = \frac{K}{K_y} - 1$$  \hspace{1cm} (4.1)

![Diagram showing the relationship between $M/M_y$, $K/K_y$, and $A$.]

Fig. 4.1 Determination of $A$

Now it is just need to get $K$ corresponding to $M=M_y$.

The relationship between $K$ and $M$ is:

$$\varepsilon_{\text{max}} = \frac{KD}{2}$$  \hspace{1cm} (4.2)

$$\varepsilon_x = \frac{2x}{D} \varepsilon_{\text{max}}$$  \hspace{1cm} (4.3)

According to equation (1.1)

$$\frac{\varepsilon}{\varepsilon_y} = \frac{\sigma}{\sigma_y} + a \left( \frac{\sigma}{\sigma_y} \right)^{\beta}$$  \hspace{1cm} (1.1)

$\sigma_x$ can be obtain from $\varepsilon_x$. Then there is
\[ M = \int_A \sigma_x x dA \quad (4.4) \]

Where

- \( \varepsilon_{\text{max}} \): Maximum strain in the cross section corresponding to \( K \);
- \( \varepsilon_x \): Strain in \( x \) position of the cross section;
- \( \sigma_x \): Stress in \( x \) position of the cross section;
- \( x \): Distance from neutral axis.

Try different \( K \), until \( M=M_y \), then \( A \) can be determined from equation (4.1).

Ramberg-Osgood Convertor™ adopts \( 2^{12} \) integration points to conduct the integration in equation (4.4).

2. Determination of \( B \)

\[ K_{\text{lim}} = \frac{2 \varepsilon_{\lim}}{D} \quad (4.5) \]

\[ K_i = \frac{i}{n} K_{\text{lim}} \quad (i = 1, 2, 3, \ldots n) \quad (4.6) \]

Where

- \( \varepsilon_{\lim} \): Specified strain limit;
- \( K_{\text{lim}} \): Curvature limit corresponding to \( \varepsilon_{\lim} \);
- \( n \): \( K-M \) data number.

Then according to equation (4.2)~(4.4), there are \( n \) \( M_i \).

To obtain Ramberg-Osgood parameters \( A \) and \( B \), apply Ramberg-Osgood equation in moment-curvature form to fit the \( n \) pairs of \( K_i-M_i \) data by least square method using Newton-Raphson iteration. Here \( n=2^7 \).

However, in practice, the curve defined by the Ramberg-Osgood relationship is considered valid only up to the value of \( K_b \). Curvatures beyond \( K_b \) represent strain states far in excess of those permitted.

\[ K_b = \frac{t}{D^2} \quad (4.7) \]

So if \( \varepsilon_{\lim} > K_b \), then \( \varepsilon_{\lim} = K_b \).

3. Multiple pipe layers calculation
When multiple pipe layers are specified by users, some variables should be treated specially.

$K_y$  Minimum one of $K_y$ of all pipe layers;

$M_y$  Sum of $M_y$ corresponding to $K_y$ of all pipe layers;

$K_b$  Minimum one of $K_b$ of all pipe layers.
5 FAULT MESSAGES & NOTES

Some faults may be encountered by users are listed below:

1. A message window as Fig. 5.1 shows.

How to solve: Make sure to fill all the blank comboboxes and edits before clicking “Run” button.
6 TECHNICAL SUPPORT & AUTHORIZATION

For technical support and authorization of Ramberg-Osgood Convertor™, please visit:

http://www.opimsoft.com

or contact:

support@opimsoft.com