Ausenco

Rethinking Grinding Efficiency in Ball Mills

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Context

Drivers of grinding energy transfer to ore in ball mills

- Charge density – charge shape and liner design
- Charge surface area
- Pulp density & rheology
- Media mass
- Classifier efficiency

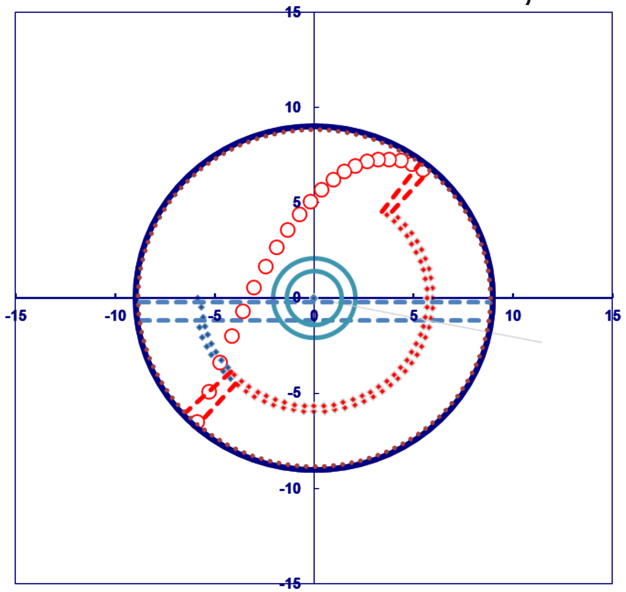
How can we increase the grinding surface area?

1. Increase the grinding surface
    - Smaller ball media, or
    - Different media shape
2. Increase dynamic packing efficiency
    - Change liner profile

Experience from Operations

How can we increase the energy transfer in ball mills? Is it a function of grinding surfaces or drawn power or both?

Ausenco's Ausgrind Expert Modelling
Dia18 x EGL 31 ft : 5500 kW , 750 t/h



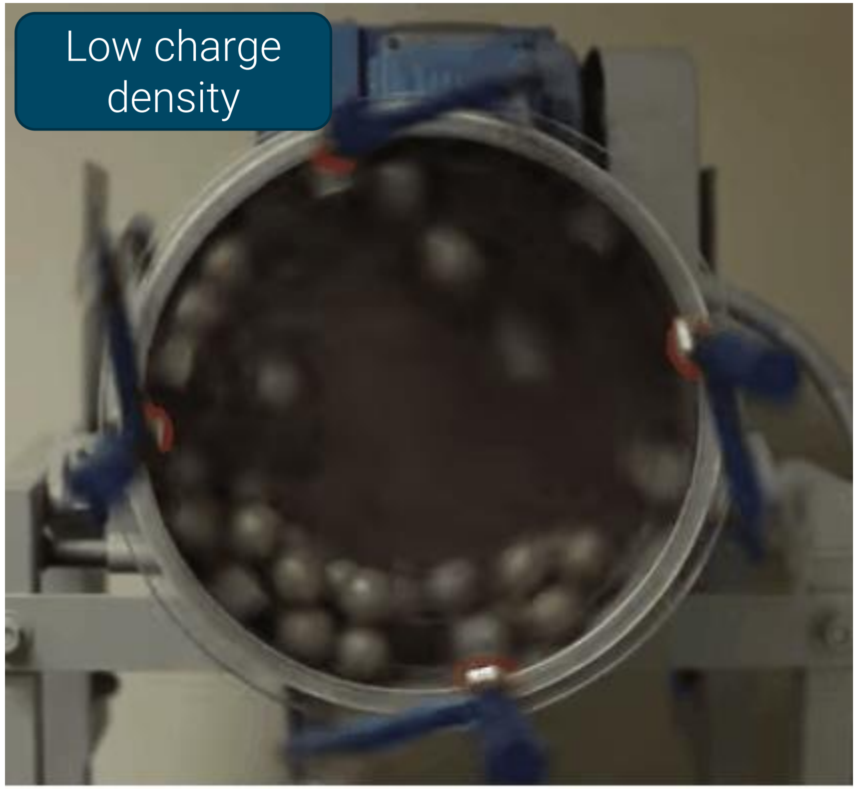
Mill Speed	= 75% Nc
Ball charge level	= 32% v/v
Pulp density	= 75% w/w
Circulating load	= 300%
Discharge trunnion diameter	= 1.3 m
Motor Power draw	= 4.7 MW
Discharge trunnion diameter	= 0.85 m
Ball charge level	= 35% v/v
Motor Power draw	= 4.7 MW

Higher ball charge level but same power draw

Modified after Morrell (2016) - Modelling the influence on power draw of the slurry phase in Autogenous (AG), Semi-autogenous (SAG) and ball mill

Do Shell Lifters affect the Shear Energy Transfer?

With Lifters

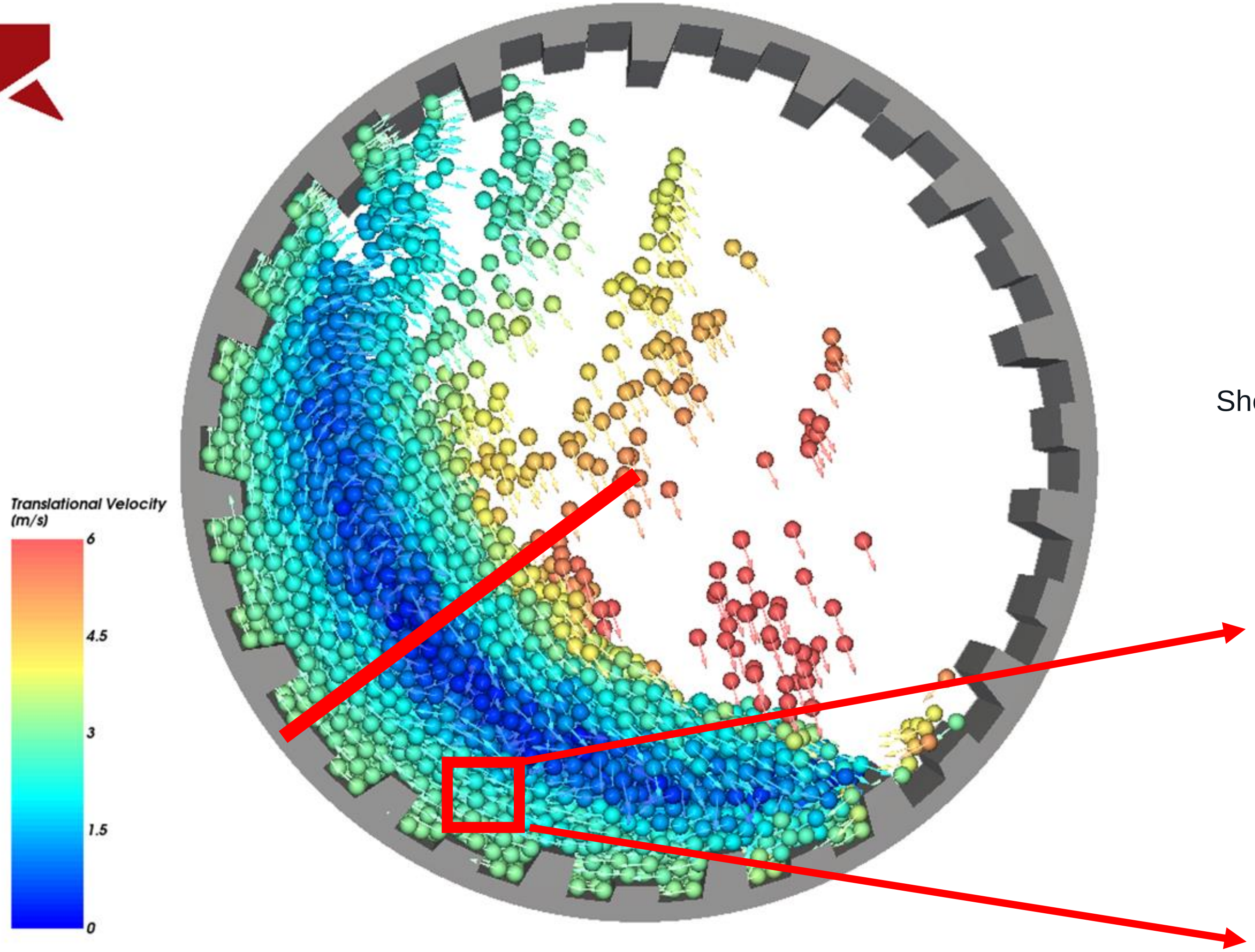


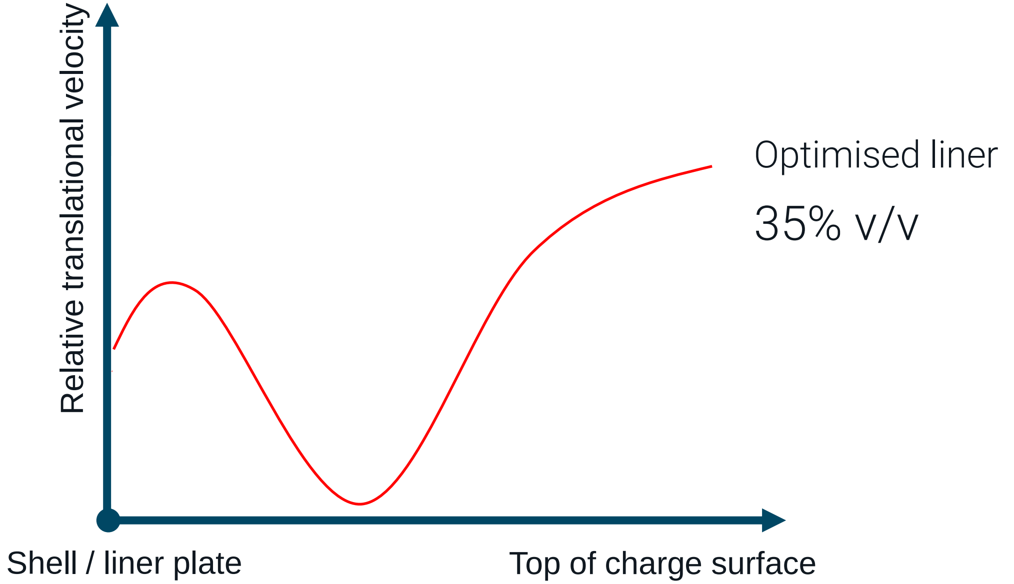
Without Lifters

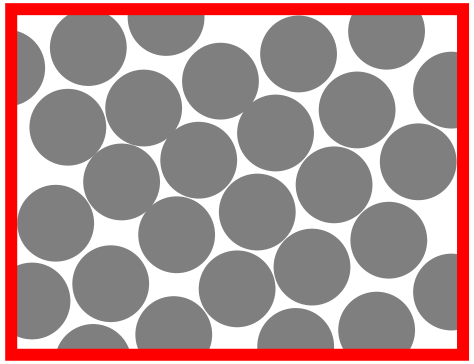
Animation courtesy of 911metallurgist

Is energy transfer in ball mills a function of dynamic voidage (porosity) fraction?

A hypothesis - Insights from DEM

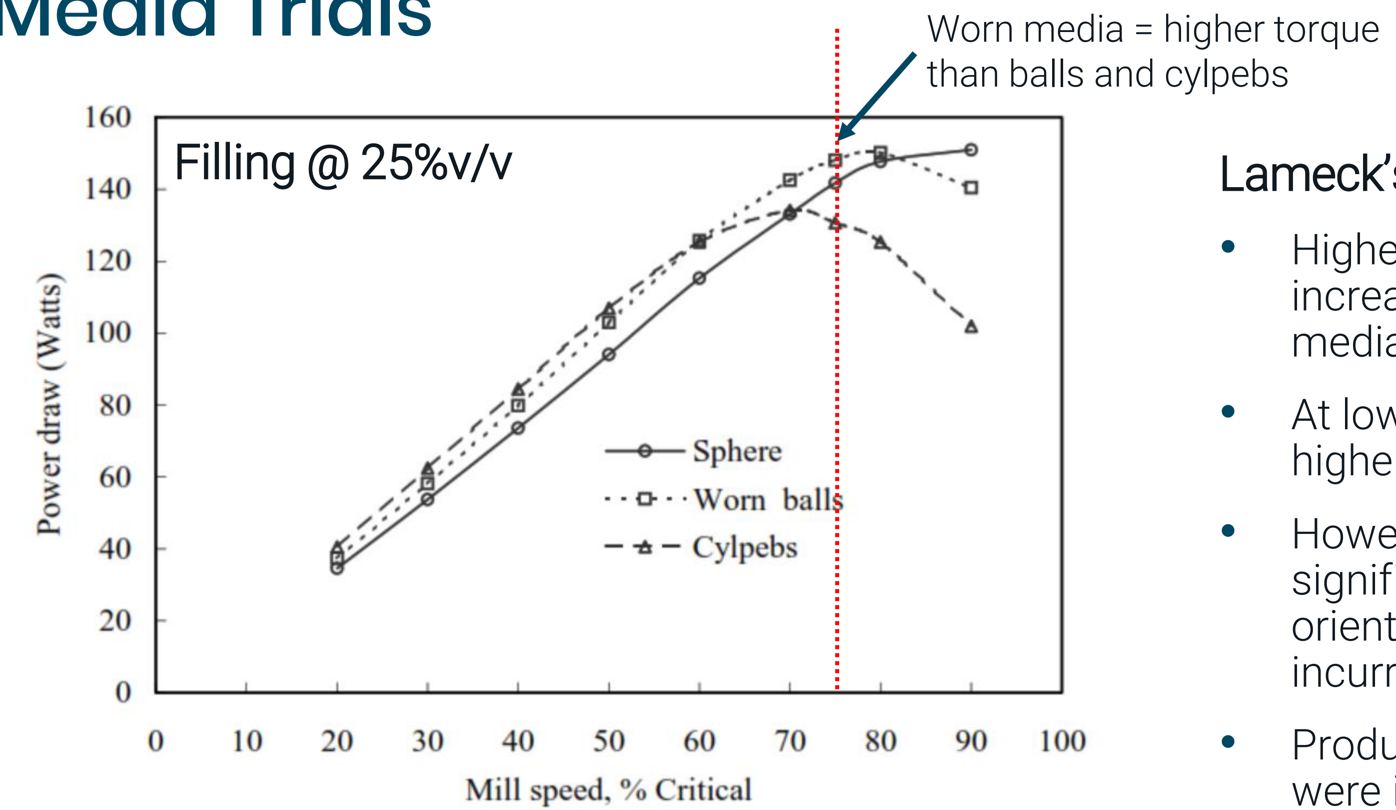


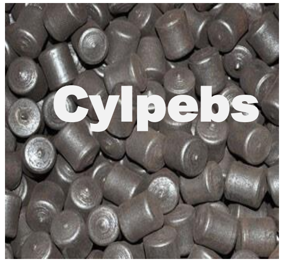




- Increase contact surface area between ore and media
- Reduce the voidage space between media (increase bulk density)

Media Trials





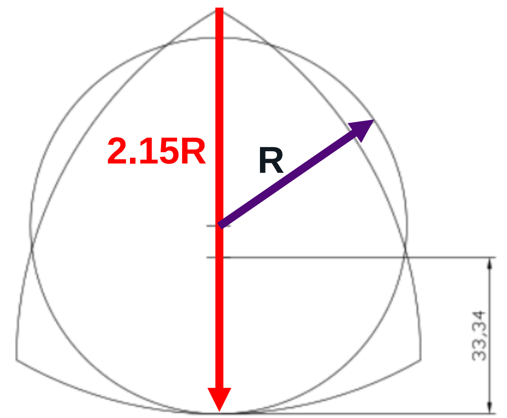
Lameck's work indicated that:

- Higher torque (power draw) can be achieved with increased packing efficiency – particularly for worn ball media
- At lower mill speeds, the cylpebs and new media draw higher power draw than the worn media and balls
- However at higher mill speeds, the cylpebs lose significant torque to draw the power – primarily due to orientation of the cylpeb shapes at the higher speeds – incurring locked charge loads
- Product comparison between worn media and balls were inconclusive

Lameck (2005) – The effects of grinding media shapes on ball mill performance (MSc thesis – University of Wits)

Relo Media

- Patented shape developed by Petar Bodurov (Tetrahedron concept)
- Originally developed for the clinker industry to increase the milling performance
- Theoretically, RELO can handle larger ore particles than a similar sized ball media with equivalent nip angle
- Increased bulk density
  - Through reduced voidage (porosity) and increased contact surface area



Ball vs RELO shape with equal volume

Ball Media Radius, mm	RELO Media Arc Radius, mm	Equivalent mass, kg	Surface Area ball, m^2	Surface Area RELO, m^2	Bulk Density ball, t / m^3	Bulk Density RELO t / m^3
20	43	0.3	0.0050	0.0055	4.68	5.15
30	64	0.9	0.0113	0.0124	4.68	5.15
40	86	2.1	0.0201	0.0220	4.68	5.15

Todor & Bodurov (2014) – Comparative analysis of the parameters of spherical and Relo body balls for drum mills (ICMMME)

Media Shape Trials – RELO Media

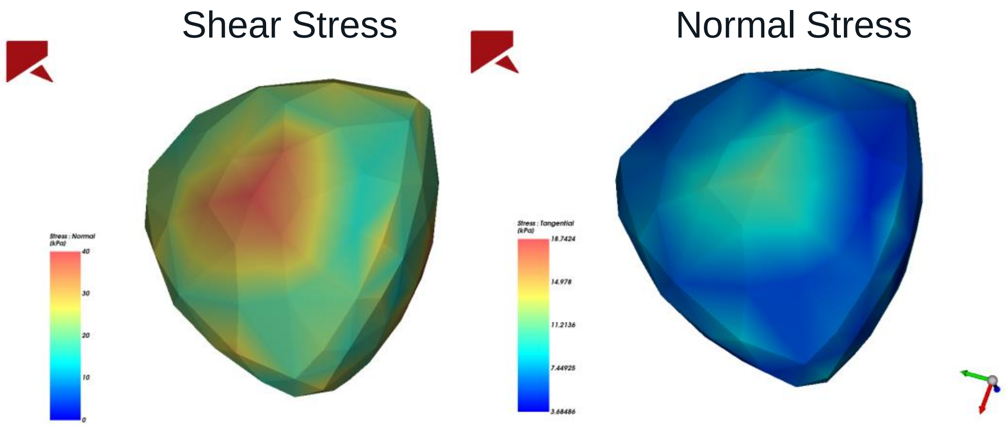
Media Shape	Test Condition	Total Mass Charge, g	Measured Power Draw (with media), kW	Measured Power Draw (with ore), kW	Estimated surface area difference against balls,%	Measured BWI, kWh/t
Balls	Similar Bond PSD	20123	402	437	-	16.6
Relo	Similar Bond PSD	19149	420	439	+5	16.3
Relo	Similar Mass	20165	424	440	+10	15.0

- Lab trials conducted using a standard Bond ball mill (@ Wardell Armstrong)
- Standard Bond ball mill procedures were followed – only the RELO media PSD and mass of charge adjusted to match spherical media
  - Closing screen 106 um
  - Target circulating load = 250%

Kolev et al (2021) – In press. Improving the energy efficiency in tumbling mills with the use of Relo grinding media (MDPI)

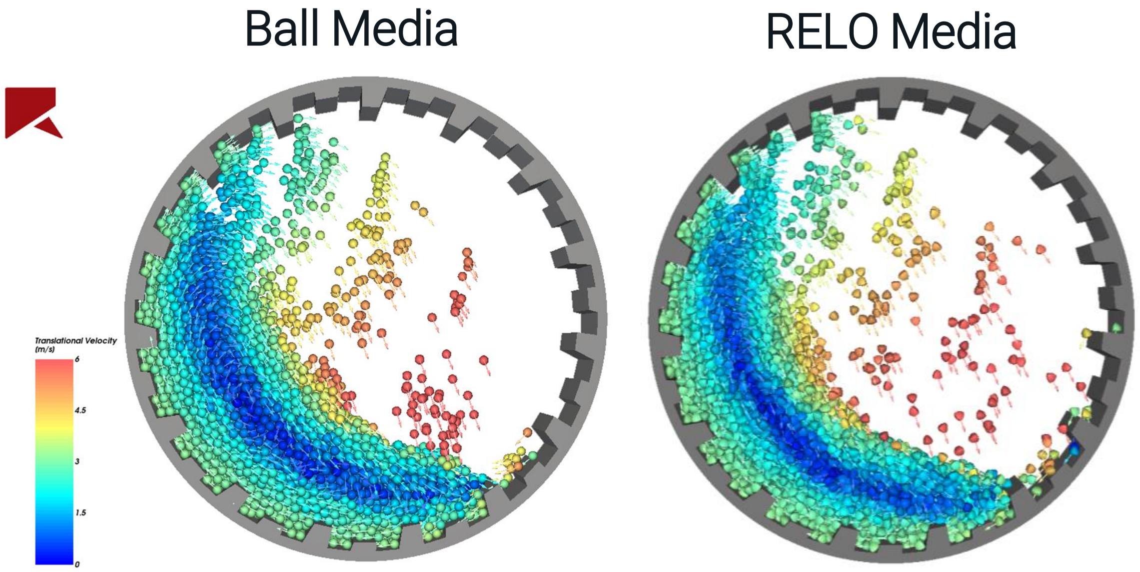
DEM Analysis

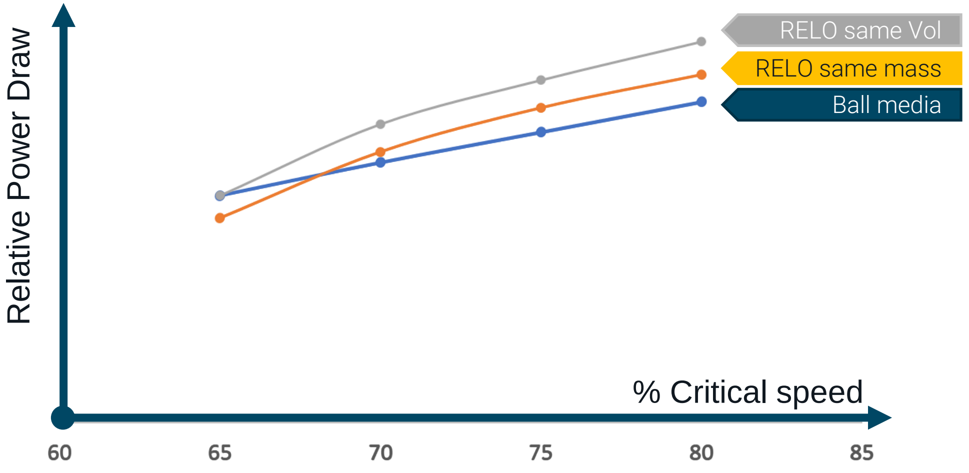
- Analysis objectives:
  - Effect of fill volume
  - Effect of mill speed
  - Effect of liner wear
- Quantify the relative shear energy and power draw
  - Between balls and RELO media



Bodurov & Genchev (2017) – Industrial tests with innovative energy saving grinding bodies (JMEST)

Effect of Mill Speed and Volume

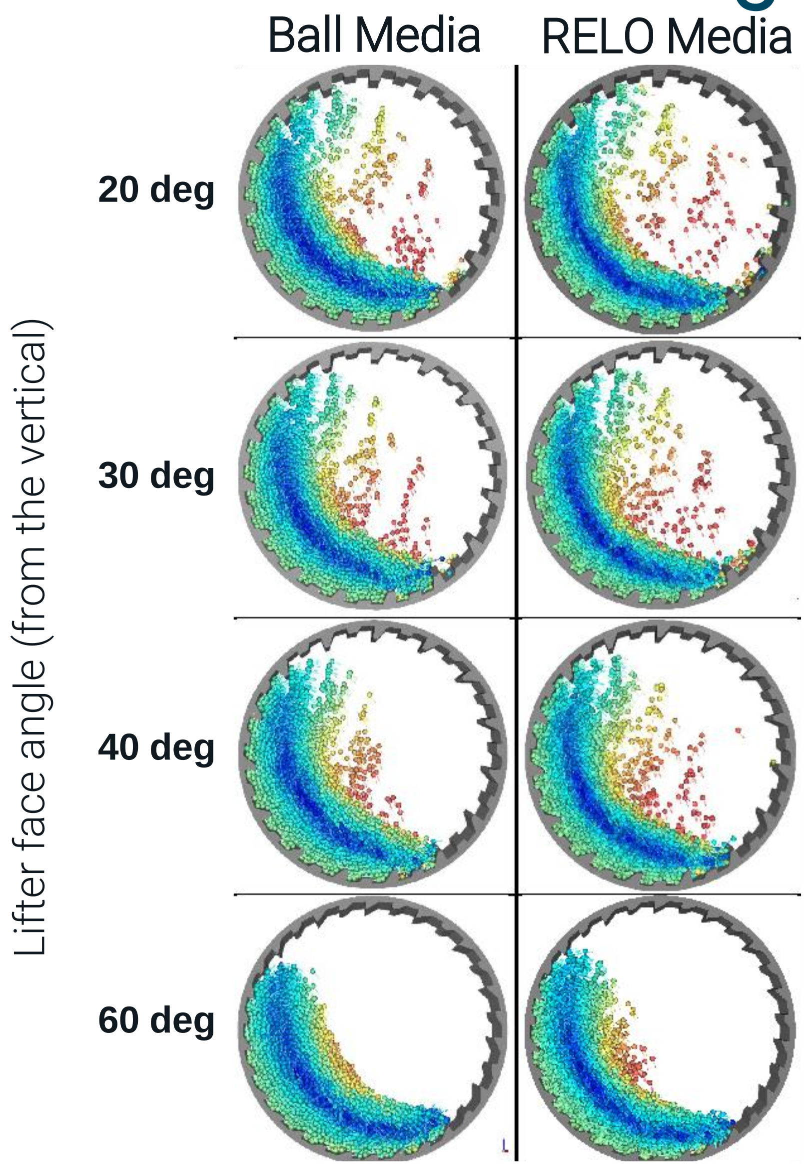


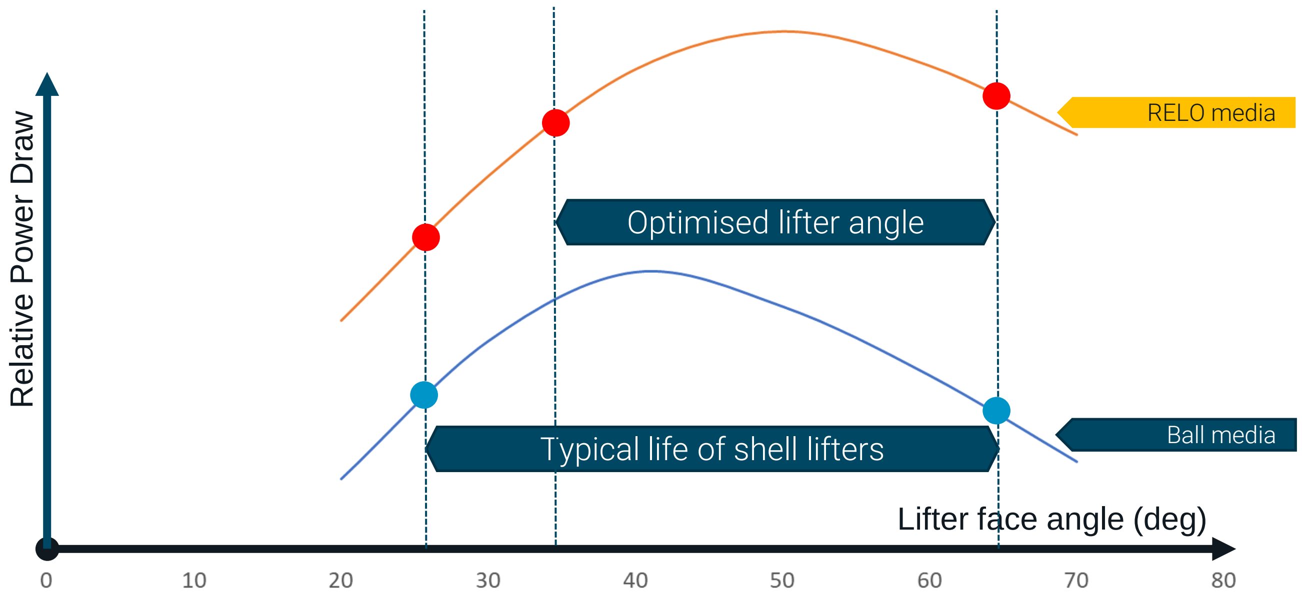


Rocky DEM used to analyse the various operating conditions

- Key outcomes for similar ball media volume:
  - Same mass of RELO media, shear power draw increase ~ +5%
  - Same volume of RELO media, shear power draw increase ~ +10%

Effect of Liner Design (Shell liners)





DEM simulations for mill with <u>same mass</u> of Ball and RELO media

Lifter Face Angle, deg	Relative Ball media shear power, %	Relative RELO media shear power, %
20	-	46
30	4	53
40	9	57
50	7	71
60	2	66

Potential

	Liner Design	Start-up Pinion Power Draw, MW	BWI, kWh/t	Mill Availability, %	COF P80, um	% Recovery	Metal Produced t/h
Balls	Conventional	23	20	93	106	85	5.93
RELO	Conventional			93	85	89	6.22
Balls	Optimised			91*	95	87	5.95
RELO	Optimised			91*	81	90	6.14

* Reduced liner life

- Assumptions
  - Circuit throughput ~ 1500t/h, Cu grade 0.5% (DWI ~ 7 kWh/m^3)
  - Similar media wear rate
  - Same mass of media
  - Same feed rate and PSD to ball mill circuit
  - No change to BBWI
  - Liner life and availability – calculated after Chandramohan et al (2019) – SAG mill liner selection to maximise productivity (Procemin)

Summary

- Insights
  - Energy transfer in ball mills is a function of grinding surfaces (surface area)
  - Changing the shape of the media (from ball to RELO):
    - Increased bulk density of the media charge
    - Increase surface area of the media by 10%
    - Increases packing efficiency (reduction in voidage space by 10%)
    - (Reduces the BWI for same target grind equivalent mass and similar PSD in the Bond test)
    - Increases shear energy dissipation / power drawn by the mill for equivalent mass of media
    - Higher shear energy dissipation is achieved for wearing lifters (change in face angle)
- Opportunity
  - RELO media in combination with optimised liner design can increase the grinding efficiency in ball mills by 10% for equivalent ball media volume
  - Requires plant trials to further validate the lab and DEM findings

- *Acknowledgements*
  - *Thanks to Weir Minerals for providing expertise in DEM simulations and analysis, RELO media for providing insightful lab test-data and Ausenco for providing the opportunity to present at Comminution 2021.*

Thank you

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