ABSTRACT

When a Titanium marketing representative talks with maintenance and process engineers, purchasing agents or management in any of our chemical processing "end use" industries, there are always one or two individuals in the audience who consistently raise the concern that “Titanium is too expensive to use in this application.” Alternative materials, such as nickel alloys, duplex stainless steels, copper-nickel alloys, etc. are seen by these individuals as being less expensive and more cost effective. While this may have been true at various times in the past, when pricing of materials was entirely different, it is definitely not true today.

In this presentation, I will show that, when using a “Normalized” price approach to compare materials, titanium is shown to be very cost competitive and can even offer a cost advantage to materials with less or similar corrosion resistance. This approach can be effectively used to overcome cost-based objections and increase the potential for titanium use in the chemical processing industry.

INTRODUCTION

In the chemical processing and other industries where titanium is used for corrosion resistance, oftentimes the first words you hear from an engineer is “Titanium is too expensive”. While the titanium marketing representatives can argue about how much better corrosion resistance of titanium is in certain environments and how life cycle costing can show that titanium is really the way to save future expenditures, more often than not the argument is lost when the cost per pound enters the discussion. So when “cost per pound” doesn’t work, how can we, as the titanium industry, overcome this conception that nickel alloys are the primary corrosion resistant materials for most applications?

COST BACKGROUND

Over the years, the metal industries, primarily the nickel alloy industry, that compete against the titanium industry for applications in the chemical process industry and other markets where titanium is valued for its corrosion resistance, have enjoyed a distinct cost advantage when compared to titanium.
Reviewing the historical pricing of nickel and the other key elements that make up the alloys, i.e. chromium and molybdenum, shows that there have been some dramatic changes in pricing – for example as shown in this graph for nickel (US Geological Survey data):

Nickel Pricing

And the same type of graph can be shown for chromium and molybdenum (US Geological Survey data):

Chromium Pricing

Molybdenum Pricing

While these charts show a very dramatic increase in pricing – of up to 7 times the average pricing in the late 1990’s, we also have to consider that titanium pricing has varied considerably (US geological Survey sponge pricing data):

Titanium Sponge Pricing

A comparison of the changes in the nickel pricing versus that of the titanium sponge, shows that, while titanium pricing has risen by a factor of two compared to the 1990’s, nickel has jumped by a factor of almost four . In the last couple of years, nickel pricing has come down and then started to rise again – becoming closer to titanium on a price per pound basis. However, all of these changes have still not been enough to offset the negative thoughts that titanium is too expensive.

Normalizing Costs

Most materials used for corrosion resistance in the industrial market (i.e., electric utility, chemical processing, oil and gas, etc) are used as a barrier, much like paint is used as a barrier to protect steel from rusting. Because of this, comparing materials or alloys only on a cost per pound basis may result in an erroneous judgment as to which is less expensive.

A much better method would be to compare the cost of protecting the surface area in a vessel or pipe that needs protection from the corrosive environment. Since each metal or alloy has a different density, a square foot of each would weigh a different amount and the amount (pounds) of material needed to protect vessels of the same size using different alloys would, obviously, be different. But one other material property also needs to be considered when attempting to compare...
different alloys – each alloy has its own mechanical properties and these can affect the thickness of material required for a certain vessel. Vessels in the chemical process industry are normally designed to ASME Code requirement, which uses the Yield Strength of a metal alloy as part of the calculation to determine the thickness required for various temperatures and internal pressures. Thus, to get a better comparison of costs, we also need to compare materials by also looking at their yield strengths. This is what I am calling a “Normalized Cost” - a cost that uses the alloy properties of density and yield strength to “normalize” its cost versus titanium. “Normalized Cost” can be easily calculated by the equation:

\[
\text{Cost} = \frac{\text{Price/Lb}}{\text{Density}} \times \text{(YS of Alloy / YS of Titanium)}
\]

Here are the material properties that I will use in the analysis:

<table>
<thead>
<tr>
<th>Material</th>
<th>Density</th>
<th>Yield Strength(ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>316L</td>
<td>0.29</td>
<td>30,000</td>
</tr>
<tr>
<td>2205</td>
<td>0.29</td>
<td>74,000</td>
</tr>
<tr>
<td>625</td>
<td>0.305</td>
<td>60,000</td>
</tr>
<tr>
<td>C276</td>
<td>0.321</td>
<td>52,000</td>
</tr>
<tr>
<td>Ti2</td>
<td>0.162</td>
<td>50,000</td>
</tr>
<tr>
<td>Ti7</td>
<td>0.162</td>
<td>50,000</td>
</tr>
<tr>
<td>Zr</td>
<td>0.24</td>
<td>35,000</td>
</tr>
</tbody>
</table>

To illustrate this methodology, let’s use Alloy pricing (price per pound for 1/4”) obtained from various sources during the 2Q2012:

Putting this information into the “Normalized Cost” equation gives a cost comparison that shows:

![Normalized Price (per Sq Ft)](chart)

As this chart shows, titanium Grade 2 offers a significantly less costly (less than 1/2 the cost) option to the competition --- nickel alloys 625 and C276. In fact, even Grade 7 titanium is less expensive that C276. This is a very significant difference and the titanium industry needs to educate our industrial end-users about this difference.

**ASME CODE NORMALIZATION**

While the foregoing normalizing methodology can be used to get a quick comparison of metals and alloys, there needs to be some consideration of ASME (Section VIII Div 1) Design Allowables in the analysis. This can easily be done by substituting Design Allowable strengths (at temperature of operation) for the Yield Strength in the “Normalized Cost” equation:

\[
\text{Cost} = \frac{\text{Price/Lb}}{\text{Density}} \times \text{(Design Allow of Alloy / Design Allow of Titanium)}
\]

This analysis gives the following results, when using the ASME Design Allowables at an operating temperature of 100F:
So, using ASME Design criteria, at both 100F and 300F, titanium is still a more cost effective solution when compared to the nickel alloys 625 and C276. At a temperature between 300F and 400F, the normalized cost of titanium does become higher than the nickel alloys, since the nickel alloys maintain more of their strength as temperatures increase.

This “Normalized Cost” analysis can be used to compare any different metal and alloys at any given operating temperature. In fact, this same type of analysis can be for heat transfer equipment and it shows that, currently, titanium is more cost effective than copper-nickel alloys.

CONCLUSION

Titanium can be shown to be very cost competitive with nickel alloys by using a simplified “Normalized Cost” Method, using yield strength to normalize cost. A better method uses the ASME Code Design Allowables to develop a more accurate “Normalized Cost” for each alloy.

Titanium Grade 2 is currently less costly, at design temperatures up to at least 300F, than nickel alloys 625 and C276.

Using this methodology in discussions with engineers in the industrial market – chemical processing, electric utility, oil and gas and other industries – can help to educate these engineers to the advantages of titanium and to promote the use of titanium in these industries.

Now is the time to use this methodology – while the comparative price per pound of titanium and the nickel alloys is to our advantage. In the future, this may change, but if engineers are educated on titanium and have used titanium, they will be more apt to continue to use it.

ACKNOWLEDGMENTS

I want to thank Mike Stitzlein and the entire management of Tricor Metals for allowing me the opportunity to develop this methodology and to thank the ITA for allowing me to make this presentation. Updates of these “Normalized Cost” charts are available on the Tricor Metals website.

CONTACT

Charles Young
Business Development Manager
Tricor Metals
3225 West Old Lincoln Way
Wooster, OH 44691
330-264-3299 x2500
www.tricormetal.com
TITANIUM IS NOT “TOO EXPENSIVE”

Charles Young
Business Development Manager

Tricor Metals Wooster Ohio
Titanium – Producer Perception

Most Abundant Metal
Excellent Corrosion Resistance
Many Alloys
An “Industrial” Metal
Readily Available
Cost Competitive

Tricor Metals Wooster Ohio
Titanium – Engineer Perception

“Exotic” Metal
Aerospace Metal
Corrosion Resistant
“Too Expensive”
“Hard to Weld”
“Un-obtainium”

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Titanium – Selling Points

Corrosion Resistance
Cost per Pound
Forms and Alloys
Availability
Multiple Sources
World-wide Industry

Tricor Metals Wooster Ohio
Titanium – Selling Points

Corrosion Resistance

Cost per pound

Forms and alloys

Availability

Multiple Sources

World-wide Industry

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Comparative Costs

Stainless Steel and Nickel Alloys Pricing
  *** nickel, molybdenum and chromium costs

Titanium Pricing
  *** titanium sponge costs
Nickel Pricing
US Geological Survey

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Molybdenum Pricing
US Geological Survey

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Titanium vs. Nickel Pricing

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Normalized Cost Analysis

- Normal Method -- Cost per pound
- Normalized Method ©
  - Correct for Density
  - Correct for Yield Strength
- More Precise Normalized Method ©
  - Correct for ASME Design Allowable

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## Comparative Alloy Data

<table>
<thead>
<tr>
<th>Material</th>
<th>Density</th>
<th>Yield Strength</th>
<th>ASME Design Allow@100</th>
<th>ASME Design Allow@200</th>
<th>ASME Design Allow@300</th>
</tr>
</thead>
<tbody>
<tr>
<td>316L</td>
<td>0.29</td>
<td>30,000</td>
<td>16,700</td>
<td>16,700</td>
<td>16,700</td>
</tr>
<tr>
<td>2205</td>
<td>0.29</td>
<td>74,000</td>
<td>25,700</td>
<td>25,700</td>
<td>24,800</td>
</tr>
<tr>
<td>625</td>
<td>0.305</td>
<td>60,000</td>
<td>31,400</td>
<td>31,400</td>
<td>31,400</td>
</tr>
<tr>
<td>C276</td>
<td>0.321</td>
<td>52,000</td>
<td>27,300</td>
<td>27,300</td>
<td>27,300</td>
</tr>
<tr>
<td>Ti2</td>
<td>0.162</td>
<td>50,000</td>
<td>14,300</td>
<td>12,400</td>
<td>10,300</td>
</tr>
<tr>
<td>Ti7</td>
<td>0.162</td>
<td>50,000</td>
<td>14,300</td>
<td>12,400</td>
<td>10,300</td>
</tr>
<tr>
<td>Zr</td>
<td>0.24</td>
<td>35,000</td>
<td>15,700</td>
<td>13,700</td>
<td>11,200</td>
</tr>
</tbody>
</table>
Comparative Costs

Relative Cost/lb compared to Ti2

- 316L: 0.17
- 2205: 0.23
- 625: 1.44
- C276: 1.42
- Ti2: 1.00
- Ti7: 2.93
- Zr: 3.65
Normalizing Procedure

- Analysis uses 0.25” thick sheet costs
  - Gets to a cost per square foot of each alloy

- Normalized
  - Using Titanium density and RT yield strength

- Simple Mathematics
  - Normalized = Price * Density* (Alloy YS/ Ti YS)
  - Normalized Cost = $$ per square foot
normalized cost comparison

relative normalized cost/sq ft

- 316L: 0.30
- 2205: 0.42
- 625: 2.72
- C276: 2.83
- Ti2: 1.00
- Ti7: 2.95
- Zr: 5.43
ASME Design Normalized

Relative Normalized Cost /Sq Ft @200F

- 316L: 0.23
- 2205: 0.20
- 625: 1.07
- C276: 1.29
- Ti2: 1.00
- Ti7: 2.95
- Zr: 4.91

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ASME Design Normalized

Relative Normalized Cost / Sq Ft @300F

- 316L: 0.19
- 2205: 0.18
- 625: 0.89
- C276: 1.07
- Ti2: 1.00
- Ti7: 2.95
- Zr: 4.99

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Normalized Comparison©

- Cost per pound -- Usual method
- Cost per square foot -- Better
  - Corrosion resistance not based on bulk
  - Area Coverage is the KEY
- Normalizing for Strength -- Best
  - More accurate comparison of the actual costs of corrosion resistance
Conclusion

- Normalized Basis useful in comparing alloys
- Titanium is even more cost effective when compared with Nickel Alloys on a Normalized Cost Basis
- Normalized Cost Chart © updated on Tricor Metals website periodically
THANK YOU !!

Charles Young
Business Development Manager
Tricor Metals
Wooster, Ohio
330-264-3299 x 2500
chuck@tricormetals.com
Tubing Cost Comparison

Background

Density

- CuNi: 0.323 lb/cu in
- Titanium: 0.162 lb/cu in

Lower weight per foot

Tubing thickness

- Titanium tube wall thickness can be lower

Increased cost effectiveness (lower cost) for Titanium
Heat Exchanger Tubing
Comparative Costs

Relative Cost/Ft

- CuNi 90-10: 0.83
- CuNi 70-30: 1.20
- Ti Gr 2: 1.00
- Ti Gr 2*: 0.78
- Ti Gr 2**: 0.65

0.065"
* 0.049"
** 0.035"

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