“Investigations on the abrasivity of iron ore slurries : selection of materials for pipelines applications in mine industry”

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Summary:

. Introduction to the ASTM standard method: procedures, equipment, data acquisition and treatment.

. Miller Index and SAR Number Machine: project and development

. Case studies: results and discussion

. Conclusions

Standard ASTM G75-07

STANDARD TEST METHOD FOR DETERMINATION OF SLURRY ABRASIVITY (MILLER NUMBER) AND SLURRY ABRASION RESPONSE OF MATERIALS (SAR)

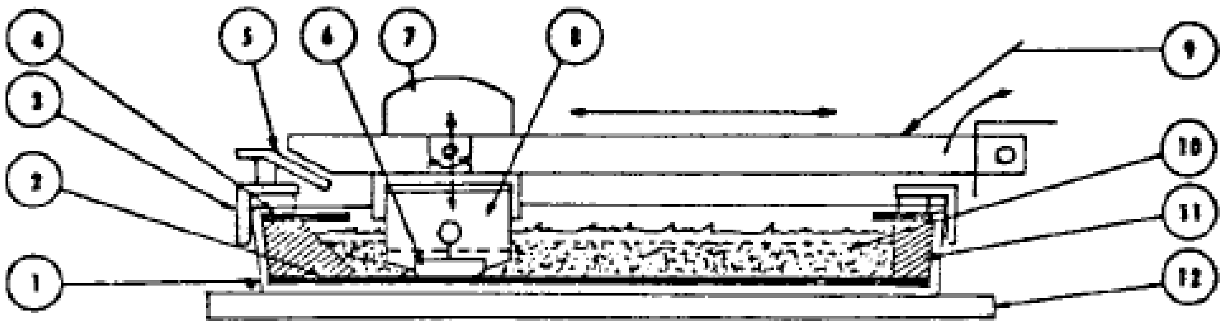
Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials

- Determining the relative abrasivity of any slurry (Miller Number) or the response of different materials to the abrasivity of different slurries (SAR Number).

- "Number Miller" slurry is a measure of the abrasiveness related to the mass loss rate of a standard metal block.

- "SAR number" is a measure of the relative abrasion response of any material in any slurry.

Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials



1 Molded Plastic Tray
2 Neoprene Lap
3 Tray Clamp
4 Splash Guard
5 Block Lifting Cam
6 Standard Wear Block 27 % CR-Iron
7 Dead Weight
8 Adjustable Plastic Wear Black Holder
9 Pivoted Reciprocating Arm
10 Sand Slurry
11 Molded Plastic Filler "V" Channel Block
12 Tray Plate

Miller Number Machine Slurry: Cross-Section.

Neoprene lap after abrasion test

Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials

The nominal composition of the chromium-iron wear block reference material is: Carbon-2.5 %, Manganese-1.0 %, Silice-0.6 %, Nickel-0.25 %, **Chromium-28 %**, Molybdenum-0.3 %, Vanadium-0.8 %.

6-h test, run in 2-h increments.

Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials

Procedure

Wear Specimen Preparation;

Slurry Preparation;

Filling Slurry Troughs;

Start the test for 2 hours;

Stop and remove the wear blocks;

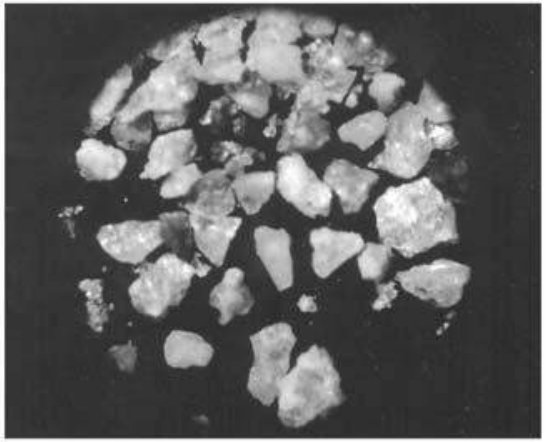
Clean and weigh each wear block;

Alternating the orientation of the wear blocks for each of the three 2-h.

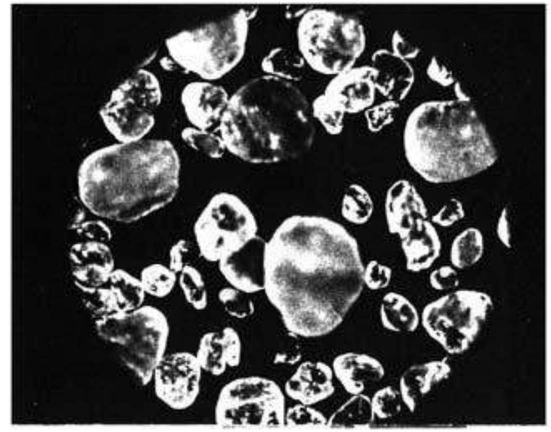
Remix any settled slurry in each trough before each 2-h run.;

Record the wear block mass loss for each run.

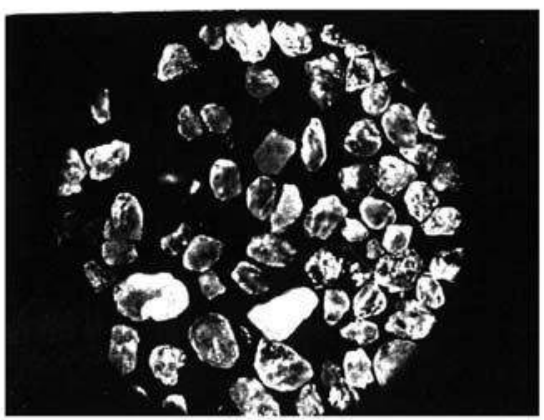
Selected abrasive particles and their correspondent Miller Number.



Bunker Hill Sand
Miller Number 218



Saskatchewan Sand
Miller Number 149



Los Angeles Sewer Sludge
Miller Number 77

AFS 50-70 Test Sand
Miller Number 136

Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials

Results:

TABLE 1 Test Data

Wear Specimen	142		143	
	Mass, g	Cumulative Loss, mg	Mass, g	Cumulative Loss, mg
Initial	16.2810	0.0	16.2670	0.0
After 2 h	16.2723	8.7	16.2580	9.0
After 4 h	16.2668	14.2	16.2500	17.0
After 6 h	16.2594	21.7	16.2406	26.4

$$MN = (18.18 \text{ h/mg}) \times (\text{mass loss rate, mg/h})$$

SAR Number = Miller Number x (7.58/SG specimen)

Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials

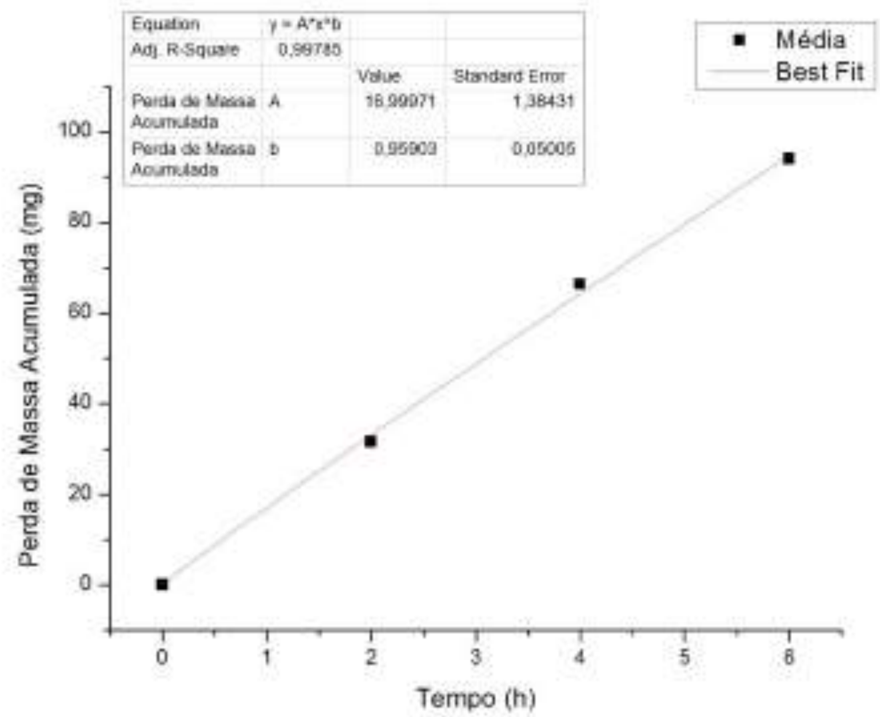
NOTE 1—Generic minerals from different sources differ greatly in abrasivity.

Material	Miller Numbers
Alundum 400 mesh	241
Alundum 200 mesh	1058
Ash (fly)	83, 14
Bauxite	9, 22, 33, 45, 50, 76, 134
Clay	34, 36
Coal	6, 7, 9, 10, 12, 21, 28, 47, 57
Copper concentration	19, 37, 58, 68, 111, 128
Gypsum	41
Iron Ore	28, 37, 64, 79, 122, 157, 234
Kaolin	7, 7, 30
Lignite	14
Limestone	22, 27, 29, 30, 33, 39, 43, 46
Limonite	113
Magnetite	64, 67, 71, 134
Mud, drilling	10
Phosphate	68, 74, 84, 134
Potash	0, 10, 11
Pyrite	194
Sand/sand fill	51, 59, 75, 85, 93, 116, 138, 149, 246
Shale	53, 59
Sewage (raw)	25
Sulfur	1
Tailings (all types)	24, 61, 76, 91, 159, 217, 480, 644

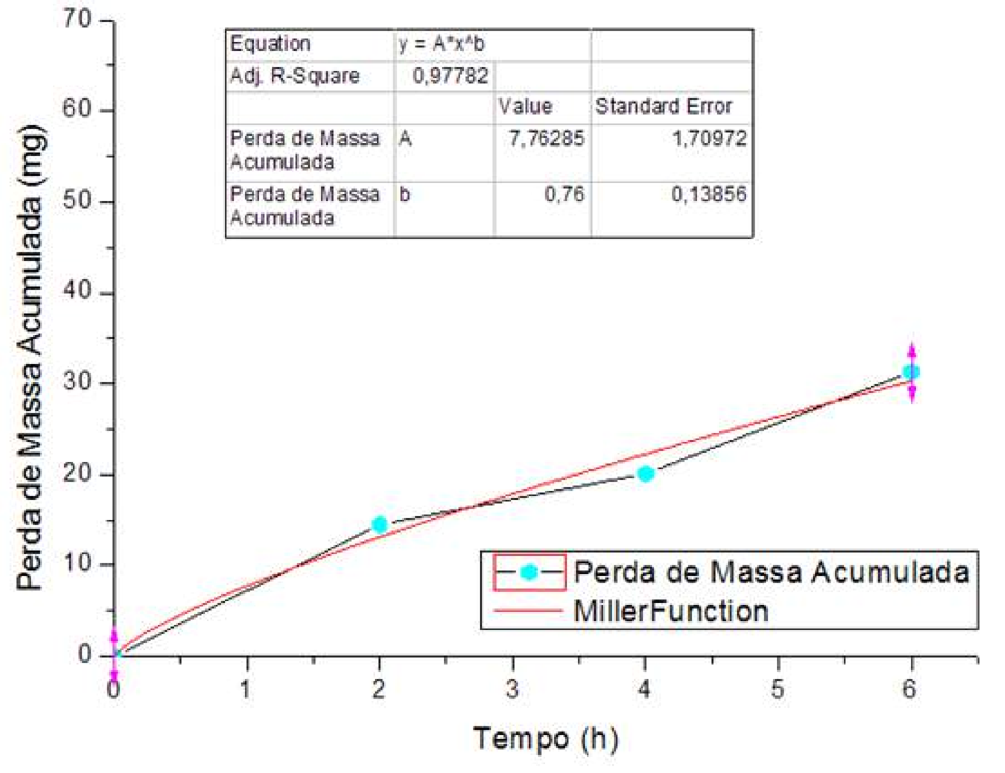
Examples of Miller Numbers for Some Slurries

How to achieve abrasivity coeficients: time dependence of mass loss

$$y = A.x^{\mathrm{B}}$$



Typical graph relating loss mass x time



Miller-Number

The Miller-Number (MN) describes the abrasivity of any slurry. It is used to rank the abrasivity of slurries in dependency of the wear of a standard reference material . The higher the Miller Number, the higher the wear damage on the reference block. It is related to the mass loss rate of a standard wear specimen two hours into an abrasive test. These tests add up to a curve in the cumulative "mass loss x time" diagram. The curve can be approximated with the potential function shown in Equation 1.

$M(t) = A \cdot t^B$ (1)

Exponential function to approximate the Miller-Test curve with:

$M(t)$ = cumulative mass loss in mg,

A = first curve fit coefficient,

B = second curve fit coefficient and

t = time in h

The mass loss rate after two hours is the slope at this point of the calculated curve. The slope is the y-value of the derivation of Equation with an x-value of two. The derivation is shown in the following Equation 2.

$M'(t) = A \cdot B \cdot t^{(B-1)}$ (2)

Equation: Derivation of Equation 1:

$M'(t)$ = mass loss rate in mg/h

A = first curve fit coefficient,

B = second curve fit coefficient and

t = time in h (for MN calculation 2)

To get a significant number to express the abrasion effects, a scaling factor C = 18,18 mg/h is used, which leads to Equation 3. The result is rounded to the next integer. Values will be approximately 1 for slurry of sulphur with 50% diluted and 1000 for 220-mesh slurry of Corundum also 50% water diluted.

$MN = C \cdot M'$ (3)

Equation 3: Calculation of the Miller-Number with

MN = Miller-Number

C = scaling factor (18,18 mg/h)

M' = mass loss rate in mg/h

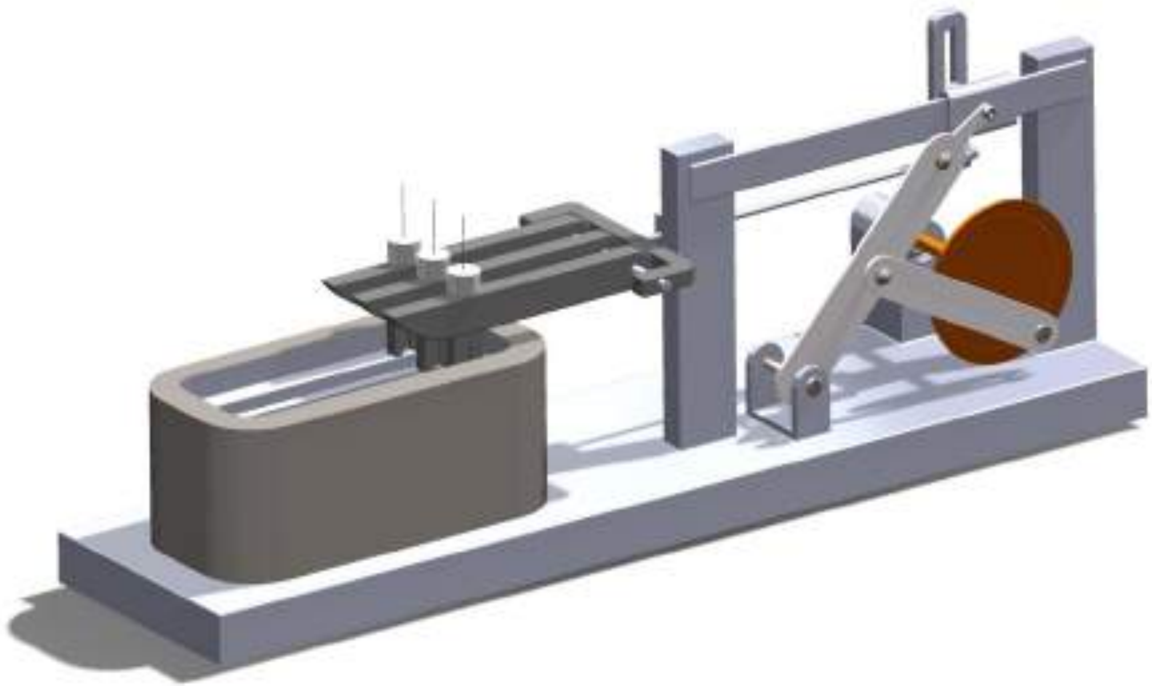
Slurry Abrasivity Response Number

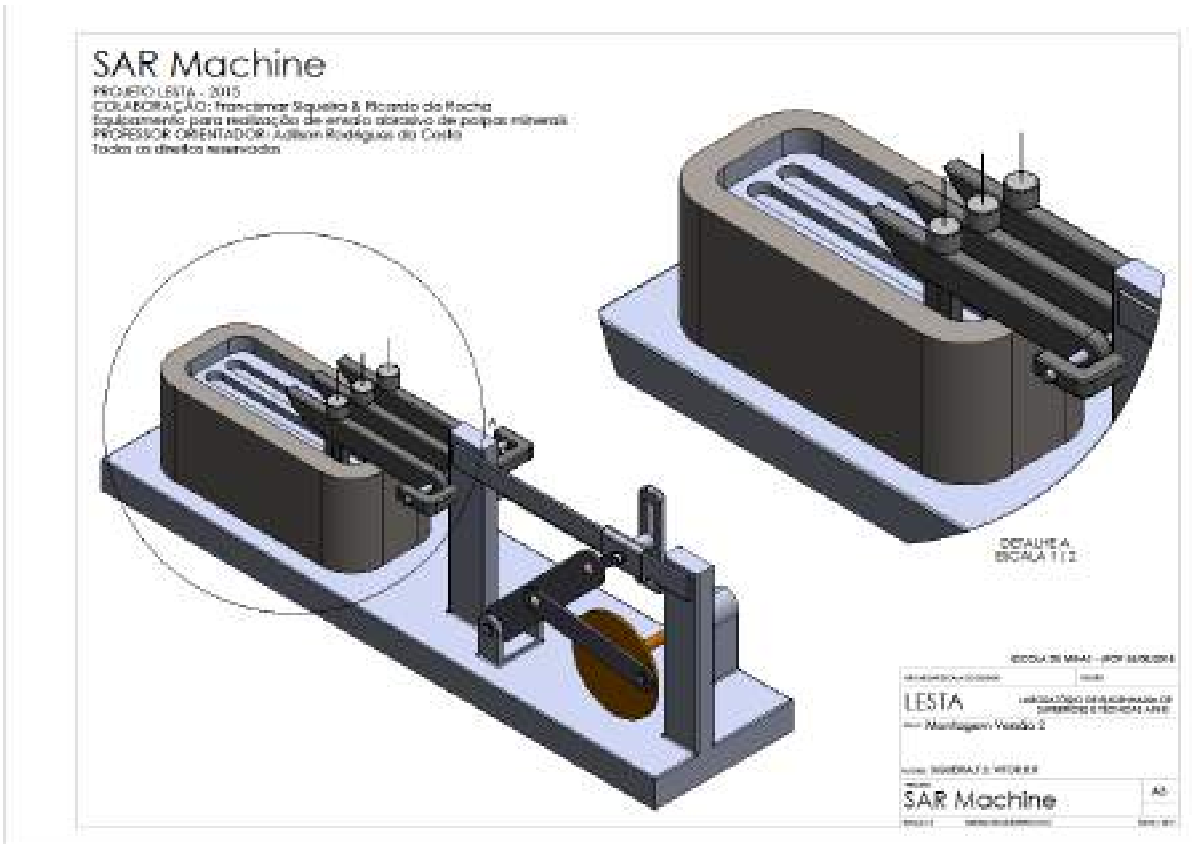
The Slurry Abrasivity Response Number (SAR-Number) is the relative abrasive response of any material in any slurry. It is generalized from the Miller Number and is not bound to the standard reference material. The SAR-Number is usually used **to rank construction materials of fluid handling equipment for special slurry**. The higher the SAR Number the poorer is the material resistance against wear.

Abrasion Test Machine: Project

Explodida.avi

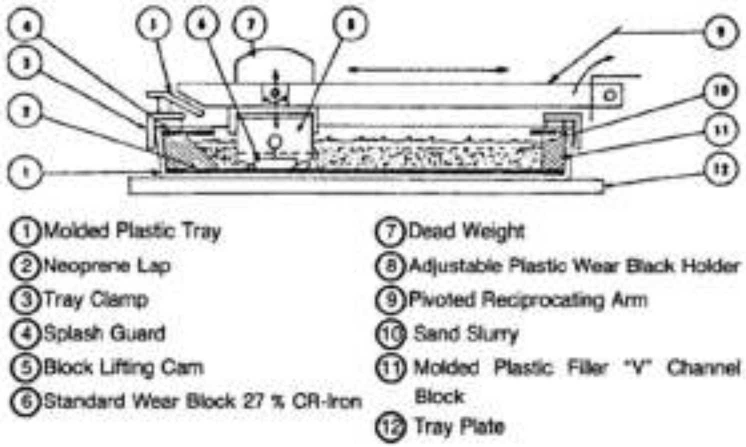
MontagemFinal 2.avi




SAR Machine
PROJETO LESTA - 2015
COLABORAÇÃO: Francismar Siqueira & Ricardo da Rocha
Equipamento para realização de ensaio abrasivo de polpas minerais
PROFESSOR ORIENTADOR: Adilson Rodrigues da Costa
Todos os direitos reservados
DETALHE A
ESCALA 1 : 2
LESTA
Montagem Versão 2
SAR Machine

Methodology

Miller Machine



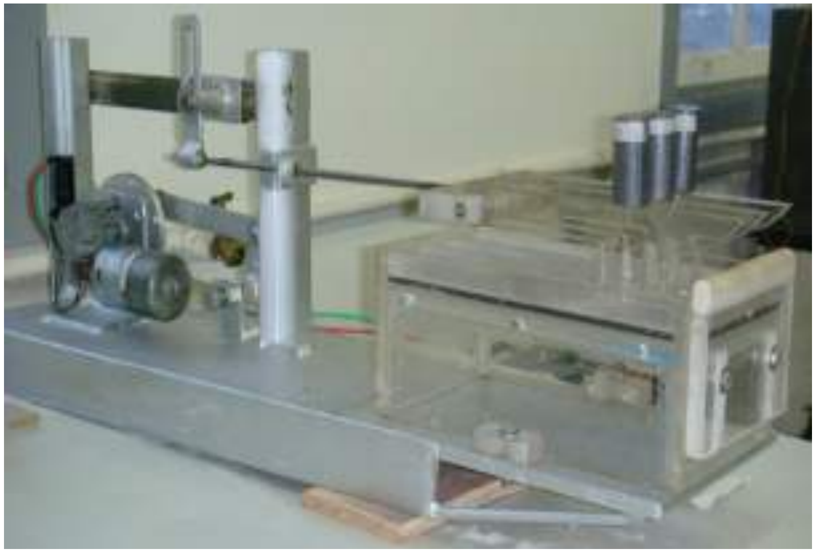


Chart of mass loss data

Time (h)	Specimen 1		Specimen 2		Specimen 3	
	Mass (g)	Mass loss (g)	Mass (g)	Mass loss (g)	Mass (g)	Mass loss (g)
0	0,0000	0,0000	1,6472	0,0000	1,5952	0,0000
2	0,0000	0,0000	1,6288	0,0184	1,5846	0,0106
4	0,0000	0,0000	1,6263	0,0025	1,5758	0,0088
6	0,0000	0,0000	1,6080	0,0183	1,5717	0,0041

	Accumulated mean mass lossMédia		
	(g)	(mg)	
	0,0000	0,0	
	0,0145	14,5	
	0,0201	20,1	
	0,0313	31,3	

Case studies

I - Investigation on the abrasivity of mining slurries in respect to the properties of the abrasive particles: concentration and grain size. Part I

- Frieder Kälber[1]; Steffen Meinhold[1] ; Francismar Siqueira[2] ; Paulo Ricardo [3] ; A. R. da Costa[4]

1 – Reutlingen University – Germany

2,3 e 4: OP School of Mines

Slurries abrasivity tests

Slurry: Iron ore (Run Of Mine – Milled)

Room temperature in the Laboratory: 25°C ± 1ºC
Relative Humidity in the Laboratory: 75%

Wear specimen :

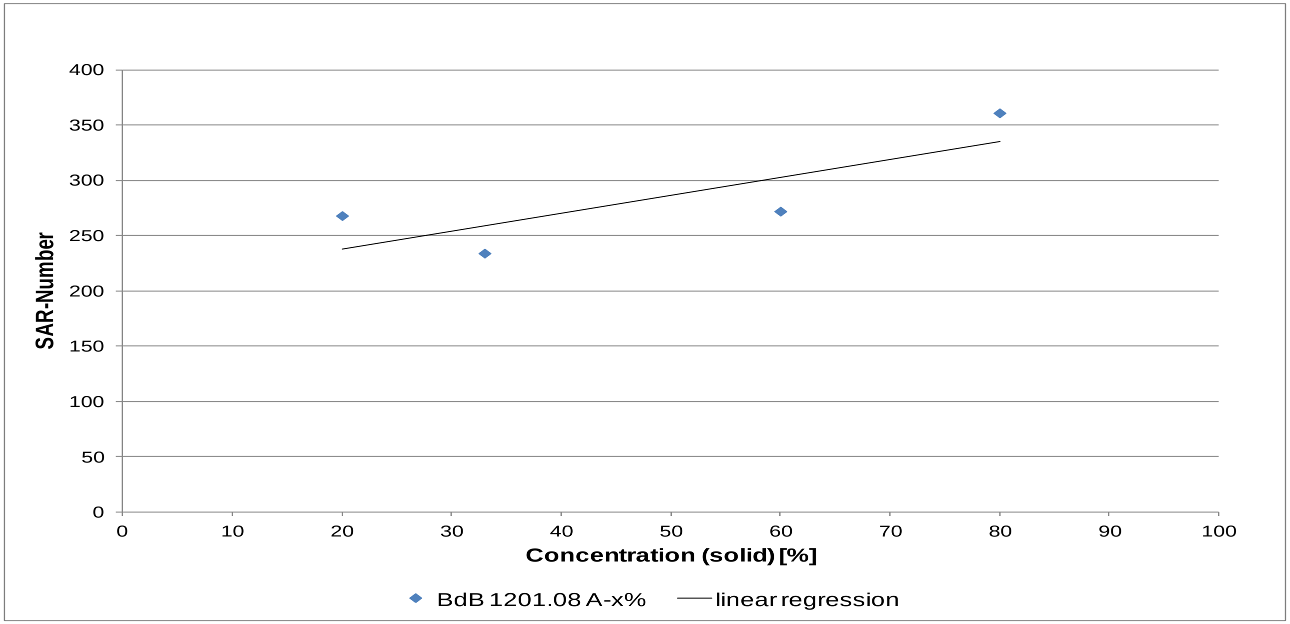
Material: API X70 Steel
Density: 7,8g/cm^3

Specimen	HV 0,01 [N/mm²] Ferrite	HV 0,05 [N/mm²] Perlite
API X70	173,8	278,8

Results of the micro hardness tests on the wear specimen

Pad material:

Descrição: Neoprene
Hardness "Shore A": 75
Elastic Constant (k) = 930 N.m^{-1}



Evolution of SAR-Number with different concentration (dilution)(slurry A (x%))

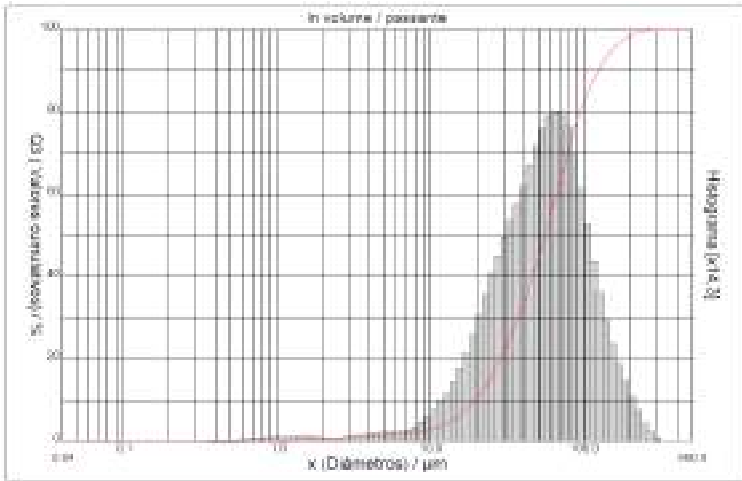
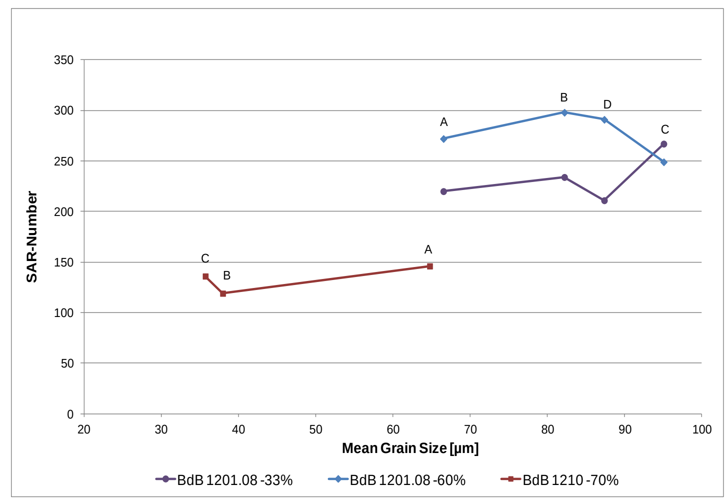


Diagram of grain size analysis of the slurry BdB 1210 A



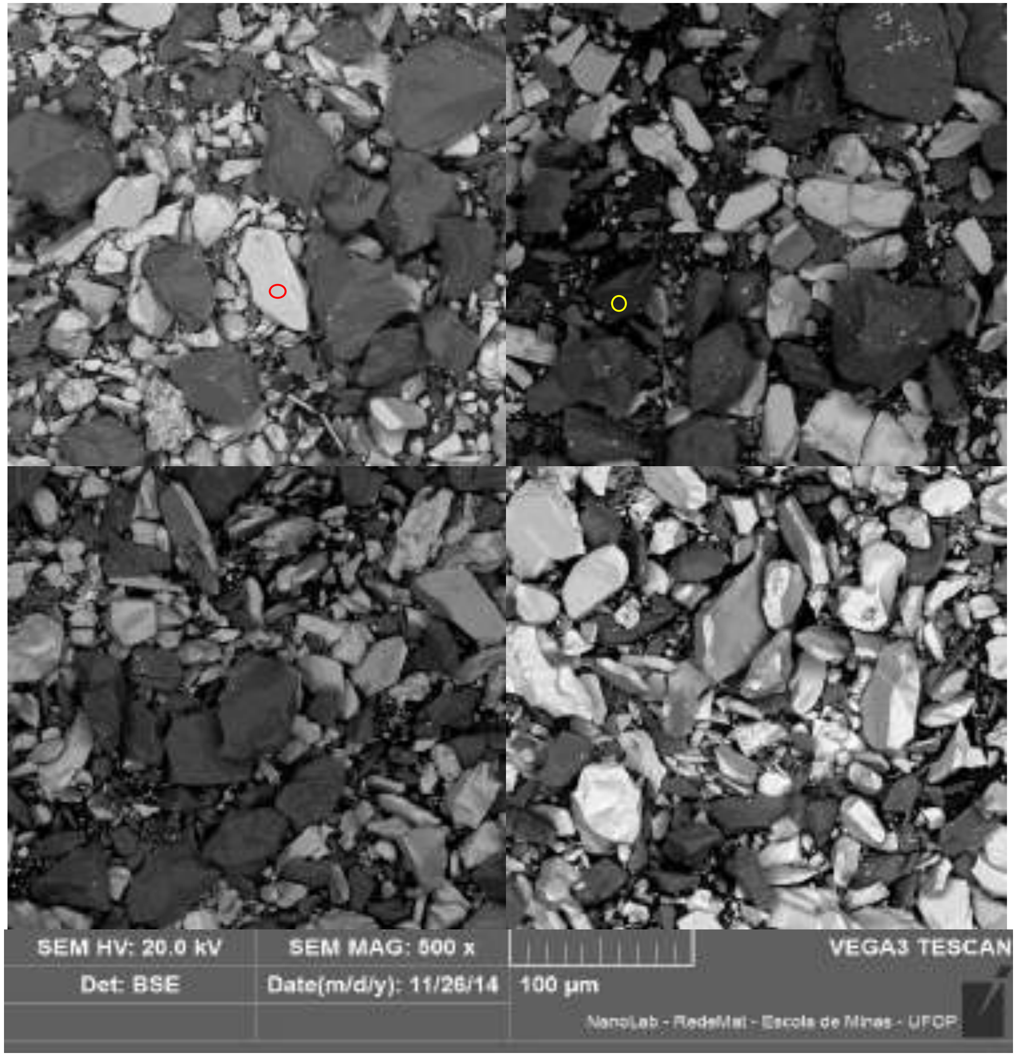
Mean grain size and related SAR-Numbers of the different batches

II - Investigation on the abrasivity of mining slurries in respect to the properties of the abrasive particles: morphology, hardness and nature of particles. Part II

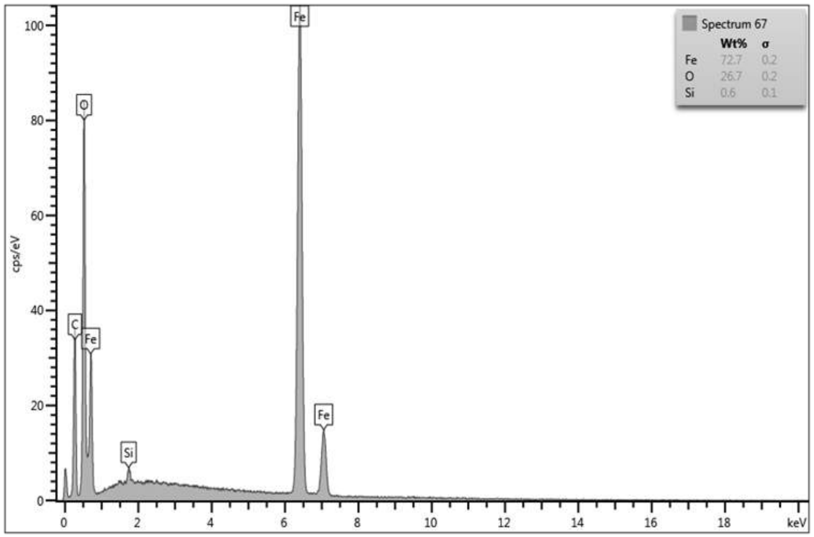
Frieder Kalber[1]; Steffen Meinhold[1] ; Francismar Siqueira[2] ; Paulo Ricardo [3] ; A. R. da Costa[4]

1 – Reutlingen University – Germany

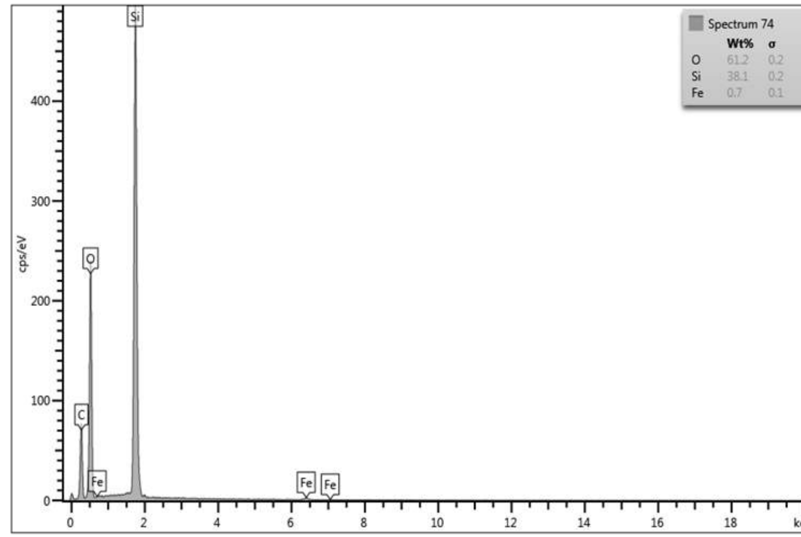
2,3 e 4: OP School of Mines



Microscopic recording of the particles of the slurries from the batch BdB 1201.08 in BSE mode: Top left: A/Top right: B/Bottom left: C/Bottom right: D



EDS diagram for bright particles (Hematite)



EDS diagram for dark particles (Silica)

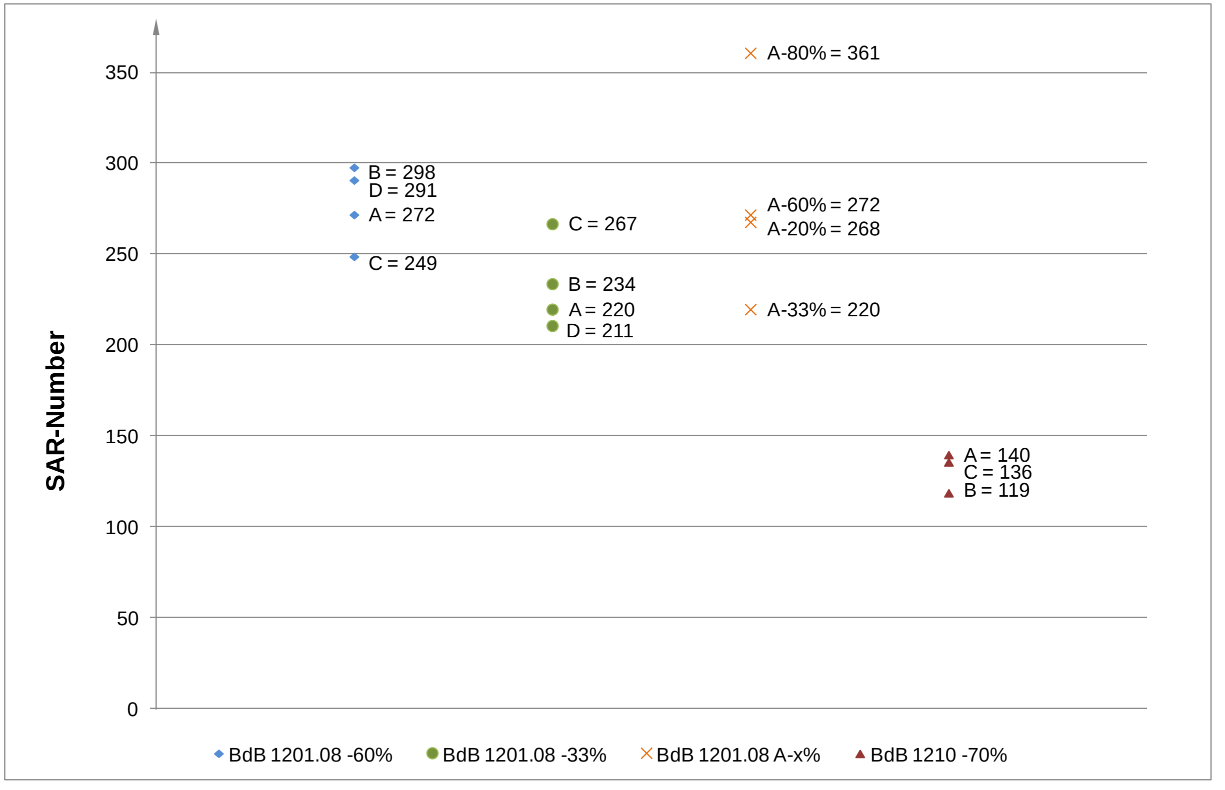
Hardness of Hematite is around 650 HV and for Silica this property may attain 1000 HV.

Slurry	BdB 1201.08 A	BdB 1201.08 B	BdB 1201.08 C	BdB 1201.08 D
Proportion hematite [%]	60	50	60	80
Proportion silica [%]	40	50	40	20

Ratio of hematite and silica in the slurries from batch BdB 1201.08

Name of sample slurry	Cumulative mass loss [mg/h]	MN-Number	SAR-Number
BdB 1201.08 A -20%	16,50	276	268
BdB 1201.08 A -33%	13,26	226	220
BdB 1201.08 A -60%	15,39	280	272
BdB 1201.08 A -80%	20,44	372	361

MN and SAR Number of the Slurry BdB 1201.08 A -x% with different

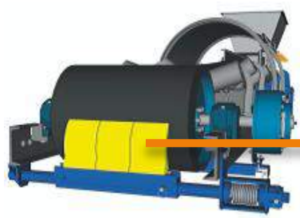

SAR-Number
0
50
100
150
200
250
300
350
B = 298
D = 291
A = 272
C = 249
C = 267
B = 234
A = 220
D = 211
A-80% = 361
A-60% = 272
A-20% = 268
A-33% = 220
A = 140
C = 136
B = 119
BdB 1201.08 -60%
BdB 1201.08 -33%
BdB 1201.08 A-x%
BdB 1210 -70%

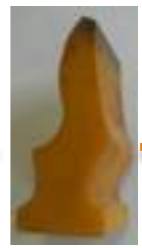
Name of sample slurry	mean diameter [µm]
BdB 1201.08 A	66,54
BdB 1201.08 B	82,2
BdB 1201.08 C	95,06
BdB 1201.08 D	87,36
BdB 1210 A	64,77

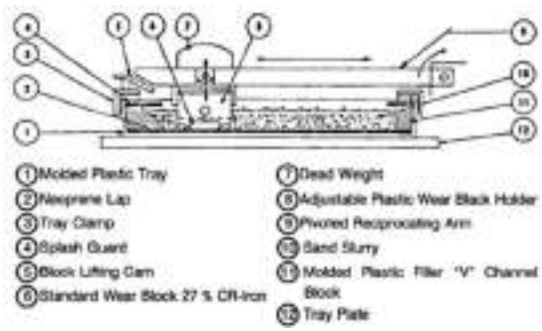
Mean grain size

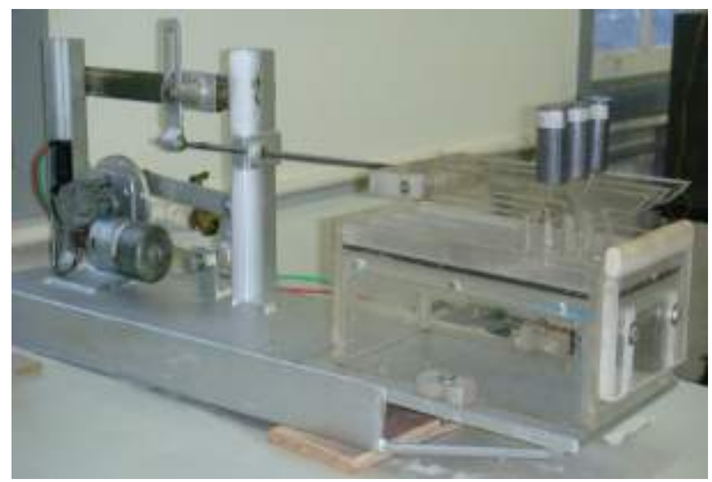
The morphology of the particles is analysed based on the BSE pictures from the SEM. Previous figure shows the pictures of the slurries BdB 1201.08 A,B C and D. In these slurries the particles look similar. The silica particles are big polyhedral bodies with a rough surface. The edges have mostly obtuse angles. This makes it possible for the particles to act as a rolling element. The hematite is mostly present in small fractures but also in greater particles. On the larger particles great planes can be seen, which is due to the hexagonal crystal system. In this case the particles are present as “Tabular Plates”. With these parallel lying surfaces the particles look like plates. The angles of the edges are likely acute. In contrast to the silica particles, these would likely perform sliding movements.

III - Wear of Polyurethane under slurry abrasivity test









Polymers in mine industry

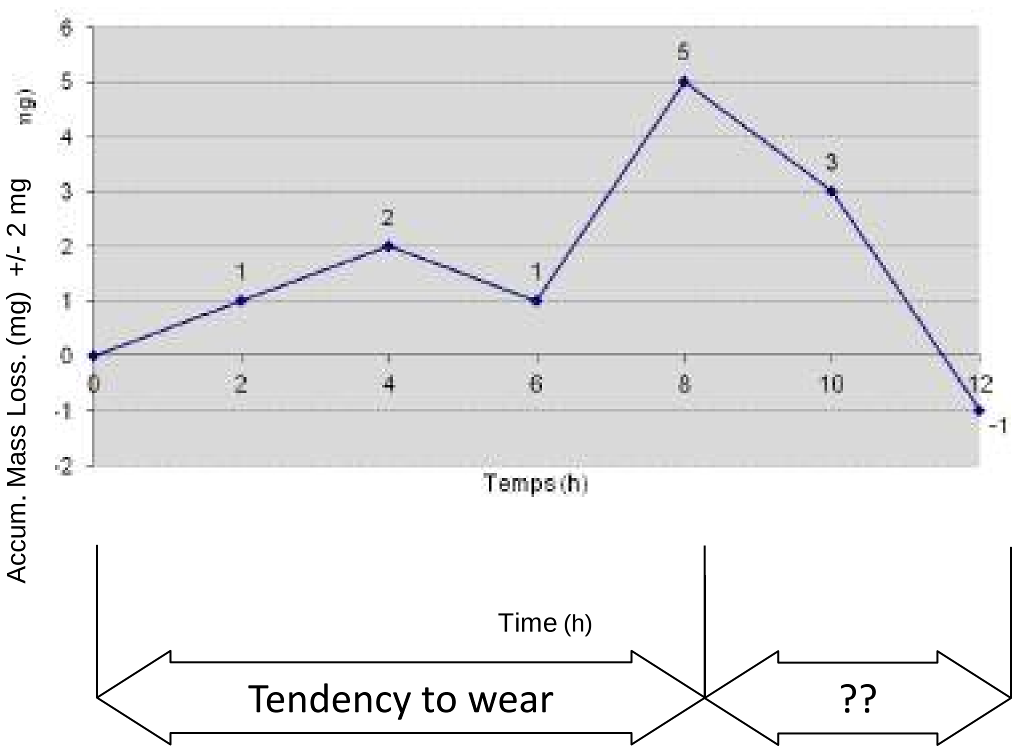
Why Polyurethane?

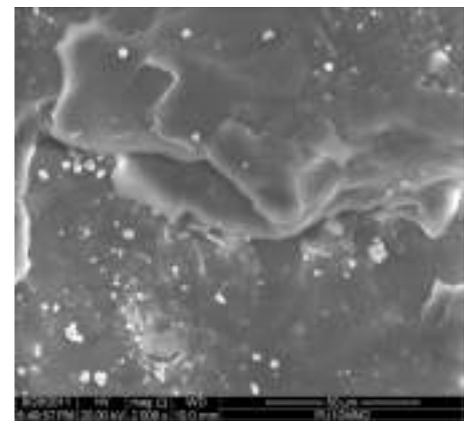
	« Adapted » Miller ASTM G75
Slurry	SiO_2 (Sílica) + Fe_3O_2 Hematite 50% de sólidos + Distiled Water Room Temperature : 18°C +/- 2°C
Sample	Polyurethane Density : 1,1 g/cm^3 Hardness : 90 Shore A
Pad	Glass Hardness : 6 Mohs

Test 1

Parameters

Load	15 g – 0,3 g/mm²



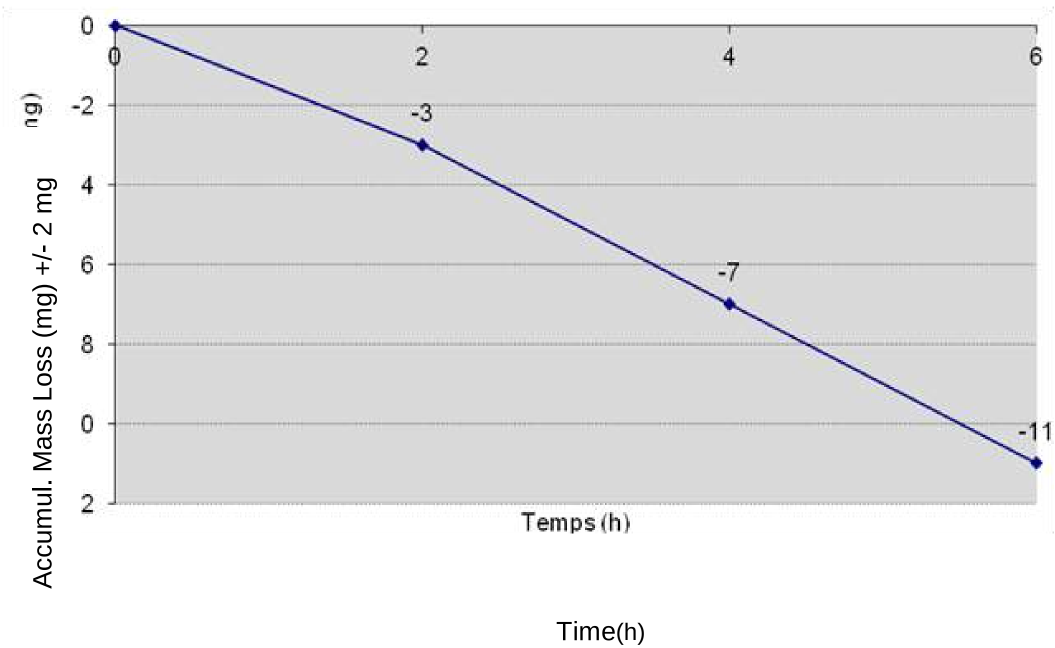


SEM – Embedded abrasive particles

Test 2

Parameters

Load	50 g – 1 g/mm²



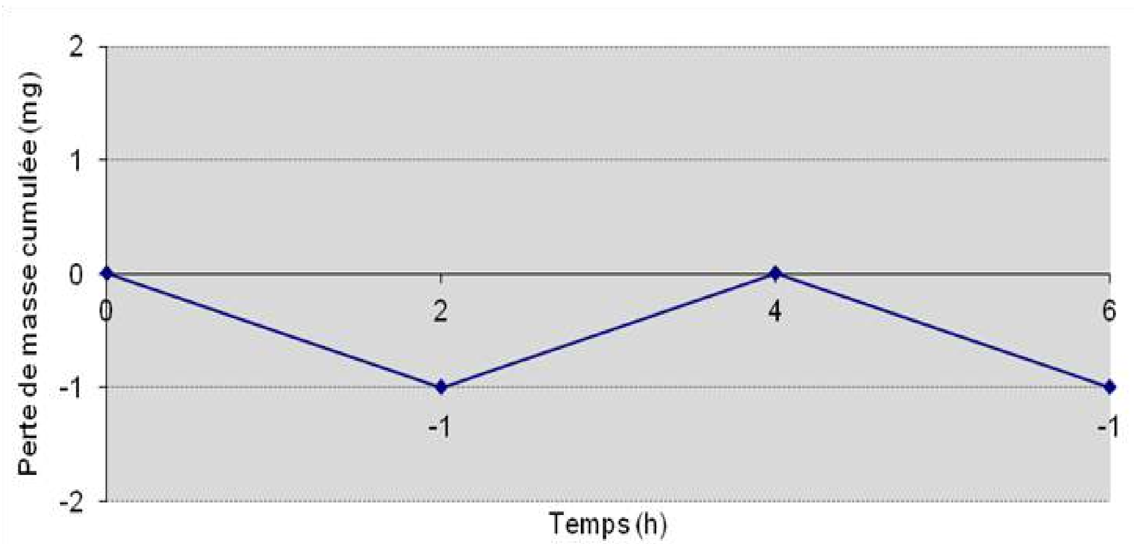
→ Particle Adhesion

→ Role of the applied charge (Load)

Test 3

Parameters

Load	0 g/mm²



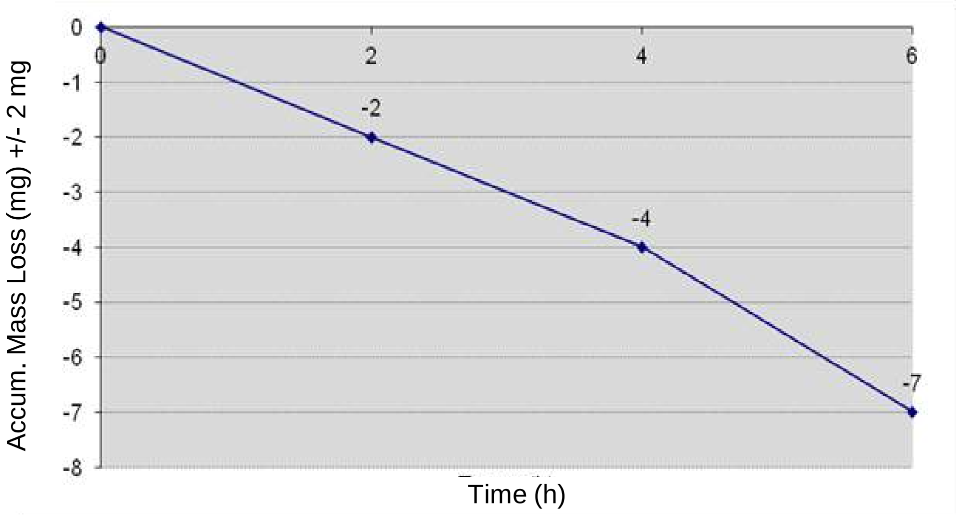
Time (h)

→ Values have no significance

Test 4

Parameters

Load	93 g – 2,0 g/mm²



→ Significant values

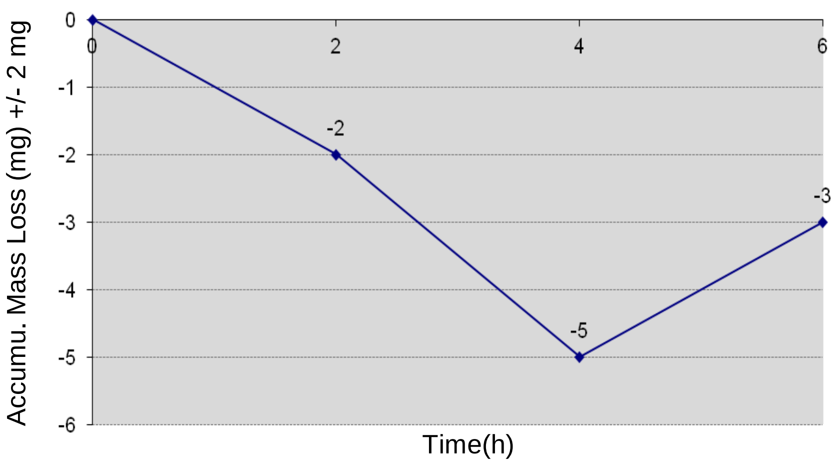
→ Increased particle adhesion

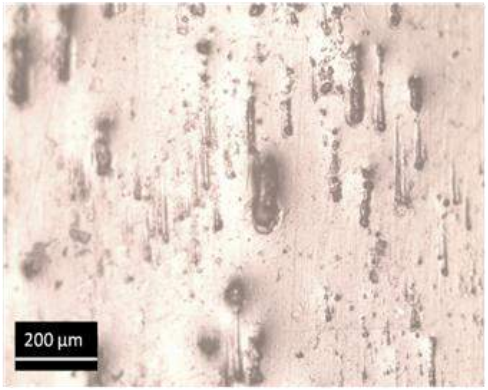
Test 5

Parameters (the same as in Test 1)

Load	15 g – 0,3 g/mm²

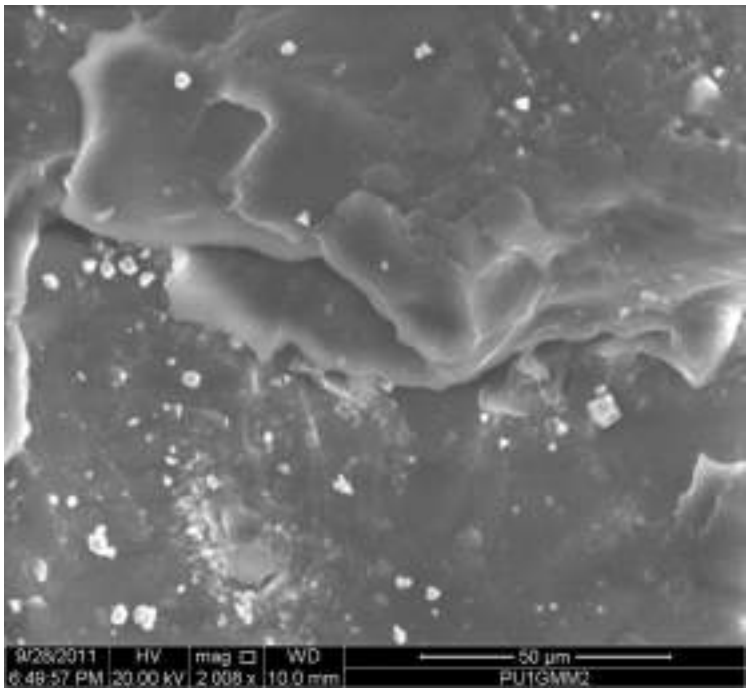
→ Previous Roughness influencing behaviour (fatigue, adhesion)

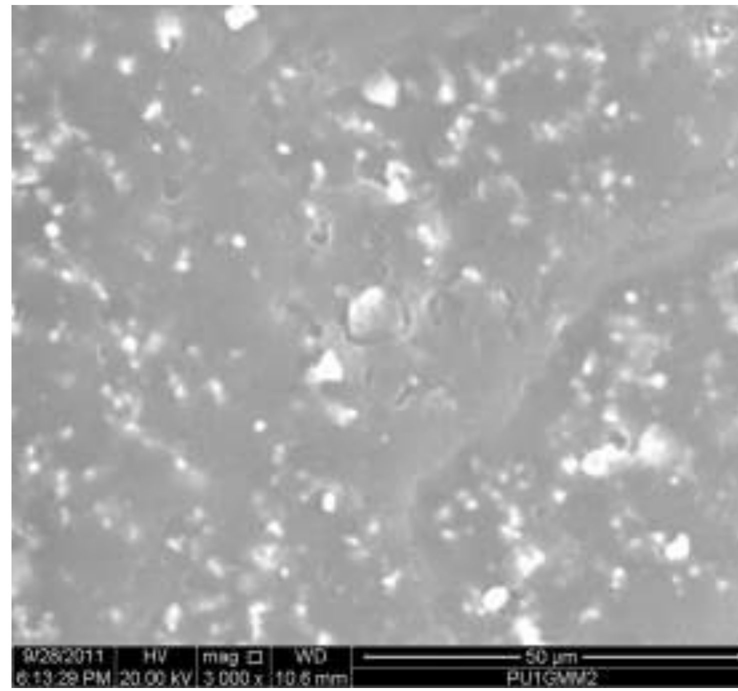




Irregularities in sample surface

Abrasive particles embeded in polyurethane and fatigue cracks





Conclusions

- Abrasion tests based on Miller`s procedures allow understand many aspects of wear phenomena and correlate them to microstructure of materials.
- Materials may be ranking accordingly to their response to the abrasivity of the slurries allowing better decision in selection of materials for engineering projects.
- Some procedures proposed in ASTM G75-07 standard need to be changed or redefined, otherwise the test can not be adopted as a “standard”.

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Thank you all!