HYDRAULIC EXCAVATOR VS. ROPE SHOVEL PERFORMANCE

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Recall Tim & John at H&L 2013
Ultra class excavator vs. shovel
> 40 m³ capacity
Specific energy comparison

Rope shovel:
- 119t payload
- 23.0 MJ

Hydraulic excavator:
- 76 t payload
- 14.7 MJ

\[ E_{\text{specific}} = 193 \text{ kJ/t} \]
Operating & maintenance cost

- OH parts
- OH lab
- Mtce parts
- Mtce lab
- Fuel/pow
- Lube
- Wear parts

$ per operating hour

- Yellow: hydraulic
- Red: rope
Cumulative cost of ownership
Sammut & Joseph, 2013 H&L

A=90% @ 7 yrs life

ΔA=12% ~ $75M ~ 10 yrs production equivalent

A=78% @ 25 yrs life
Availability

\[
A = \left\{ \frac{\text{Available hours}}{\text{Scheduled hours}} = \frac{\text{Available hours}}{(\text{Calendar hours} - \text{Scheduled delays})} \right\} \times 100\%
\]
## Operations’ Availability data

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<th>Mined ore</th>
<th>Region</th>
<th>#</th>
<th>6000</th>
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f(x) = -5.89 \ln(x) + 140.88
R² = 0.89

f(x) = -3.02 \ln(x) + 119.58
R² = 0.62

Availability

Availability (%)  

Hours of service

0  10000  20000  30000  40000  50000  60000
Joseph & Sammut 2013 modified availability – cost assessment

A=87% @ 7 yrs life

ΔA=20% ~ $75M ~ 10 yrs production equivalent

A=67% @ 25 yrs life
Productivity per m³ capacity

The graph shows the productivity per m³ capacity as a function of hours of service. The equation is given by:

\[ f(x) = -20.64 \ln(x) + 1257.19 \]

with \( R^2 = 0.49 \).
Productivity over 25 years

Productivity (t/shift)

years of operation

Rope shovel

Hydraulic excavator

Δ \sim \text{dig cycle time}
Maintenance cost per m³

$$f(x) = 0.1 \exp(-0.1x)$$
$$R^2 = 0.79$$
Comparing operating and maintenance costs

- rope sh.
- hyd exc.

Operating + maint. costs ($M) vs. year

- Δ ~ complexity
Revisiting the cost of ownership

△A = 20% ~ $53M ~ 7 yrs production equivalent

A = 87% @ 7 yrs life

A = 67% @ 25 yrs life
Productivity & Maintenance Cost as a function of Availability

- **f(x) = −0.46x + 0.55**
  - $R^2 = 0.13$

- **f(x) = 397.28x + 682.07**
  - $R^2 = 0.06$

- **f(x) = 2534.88x − 1364.79**
  - $R^2 = 0.72$

- $\Delta \sim 4X$

- $\Delta \sim 5.5X$

- **Productivity (t/m3 bucket capacity)**

- **Cdn$/ per t/m3 maintenance cost**
Conclusions

More Q’s
for OEMs & users

... coming at H&L 2019
Impact of blast quality on shovel & crusher - minimizing E used

@ Productivity ~ 4295 tph
Power and Energy per cycle

\[ E_{\mu} = 0.13 \text{ MJ} \]

\[ \Sigma E_{350} = 4,402 \text{ MJ} \]

\[ E_{\mu} = 12.6 \text{ MJ/cycle} \]
GET wear = $f(E_s)$, Nm/m$^3$

![Graph showing the relationship between Specific Energy, $E_s$ (GPa) and Vickers Number, $H_v$. The equation fitted to the data is $f(x) = 589.47 \ln(x) - 2496.29$ with $R^2 = 1$.](image)
Predicting tooth wear - example

- 9 tooth lip system
- Duty cycle is ~48 s and shovel has 85% availability and 80% utilization = 3672 cycles
- Energy per cycle = 12.6 MJ
- Wear energy expended per tooth ~ 5140 MJ
- Tooth steel 500 Hv, $E_s = 1200$ GPa ($GJ/m^3$)
- Predict volume lost = $5.14/1200 = 0.0043 \ m^3$
- Single shovel tooth measured losing 70 lb (31.75 kg, 0.0043 $m^3$) mass in 3 days.
dig force, $F_{\text{dig}} = \eta P/v$
**Dig force vs. blast quality**

- Better fragmentation
- Lower dig resistance
- Lower specific energy
- Lower GET wear

- Range of dig resistance proportional to blast quality
- Loose material flow dig and slip
- Peak hard digging

N vs. F dig resistance (MN)
Fill factor = $f(\text{blast} \& \text{flow})$
Balancing E blast vs. shovel vs. crusher

<table>
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<td>Hole Diameter, D</td>
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<td>Charge Length, L</td>
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<td>Powder Factor (by mass)</td>
<td>0.17 kg/tonne</td>
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<td>Powder Factor, PF</td>
<td>0.45 kg/m³</td>
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<td>Charge Weight per hole</td>
<td>589.40 kg/hole</td>
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Traget shovel/excavator
- Dipper/Bucket capacity: 44.0 l/cm
- Max particle size: 1.18 m
- Percent Undersize: 0.5 m

Predicted Fragmentation
- Percent Oversize: 11.9%
- Percent In Range: 80.8%
- Percent Undersize: 7.4%

1/3 shovel lip, $x_c$
- maximum blast particle target
Conclusions

Next time – see you at H&L 2019