

# **Wear Property and Impact Test Rig Design for Comparing Wear Liners used in Transfer Chutes**

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## **Abstract**

*BHP Billiton Iron Ore is in the process of selecting wear liners for installation in their transfer chutes. Wear liners are chosen to maximise service life, while minimising maintenance costs and downtime. Since there are many types available, it is desirable to obtain empirical evidence from preliminary wear tests prior to making final selections for site trials. The purpose of this project was to develop laboratory tests that could be applied to full sized wear liner samples to compare their abrasion and impact resistance. A large scale Dry Sand Rubber Wheel abrasion test was designed and constructed at UWA, accommodating the large samples whilst simulating the required abrasion mechanism. Furthermore, a new method for quantifying abrasive wear using surface replication techniques was attempted. This showed that the need to weigh samples could be eliminated if the abrasion test produces a clearly defined wear scar. A drop-weight impact test rig was also constructed, to investigate impact resistance. Preliminary tests and surface examination indicated that forces required to cause observable microcracking were greater than those able to be created using this test rig.*

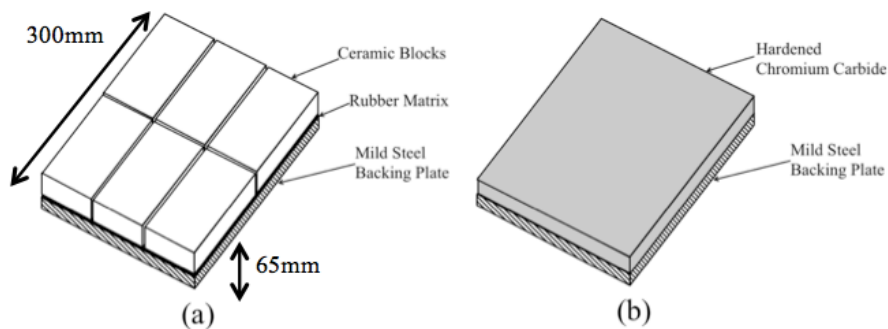
## **1. Introduction**

The successful operation of BHP Billiton Iron Ore (BHPBIO) in Western Australia is reliant on effective transfer of bulk solids, achieved through large-scale conveyor systems on site. Due to their size and location, these systems include multiple transfer points, at which material must pass through a transfer chute. This is a structure designed to control the material flow to improve both the efficiency and safety of the transfer point. To optimise productivity, the transfer rate in these chutes is often very fast; in conjunction with the coarse nature of the conveyed material, this results in significant impact and abrasive damage to the inside of the chute walls. Wear liners are a sacrificial layer of material installed on the inside, to protect the chute from damage and enhance its service life.

Wear liner performance is important because liner failure exposes the chute itself to damage, which leads to safety concerns, reduced productivity and increased repair cost. The liner must be replaced before operations can continue, requiring closure of the chute, causing down time and increased maintenance costs. The current wear liners are not performing as required. The resulting failures have the potential to necessitate chute closure and cause over 50% of maintenance time to be dedicated to wear liner repairs. Empirical evidence is desirable in selecting the best alternative, rather than using data provided by the vendors alone, and so laboratory testing is to be conducted prior to site trials. This project specifically considers the abrasion and impact testing of wear liners, and involves the design of abrasion and impact test

rigs that may be used on full sized wear liner samples, to assist in assessing the relative performance of the wear liner types available.

A wide range of wear liners are available, from a number of vendors. Due to the size of the transfer chutes used by BHPBIO, one wear liner tile typically measures 300mm by 300mm, with thickness depending on the type used. The first of these are rubber-ceramics, shown in Figure 1(a), consisting of ceramic blocks, either chemically bonded to a mild steel backing plate with a rubber matrix or coated in rubber. Rubber-ceramics are often used with highly abrasive material, but are less suited to impact wear. Polyurethane-ceramic types are similar, except replacing rubber with polyurethane. Another type is weld-overlay, in which the exposed surface is a hardened chromium carbide layer, bonded to a steel plate, as in Figure 1(b).



**Figure 1 Wear Liner Types: (a) Rubber-Ceramic. (b) Weld Overlay.**

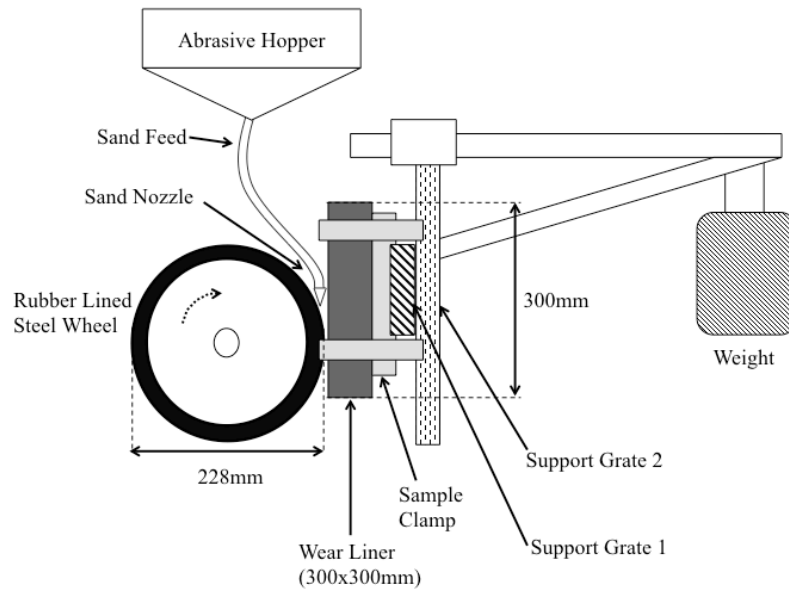
The purpose of this project was to develop experimental methods to investigate the relative wear performance of the wear liners being considered by BHPBIO. These methods must be compatible with the full size wear liner samples, as provided by the vendors. The main objectives of this project were to establish these test methods, devise a method for quantifying the wear induced and evaluate the success of these experiments, in causing wear to the wear liner samples.

To assess abrasion wear, an updated version of the Dry Sand Rubber Wheel (DSRW) test was designed and approved by the BHPBIO client. To test impact resistance, a drop-weight test was designed. To quantify the induced wear, surface replication was investigated.

## **2. Abrasion Testing: the DSRW Test Rig**

### **2.1 Test Rig Design**

The final DSRW test rig design was based on the test rig outlined in ASTM G65 (2010), with the required design changes to accommodate the wear liner samples. The DSRW test is often used for ranking the abrasive resistance of metals and ceramics. The test consists of a plane specimen loaded from one side, positioned against a rubber-lined rotating wheel, with an abrasive grit allowed to roll between. The schematic for this design is shown in Figure 2.



**Figure 2 Wear liner compatible DSRW schematic diagram.**

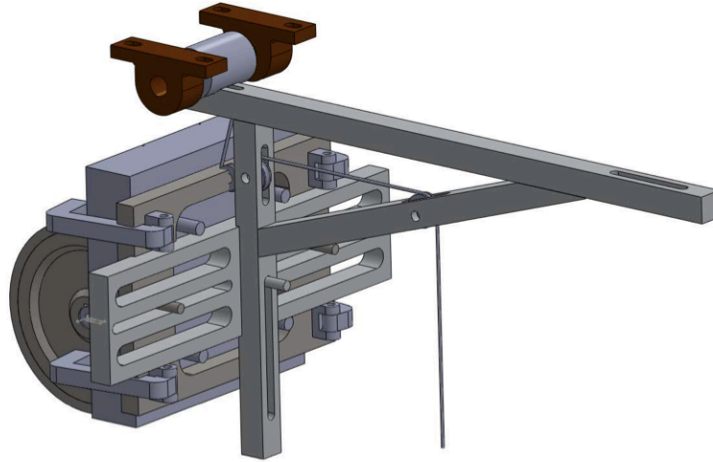
Similarly to the standard DSRW test, this design correctly simulates the desired three-body abrasive wear, as the abrasive grit feed is still allowed to roll over the specimen surface and change orientation. The test rig should therefore produce wear that is, despite being concentrated to a small area, an imitation of wear to which wear liners are exposed on site.

The sample support for this DSRW test is compatible with the size and weight of the wear liners to be tested. The support system consists of two parts; the sample clamp to hold the sample in place and the support grates to allow for horizontal and vertical repositioning.

The sample support system accommodates the increased sample size and weight. Furthermore, it is be compatible with both full sized wear liner plates (300x300mm) and the half wear liner plates (300x150mm), because samples were provided in each of these sizes. It also allows for variable positioning of the sample against the rubber wheel and sand feed, to allow for testing multiple points on the wear liner surface, while not significantly changing the test conditions. This was required firstly because the wear scars produced in DSRW tests are typically a maximum of 30x10mm in area. Since the samples have up to 300x300mm of area exposed, being able to test different points on the sample surface allows for more wear measurements to be taken per wear liner type. Secondly, individual wear liner tiles of this size, depending on the material and vendor, are expensive; multiple tests are not economically viable if only one test per sample can be conducted. Allowing for multiple separate tests to be conducted on one wear liner sample eliminates the necessity of buying more than one sample of each wear liner.

Variable positioning was achieved using two sample grates on the sample holder, as shown in Figure 3. These grates do not allow full access to the sample surface, but significantly increase the accessible points, an important improvement from a non-moveable sample holder. The first sample grate allows horizontal movement. Pins from the sample clamp are aligned in the horizontal holes as shown and can be fixed in varied positions along this axis. Each horizontal hole is 180mm long, with the pin fixed in the centre of this hole when the sample is centred.

Similarly, the support grate located in the vertical beam as shown enables vertical repositioning, via another pin aligned with a 160mm vertical hole. This equates to 180x160mm area of the sample surface being accessible.



**Figure 3 DSRW sample holder, with support grates for sample realignment.**

The sample is weighted at approximately 200N against the wheel. The rubber lined steel wheel for this DSRW test rig is similar to that in ASTM G65 (2010); the total wheel diameter was 228mm, including a 12mm thick outer layer of chlorobutyl rubber moulded to the surface. This was selected because as compared with polyurethane and other available rubbers, chlorobutyl rubber has a greater resistance to friction induced temperature increases which lead to softening the rubber. This is important as such softening reduces the wear rate produced by the test rig, and also can lead to damage of the wheel itself.

Under load, the device is capable of producing a minimum rate of revolution of 100 rpm and maximum 250rpm. This was selected to replicate the wheel speed of  $200 \pm 10$ rpm, used in the standard (ASTM 2010), but to allow for variation if early trials indicate a faster or slower speed is required.

The nozzle produces grit feed rate of approximately 300g/min. This is regulated by a ball valve at the base of the abrasive hopper. The grit feed is produced as close to a streamline flow as possible. Turbulent grit flow results in an uneven distribution of grit at the contact point between the sample and the wheel, producing uneven wear scars. The feed nozzle opening is located as close as possible to the joint between the wheel and the samples as the apparatus configuration allows.



**Figure 4 Newly Constructed DSRW Test Rig at UWA.**

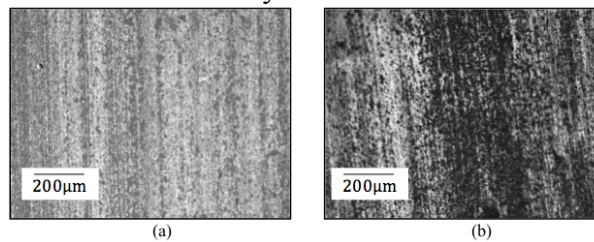
## 2.2 Abrasive Grit Selection Tests

For the wear liner testing, alumina grit was selected, with grain size determined experimentally. Selection was based on availability, cost and performance. As a part of optimising the parameters of the DSRW test, a similar, smaller scale abrasion was used to compare the performance of the alumina grain sizes. Three grain sizes were tested: 1-0.5mm, 0.5-0.2mm, and 0.3F (0.2-0.075mm), and grit performance was assessed by comparing both the extent of comminution of the grit and wear observed on the test sample.

Larger grain sizes for the alumina grits tested result in greater wear rates for alumina ceramic samples. The 1-0.5 sized grit produced 25% increased weight loss from the 0.5-0.2 type, and 100% increased weight loss from the 0.3F type. It was also found that the larger grits tended to undergo more comminution, however there was some size break down for each grain size. This implies the 1-0.5 grit should be used in the final test rig.

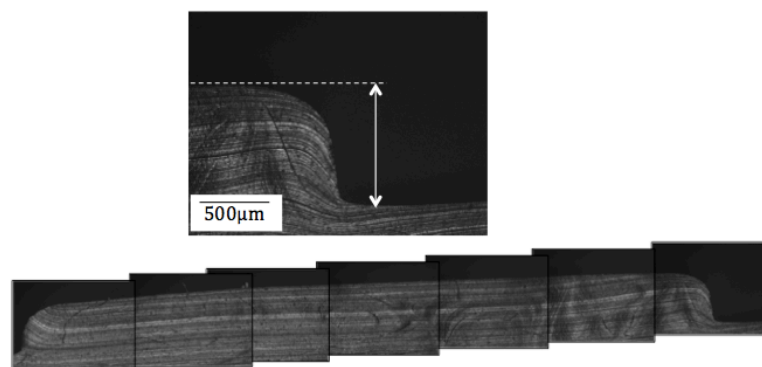
## 3. Quantifying Wear: Surface Replication Trial

The initial surface replicas were assessed for their accuracy for recreating a worn surface. Measuring the depth of a wear scar was attempted, by taking cross sections of a wear scar replica to create a depth profile. Figure 5 shows at the magnification investigated, the level of detail present on the replica surface is comparable to the original surface. There is clear evidence of the linear scratches caused by the abrasive.



**Figure 5** Optical Microscope images comparing original surface and RepliSet replica surface. (a) Original (b) Replica

The possibility of depth profiling using surface replication was necessary because a method to quantify wear caused by the DSRW test rig without using weight losses was required. Optical micrographs of the larger wear scar replica are shown in Figure 6.



**Figure 6** Replica Depth Profile. Top: edge of wear scar. Bottom: Full profile.

Figure 6 reveals a clear change in depth from the unworn surface to the wear scar at both ends of the profile. This differentiation indicates that measuring wear scar depth is a potential method for quantifying wear in the newly designed DSRW abrasion test, provided that the tests are sufficient duration to create a sufficiently deep and defined scar.

## 4. Impact Testing: Drop-Weight Impact Test

### 4.1 Test Rig Design

A simple test rig was constructed to facilitate the 1m drop-weight impact test, as shown in Figure 7. A 1m high table was fitted with a rolling guide to direct the 7.26kg shot put weight. A PVC pipe was fitted at the end of the rolling guide to direct the first half of the weight's trajectory, before being allowed complete free-fall to the sample.

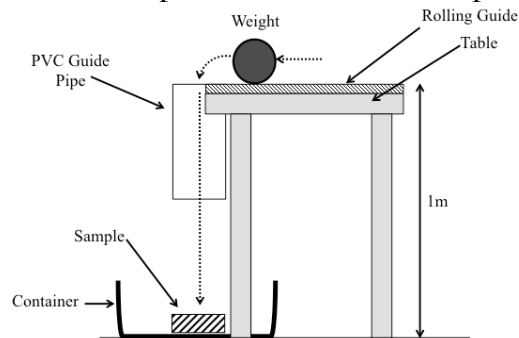


Figure 7 Drop-weight test schematic diagram.

### 4.2 Test Rig Evaluation

Very little effect was observed on the tile surface from the impact test with no prior scratching or stress concentrators. To address this, two stress concentrators were used: a surface scratch, and placing a ball bearing at the point of impact. For the surface scratch: despite a series of diamond tipped tools being used, a satisfactory surface scratch could not be produced on the ceramic wear liner tiles. Using the ball bearing at impact; there were some surface inhomogeneities that could be attributed to fracture, but there was not solid evidence, so at this point is inconclusive. Further examination is therefore required, and perhaps a more damaging, concentrated impact test.

## 5. Conclusions and Future Work

More work is required before performance comparison tests can be completed. While the DSRW test rig has been constructed using the previously discussed design specifications, experimental trials are required for the test rig to be calibrated and final parameter selection for comparative experiments are yet to be completed. For the impact testing, there must be investigations into how to improve the stress concentrators. This should include (but not be limited to) using a sharper, pointed object at the impact point, better surface scratch/cutting procedures and a harder impact weight.

Further development of these test rigs will allow for more reliable wear liner selection and assist in elongating service life, reducing maintenance costs and improving equipment performance at BHPBIO.

## 6. References

ASTM 2010, *Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus* in ASTM G65-04 (2010), ASTM International, West Conshohocken, PA, USA.