Comparative galling resistance of super duplex stainless steel alloys

Rodney Rice, Langley Alloys
What is galling?

Galling is when two surfaces in contact seize up as a result of cold welding.

Most commonly seen on **fasteners** made from **stainless steel, aluminium or titanium**

- corrosion resistance derives from a passive oxide surface layer
- under high contact-force this oxide can be deformed/broken/removed
- bare reactive metal is then exposed
- these exposed surfaces can more easily fuse together
- in threaded fasteners galling freezes the threads
- applying further force may shear off the bolt head or strip the threads
Historical relevance to Langley Alloys

Our product portfolio includes a number of trademarked **cupronickel** alloys, which are widely used in various types of subsea connectors.

Our **Hiduron®** alloys are selected due to their unique combination of attractive properties:

- non-fouling in marine applications
- long-term corrosion resistance
- non-magnetic
- highest-strength copper alloys
- Resistant to galling, particularly coupled to stainless steels

Therefore, we had previously undertaken galling tests of these alloys in combination with various other alloys to support customers.
Relevance to Super Duplex Stainless Steels

**Super duplex** alloys are well-suited to many applications because of their **strength, corrosion resistance, cost effectiveness**.

**Use within valves and fasteners is common.**

Aspects of the application that influence galling:

i) alloy pairings  
ii) loads/forces experienced  
iii) continuous or intermittent rotation  
iv) use of coatings / lubricants / surface treatment
ASTM G98-02
Standard Test Method for Galling Resistance of Materials

1. ‘Button and block’ test configuration
   i) Test pieces subjected to a constant, compressive load
   ii) ‘Button’ is rotated through 360°
   iii) Specimens examined by eye
   iv) If undamaged, load increased
   v) If damaged, ‘threshold stress’ is identified

2. Issues with the test methodology
   a) concentrating stress in the contact region
   b) lack of statistical analysis
   c) lesser number of replicates / repeatability
ASTM G196-08
Test Method for Measurement of Galling Resistance of Material Pairs

1. ‘Button on button’ test configuration
   i) Similar approach as before (load, rotate, assess for galling)
   ii) However, test multiple sample pairings per load
   iii) Report number of incidences of galling at each load
   iv) Test at increasing loads
   v) Plot chart to establish load for 50% galling incidence

2. Improvements with the test methodology
   a) greater repeatability
      ▪ consistent stress across contact region
      ▪ more tests = more consistent results
   b) considers ‘stochastic’ nature of galling

Duplex Seminar & Summit 2018
‘Stochastic’

“having a random probability distribution or pattern that may be analysed statistically but may not be predicted precisely”

Brownian motion – as per the classic experiment, observing the movement of smoke particles in air

Stock Market – longer-term trends can be projected, but short-term results can vary markedly

Traffic Flow – journey times can be modelled, but the actions of individuals drivers can have an impact!
ASTM G196-08
Test Rig utilised by ESR Technology / National Tribology Centre

Real-time data-logging, including reporting of strain

Close-up showing samples under load
Curve fitting of results
Galling $G_{50}$ value established after a series of tests at different loads

- Other test methods generate a **galling threshold stress**
- $G_{50}$ value represents the load at which galling has a **50% likelihood** of occurring in the given conditions
- This is more representative of real world performance and provides a more consistent measure
Additional recording from torque cell
Helps to distinguish between simple burnishing and more severe galling

Very light galling towards end of the test

Mid-face galling from half-way through the test

**Burnishing** of the test pieces only – no galling observed. **Note the lower torque reading**

Heavier galling half-way through the test
Limited test results from ASTM G196-08 available

- Development of **new alloys** is relatively **infrequent**
- G196-08 was formally published by ASTM in **2008**
- G196-08 requires **large numbers** of samples/tests
  - 4-5 different loads, 10+ tests per load, 2 samples per test

Consequently

- Earlier studies/articles used other test methodologies
- Research papers focus on specific challenges
  i.e. influence of temperature
Langley Alloy test results – matching pairs of samples

1. Results
   - Super Duplex performs better than other alloys
   - **Ferrallium 255-SD50 >> Alloy 32750**

2. What material characteristics influence galling
   - Strength?
   - Hardness?
   - Microstructure?
What **material** characteristics influence galling?

There is a good correlation between 0.2%PS vs $G_{50}$ for the stainless steel alloys.
What **material** characteristics influence galling?

<table>
<thead>
<tr>
<th>Item</th>
<th>Discussion</th>
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</thead>
<tbody>
<tr>
<td>1. Strength</td>
<td>Higher strengths</td>
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<tr>
<td></td>
<td>- More difficult to deform metal</td>
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<tr>
<td>2. Composition</td>
<td>Silicon, Manganese</td>
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<td></td>
<td>- As per S21800 (Fermonic 60 / Nitronic 60)</td>
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<td>3. Precipitates</td>
<td>- Sulphides</td>
</tr>
<tr>
<td></td>
<td>- Particles</td>
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<tr>
<td></td>
<td>- Influence of sulphide inclusions as lubricants</td>
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<td></td>
<td>- Hard carbide particles can enhance wear resistance</td>
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<tr>
<td>4. Hardness</td>
<td>Surface properties</td>
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<tr>
<td></td>
<td>- More difficult to deform metal</td>
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<tr>
<td>5. Microstructure</td>
<td>Bulk properties</td>
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<tr>
<td></td>
<td>- Various studies for tool steels and carbon steel sheet</td>
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<tr>
<td>6. Oxide layer</td>
<td>Strength &amp; Thickness</td>
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<td></td>
<td>- Influenced by composition and (thermal) history</td>
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**Super Duplex = higher-strength + robust oxide layer (25%Cr) + ……??**
Summary

1. Resistance to galling is an important property for product designers/engineers
2. ASTM G196-08 is a more relevant test of galling properties
3. Super Duplex performs better than other alloys that were tested
4. Ferralium 255-SD50 performs better than Alloy 32750
   - increase in galling resistance is roughly comparable with increased strength
5. Improved understanding of mechanism can aid future development
Many thanks to Paul Tweedale – Principal Consultant, for support with the associated test programme.