

# SAG Mill Optimisation and Increasing Throughput at the Phu Kham Copper-Gold Operation

Dr Rajiv Chandramohan – Mill Ops 2018

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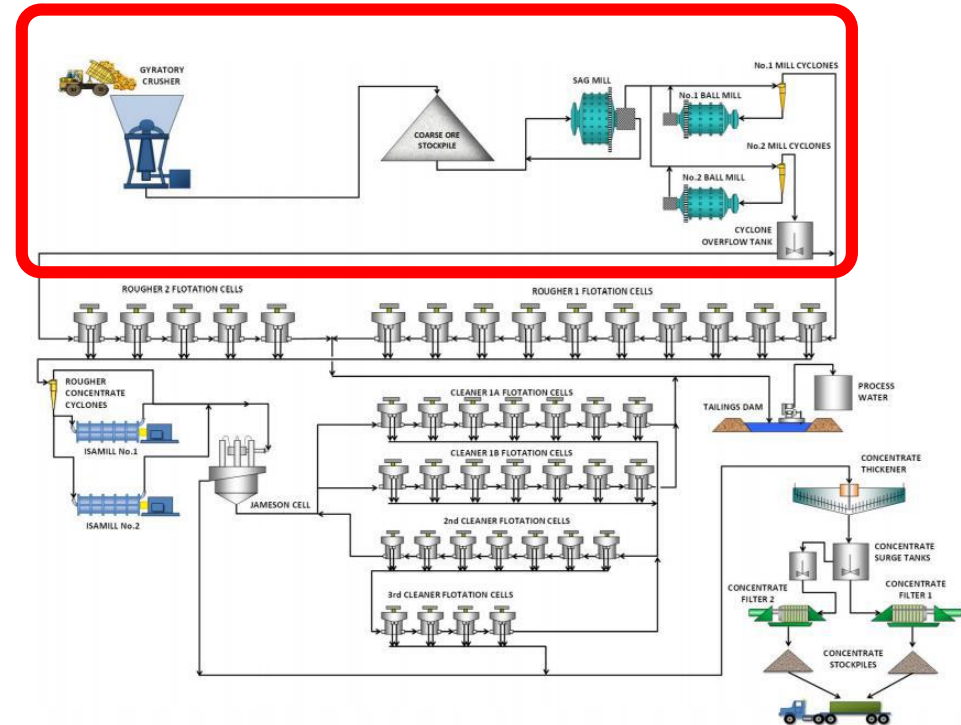
# Phu Kham Copper Gold Operation



- Located in Laos (Laos People's Democratic Republic)
- Operated by Phu Bia Mining Ltd: 90% owned by PanAust Limited and 10% owned by Laos Government
- Commissioned in 2008 – nameplate production of 12Mt/y
  - currently 19M/y with the addition of second ball mill
- Considered to have the lowest installed capital cost per tonne of throughput – Lane & Dickie 2009

# Phu Kham Comminution Flowsheet

- Primary Crusher CSS ~ 110 mm
- 34 ft x 18 ft (EGL) SAG mill, 13 MW
- Two 24 ft x 38 ft (EGL) ball mills, 13 MW each
- SAB circuit
- SAG mill limited
  - High diorite and skarn feed
- Circuit grind ~ 106  $\mu\text{m}$
- Theoretical maximum comminution circuit capacity 3100 t/h (SAG Ecs 4.2 kWh/t)
- Flotation circuit capacity limit ~ 2700 t/h
- Advanced process control – minimising operator interaction



# Context

## Objective

- Evaluate six liner design for optimal SAG mill performance
  - Predict liner life (availability)
  - Determine operating conditions to maximise power draw
  - Determine onset of slurry pooling
- Optimise SAG mill for variable competency
  - Emphasis on competent ore

## Ausgrind (built on +30 yrs of operating data)

- Published in Comminution 2018 and Procemin 2013
  - Comminution circuit design and optimisation
  - Liner wear prediction model
  - SAG mill trajectory model
  - Slurry pool model



# Optimising SAG Mills

- **Design objective**

- Increase instantaneous throughput at start-up (75%Nc, 15% v/v ball load, 28% v/v total charge)
- Increase liner life
- Increase volumetric slurry flow for greater than 2500 t/h ore feed rate
- **Maximise power draw = increase in throughput**

- **Design Limitation**

- *Max bearing pressure reading 75 bar / total liner + charge mass = 1200 t*
- *Must not exceed operational sound level of 55 dB*

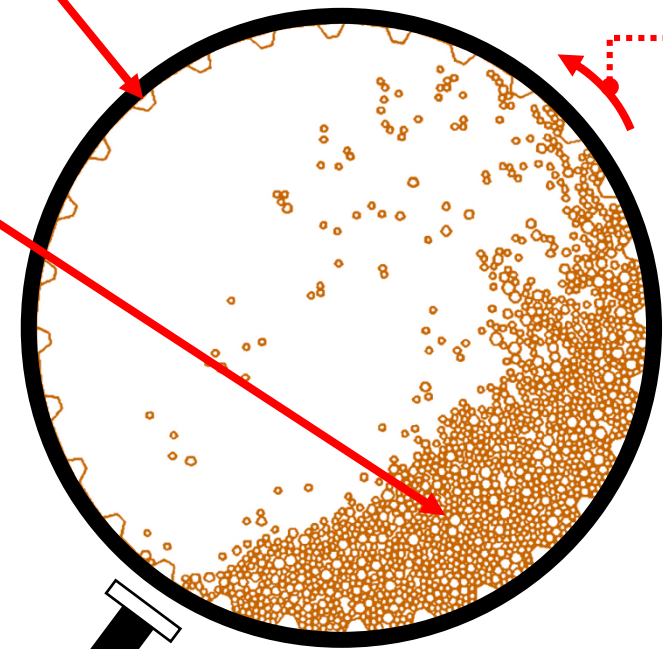
**Lifters + liners =**  
protects the shell from wear

**Charge (mill load) =**  
rocks + steel media + slurry = Power draw

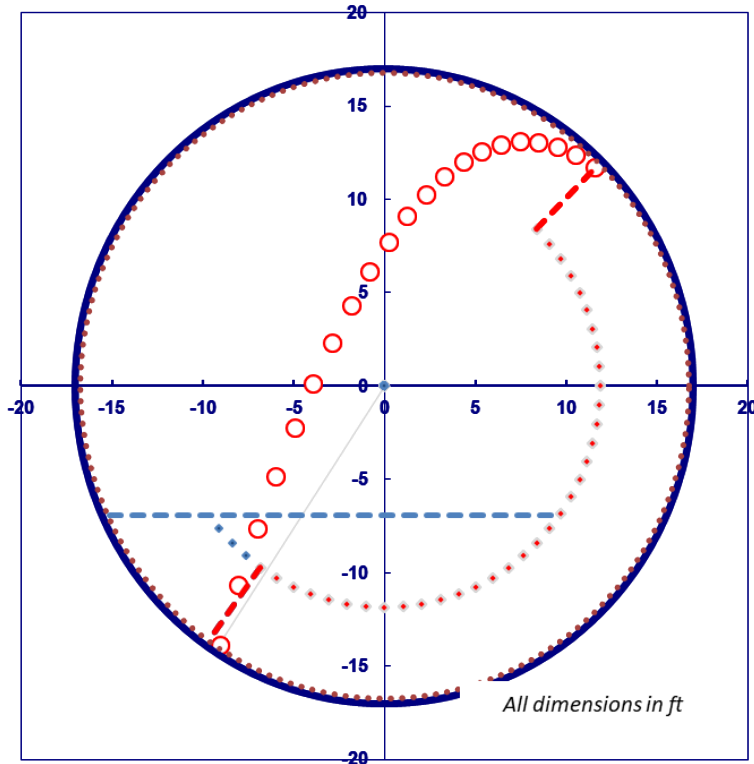
**Controller:**  
Mill speed, Nc = adds energy for breakage = power draw

**Controller:**  
Microphone, dB = indicates direct shell impact

**Controller:**  
Load cell, t = Indicator of total mill charge (ball + rock + slurry)



# Ausgrind SAG Mill Optimisation Tool

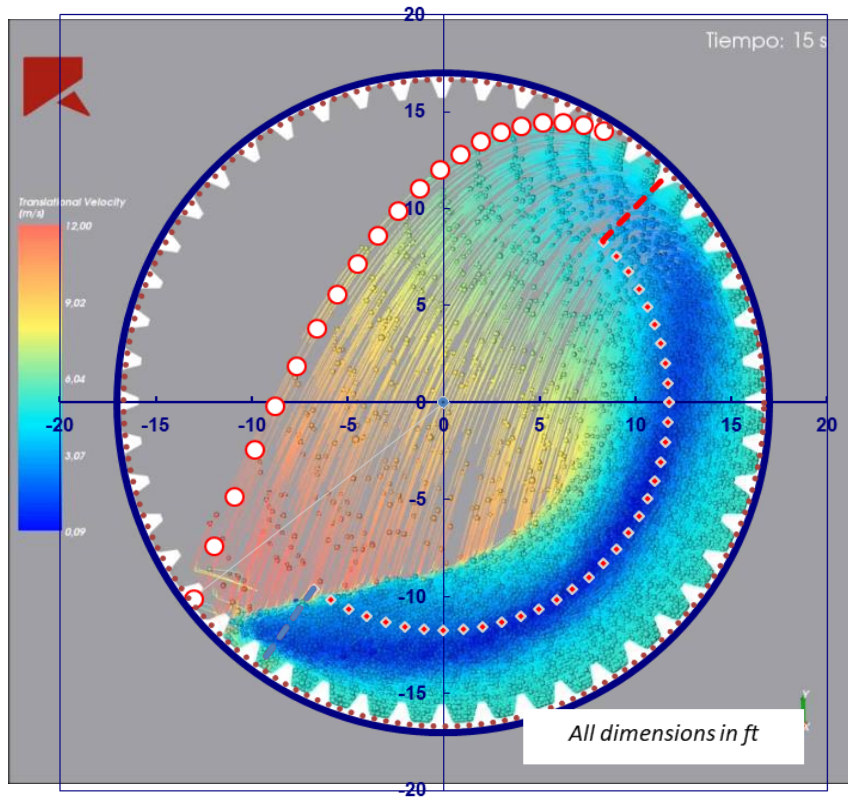


**No Pooling = 12.3 MW (14% grate OA)**

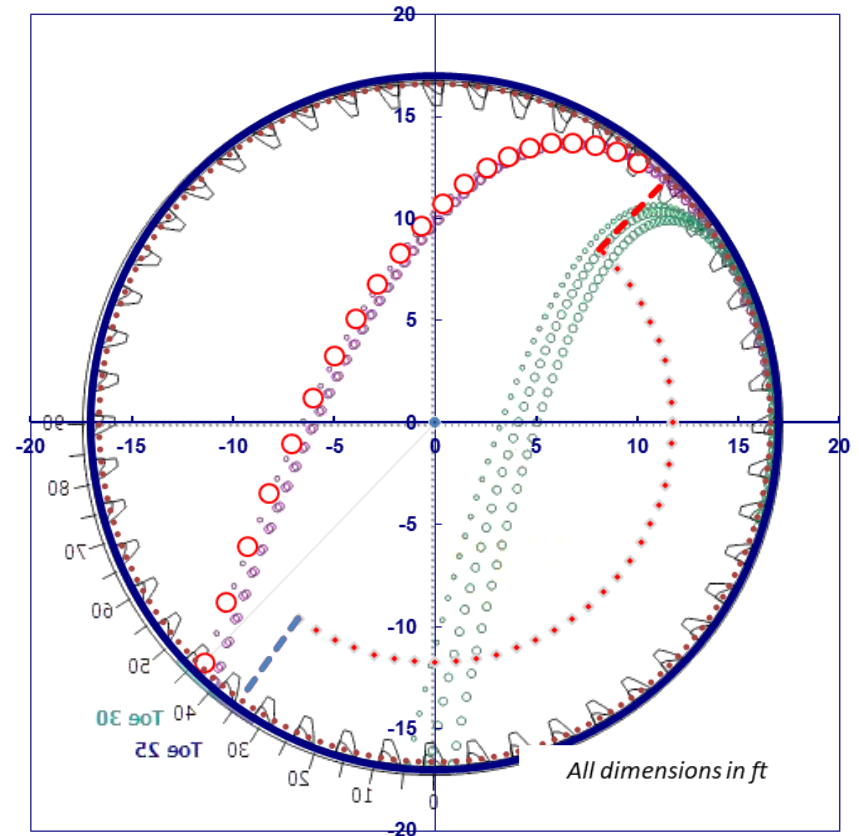
**Pooling = 11.6 MW (5% grate OA)**

- **Trajectory calculation**
  - Molycop tools' spreadsheet calculation (based on Powell trajectory model 1991)
- **Power Model calculation (Charge profile)**
  - Morrell power draw 2016 (presented at Comminution 2014)
- **Slurry Pool calculation (discharge capacity)**
  - Latchireddi slurry pool model 2002

# Trajectory and Charge Profile Validation



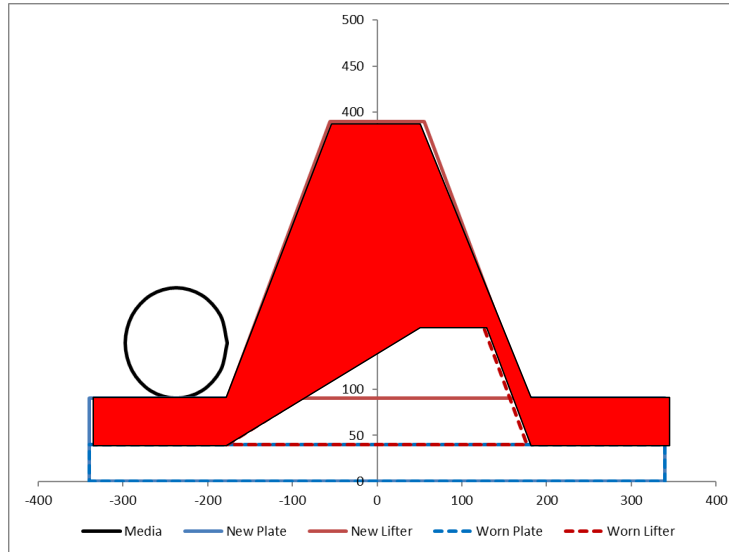
DEM Validation



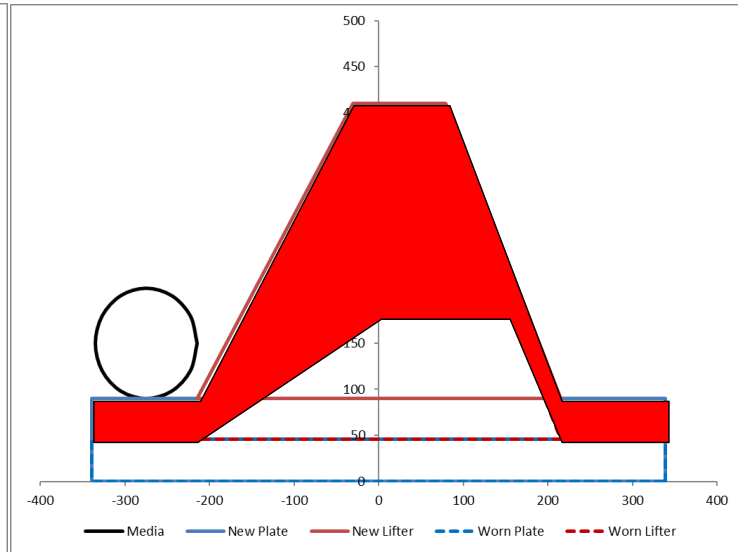
MillTraj Validation

# Parametric Liner Wear Model

Base case liner design



Test liner design

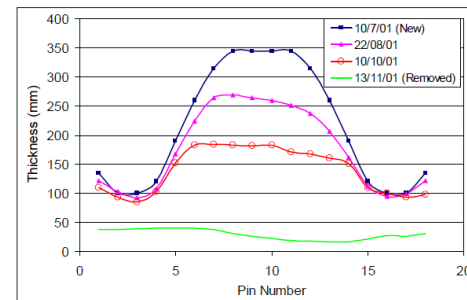


- **Parametric model**

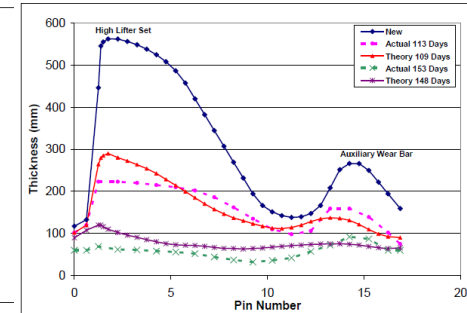
- Plate thickness and face angle are linked parametrically
- *Bird et al – Applying mill control to account for liner wear on the Cadia 40ft mill, SAG 2015*
- New liner's thickness and face angle dimensions are adjusted to match the equivalent cross-sectional area / volume loss as the base case (RED AREA)
- Extended life of the test liner is then calculated by determining time taken to reach critical face angle or plate thickness

# Liner Wear Predictions (Cadia Data)

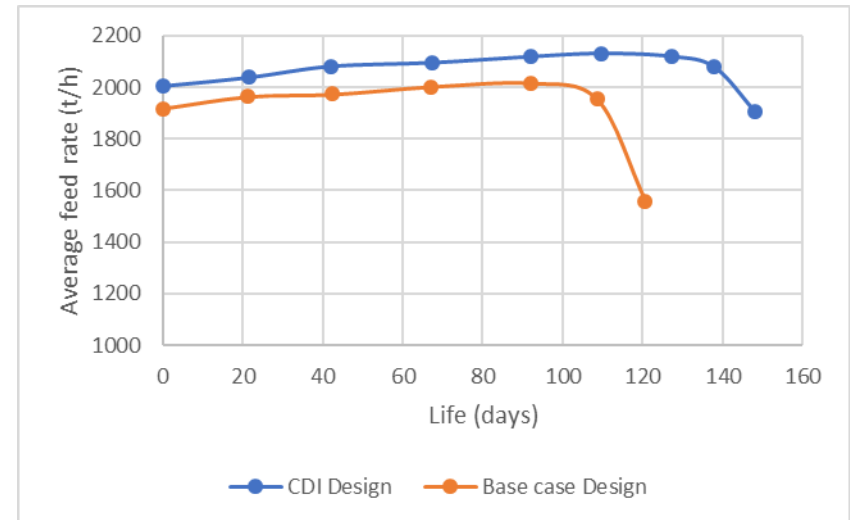
Shell Profile	Base case	CDI design
Face angle (deg)	30	28
Rear angle (deg)	40	5
Lifter height (mm)	250	422
Plate thickness (mm)	115	145
Total mass (t)	351	420
Life to max performance (days)	90	113
Life at change out (days)	120	143



Base case



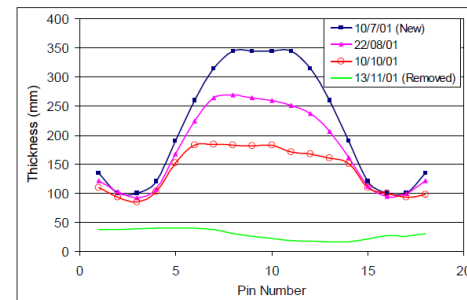
CDI Design



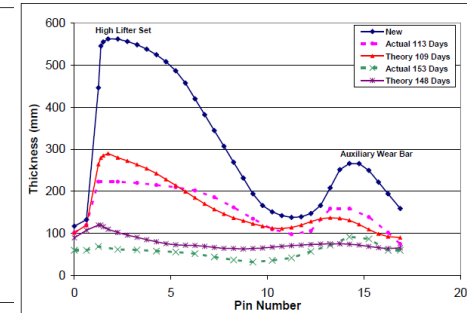
Hart et al – Development of Shell Liner Design at Cadia using DEM, SAG 2006

# Liner Wear Predictions (Cadia Data)

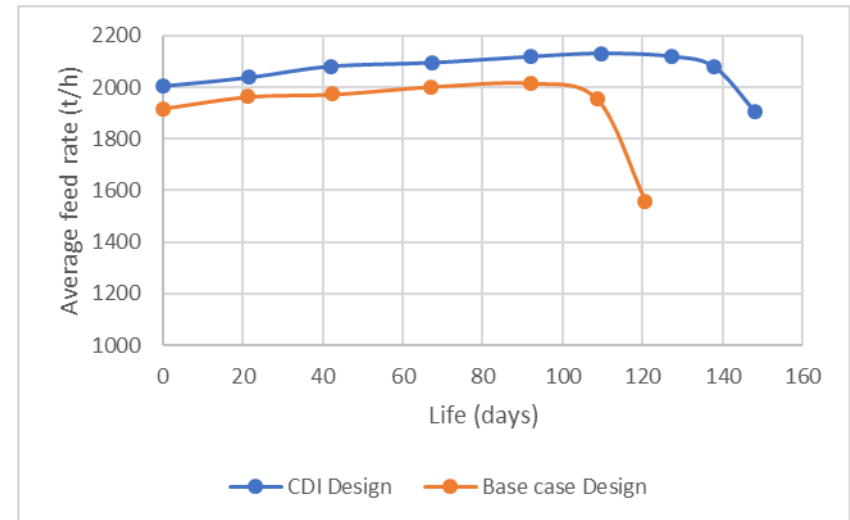
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<b>Predicted (Ausgrind)</b>	-	<b>119</b>
Life at change out (days)	120	143
<b>Predicted (Ausgrind)</b>	-	<b>149</b>



Base case



CDI Design



Hart et al – Development of Shell Liner Design at Cadia using DEM, SAG 2006

# Liner Wear Predictions (Phu Kham)

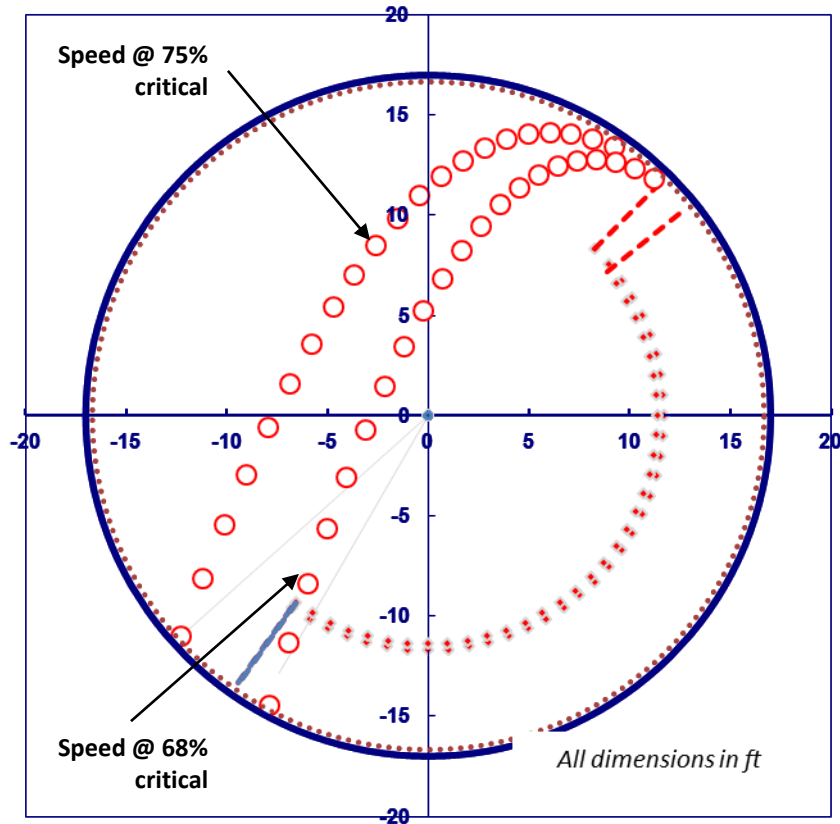
Shell Profile	Base case	Design 1	Design 2	Design 3
Face angle (deg)	22	25	35	30
Rear angle (deg)	22	9	10	23
Lifter height (mm)	300	310	340	320
Plate thickness (mm)	90	120	130	90
Life at change out (days)	161	\	177	158
<b>Predicted (Ausgrind)</b>	-	<b>183</b>	<b>173</b>	<b>155</b>

## Assumption:

- Same tonnes processed
- Similar rate of mass loss
- Similar type of ore processed
- Based on baseline 96 % availability
- Minimum plate thickness = 40 mm
- Minimum worn lifter face angle = 60 deg

# Performance Evaluation

# Base case (In use for last 10 years - 2017 March)



New shell liner & lifter design

## Baseline operating conditions

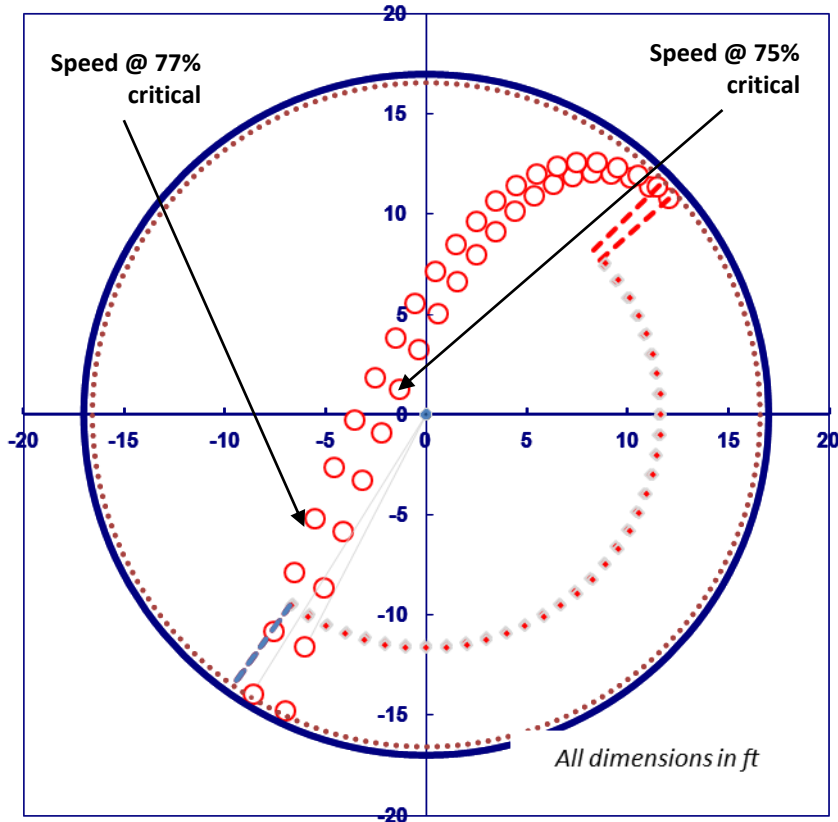
- Face angle = 22 deg
- Mill speed = 75 % critical (shell impact)
- Total charge = 28 %v/v
- Ball charge = 15 % v/v
- Power draw = 11.8 MW

## Revised operating conditions to minimise shell impact

- Mill speed = 68 % critical (impact at toe)
- Total charge = 28 %v/v
- Ball charge = 15 % v/v
- Power draw = 10.6 MW

Lost opportunity to maximise power draw = reduced throughput

# Design 2 (2017 March to September)



New shell liner & lifter design

## Baseline operating conditions

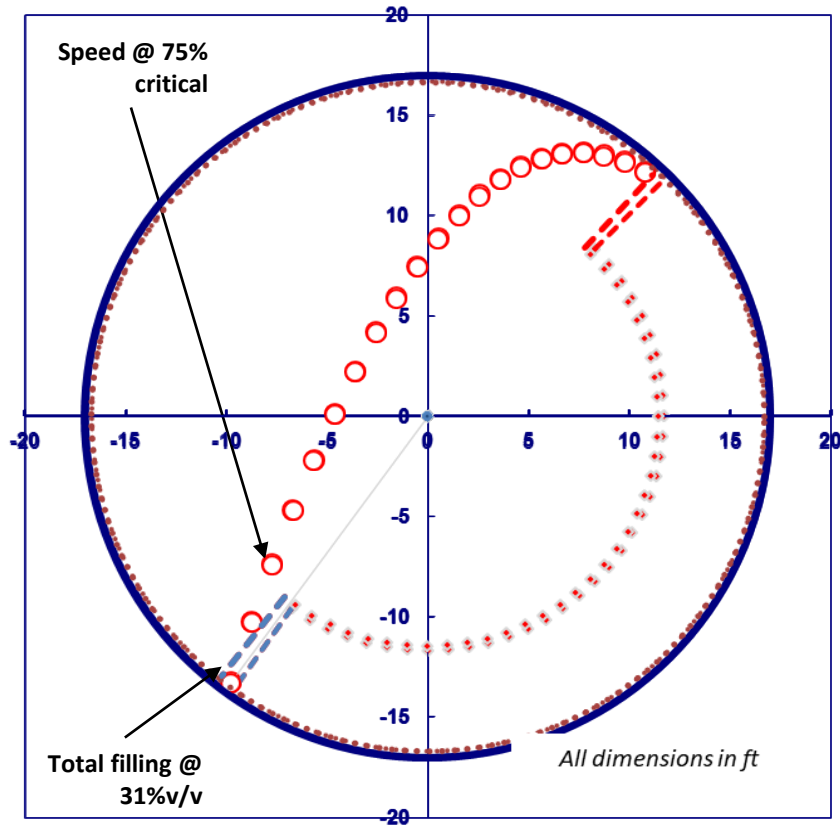
- Face angle = 35 deg
- Mill speed = 75 % critical (impact within charge )
- Total charge = 28 %v/v
- Ball charge = 15 % v/v
- Power draw = 11.6 MW

## Revised operating conditions to maximise power

- Mill speed = 77 % critical (impact at toe)
- Total charge = 28 %v/v
- Ball charge = 15 % v/v
- Power draw = 12.0 MW
- High bearing pressure
- Mill speed limited by noise

Increased mill speed to maximise power draw = increase throughput

# Design 3 (2017 October to 2018 March)



New shell liner & lifter design

## Baseline operating conditions

- Face angle = 30 deg
- Mill speed = 75 % critical (shell impact)
- Total charge = 28 %v/v
- Ball charge = 15 % v/v
- Power draw = 11.9 MW

## Revised operating conditions to minimise shell impact

- Mill speed = 75 % critical (impact at toe)
- Total charge = 31 %v/v
- Ball charge = 17 % v/v (increased ball load to maintain similar rock ratio)
- Power draw = 12.4 MW
- Load increased to minimise shell impact

# Performance Overview

Shell liner performance summary	Base case	Design 2	Design 3
Face angle, deg (vertical)	22	35	30
Liner / Lifter thickness, mm	100 / 300	130 / 340	90 / 320
Discharge system type	Radial	Curved	Radial
Grate Open Area / aperture, %/mm	14.5 % / 25 mm	14.5 % / 25 mm	15.6% / 30 mm
Total mass limit, t	1200		
Total liner package mass, t	485	610	480
<b>Theoretical max filling based on 15% ball charge load, %v/v</b>	<b>34</b>	<b>31</b>	<b>38</b>
Max speed for new install, % Nc	68	77	75
Ball charge at start up, % v/v	15	15	17
Available power for new install, MW	10.6	12.0	12.4
<b>Operational limit</b>	<b>High lifter face angle = shell impact</b>	<b>High lifter mass = limited mill load and operational speed</b>	<b>None</b>
Instantaneous throughput for hard ore (@ S.E = 6.0 kWh/t), t/h	1770	2000	2100

# Milling Performance Comparison (30 days)

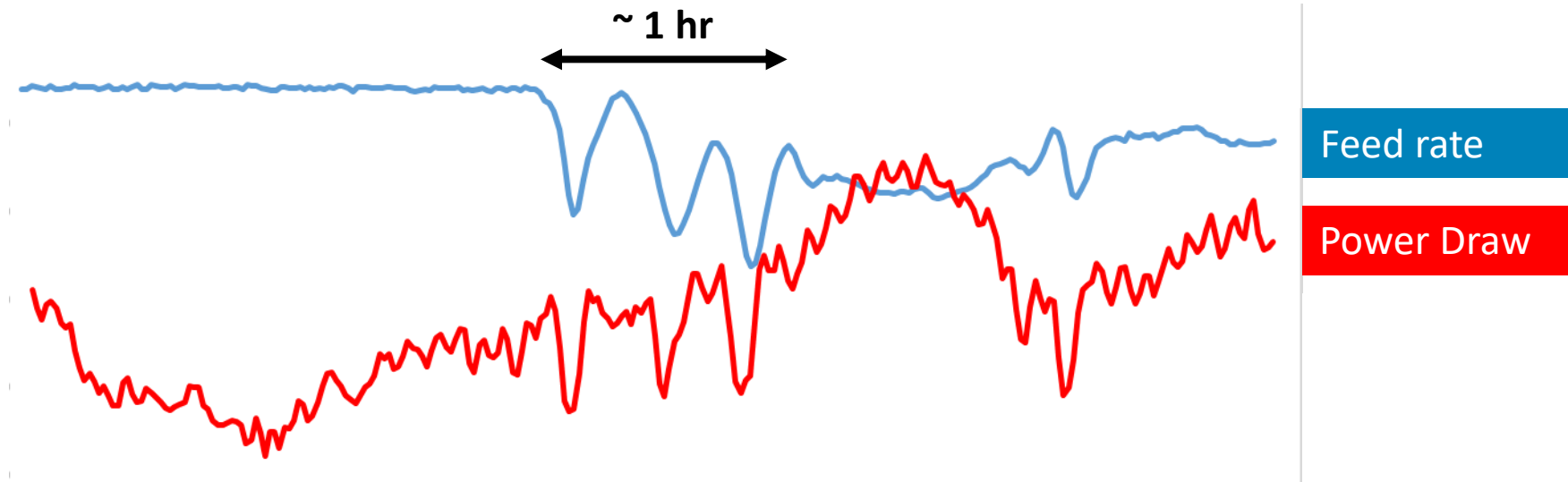
	Base case 25th percentile	Design 2 25th percentile	Design 3 25th percentile	Base case 80th percentile	Design 2 80th percentile	Design 3 80th percentile
Specific Energy (kWh/t)	5.3			6.7		
Feed rate (t/h)	1648	1748	1835	1800	2240	2175
Pinion Power Draw (MW)	10.3	10.9	10.9	11.0	12.5	12.0
Mill speed (%Nc)	68	71	70	70	78	78
Mill noise (dB)	49	50	51	51	60	57

- **Remarks**

- The SAG mill operating with design 2 & 3 liner systems improved the overall performance
- Design 2 liner package was the heaviest – which resulted in reduced operable charge volume
  - Increasing the likelihood of direct shell impact

# Optimisation Strategies

# Ore Variability (SG changes)



- **Remarks**

- Transitioning from friable low SG ore to competent high SG feed caused frequent disturbances
- Advanced mill control was not adequate to resolve sudden changes in feed composition
- Inclusion of inferred ore SG measurement improved overall response of the controller

# Ore Variability (SG changes)

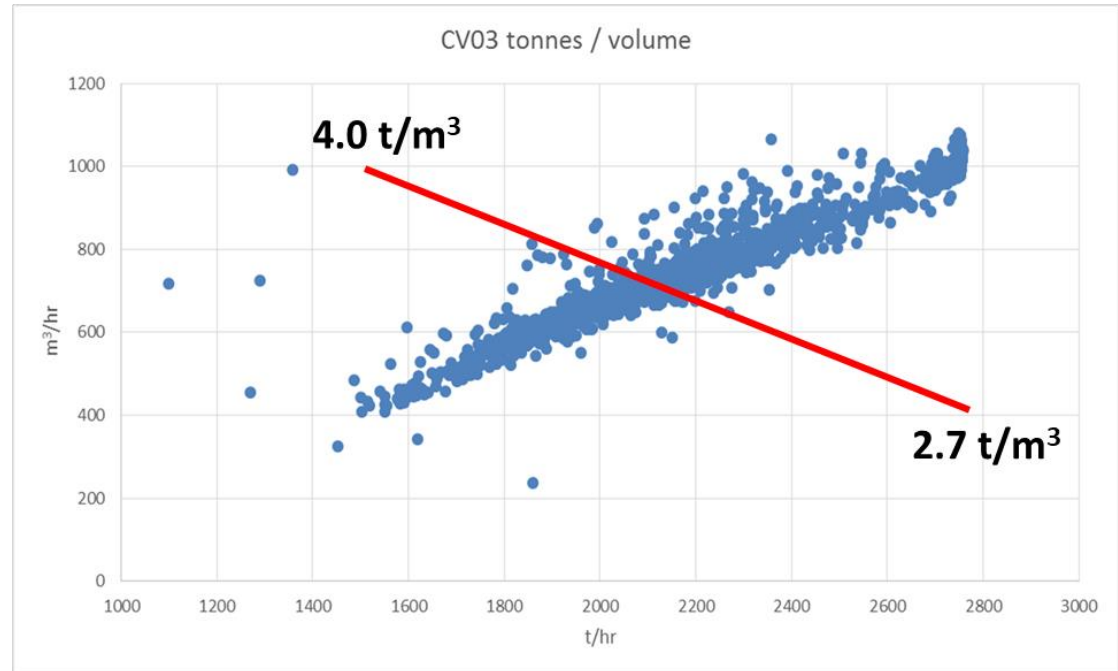


$$+ \quad \text{SAG mill feed weightometer reading} \quad = \quad \text{Inferred Ore SG}$$

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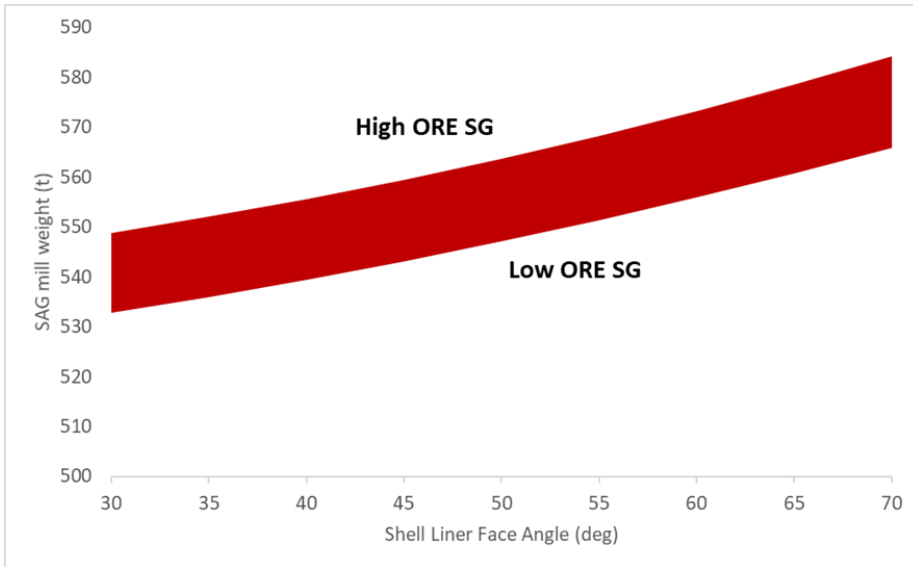
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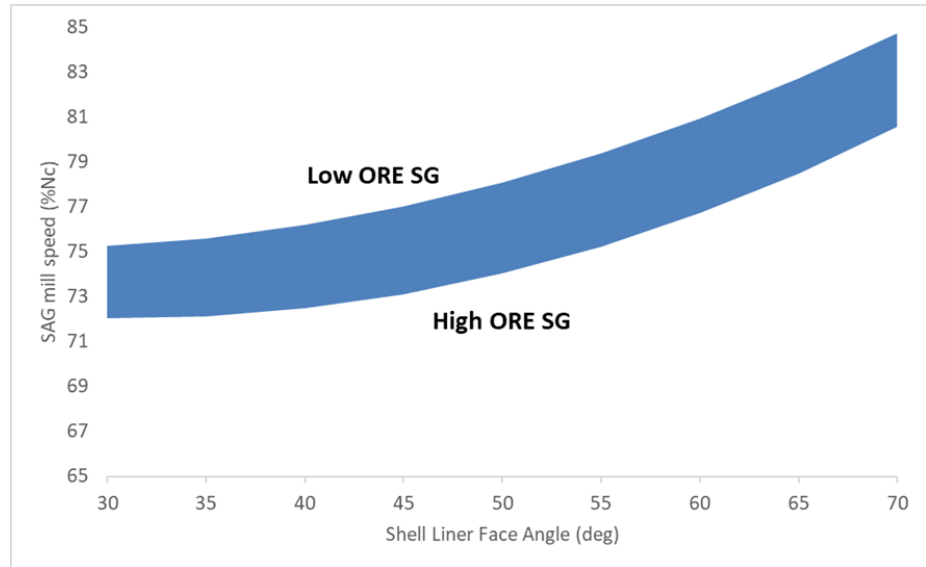
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# Operating Charts



Total mill filling mass as a function of lifter face angle



Mill speed as a function of lifter face angle

# Conclusions

- **Phu Kham Production Increase**
  - Improvements to process control with correct set points for variable feed
  - Improved liner design = maximised power draw at start up
  - Increased feedrate for competent ores ~ 20% increase
- **Ausgrind's Liner wear & trajectory model**
  - The liner wear design, wear prediction and trajectory models show good correlation with actual operational data.
  - The model outcomes were successfully applied in the case study for improved results
  - Used to define safe operating conditions (setpoints)
- **Success at Phu Kham**
  - Technical expertise (tools)
  - Site team coordination and involvement
  - Vendor involvement

## Acknowledgements

Ausenco, the Phu Kham operational team and Phu Bia Mining management for their support to publish the recent successful collaboration

Thank you.

[www.ausenco.com](http://www.ausenco.com)

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