TECHNICAL REPORT
MEASUREMENT OF BULK COAL SLIDING FRICTION ON VARIOUS WEAR PLATE PRODUCTS

FOR
ALLOY STEEL INTERNATIONAL PTY LTD
Technical Letter: Measurement of Bulk Coal Sliding Friction on Various Wear Plate Products

Distribution: Alloy Steel International Pty Ltd

Limitation Statement

The sole purpose of this technical report and the services performed by Rockfield Technologies Australia Pty Ltd (RTA) was to experimentally measure the frictional forces acting between lightly consolidated bulk coal samples and wear plate samples.

No warranty, or guarantee, whether expressed or implied, is made with respect to data not directly measured during this investigation, or to the observations and conclusions expressed as a result of that data.

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Executive Summary

Rockfield Technologies Australia Pty Ltd was contracted by Alloy Steel International Pty Ltd to experimentally measure the effective coefficient of sliding friction between bulk coal and four wear plate samples. The primary purpose of the experimentation was to determine the frictional performance of the Alloy Steel ARCOPLATE ARCO ALLOY 1600, in both as supplied (pre-polished) and worn conditions. The worn ARCOPLATE ARCO ALLOY 1600 sample was taken from an excavator bucket post-excavation of 61 Million BCM of overburden and coal. Two alternative commercially available wear plate products (Utility Stainless steel - ASTM A240 UNS S41003 and 400HB Q&T Steel Plate) were also tested for comparison and benchmarking of the ARCOPLATE ARCO ALLOY 1600 results.

A purpose-designed test cell (shown on the cover of this report) was designed and commissioned for operation with a conventional Jenike Shear cell test bed, located at the School of Engineering at James Cook University, Queensland, Australia.

A medium-volatile, bituminous coking coal from Gregory Mine in Queensland’s Bowen basin was used for the testing. The moisture content of the coal samples used in each test was determined in accordance with Australian Standards. Coal moisture content was consistent throughout the testing program and ranged between 7.0% and 7.5% by mass.

The Alloy Steel ARCOPLATE ARCO ALLOY 1600 performed very well with respect to the alternative products tested. In the as-supplied, pre-polished condition, the ARCOPLATE ARCO ALLOY 1600 exhibited 23% less frictional resistance than the Utility Stainless Steel - ASTM A240 UNS S41003. In the worn condition, the ARCO ALLOY 1600 exhibited 39% less frictional resistance than the Utility Stainless Steel - ASTM A240 UNS S41003.

There was little discernable difference between the measured frictional resistance of the Utility Stainless Steel - ASTM A240 UNS S41003 and the 400HB Q&T Steel Plate. This is due to the similar surface finish of the two products in their as-supplied condition.
**Introduction**

Alloy Steel International Pty Ltd manufactures ARCOPLATE ARCO ALLOY 1600, a Chromium Carbide Overlay Plate product that possesses very high resistance to abrasive wear [1]. The ARCOPLATE product is widely employed throughout the mining and mineral processing industries as a result of this key performance feature.

The ARCOPLATE product has also developed an industry reputation for reducing ‘hang up’ or ‘carry back’ of low flowability materials, due most likely to low frictional resistance properties of the high Chromium ARCO ALLOY 1600. Furthermore, observations have been widely made that this anti-hang up performance is further enhanced as the ARCOPLATE wears during service.

To quantify the frictional performance of the ARCOPLATE ARCO ALLOY 1600, Alloy Steel International Pty Ltd contracted Rockfield Technologies Australia Pty Ltd to conduct sliding friction experiments to determine the frictional performance of the ARCOPLATE ARCO ALLOY 1600 in as supplied and worn conditions, and compare this performance with measurements taken using two alternative commercially available wear plate products (Utility Stainless steel - ASTM A240 UNS S41003 and 400HB Q&T).

With Australian Coal exports tipping $25 Billion in the 2006/07 financial year, the potential for adoption of the ARCOPLATE advanced wear and anti-hang up lining material within this sector of the mining industry is enormous. As such, Alloy Steel International requested that coal be used as the candidate bulk solid for the testing program.

**Experimental Apparatus**

A purpose-built test cell was designed and commissioned for the testing program. Both the test cell and accompanying measurement system was developed for use with an existing Jenike test bed located at the School of Engineering at James Cook University. Shown in Figure 1, the apparatus allows for a coal sample volume of 1.7 litres to be consolidated to an appropriate level against the wear plate surface being tested for frictional performance. The carriage (to which the candidate wear plate sample is fastened) is subsequently driven at constant speed by the geared motor on the Jenike test bed and the frictional resistance at the wear surface is directly measured and recorded via load cells. The carriage displacement and sample consolidation are also recorded during each experiment [2].

**Coal Type**

A medium-volatile, bituminous coking coal from Gregory Mine in Queensland’s Bowen basin was made available by James Cook University for the testing program. Due to the size of the test cell, the coal earmarked for testing was sieved at 3/8 inch (9.53mm) to remove the larger particles before preparing samples of the coal for testing (i.e. mixing and moisture addition).
Experimental Procedures

The following key procedures were developed and adopted for the sliding friction experiments, and have been based on Australian Standards methods for soils testing [3]:

1. Preparation of coal samples [4].
2. Sliding friction test procedure [2].
3. Measuring coal sample moisture content [5].
Experimental Program
Tests were conducted for each of the four wear plate samples, at two different levels of consolidating load, providing a core set of eight experiments. A further four experiments were conducted as replicates to ensure repeatability in the test results.

Results
Table 1 contains coefficient of sliding friction and corresponding sliding friction angle results for the eight core experiments. Table 2 contains corresponding coal sample moisture content results. Table 3 contains coefficient of sliding friction results for repetition tests conducted for three randomly selected core experiments.

Table 1 Coefficient of sliding friction and corresponding sliding friction angle results

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Friction Coefficient [-]</th>
<th>Sliding Friction Angle [Degrees]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wall Pressure 1 (9.35 kPa)</td>
<td>Wall Pressure 2 (13.1 kPa)</td>
</tr>
<tr>
<td>Pre-Polished ARCOPLATE</td>
<td>0.33</td>
<td>0.34</td>
</tr>
<tr>
<td>Worn ARCOPLATE (Excavator bucket - 61 Million BCM)</td>
<td>0.26</td>
<td>0.27</td>
</tr>
<tr>
<td>Utility Stainless Steel ASTM A240 UNS S41003</td>
<td>0.44</td>
<td>0.43</td>
</tr>
<tr>
<td>400HB Q&amp;T Steel Plate (Brand 1)</td>
<td>0.43</td>
<td>0.44</td>
</tr>
</tbody>
</table>
From the bulk coal sliding friction test results presented in Tables 1 – 3, the following observations are made regarding the validity of the testing procedures:

- The purpose-built testing apparatus was successful in measuring the frictional resistance to bulk coal sliding on various wear plate surfaces.
- A high level of repeatability of the test results was also shown for three randomly selected test conditions.
- The moisture content results for the coal test samples showed a satisfactory level of consistency throughout the testing program.

### Table 2 Coal sample average moisture content results

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Wall Pressure 1 (9.35 kPa)</th>
<th>Wall Pressure 2 (13.1 kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Polished ARCOPLATE</td>
<td>7.2</td>
<td>7.2</td>
</tr>
<tr>
<td>Worn ARCOPLATE (Excavator bucket - 61 Million BCM)</td>
<td>7.0</td>
<td>7.3</td>
</tr>
<tr>
<td>Utility Stainless Steel ASTM A240 UNS S41003</td>
<td>7.3</td>
<td>7.3</td>
</tr>
<tr>
<td>400HB Q&amp;T Steel Plate (Brand 1)</td>
<td>7.5</td>
<td>7.3</td>
</tr>
</tbody>
</table>

### Table 3 Sliding friction angle results for repetition tests

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Wall Pressure [kPa]</th>
<th>Sliding Friction Angle [degrees]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Core Test</td>
</tr>
<tr>
<td>Worn ARCOPLATE (Excavator bucket - 61 Million BCM)</td>
<td>9.35</td>
<td>14.7</td>
</tr>
<tr>
<td>Utility Stainless Steel ASTM A240 UNS S41003</td>
<td>13.1</td>
<td>23.3</td>
</tr>
<tr>
<td>400HB Q&amp;T Steel Plate (Brand 1)</td>
<td>13.1</td>
<td>23.6</td>
</tr>
</tbody>
</table>
Conclusions
The following conclusions are made regarding the measured bulk coal frictional performance of the various wear plate products tested:

- In the as-supplied, pre-polished condition, the ARCO ALLOY 1600 exhibited 23% less frictional resistance than the Utility Stainless Steel - ASTM A240 UNS S41003.
- In the worn condition, the ARCO ALLOY 1600 exhibited even greater performance, exhibiting 39% less frictional resistance than the Utility Stainless Steel - ASTM A240 UNS S41003.
- In the as-supplied, mill-finish condition, there was little discernable difference between the frictional performance of the Utility Stainless Steel - ASTM A240 UNS S41003 and the 400HB Q&T Plate.

References
2. AS1289.2.1.1-1998. Methods of testing soils for engineering purposes; Method 6.2.2 - Soil strength and consolidation tests—Determination of the shear strength of a soil—Direct shear test using a shear box.