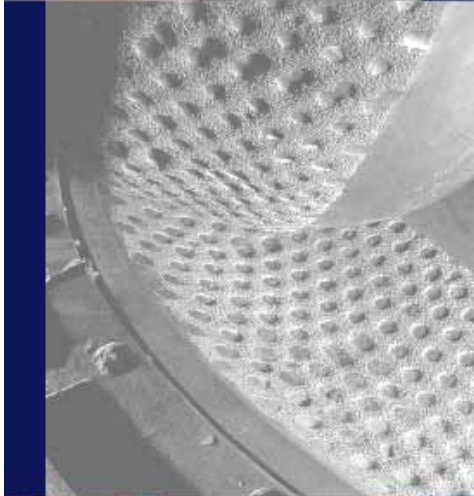




Innovation and Optimization in Difficult Times

MMMA Seminar – 08 May 2009



MAGOTTEAUX

SHAPING A WORLD OF PERFORMANCE

Milling circuit optimization
Methodology and objectives

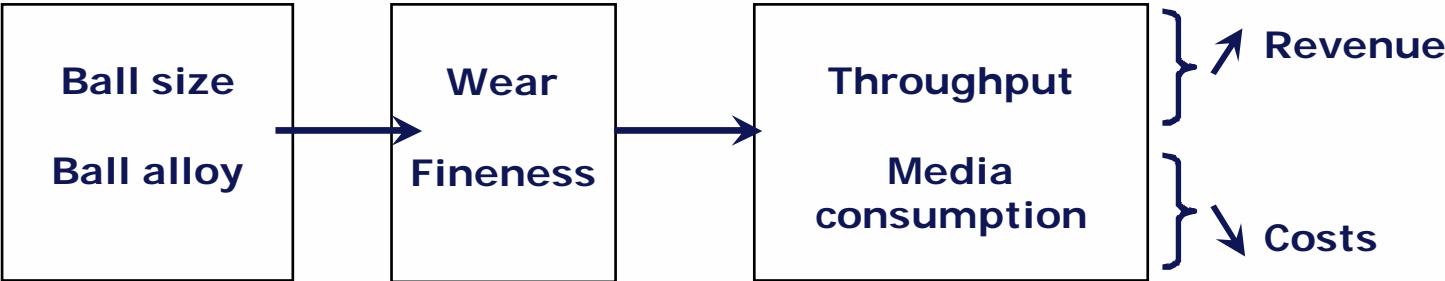
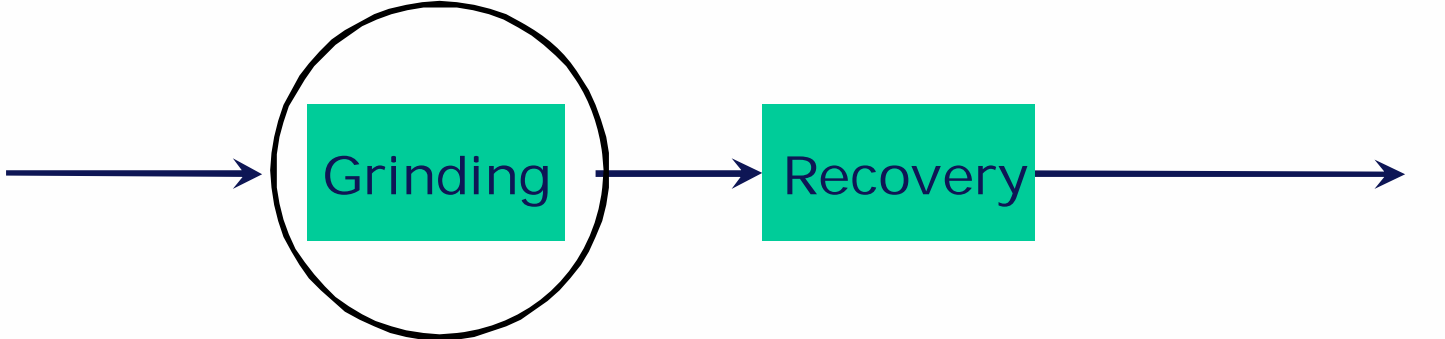


Michel Legros – Sales Engineer
Johan Dahner – Process Engineer

Agenda

- From grinding to concentration
- Milling
 - ✓ Wear Mechanisms
 - ✓ Liner design optimization
 - ✓ Alloy optimization
 - ✓ Total milling cost
- Down Processing
- Examples & Conclusions

From Grinding...

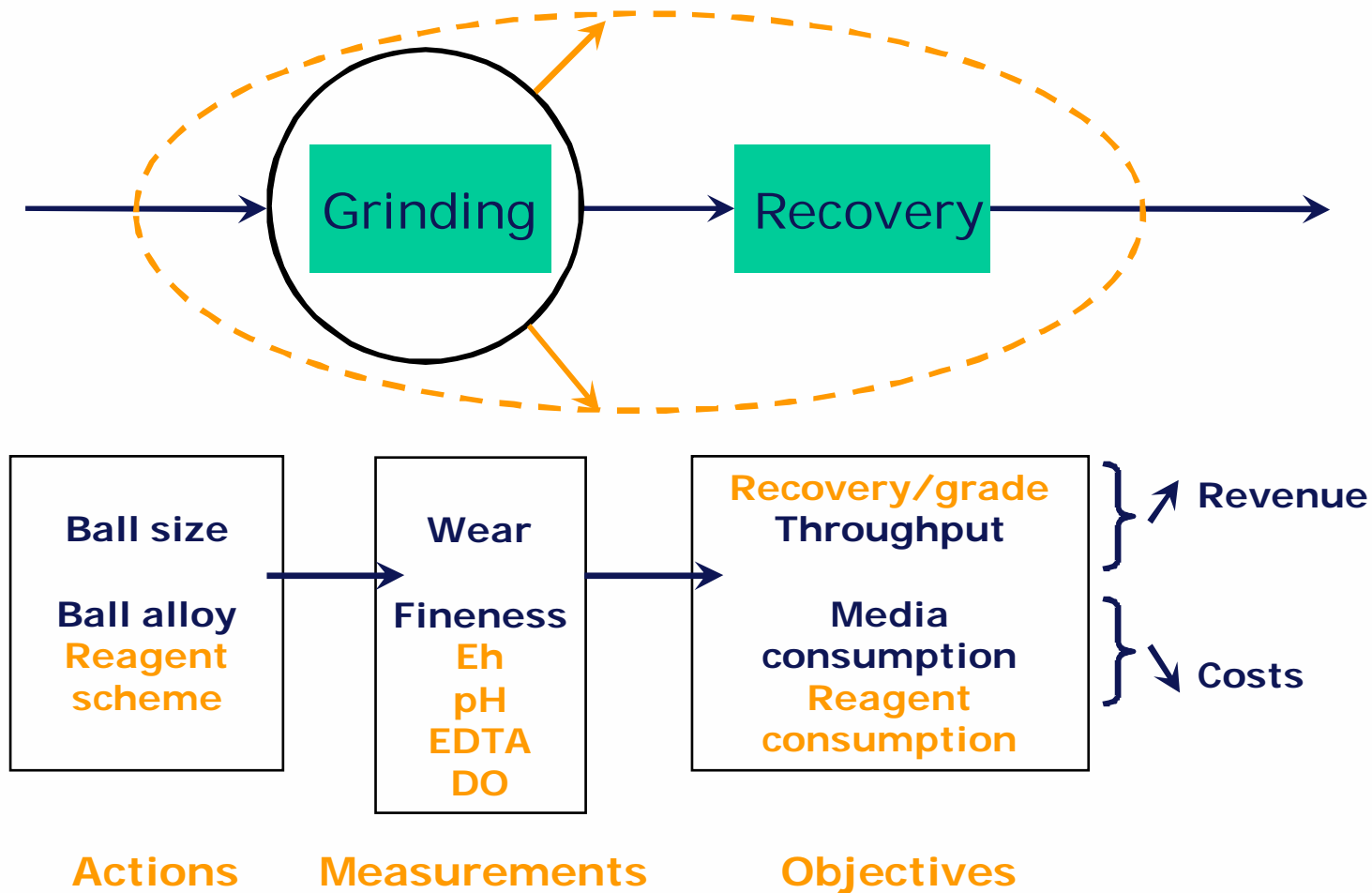


Actions

Measurements

Objectives

... to Concentration



Right alloy gives right particle surface chemistry

From Grinding to Concentration

Product
=
tailor-made solution
to optimize wear & chemistry

A change in grinding media alloy has the potential to:

- ✓ Reduce media consumption due to lower wear rate;
- ✓ Reduce reagent consumption as the system is cleaner;
- ✓ Alter the pulp chemistry which may have a positive impact on flotation performance.

→ Which can result in reduced operating costs and increased revenue.

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Wear Mechanisms

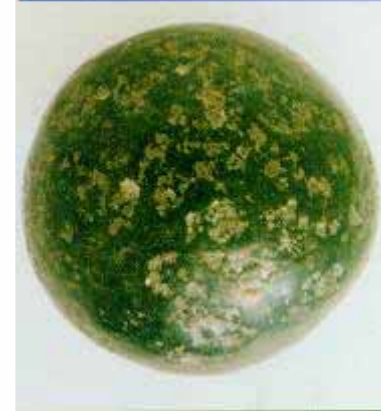
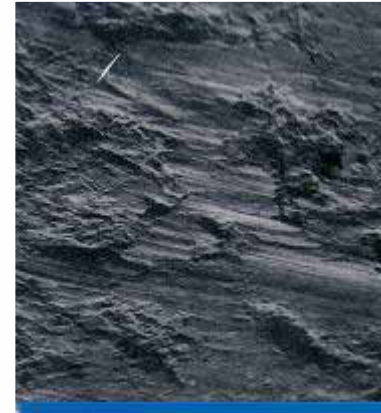
Wear Mechanisms



Abrasion



Corrosion



Impact

Wear Mechanisms

ABRASION

1. TYPE OF MINERALS, PERCENTAGE, HARDNESS

2. INFLUENCE OF GRANULOMETRY (ORE FEED SIZE)

- ✓ F_{100}
- ✓ F_{80}
- ✓ $F_{100} - F_{80}$

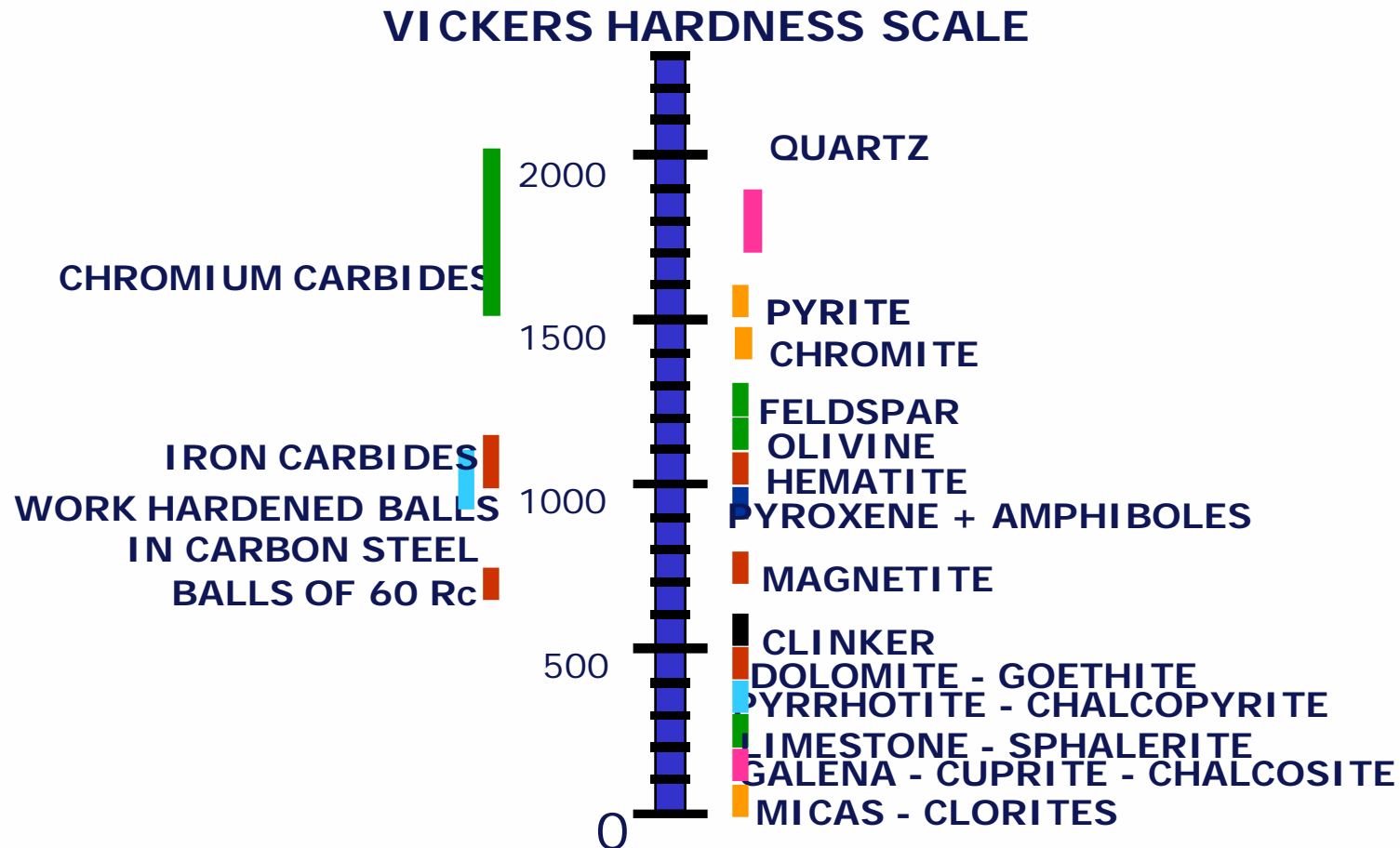
3. INFLUENCE OF SHAPE OF PARTICLES
(COARSE GRINDING)

- ✓ SPHERICAL (CLINKERS)
- ✓ ANGULAR, EDGE SHAPE
- ✓ LAMILAR SHAPE (EX : MICAS)

4. MILL DIAMETER

Wear Mechanisms

HARDNESS OF MINERALS AND METAL/METALLIC PHASES



Wear Mechanisms

CORROSION

1. WATER COMPOSITION

- ✓ pH
- ✓ IONS Cl^- , $\text{S}^{=}$
- ✓ CONDUCTIVITY OF WATER

2. ORE COMPOSITION

- ✓ CONDUCTIVE MINERALS

Fe_3O_4 , Fe_2O_3 , $\text{FeO} \cdot \text{Cr}_2\text{O}_3$

All sulphides minerals (Pyrite, Chalcopyrite, Chalcosite, Pyrrhotite,...)

- ✓ NON CONDUCTIVE MINERALS

Quartz

Silicates (Feldspar, Pyroxenes, ...)

Carbonates (Ca CO_3 - Mg CO_3)

Wear Mechanisms

CORROSION (cont'd)

COMPETITION BETWEEN ABRASION AND CORROSION

ABRASION IS HIGHER IN PRIMARY MILLS

CORROSION IS HIGHER IN SECONDARY AND REGRIND MILLS

Wear Mechanisms

IMPACTS

1. SIZE OF BALLS
2. TYPE OF DISCHARGE
 - OVERFLOW
 - GRATE
3. INFLUENCE OF LINING LIFTING EFFECT AND SPEED DEFINING TRAJECTORIES
4. INFLUENCE OF % SOLIDS
5. INFLUENCE OF FILLING COEFFICIENT
6. INFLUENCE OF THE ORE GRINDABILITY
7. GRINDOUT PROCEDURE
 - OVERFLOW MILLS
 - GRATE DISCHARGE MILLS
 - SAG MILLS

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Impacts: Liner Design Optimization

The liners in the mills have 2 main tasks:

- ✓ to protect the mill shell from damage due to wear
- ✓ to transmit energy to the ball charge → grinding

Compromise between lifetime and efficiency

Some examples for coarse milling:



1) 75% Vc
J=30%
Angle 22°



2) 75% Vc
J=30%
Angle 5°



3) 85% Vc
J=30%
Angle 22°

Impacts: Liner Design Optimization

Example of trajectory simulation:



Sag Mill

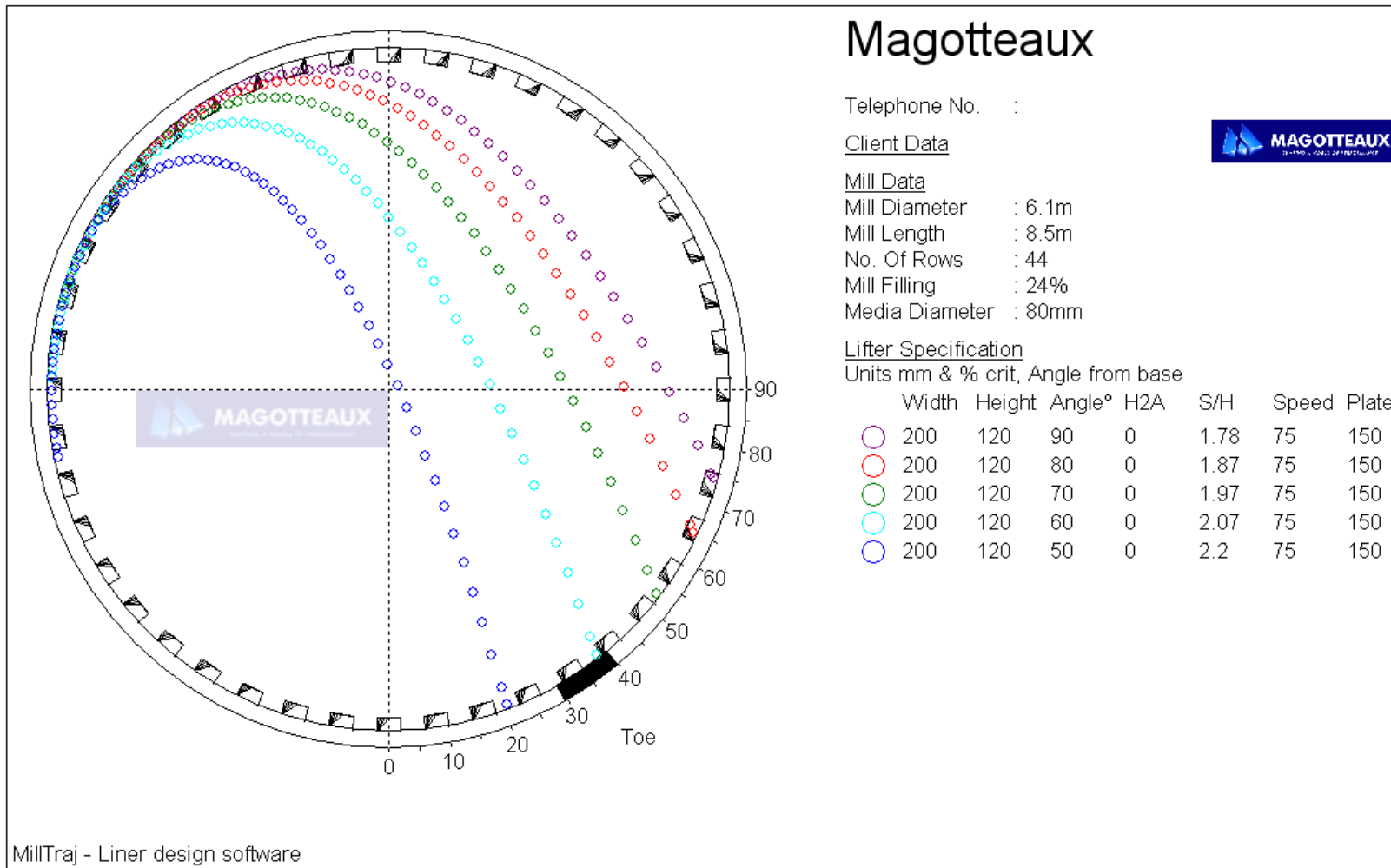
Hlift 12 mm

Angle 22°

Vcr = 75 % - J = 30 %

Impacts: Liner Design Optimization

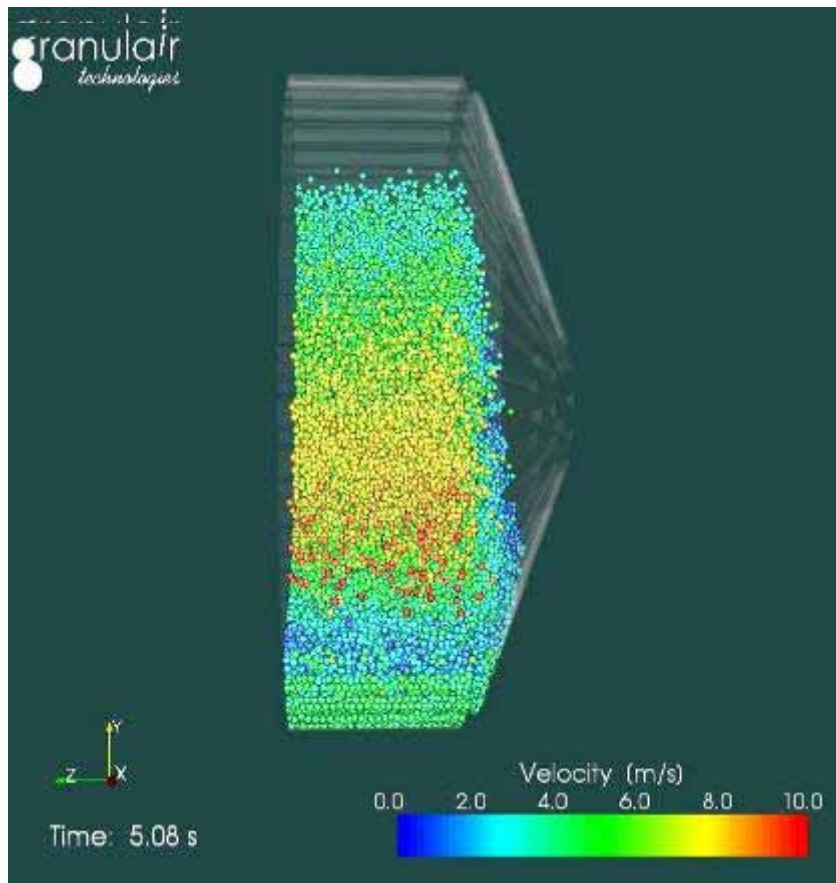
Other example of trajectory simulation:



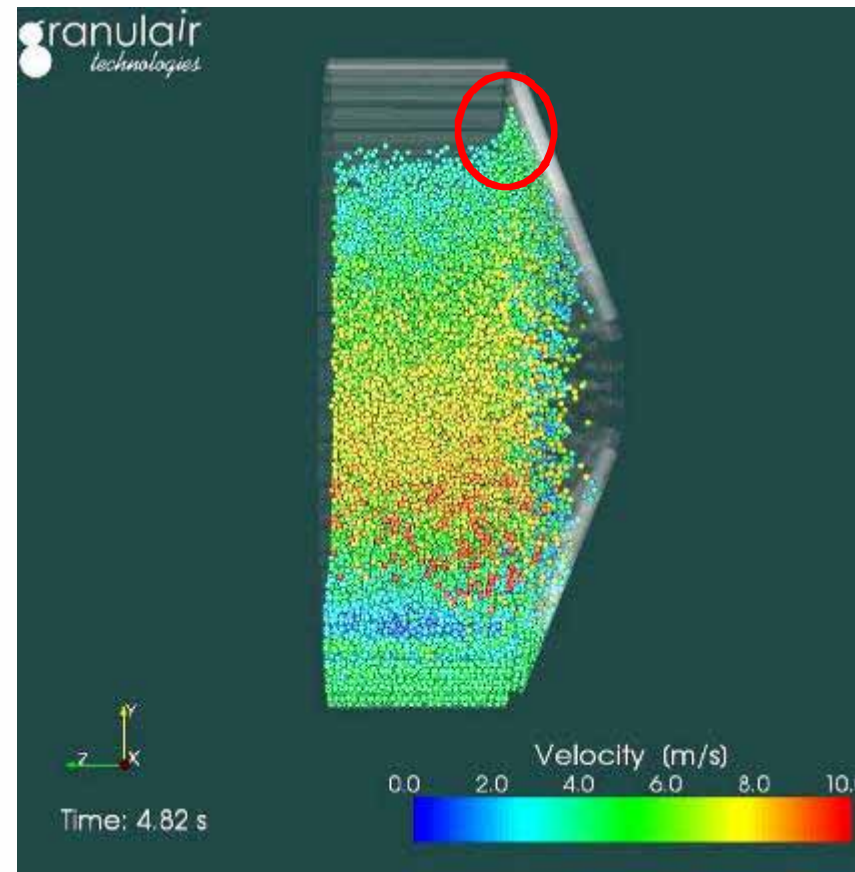
Impacts: Liner Design Optimization

Influence of end liners (DEM simulation):

Optimised end liners



Aggressive end liners



Both cases with optimised shell liners

Impacts: Example

Primary Mill (dia 5.5m using 90 mm balls).

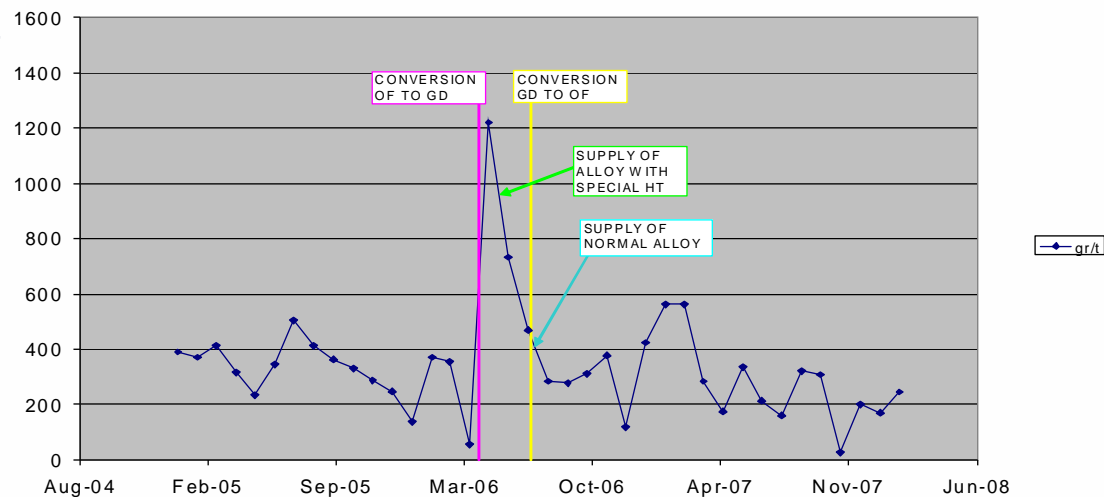
Conversion from OVERFLOW to GRATE DISCHARGE.

Very aggressive lifters on the grates - lift = 200 mm
- attack angle = only 5°

The balls and liners started to break and spall (see pictures)

Wear increased from 388 up to 1200 gr/T (3 x more)

Supply of balls with a special heat treatment was required and wear went down.



Impacts: Example

EFFECT ON BALLS 



 EFFECT ON LINERS

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Corrosion/Abrasion : Alloy Optimization

- ✓ Marked ball test
- ✓ Survival test
- ✓ Continuous wear monitoring
- ✓ Sampling



5 steps to alloy optimization



STEP 1: SAMPLING

- Grinding media samples
- Pulp and water samples
- Data collection

STEP 2: TECHNICAL STUDY

- Benchmark consumption (wear monitoring)
- Define segmentation A/C/
 - A/C based on step 1
 - I based on liner design and milling conditions
- Pulp chemistry survey

STEP 3: RECOMMENDATION / TEST

- Marked ball test (MBT)

STEP 4: SUPPLY

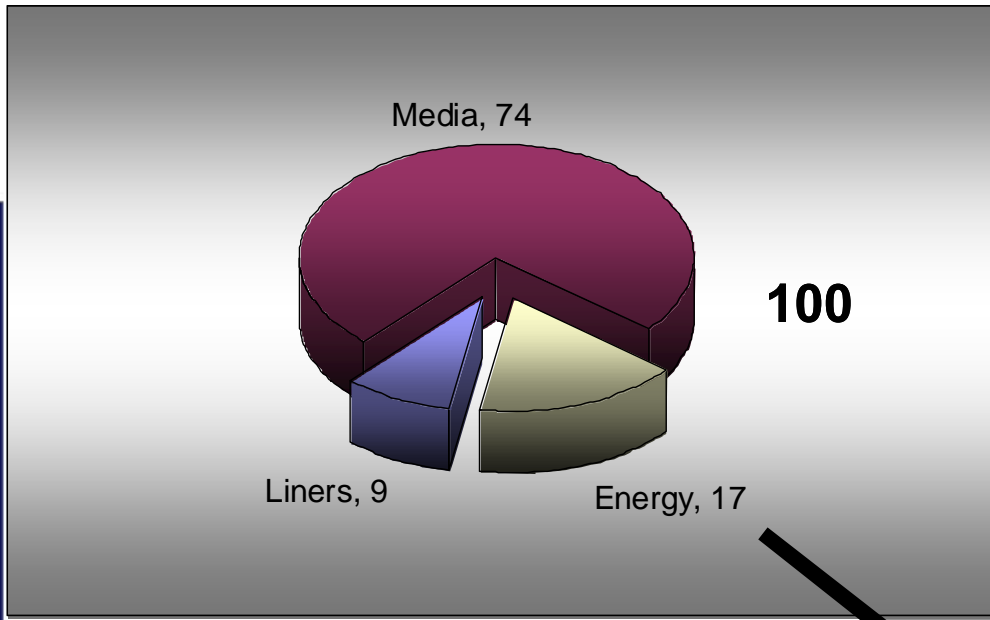
- Industrial test
- Benchmark consumption new alloy

STEP 5: CONTINUOUS OPTIMIZATION

Agenda

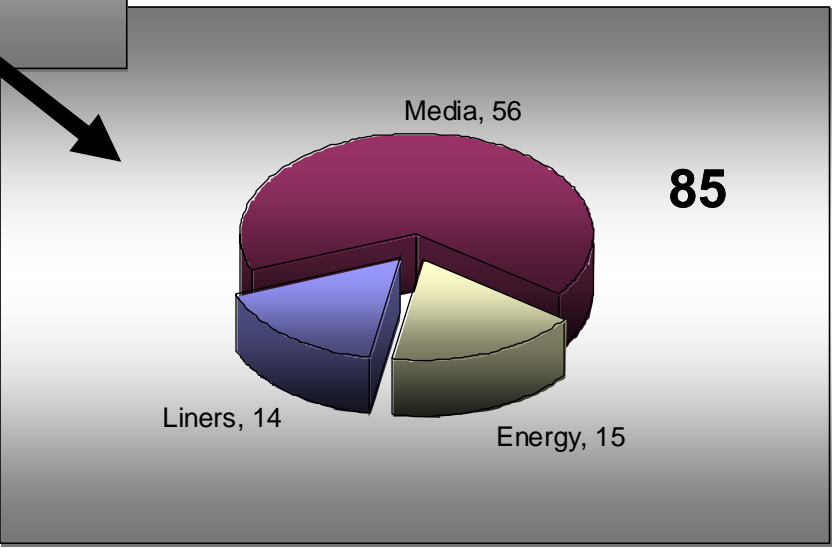
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Reducing Milling Costs by optimizing:



- ✓ liner design
- ✓ ball charge alloy

Liner (+ 50%):	9	→	14
Media (-25%):	74	→	56
Energy (-10%):	17	→	15



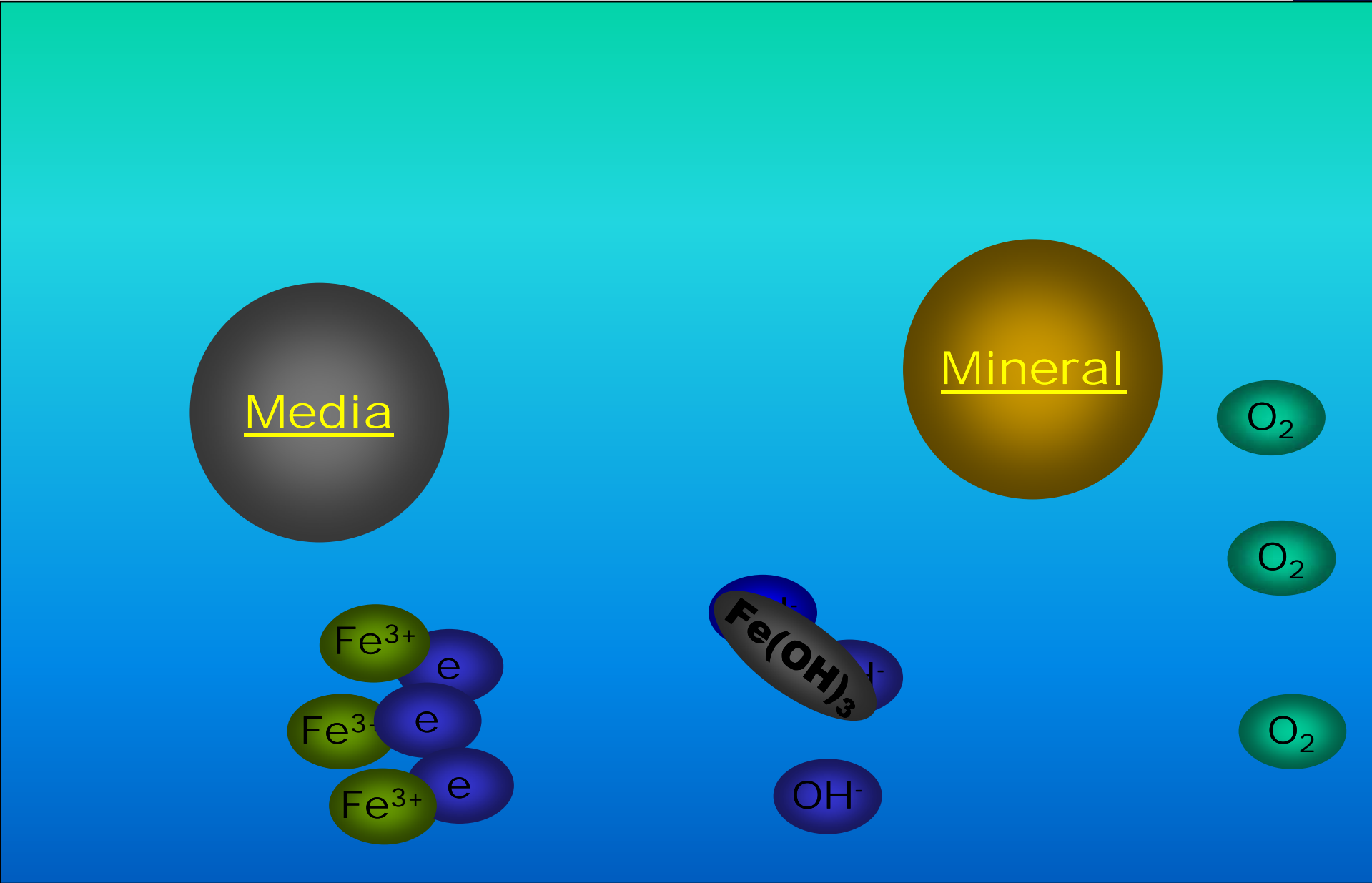
Cost Reduction: 100 → 85

Based on specific Case, results may differ from plant to plant

Agenda

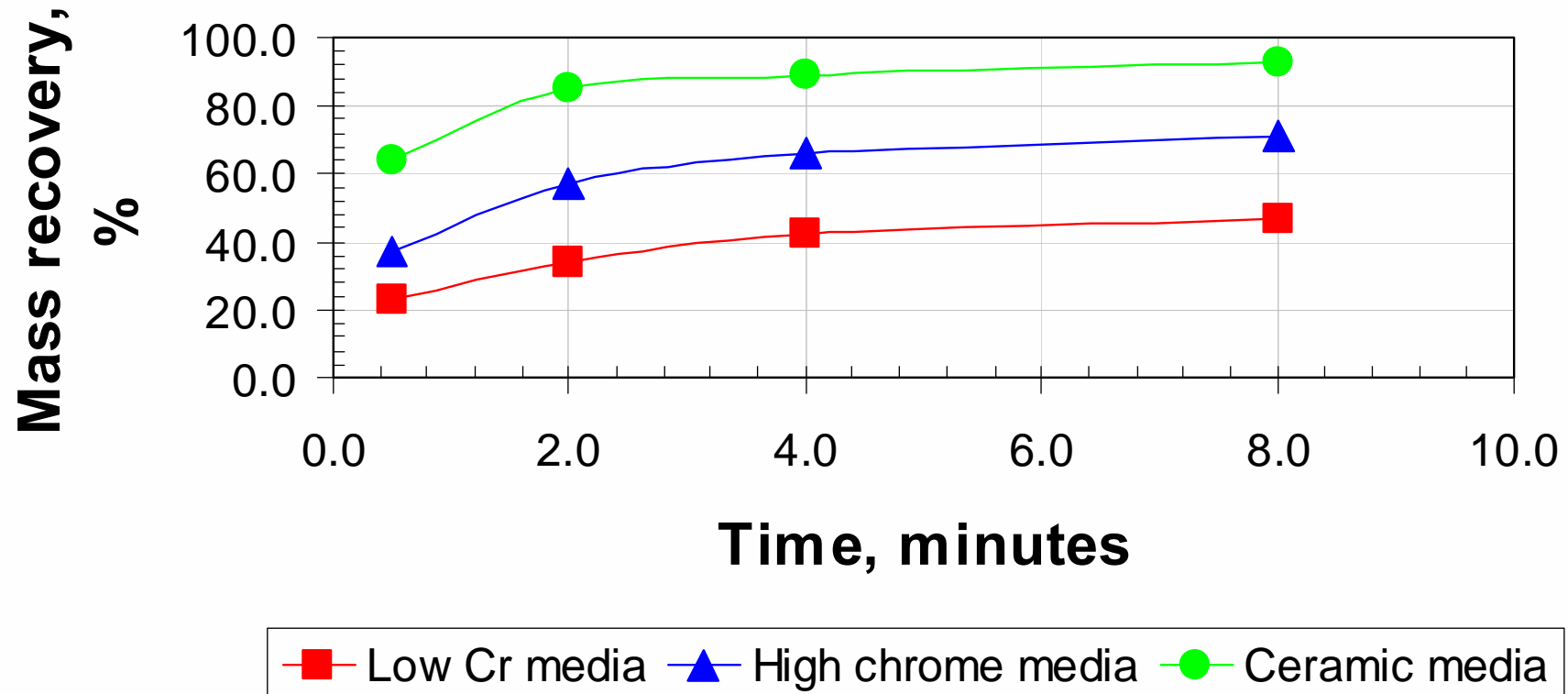
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What happens in grinding mills?



How the ore is prepared affects its flotation

Grinding with different media affects flotation behaviour.



Pulp Chemistry modification

Change from low chrome to high chrome grinding media has an impact on the pulp chemistry by:

- ✓ Shifting the Eh to more oxidising potentials,
- ✓ Increasing the level of oxygen in the pulp, and
- ✓ Reducing the EDTA extractable iron in the pulp.

This has been noted for Cu, Pb/Zn, Ni, Au and PGM ores.

Agenda

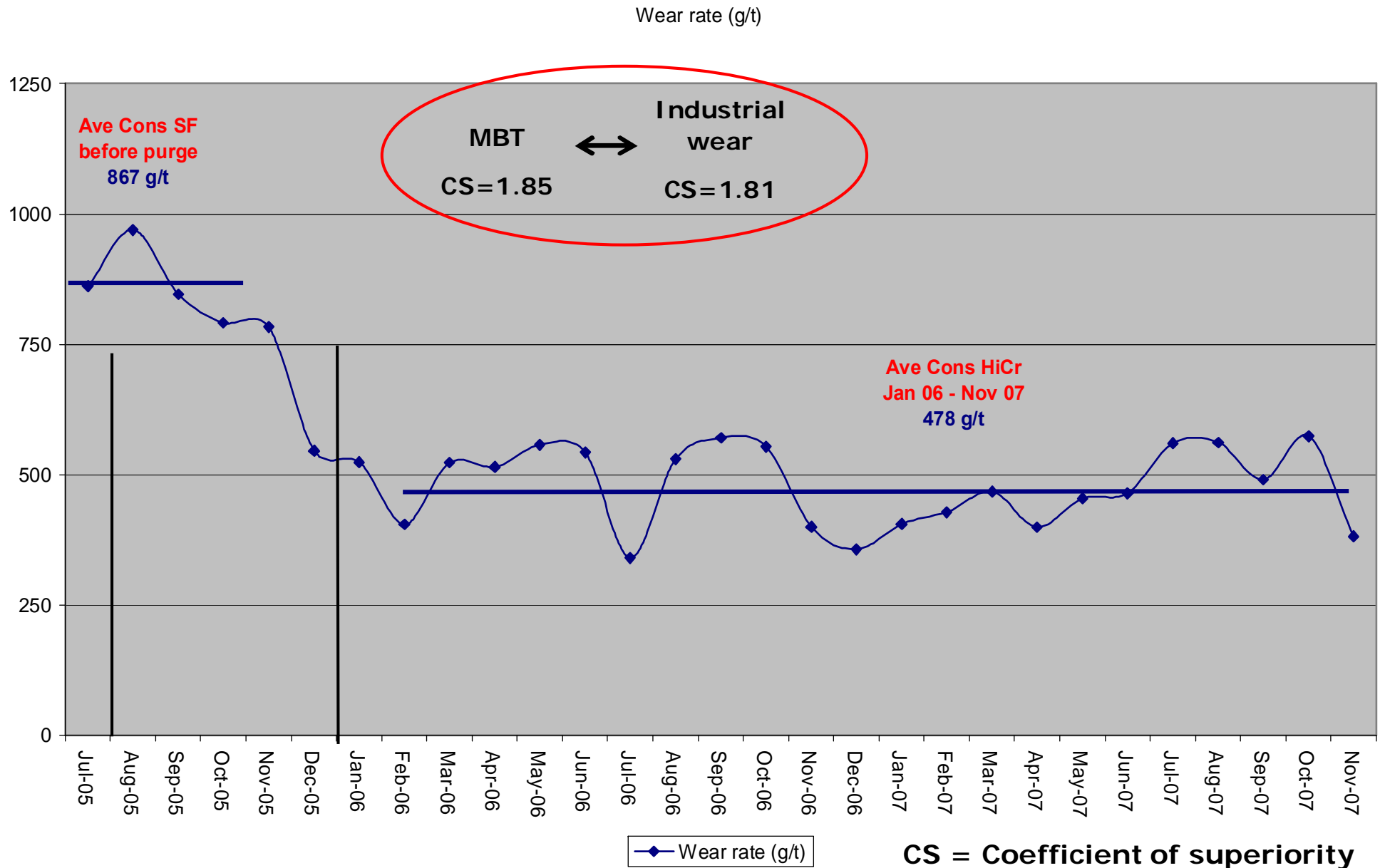
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Example: MBT Results

	mm lost	CS vs REF
HiCr 12% REF	3.24	1.00
HiCr 12% HT B	2.97	1.09
HiCr 12% HT C	2.78	1.17
HiCr DEV A	2.66	1.22
HiCr DEV B	2.53	1.28
HiCr DEV C	2.27	1.43



Example: Wear relation between industry & MBT

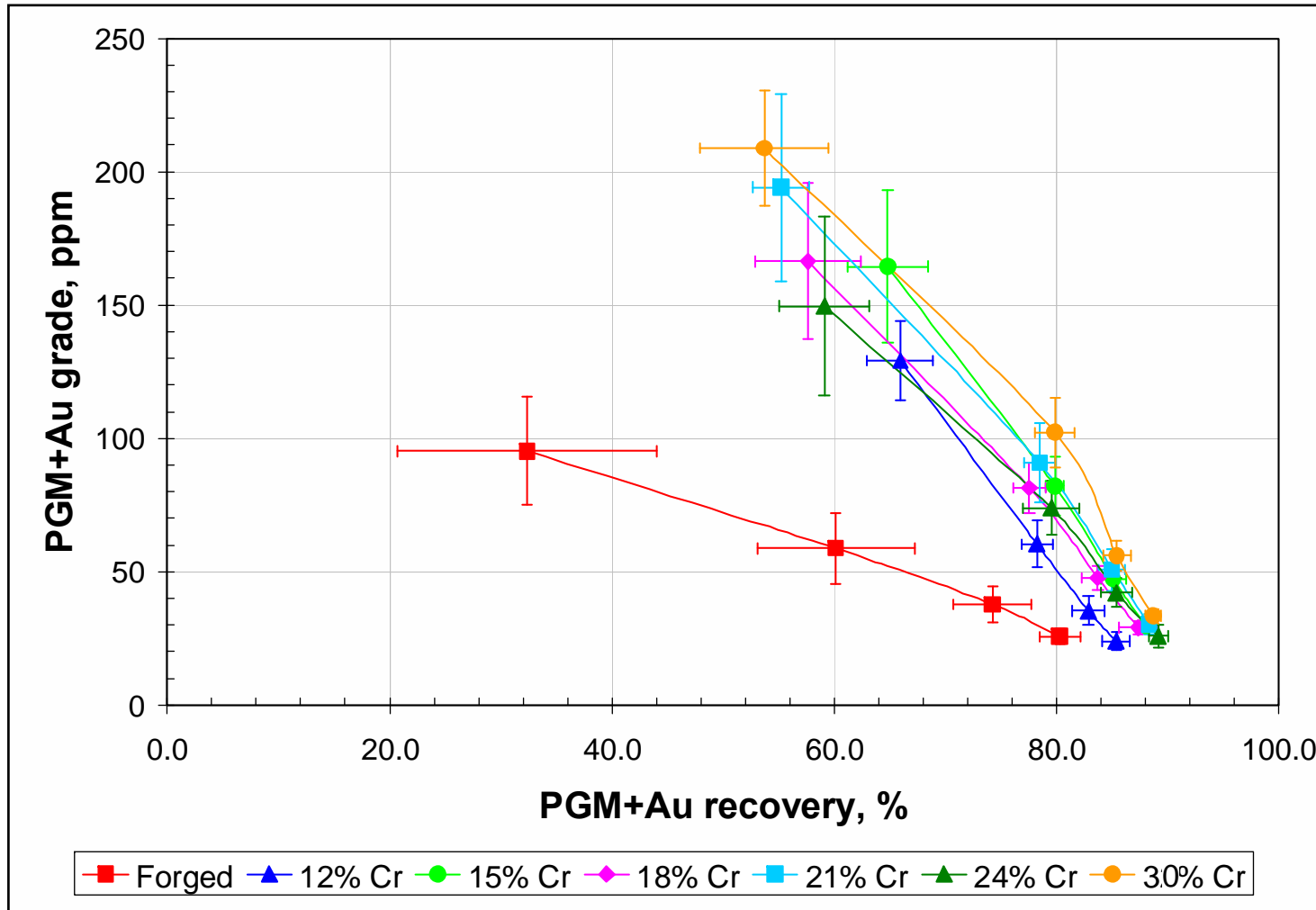


Examples: Pulp Chemistry Survey

Media	Pulp chemistry			
	pH	Eh, mV (SHE)	DO, ppm	EDTA Fe, %
Forged steel	9.13	-242	0.16	0.468
12% Cr	9.52	38	0.56	0.057
21% Cr	9.37	71	0.76	0.034



Examples: Influence on Grade/Recovery



Conclusions

**Product
=
tailor-made solution
to optimize wear & chemistry**

A change in grinding media alloy has the potential to:

- ✓ Reduce media consumption due to lower wear rate;
- ✓ Reduce reagent consumption as the system is cleaner;
- ✓ Alter the pulp chemistry which may have a positive impact on flotation performance.

→ Which can result in reduced operating costs and increased revenue.

Thank you for your attention

Any questions ?