What is the best way to calculate the wall thickness of clad pipe?

by Liane Smith (Hitech Limited, United Kingdom)

It seems a simple matter to calculate the wall thickness of pipe, doesn’t it? It is one of the simplest stress analysis formulas taught in most science and engineering courses:

\[
t = \frac{PD}{2S}
\]

where

- \( t \) = wall thickness (mm)
- \( P \) = design pressure (MPa)
- \( D \) = nominal inside diameter (mm)
- \( S \) = specified minimum yield strength (MPa)

When designing real pipelines, using ASME B31.8 for example, due account has to be taken for statistical variations in the pipe dimensional tolerance by including a design factor \( F \) where typical values (from 0.4 to 0.8) are listed in ASME B31.8 table 841.114A. The yield strength value also has to be de-rated by a factor \( T \) for pipelines operating above 120°C, where values for \( T \) are listed in table 841.116A. Finally, depending upon the type of pipe product, there is a further longitudinal joint factor, \( E \), with values listed in table 841.115A. Even given these complications the formula for pipe wall remains fairly simple:

\[
t = \frac{PD}{2SFET}
\]

But what is the wall thickness calculation when there is a metallurgically bonded clad layer inside the pipe? Clad pipe doesn’t have a continuous yield strength value across its full thickness — in general the cladding layer is less strong than the backing steel. So what value should be taken for \( S \) in a calculation? The answer, according to code ASME B31.8, is simple: just ignore the cladding layer and calculate the wall thickness based only on the backing steel properties. The answer produced gives the wall thickness required for the backing steel and the cladding layer just has to be added as an extra. But ASME B31.8 is not the only pressure code in the world! Japanese code JIS G3601 (first published in 1979 and revised in 1989) covers clad steel products greater than 8mm thick to be used for various applications, including nuclear reactors. The allowed unbonded area depends upon the class, between 1.5% and 5% of the overall area with limits on the size of any individual unbonded portion. In this code the value of yield stress for clad items is based on the weighted average of the yield strength of the backing steel \( b \) and the cladding material \( s \). In mathematical terms:

\[
S = \frac{(sA_b + bA_s)}{A_s + A_b}
\]

Using the ASME formula:

\[
\frac{tm}{t} = \frac{PD}{2SFET}
\]

and substituting for \( S \) from JIS G3601 and solving for \( t \) gives:

\[
t = \frac{PD-2SFET}{2SFET} = \frac{PD}{2SFET} - \frac{SA}{2SFET}
\]

This means that the cladding thickness is able to contribute to the strength of the pipe to some extent, thus reducing the total pipe wall thickness, the pipe weight and the amount of girth welding and filler required. Weight saving would give benefits in reduced cost of pipe purchased, transported and installed. All of these factors reduce the overall cost. Whilst each may be a small effect, the total saving may well be significant in a given project.

Next time you are considering clad pipe, check your sums first and decide which code you want to apply.

Readers’ comments on this article are welcome.

About the author:

Liane Smith is an associated editor to Stainless Steel World and has her own consultancy firm, Hitech Ltd, in the field of corrosion analysis, materials selection and welding.

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