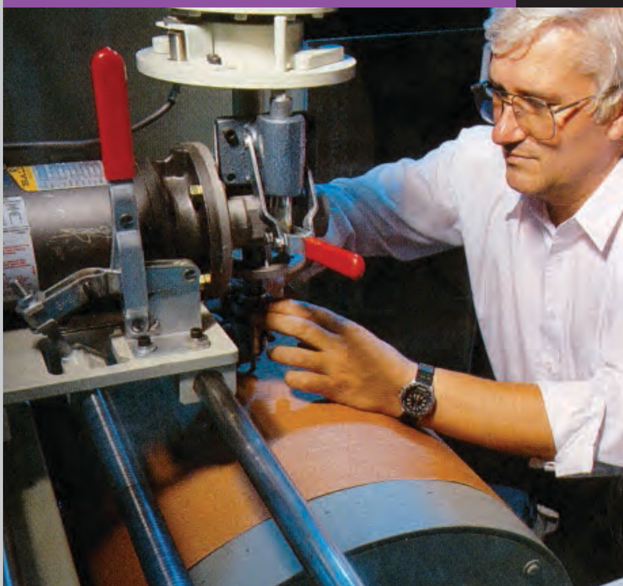
Total Steel

TECHNICAL BULLETIN 3



Wear Management Centre

Report on the Wear Resistance of EHSP and BHN 360

Report Ref 0367/3 August 1999

Client: Total Steel of Australia Pty Ltd

total quality total service **Total Steel**

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Attention:	Mr Les Francis
Order No:	6129
Report:	Report on the wear resistance of EHSP and BHN360.
Report Ref:	0367/3
Date:	20 August 1999

Executive Summary

- For low stress sliding abrasion (LSSA), EHSP showed superior wear resistance to BHN360 plate.
- For high stress two body abrasion (HSTBA), EHSP showed superior wear resistance to BHN360 plate.
- LSSA and HSTBA resistance usually equates to the performance of chute and bin liners where the ore is continually being dragged across the surface of the wear plate.
- The wear test results are only used as a relative guide to a material's suitability for various wear situations. As a consequence, they are considered an aid in understanding the application of these materials, thus reducing the need for unnecessary site trials. It is recommended that comparative site trials be carried out to further prove the suitability of EHSP due to the dynamic nature of operating environments.

Note: JFE is the merged identity of NKK and Kawasaki Steel. EHSP was manufactured under the NKK name at the time of this report.

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1.0 OBJECTIVE

1. To compare the wear resistance of EHSP and BHN360 in:

- Low stress sliding abrasion (LSSA)
- High stress two body abrasion (HSTBA)

2.0 SPECIMEN PREPARATION

The following plates were submitted to the Wear Management Centre to be made into specimens for wear testing.

Plate Identification:

1. 12mm plate JFE EHSP — Heat Number: DA64401 10184

2. 12mm plate BHN360 — Heat Number: 8976098

The specimens presented for wear testing were:
- the ground top surfaces;
- the ground surface 3mm below the surface of the plate.

3.0 TEST RESULTS

3.1 Low Stress Sliding Abrasion Test Results

The results of low stress sliding abrasion (LSSA) tests using the Dry Sand Rubber Wheel (DSRW) wear test (Appendix 6) are shown in Table 1 and figure 1. The DSRW test was performed on the ground surface of the BHN360 and EHSP plates and three millimetres below the surface of the EHSP.

The results of DSRW testing on the surface of the plates showed EHSP to have a greater wear resistance than BHN360. It is possible the improved wear resistance of the EHSP over BHN360 is due to the inclusion of fine carbides in the microstructure of the EHSP. [1]

Because of the lower surface hardness compared to the through hardness of the 12mm EHSP plate, DSRW tests were also performed three millimetres below the surface. The wear resistance of EHSP increased below the surface, thereby making EHSP considerably more wear resistant than BHN360.

This property usually equates to the performance of liners in chutes and bins carrying ore less than 50mm.

3.2 High Stress Two Body Abrasion Test Results

The results of high stress two body abrasion (HSTBA) tests using the Pin-On-Drum (POD) wear test (Appendix 6) are shown in Table 1 and figure 2. The POD test was performed on the ground surface of the 12 mm thick plates.

For HSTBA, EHSP showed greater wear resistance than BHN360.

Table 1: Wear test results (average) for EH-SP and BHN360.

No.	Material Type	DSRW Mass Loss (grams)	POD RWR*
1	EHSP	0.3961	1.16
2	BHN360	0.4659	1.28

* RWR - relative wear rate = (wear rate of specimen) / (wear rate of reference K1040)

4.0 Remarks

- For low stress sliding abrasion (LSSA) and high stress two body abrasion (HSTBA), EHSP showed superior wear resistance to BHN360 plate.
- LSSA and HSTBA resistance usually equates to the performance of chute and bin liners where the ore is continually being dragged across the surface of the wear plate.
- The wear test results are only used as a relative guide to a material's suitability for various wear situations. As a consequence, they are considered an aid in understanding the application of these materials, thus reducing the need for unnecessary site trials. It is recommended that comparative site trials be carried out to further prove the suitability of EHSP due to the dynamic nature of operating environments.

5.0 References

1. Metlabs Report 8T15/M1 1 July 1998

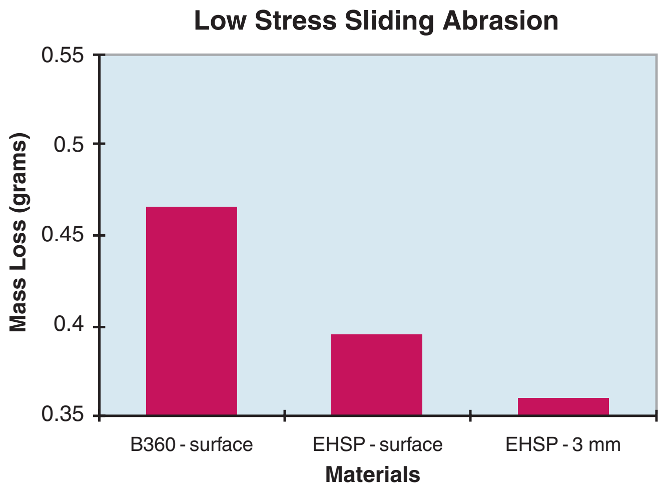


Figure 1a

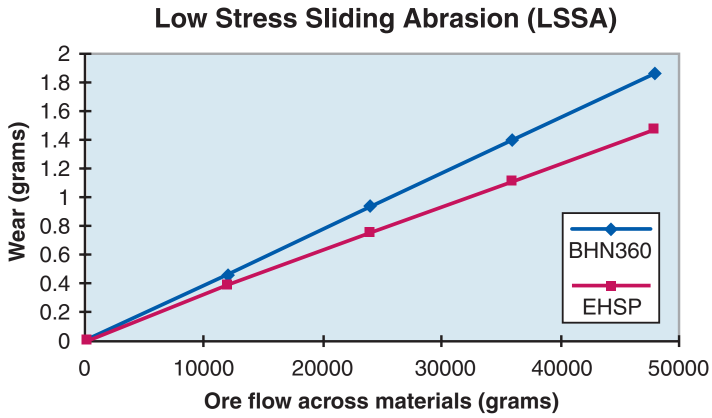


Figure 1b

Figure 1: Low Stress Sliding Abrasion (LSSA) test results using the Dry Sand Rubber Wheel (DSRW) wear test. The lower the mass loss the greater the low stress sliding abrasion (LSSA) wear resistance.

Figure 1(a) shows the mass loss on BHN360 and on EHSP. The wear resistance of EHSP is greatest once the top few millimetres is worn off. Figure 1(b) combines the wear rates at the surface and below the surface of EHSP to show the increasing difference between EHSP to BHN360 with respect to ore flow across each material.

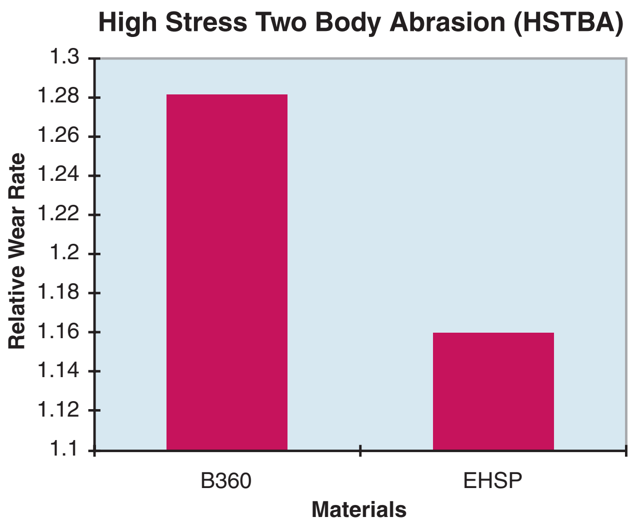


Figure 2a

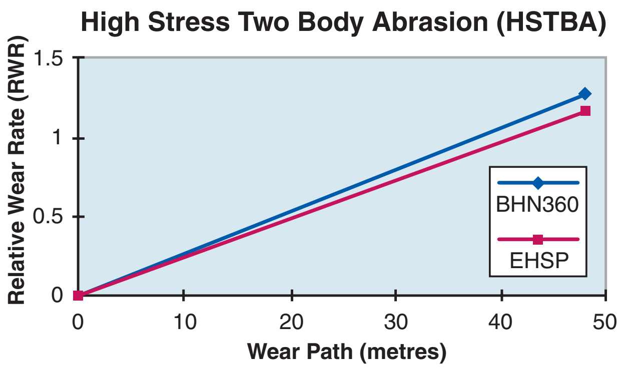


Figure 2b

Figure 2: High Stress Two Body Abrasion (HSTBA) wear test results on the Pin On Drum (POD) wear tester. The lower the Relative Wear Rate (RWR), the greater the HSTBA wear resistance.

Figure 2(a) shows the RWR for each material and figure 2(b) shows the RWR versus length of wear path over abrasive alumina paper.

6.0 Appendixes

6.1 Description of wear tests

- Overview of tests at Wear Management Centre
- Dry Sand Rubber Wheel test (DSRW) - Low stress sliding abrasion (LSSA)
- Pin-On-Drum test (POD) - High stress two body abrasion (HSTBA)

Our Aim

- The mitigation of materials & component wear in the mining, manufacturing, agricultural & public sectors.
- To provide practical solutions to wear problems through feedback from well regarded testing techniques and materials/design knowledge.
- To promote a better understanding of wear mitigation through education and R&D programs.

Overview

Wear Mitigation – to find the right material/component for the job.

Uncontrolled wear is estimated to cost Australian industry 6% of the Gross National Product. Abrasive wear is responsible for costs of approximately one dollar per tonne within the mining and mineral processing industries, and 20% of operating costs within the agricultural industry.

Accordingly, a facility to aid in material selection, material processing optimisation and alloy/component design has the potential to increase the competitiveness of Australian industry, through the introduction of systems that minimise wear.

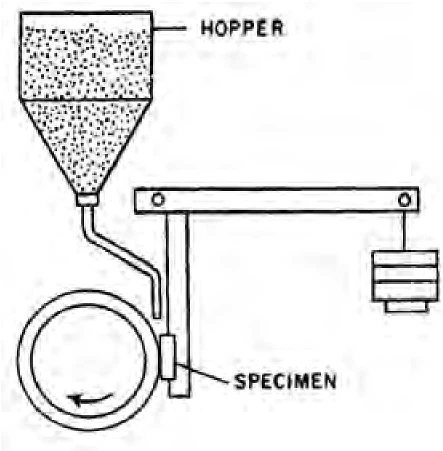
The Wear Management Centre, jointly managed by the Materials Institute of Western Australia (MIWA) and the Advanced Manufacturing Technologies Centre (AMTC), has a comprehensive collection of wear testing equipment located at the AMTC Subiaco.

The services available are shown in the tables below.

Test	Test Type	Examples of Industrial Applications
Low stress sliding abrasion (three body abrasion)	Dry Sand Rubber Wheel (DSRW)	Simulates wear of chute & bin liners in post crushed ore, chain links and conveyor belt wear.
High stress sliding abrasion for very hard materials such as tungsten carbide.	Dry Sand Steel Wheel (DSSW)	Similar applications to DSRW.
Low stress scratching abrasion	Wet Sand Rubber Wheel (WSRW)	Pipes, pumps & valves.
High stress abrasion (two body abrasion)	Pin On Drum (POD)	Unloading of dump trucks, bucket liner materials and roll crusher liners.
Medium stress sliding and impact	Paddle Tester	Chute liners, grizzly bars and impact plate liners.
Gouging abrasion	Pendulum Groove Test (PGT)	Ground engaging tools, conveyor top cover rubber.
Measures abrasion index of ore & degree of ore particle degradation	Ore Abrasivity Tester (OAT)	
A general abrasion test that has been integrated into many international standards.	Taber Abrader	Coatings, ceramic tiles, carpets, fabrics, plastics, rubbers, glass, furniture, flooring, paper and wood products

- ## Consultancy and Education Services

Service	Description
Wear Project Design & Management	Broker and manage projects using internal and/or external facilities. Additionally, if required, will: • Conduct tests (laboratory/field) • Recommend changes • Set Key Performance Indicators (KPI) to measure improvements • Follow up on improvements
R&D - Materials Development and Component Prototyping	Component/Materials development is supported, on site, by the following: • Component prototyping facilities (CAD/CAM); • Foundry; • Welding laboratory (consumable development); • Wear laboratory; • Machine shop with CNC capabilities; • Heat treatment furnaces; • Ceramics laboratory; • Mechanical testing facilities; and • Metallography laboratory.
Quality Assurance	• Monitoring the consistency of a material and/or material processing from either a supplier and/or end user perspective. • Wear Performance Indicators, specified as part of the material's specification, can be used as a means of maintaining quality control.
Materials/Component Audits	• On site assessment of current materials practice (wear environment, wear behaviour, material types, component design and life/cost) and component design. • Recommendations for new materials and/or design modifications. • Assessment and reporting of life improvement.
Relative Ranking of Materials	• Evaluation of materials and/or material processing from either a supplier and/or end user perspective. • Can be used to assist in continuous improvement programs and materials development.
Wear Failure Analysis	• Analysis of the contributions of wear to the failure or under performance of materials/components.
Evaluation of Wear Media	• Ore Abrasivity Testing (OAT) provides a measure of the abrasivity the ore and the degree to which the ore degrades. • Can be used as a relative measure of a materials suitability in grinding situations and, additionally, an ore's grindability.
Engineering of Software Systems for Continuous Improvement	• Software systems analysis and design. Project management of systems development. Systems for: • Materials usage mapping and trial/life history focusing on continuous improvement; and • Materials performance tracking and life prediction.
Wear Test & Equipment Design	• Assessment of wear situation. • Recommend an existing test or design a new test (laboratory or field) and/or equipment.
Education Seminars	• Seminars by wear materials and fabrication / manufacturing experts. • General courses in wear. • Specifically designed courses in wear. • Translate project outcomes into educational systems.
Field & Laboratory Testing Manual	• Production and maintenance of a generalised manual based on site applications of supplied products and end user experience.
Resource Centre	• MIWA members have access through the Library Information Services at AMTC Subiaco and East Perth, to over 100 'materials, related journals and books. Fee for service includes inter-library loans, on-line searches and research.
Company/Consultant Capability Database	• The TRANSMAT capability database was established, through MIWA, to assist the transfer of knowledge in the 'materials' industry. TRANSMAT provides the link between the 'materials' problem and the infrastructure and experts who can provide the solutions.
Internet	• An internet site dedicated to wear of materials and components will be maintained. This site will offer general information on wear, current projects and, as a member of MIWA, provide suppliers with a means of advertising their products.



Dry Sand Rubber Wheel

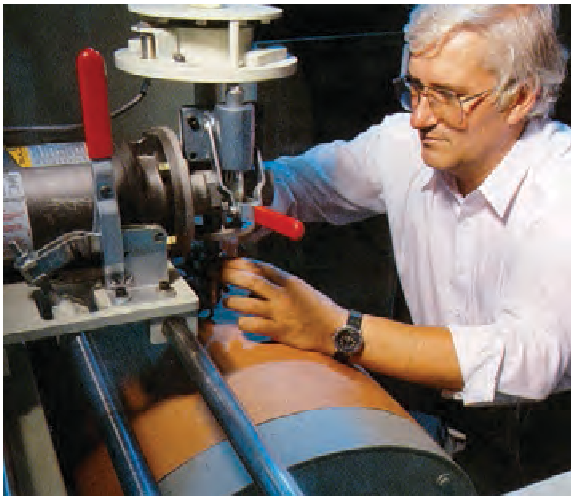
Low stress sliding abrasion

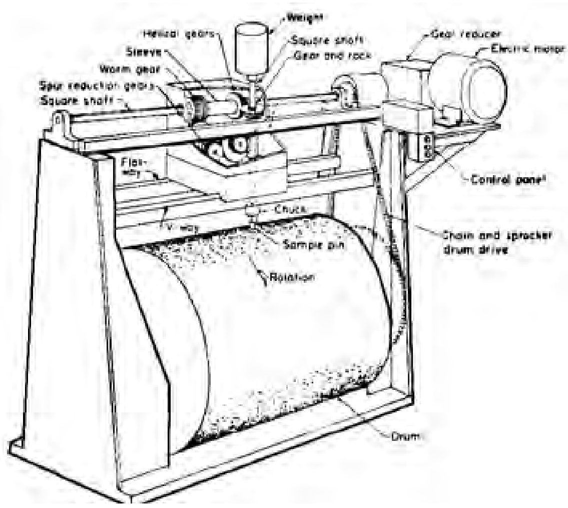
The DSRW test apparatus simulates sliding or rolling low-stress, three body abrasion. The test consists of a rubber wheel that turns at 200 rpm against the specimen to be tested. A sand hopper allows sand to flow in between the rubber wheel and the specimen, creating a dry abrasive condition. A schematic of the test is shown adjacent.

This test is based on the standard ASTM G 65. A comparison between operating conditions of the DSRW test at AMTC Subiaco and the ASTM G 65 are given in table below.

DSRW testing can be performed under non-standard conditions to suit the clients requirements. Variables that can be changed are wheel rotating speed, applied load, sand size and number of revolutions.

Operating Condition	ASTM G-65 Value	Actual Machine Value
Wheel Rotating Speed	200 rpm	same as standard
Applied Load	130 N	137 N
Testing Duration	Procedure A, 6000 revs	same as standard
Reference Material	AISI D2 Tool Steel	same as standard
Sand Type	quartz grain sand	same as standard
Sand Size	AFS 50-70 (-300+212µm)	AFS 50-100 (-300+150µm)
Sand Flow Rate	300 - 400 g/min	400 - 450 g/min
Wheel Hardness	60 ± 2 Shore A Durometer	same as standard
Run-in Period for New Wheels	not specified	6000 revs
Coefficient of Variation	<7%	<5%
Testing Requirements per Material	not specified	1x reference; 2 x test material
Wear Result	volume loss (mm^3)	same as standard





Pin On Drum

High stress two body abrasion

The POD test apparatus simulates high stress two-body abrasion. This condition is simulated by abrading a 6.35 mm diameter pin of a test material across dry abrasive paper under a load of 137N. The pin rotates on its own axis whilst moving across continually fresh abrasive in a non-overlapping pattern. After the pin has travelled 48 metres, the test is terminated and the weight loss of the pin is recorded. The wear resistance is reported as the Relative Wear Rate (RWR) of the test material to the reference material. The standard test condition for POD testing is summarised in the table below. The coefficient of variation for this test is less than 7%.

POD testing can be performed under non-standard conditions to suit the clients requirements.

Operating Variables & Details	Actual Machine Value	Possible Variation
Load (Newton)	60	10 - 60
Wear Path Length (m)	48	< 48
Pin Rotating Speed (rpm)	80	< 80
Drum Rotating Speed (rpm)	1800	< 7000
Pin Sliding Speed (rpm)	50	50
Test Reference Material	Bisalloy 500 or K1040	
Coefficient of Variation	6.5%	
Testing Requirements per Material	2 tests of reference and 2 test specimens of the test material	
Wear Result	Relative Wear Rate (RWR)	

6.2 Dry Sand Rubber Wheel Test Result Sheets

6.3 Pin On Drum Test Result Sheets

Dry Sand Rubber Wheel Abrasion Test Result Sheet - Metallic Materials

TEST DETAILS

Wear Test No:	DM99
Date:	1-Jul-99
Operator	FR

TEST DESCRIPTION

Test Conditions

Wheel Rotating Speed (rpm):	200	Wheel Diameter (mm):	221.6
Total Wheel Revolutions:	6000	Wheel ID:	6
Applied Load (N):	130		
Dead Weight (kg):			
- Blue machine	3.75		
- Grey machine			
Abrasive / Sand:	IMDEX 50/100 screened		

Test Material:	**Material Type**	**Hardness**	**Density**	
Test Sample:	Bisalloy360	38RC	7.80E +06	g/m^3
Reference Material:	K110	59RC	7.80E +06	g/m^3

Apparent Density:

- White Cast Iron:	7.70E +06	g/m^3
- Engineered Steel:	7.80E +06	g/m^3

RESULTS

	Sample 1	**Sample 2**	**Sample 3**	**Reference**
Initial Mass (g):	172.6582	172.5679		171.4515
Final Mass (g):	172.1730	172.1213		171.3306
Mass Loss (g):	0.4852	0.4466		0.1209
Volume Loss(cubic m):	6.2205E-08	5.726E-08		
Adjusted Vol Loss (cubic m):	6.417E-08	5.9065E-08		

SUMMARY

No tested:	2
Av Mass Loss (g):	0.4659
Av Volume Loss (cubic m):	5.9731E-08

COMMENT

Dry Sand Rubber Wheel Abrasion Test Result Sheet - Metallic Materials

TEST DETAILS

Wear Test No:	DM101
Date:	2-Jul-99
Operator	FR

TEST DESCRIPTION

Test Conditions

Wheel Rotating Speed (rpm):	200	Wheel Diameter (mm):	221.6
Total Wheel Revolutions:	6000	Wheel ID:	6
Applied Load (N):	130		
Dead Weight (kg):			
- Blue machine	3.75		
- Grey machine			
Abrasive / Sand:	IMDEX 50/100 screened		

Test Material:	**Material Type**	**Hardness**	**Density**	
Test Sample:	EHSP	41RC	7.80E +06	g/m^3
Reference Material:	K110	59RC	7.80E +06	g/m^3

Apparent Density:

- White Cast Iron:	7.70E +06	g/m^3
- Engineered Steel:	7.80E +06	g/m^3

RESULTS

	Sample 1	Sample 2	Sample 3	Reference
Initial Mass (g):	172.0785	172.0472		161.5751
Final Mass (g):	171.6888	171.6447		161.4566
Mass Loss (g):	0.3897	0.4025		0.1185
Volume Loss(cubic m):	4.9962E-08	5.1603E-08		
Adjusted Vol Loss (cubic m):	5.154E-08	5.3233E-08		

SUMMARY

No tested:	2
Av Mass Loss (g):	0.3961
Av Volume Loss (cubic m):	5.0782E-08

COMMENT

Dry Sand Rubber Wheel Abrasion Test Result Sheet - Metallic Materials

TEST DETAILS

Wear Test No:	DM103
Date:	13-Jul-99
Operator	FR

TEST DESCRIPTION

Test Conditions

Wheel Rotating Speed (rpm):	200	Wheel Diameter (mm):	221.6
Total Wheel Revolutions:	6000	Wheel ID:	6
Applied Load (N):	130		
Dead Weight (kg):			
- Blue machine	3.75		
- Grey machine			
Abrasive / Sand:	IMDEX 50/100 screened		

Test Material:	Material Type	Hardness	Density	
Test Sample:	EHSP	44	7.80E +06	g/m^3
Reference Material:	K110	59RC	7.80E +06	g/m^3

Apparent Density:

- White Cast Iron:	7.70E +06	g/m^3
- Engineered Steel:	7.80E +06	g/m^3

RESULTS

	Sample 1	Sample 2	Sample 3	Reference
Initial Mass (g):	130.7975	130.6581		158.4403
Final Mass (g):	130.4453	130.2928		158.3255
Mass Loss (g):	0.3522	0.3653		0.1148
Volume Loss(cubic m):	4.5154E-08	4.6833E-08		
Adjusted Vol Loss (cubic m):	4.658E-08	4.8313E-08		

SUMMARY

No tested:	2
Av Mass Loss (g):	0.35875
Av Volume Loss (cubic m):	4.5994E-08

COMMENT

Repeat tests of EHSP with 3 mm taken from surface to expose harder carbide layer

Pin-On-Drum Wear Test Result Sheet - Metallic Materials

TEST DETAILS

			Test Sample	Reference
Wear Test No: OM	21	Material:	Bisalloy360	K1040
Date:	1/07/99	Supplier:	Total Steel	
Operator	Frances	Density (g/m^3):	7.80E+6	7.80E+6
Project Code:	Total Steel	Hardness:		56RC

TEST DESCRIPTION

Abrasive Paper:	Alumina	Distance b/w wear tracks:	20 mm
Grade:	120	Carriage Speed Indicator:	185
Applied Load (N):	60	Wear Path (30 laps setting):	48 m
		Sliding Speed	50 mm/sec
		Time per drum rotation:	34 sec
		Drum Speed Indicator:	220
		Pin Rotating Speed:	80 rpm

RESULTS

	Test 1		Test 2		Test 3 (opt)	
	Reference 1		Reference 2		Reference 3	
Initial Mass	3.6217	g	3.3154	g	7.5649	g
Final Mass	3.3154	g	3.0022	g	7.2352	g
Mass Loss	0.3063	g	0.3132	g	0.3297	g
Volume Loss	3.9269E-08	m^3	4.01538E-08	m^3	4.227E-08	m^3
	Specimen 1		Specimen 2		Specimen 3	
Initial Mass	2.7507	g	2.7937	g	2.3486	g
Final Mass	2.3486	g	2.3806	g	1.9444	g
Mass Loss	0.4021	g	0.4131	g	0.4042	g
Volume Loss	5.1551E-08	m^3	5.29615-08	m^3	5.182E-08	m^3

SUMMARY

No of samples:	3	RWR 1 =	1.3128
Relative Wear Rate	RWR = WR (specimen)/WR (ref)	RWR 2 =	1.3190
		RWR 3 =	1.2260
	Average	**RWR =**	**1.2859**

Pin-On-Drum Wear Test Result Sheet - Metallic Materials

TEST DETAILS

			Test Sample	Reference
Wear Test No: OM	24	Material:	EHSP	K1040
Date:	2/07/99	Supplier:	Total Steel	
Operator	Frances	Density (g/m^3):	7.80E+6	7.80E+6
Project Code:	Total Steel	Hardness:		56RC

TEST DESCRIPTION

Abrasive Paper:	Alumina	Distance b/w wear tracks:	20 mm
Grade:	120	Carriage Speed Indicator:	185
Applied Load (N):	60	Wear Path (30 laps setting):	48 m
		Sliding Speed	50 mm/sec
		Time per drum rotation:	34 sec
		Drum Speed Indicator:	220
		Pin Rotating Speed:	80 rpm

RESULTS

	Test 1		Test 2		Test 3 (opt)	
	Reference 1		Reference 2		Reference 3	
Initial Mass	8.2225	g	7.8943	g		g
Final Mass	7.8943	g	7.5649	g		g
Mass Loss	0.3282	g	0.3294	g		g
Volume Loss	4.2077E-08	m^3	4.925E-08	m^3		m^3
	Specimen 1		Specimen 2		Specimen 3	
Initial Mass	2.7631	g	2.7669	g		g
Final Mass	2.3824	g	2.3827	g		g
Mass Loss	0.3807	g	0.3842	g		g
Volume Loss	4.8808E-08	m^3	4.92564E-08	m^3		m^3

SUMMARY

No of samples:	2	RWR 1 =	1.1600
Relative Wear Rate	RWR = WR (specimen)/WR (ref)	RWR 2 =	1.1664
		RWR 3 =	
		Average RWR =	**1.1632**

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