LULEÅ UNIVERSITY OF TECHNOLOGY

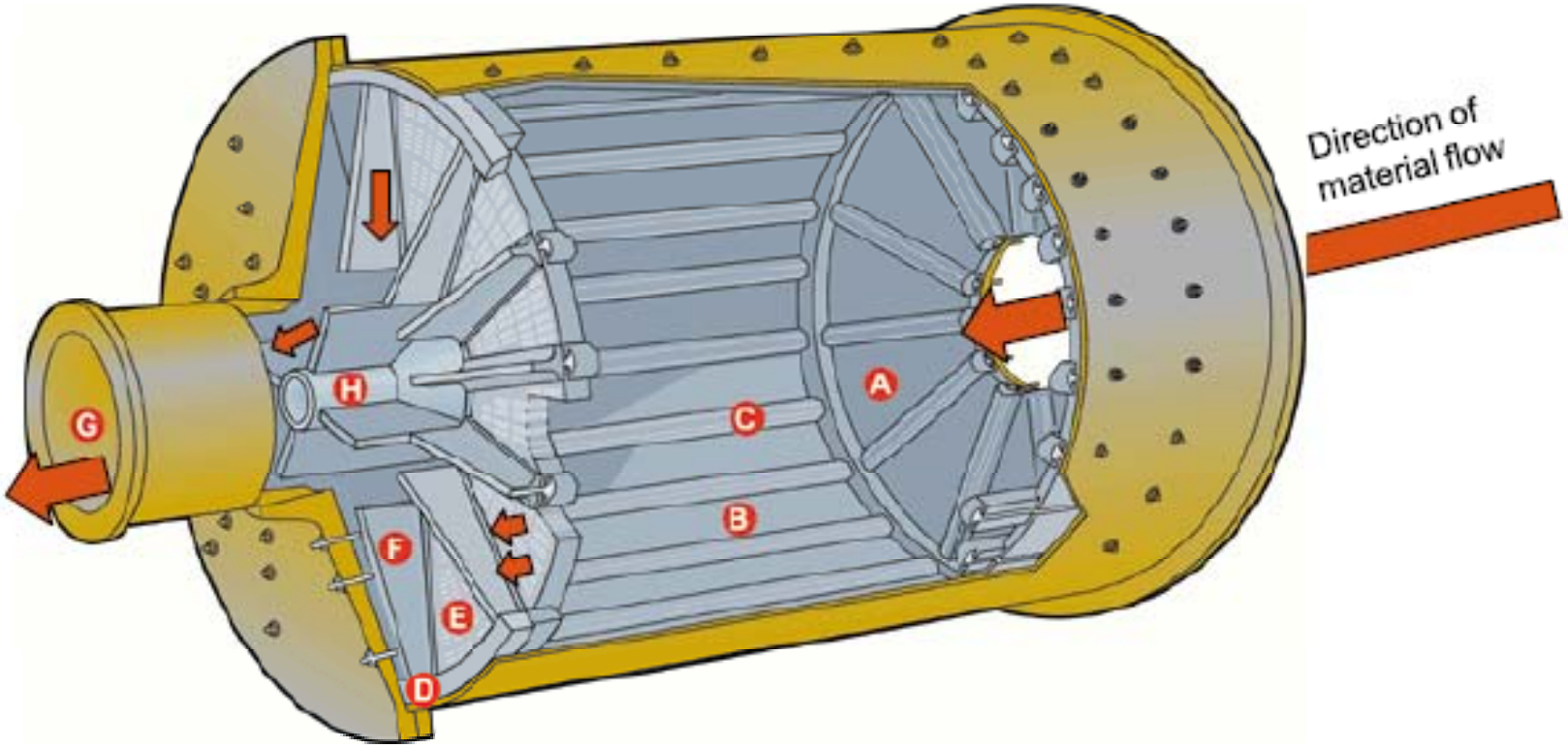
Increased production systems effectiveness through condition monitoring and prognostics

Jan Lundberg,
professor Machine element
AND
professor Operation and Maintenance engineering,
product development for design out maintenance

Introduction

Mining and ore dressing plant mills are bottle necks for the mining industry. The downtime costs are very significant, thus the following questions needs to be answered:

- What are the optimum replacement intervalls for rubber liner used in mills and how to measure the wear of liners?
- If cracks appear at the mill shells, how large can these cracks be, before the mill has to be stopped and repaired and how to measure the cracks?


Direction of material flow
A
B
C
D
E
F
G
H

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Project

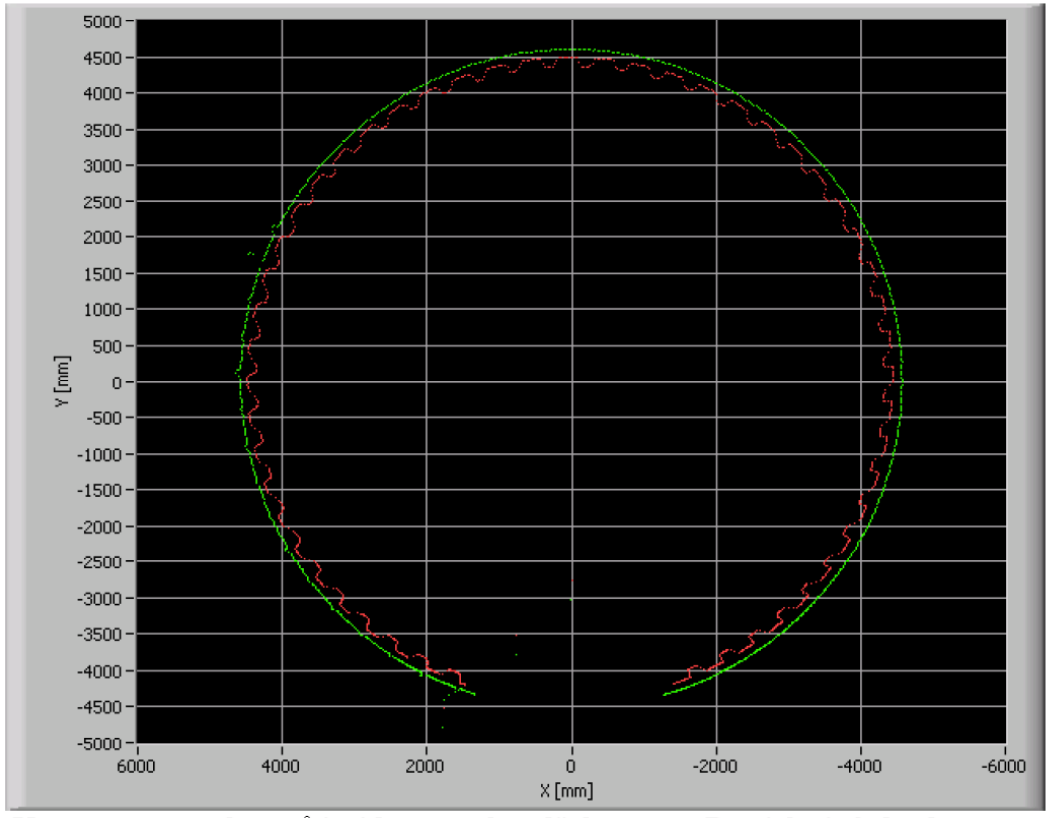
- Duration 2008-08-04-----2012-08-04
- Financed by Vinnova, Boliden Mineral AB, LKAB, Metso Minerals and Ringhals AB
- Total budget 10.5 MSEK
- 2 PhD students
- Project manager: Jan Lundberg

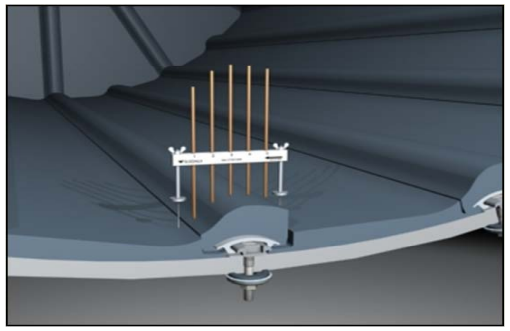
Methods

- Systematic testing and evaluation of measurement methods
- FEM calculations of the crack behavior at the mill shells using measured surface stresses during rotation
- Comparative analysis for gross profit during one replacement cycle is carried out for various replacement intervals.
- Time sampling is done to investigate the economic efficiency and observing the pattern for various parameters during life cycle of liners
- A trade- off is set up between total earnings and replacement cycles for getting optimum time for replacement
- Development of theoretical models using real process data for prediction of optimum replacement intervals of liners and the corresponding profit

Results

Developer: Damill AB





Method	Contact	Detection of internal defects	Temperature range	Flaw type	Wireless	Cost	Sensor type
Ultrasound	Yes	Yes	up to 250°C (higher temp special probes)	Surface & embedded cracks	No	Moderate to high	Probe
Eddy current	Yes	Yes	up to 150°C (higher temp special probes)	Surface & embedded cracks	No	Moderate	Probe
Acoustic emission	Yes	Yes	up to 150°C (higher temp special probes)	Surface & embedded cracks	No	Moderate to high	Probe
Magnetic particle testing	Yes	Yes	up to 100°C	Surface cracks	No	Low to moderate	Magnetic particles/ wet magnetic fluorescent particles
Bleeding composites	Yes	No	N/A	Surface cracks	Yes	N/A	Film/matrix
Fatigue damage sensor	Yes	No	N/A	Surface cracks	Yes	Moderate to high	Sensor/shim
Fiber optic sensors	Yes	No	up to 200°C	Surface cracks	No	High	Optical fibre
Strain gauges	Yes	No	up to 250°C (higher temp special probes)	Surface cracks	No	Low to moderate	Gauge
Piezoelectric paint sensors	Yes	No	N/A	Surface cracks	No	High	Film/electrode
Fluorescent crack sensors	Yes	No	220°C (special coatings high temperature)	Surface cracks	No	Moderate to high	Film/matrix

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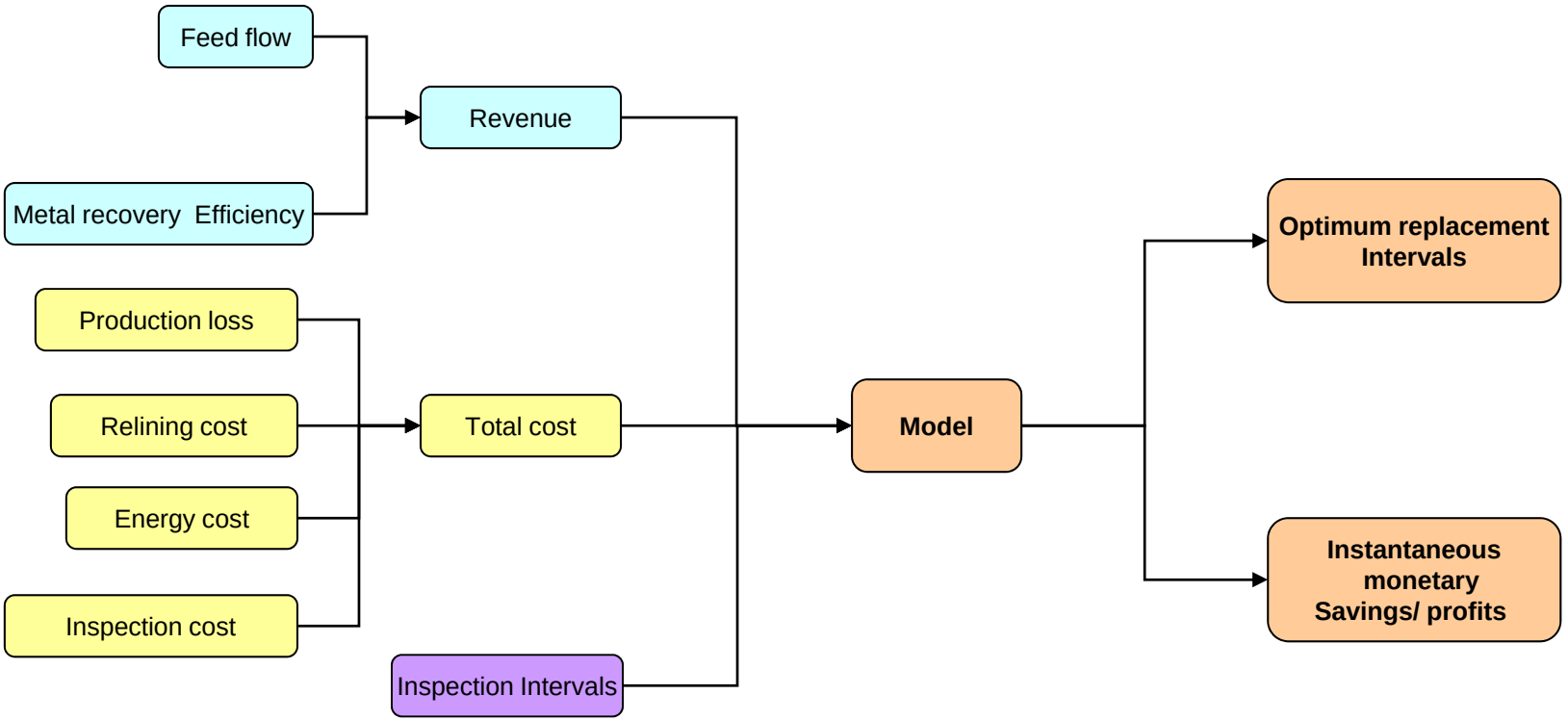
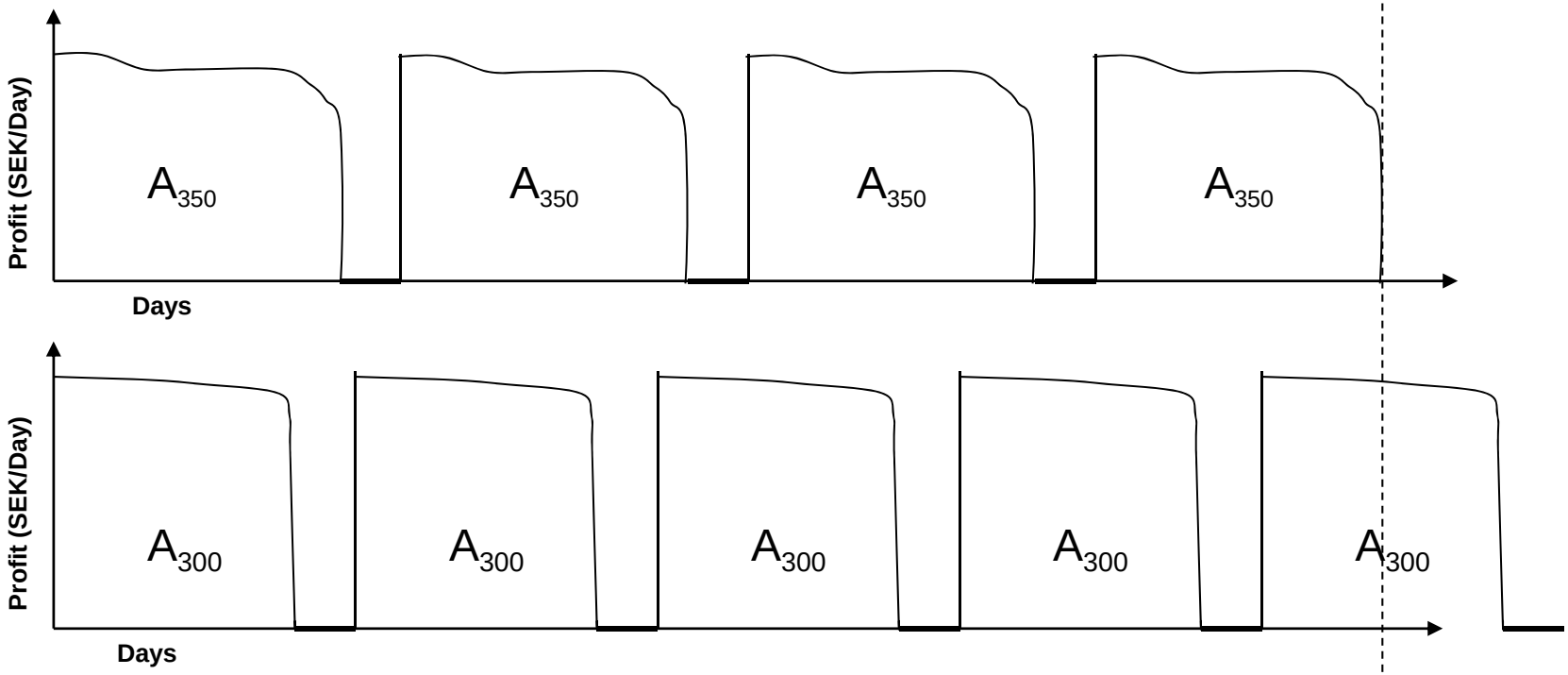
Parameters affecting liner replacement intervals & profit





Case 1: Gross Profit (P_{350}) = ($4*A_{350} - 3*C_{DC}$)

Case 2: Gross Profit (P_{300}) = ($4*A_{300} + x*A_{300} - 4*C_{DC}$)

Compare: If ($P_{300} > P_{350}$) Then Replace after 300 Days

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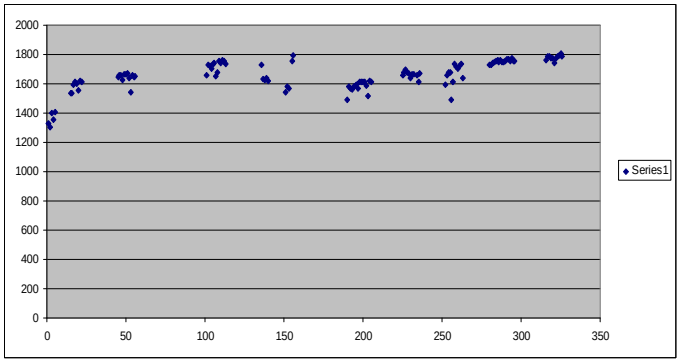
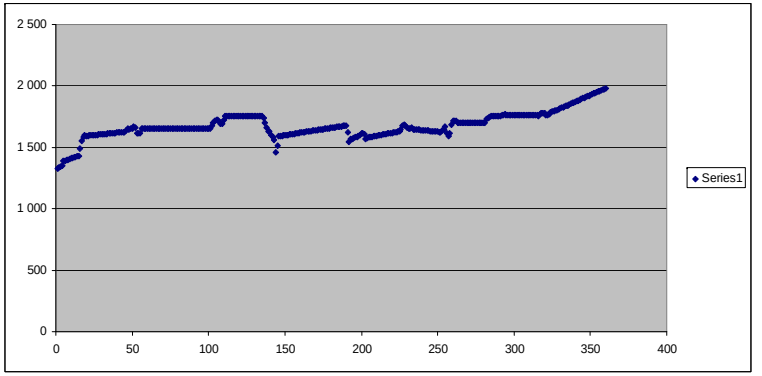
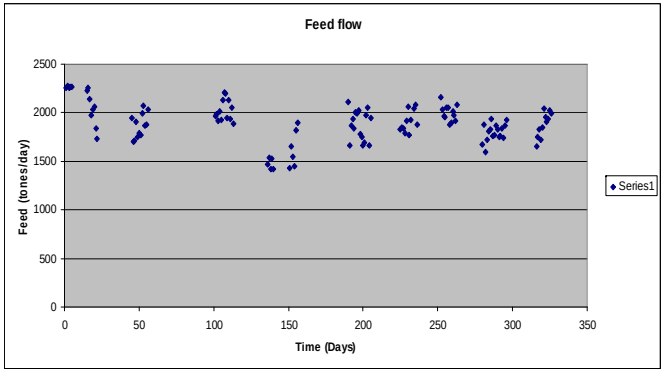
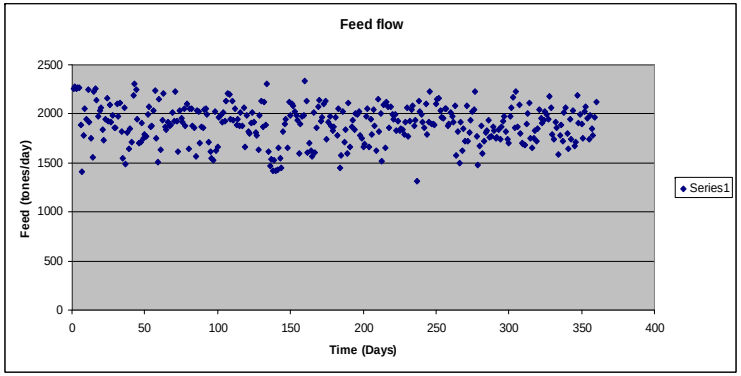
Power Consumption



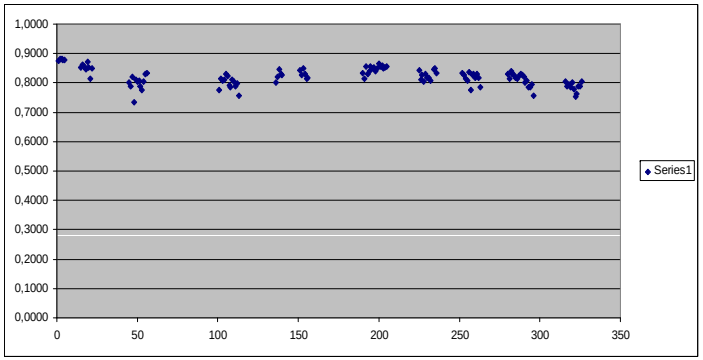


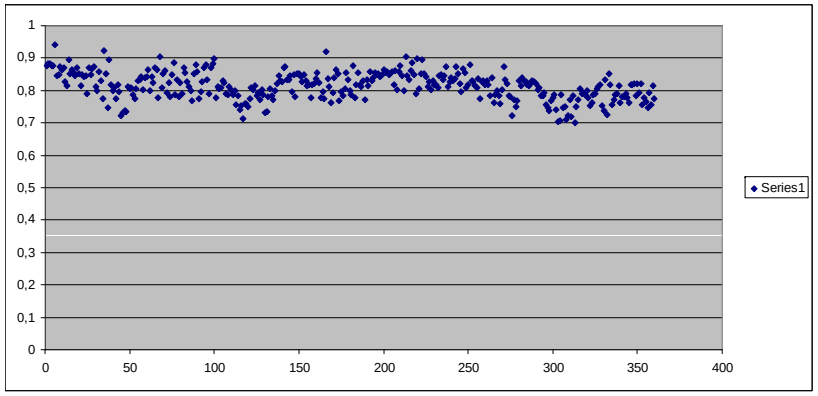
Feed flow





Process efficiency





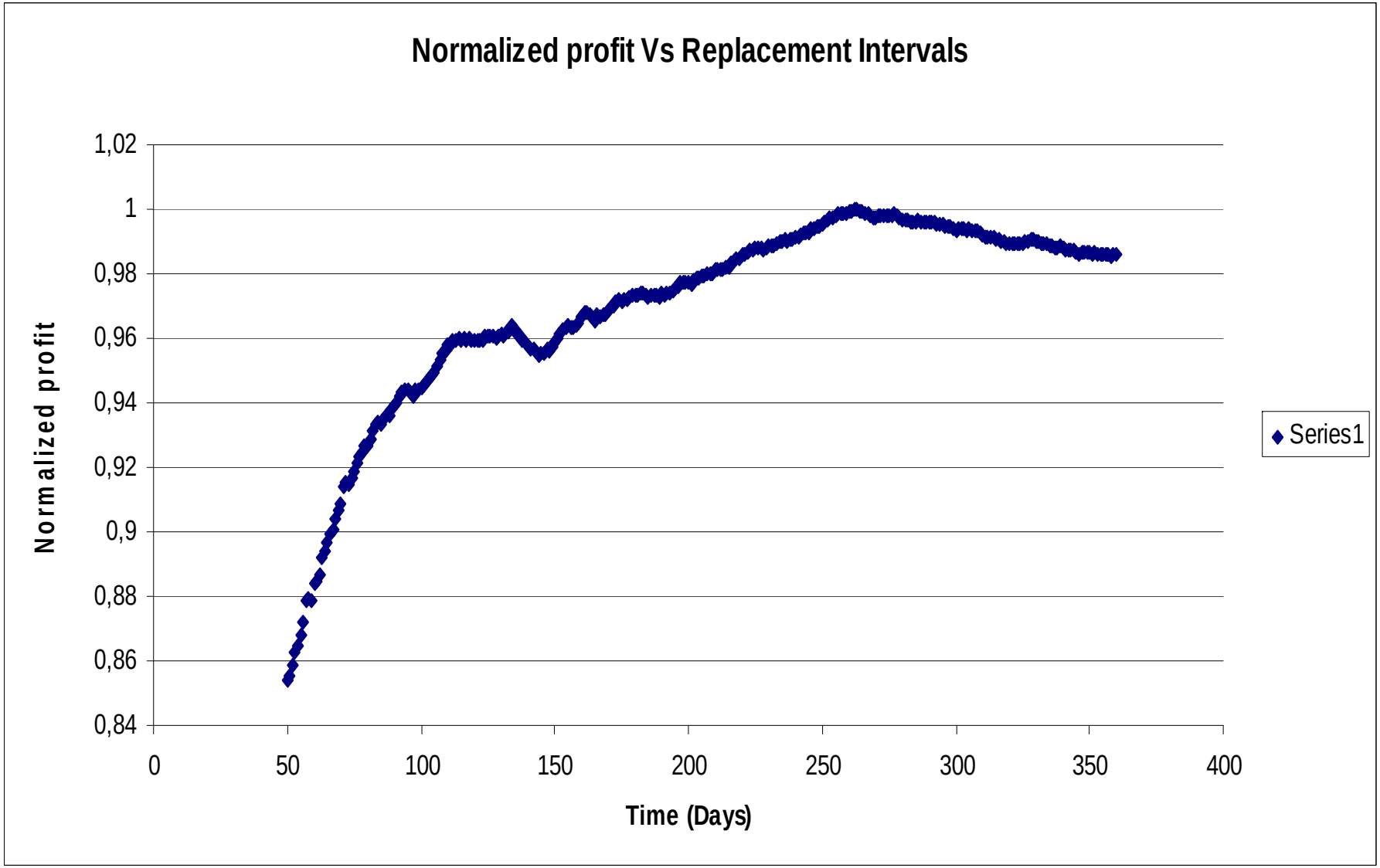
$$P^{j}_{time\,sample} = \left[\left(\sum_{i=1}^{k} M_i \right) \cdot \Omega \cdot \alpha \cdot \eta_p - \left(\left(\sum_{i=1}^{k} E_i \right) \cdot C_{pow} + \frac{C_{rep}}{(T_{Cycle} + T_{rep})} \cdot t_{in} + \right. \right.$$
$$\left. \left. + t_{in} \cdot C_{ins} + \frac{C_{DT}}{(T_{Cycle} + T_{rep})} \cdot t_{in} \right) \right]$$

$$P = \sum_{j=1}^{s} P^{j}_{time\,sample}$$ Where,

Gross profit $$P_{gross} = P \times \left(\frac{n \times 365}{T_{Cycle} + T_{rep}} \right)$$

For the period of “n” year the *average profit* per year will be $$P_{avg} = \frac{P_{gross}}{n}$$

A computer program was made on visual basic to simulate the model for various replacement days (ex. 360 to 1)


Normalized profit Vs Replacement Intervals
Normalized profit
1,02
1
0,98
0,96
0,94
0,92
0,9
0,88
0,86
0,84
0
50
100
150
200
250
300
350
400
Time (Days)
Series1

Future research within the project

- The liner replacement model will be developed for multiple ores types. A demonstrator will be delivered. Eventually also the replacement of individual liners will be incorporated
- FEM calculations, considering the influence of the wear of liners on the crack propagation at the shell will be performed

Nominated to first price at the contest (Stora Produktivitetspriset 2010)

"Dubbelprofessor" Jan Lundberg nyligen utsett som professor i drift och underhållsteknik , och hans doktorand Rajiv Dandotiya.

- Som det ser ut nu kommer vi förmodligen att skaffa oss en helt annan framförhållning och det innebär direkt pengar för oss så jag är väldigt nöjd med detta, säger Jonas Fjellner projektledare vid Boliden Mineral AB.

Publications so fare

1) "A systematic evaluation of devices for measuring abrasive wear of mill liners", Proceedings of the 22nd International congress on Condition monitoring and diagnostic engineering management: COMADEM 2009, 9-11 June 2009, San Sebastian, Spain
2) "Crack detection methods for Mining Mill Machinery", J. Nordström, A. Parida, R. Dandotiya and J. Lundberg (2009), Proceedings of 22nd International Congress of Condition Monitoring and Diagnostic Engineering management, June 09-11, Spain, pp.313-321 and published in AMMJ
3) "Mathematical model for optimum replacement interval of grinding mill liners", International Conference on Quality, Reliability and Infocom Technology: ICQRIT 2009, 18-20 December 2009, Delhi, India
4) "Evaluation of abrasive wear measurement devices of mill liners", International Journal of Condition Monitoring and Diagnostics Management: COMADEM, Article accepted.

The first three publications will be found on the following link.
http://www.ltu.se/staff/r/rajdan?l=en

Conclusions

- A theoretical model is developed which have the capacity to predict the optimum replacement interval for liners in a mill and the corresponding profit
- The results obtained for optimum replacement interval shows an approximate increase of 1.0152 % in gross profit per year by changing the current replacement policy to the proposed policy
- An alternate way of decision making without using periodic wear measurements of mill liners due to the unavailability of enough wear data to analyze is developed
- The project has promoted the development (Damill AB) of a new laser based method for faster measurement of the wear of liners

Thank You for the attention!

Questions?