

https://dspace.org/

Simulation of multiple closed loop milling circuits

Rabins, Richard

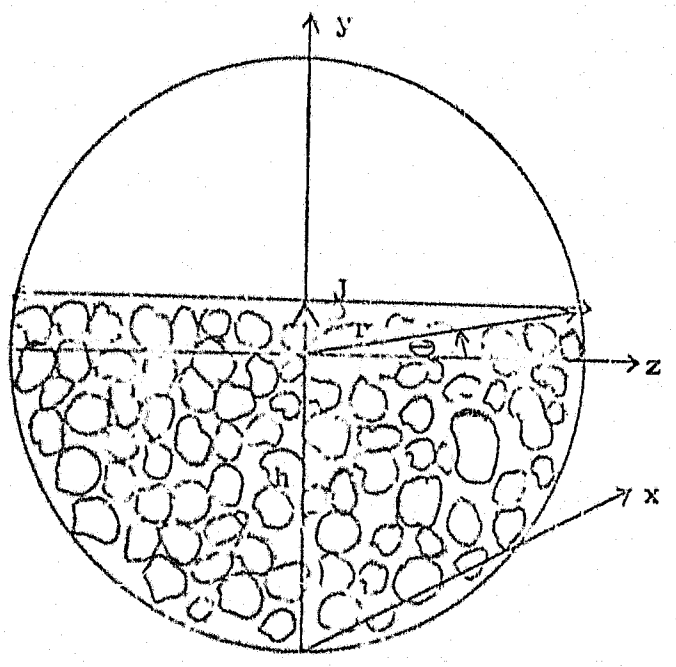
2015-07-02
http://hdl.handle.net/10539/18047

Downloaded from a DSpace repository. https://dspace.org/

```
L.0588 GO TO 46
L.0589 36 YESNO6=0.0
L.0591 46 CONTINUE
L.0592 SORT
L.0593              TIMER FINI(M=1,7,OUTDEL=0.02
L.0594              PRTPLT PRODS(PCW01,X1A,X2A)
L.0595              PRTPLT CIRCLD(MMASA1,MMAS01,MMASC1)
L.0596              PRTPLT X3A(X4,X5,X6)
L.0597 PRTPLT MPWER1(YESNO1,YPWER2,MPWER3)
L.0598 PRTPLT MPWER4(YESNO4,YESNO2,YESNO3)
L.0599 PRTPLT S1(S2,S3,S4)
L.0600 PRTPLT X7(X8,)9,X10)
L.0601              END
L.0602              STOP
L.0603 ENDJOB
L.0604 /*
```

APPENDIX 2

THE EXTENSION OF THE DISCRETE SUB-MILLS CONCEPT FOR THE PEBBLE MILL TO AN INFINITE NUMBER OF SUB-MILLS



In section 4.4.4.1 it was shown that the flow of material down the length of the mill is given by:

$$\text{Flow} = (Z)(J)(dh/dx)$$

For a continuous system we can write:

$$\text{Flow}(x,t) = (Z)(J(x,t))\left(\frac{\partial h(x,t)}{\partial x}\right)$$

where:

$h(x,t)$ = height of the mill charge at point x along the mill and at time t

Z = a constant

$J(x,t)$ = width of the charge surface at point x along the mill and at time t

Assume that $J(x,t)$ is a constant in the region of operation (i.e. where Θ is small), and, since the sign of

dh/dx is negative, to ensure that the overall flow is positive the overall flow equation must be:

$$\text{Flow}(x,t) = -Z'\left(\frac{\partial h(x,t)}{\partial x}\right)$$

where:

$$Z' = (Z)(J(x,t))$$

now

$$\frac{\partial m(x,t)}{\partial t} = \frac{\partial \rho A(x,t)\Delta x}{\partial t} = \text{Flow}(x,t) - \text{Flow}(x+\Delta x,t) \quad \ldots \text{ A2.0}$$

where:

$\frac{\partial m(x,t)}{\partial t}$ = rate of change of mass at a point x along the mill and at time t

$A(x,t)$ = cross-sectional area of the charge at point x along the mill at time t

ρ = density of mill charge

A2.0 can be rewritten as:

$$\frac{\partial \rho A(x,t)}{\partial t} = \frac{\text{Flow}(x,t) - \text{Flow}(x+\Delta x,t)}{\Delta x}$$

or

$$\frac{\partial \rho A(x,t)}{\partial t} = -\frac{\partial \text{Flow}(x,t)}{\partial x} = \frac{\partial Z' \partial h(x,t)}{\partial x \partial x}$$

but $J(x,t)$ has been assumed constant, therefore the above equation becomes:

$$\frac{\partial A(x,t)}{\partial t} = \frac{Z'}{\rho}\left(\frac{\partial^2 h(x,t)}{\partial x^2}\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \text{ A2.1}$$

Assuming that $\sin\Theta = \Theta$ for values of Θ in the operating region, (see Appendix 3 for an error analysis of this), it can be shown that:

$$h(x,t) = r + r\Theta(x,t) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \text{ A2.2}$$

$$A(x,t) = \tfrac{1}{2}\pi r^2 + 2r^2\Theta(x,t) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \text{ A2.3}$$

Substituting A2.2 and A2.3 in A2.1, the following equation results:

$$2r^2\frac{\partial \Theta(x,t)}{\partial t} = \frac{Z' r \partial^2 \Theta(x,t)}{\rho \partial x^2}$$

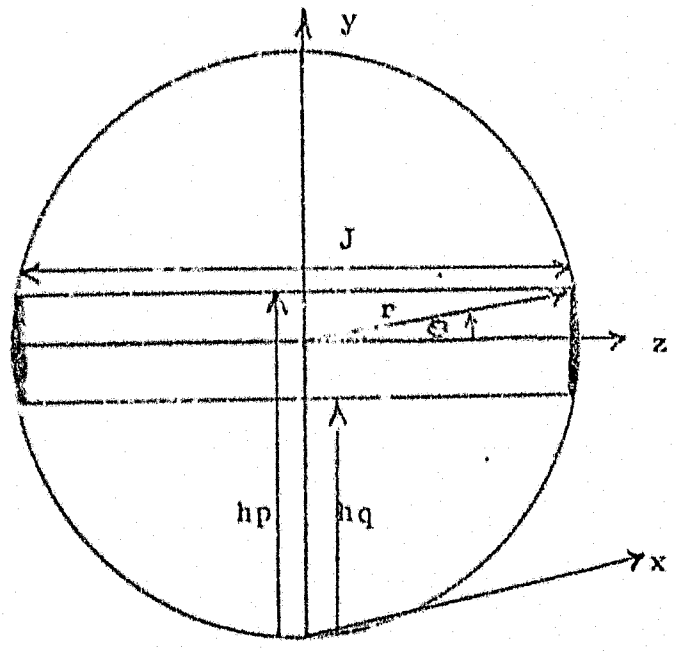
APPENDIX 3

JUSTIFICATION OF ASSUMPTIONS USED IN DERIVATIONS

Assumption 1:

$$J(hp - hq) = Ap - Aq$$

(For the mill approximately one half full)



Consider the above figure. The error of the assumption is due to the fact that the shaded regions are not included in the area calculation.

It can be shown that when the mill mass varies by 15% about the one half full point:

$\frac{J}{2} = 0.993r$ (0.7% error)

Therefore, in this case, the maximum error in area will be 1.4%.

In the case of a 30% variation about the one half full

point:

$\frac{J}{2} = 0.971r$

resulting in a 6% error in area.

Assumption 2:

Sin Θ = Θ in the operating region of the mill.

A 15% mill mass fluctuation means that Θ is 6.8°. This results in a 0.3% difference between Θ and sinΘ .

A 30% mill mass fluctuation means that Θ is 13.8°. This results in a 1% difference between Θ and sin Θ .

APPENDIX 4

DERIVATION OF BULK DENSITY FUNCTION

bulk density $= \dfrac{\text{total mass}}{\text{total volume occupied}}$

total mass $= MM + X_1 + X_2$

total volume occupied (assuming 40% voids) $= 1.4\left(\dfrac{MM}{W}\right)$

therefore:

bulk density $= \dfrac{W}{1.4} + \dfrac{W(X_1 + X_2)}{1.4(MM)}$

APPENDIX 5

LIST OF FIGURES

		Page
1.	Schematic Diagram of the Blyvooruitzicht Gold Mining Co. Limited's Milling Circuit	6
2.	Response of the Linear and non-Linear Blyvooruitzicht Simulators to a Step Change in Water Addition to the Head Tank (60 tons/hour to 120 tons/hour)	14
3.	Response of the Linear and non-Linear Blyvooruitzicht Simulators to a Step Change in Rod Mill Feed (70 tons/hour to 50 tons/hour)	15
4.	Schematic Diagram of the Buffelsfontein Gold Mining Co. Limited's Milling Circuit	21
5.	Response of the Buffelsfontein Simulator to a Step Change in Head Tank Water Addition (112 tons/hour to 224 tons/hour)	28
6.	Response of the Buffelsfontein Simulator to a Step Change in Rod Mill Feed (100 tons/hour to 75 tons/hour)	29
7.	Ideal Operation of the "Digicon"	36
8.	Schematic Layout of the "Digicon"	37
9.	Results of the Simulations of the Pebble Mill split into 3, 5 and 15 Sub-Mills under "Digicon" control	50
10.	Results of Tests on the Blyvooruitzicht Simulator where Noise has been added to the Power Signal. (The 5 Sub-Mills Pebble Mill Power Model has been used)	52
11.	Comparison of one Cycle of Responses of Buffelsfontein Simulator, under "Digicon" Control, with a Single Mill Model and a 5 Sub-Mills Model	55
12.	Percentage Liberation of Gold in discretely sized crushed Ore	63
13.	Controlled and Uncontrolled Responses of Buffelsfontein Circuit to a Step Change in Rod Mill Feed (100 tons/hour to 110 tons/hour). (Product size)	64

		Page
14.	Controlled and Uncontrolled Responses of Buffelsfontein Circuit to a Step Change in Rod Mill Feed (100 tons/hour to 110 tons/hour). (Circulating Load)	65
15.	Schematic Diagram of Buffelsfontein Circuit with Control Configurations included	67
16.	Comparison of Responses of Buffelsfontein Simulator to Set Point Control with Single Feed Back, "Parallel" Feed Back and "Cascaded" Feed Back. (Product Size)	69
17.	Comparison of Responses of Buffelsfontein Simulator to Set Point Control with Single Feed Back, "Parallel" Feed Back and "Cascaded" Feed Back. (Circulating Load) ...	70
18.	Response of Buffelsfontein Simulator to a Value of Set Point Control higher than 75% less than 75μm	72
19.	Response of Buffelsfontein Simulator to Set Point Control with Feed Back to Pump Speed from Product Size	73
20.	Comparison of Controlled and Uncontrolled Responses of Buffelsfontein Simulator to noisy Rod Mill Feed	74
21.	Comparison of Product Size and Circulating Load of Buffelsfontein Circuit under "Digicon" Control with Product Size and Circulating Load of Buffelsfontein Circuit under Control of Alternative Controller ...	77
22.	Comparison of Mill Power Characteristics of "Digicon" Controller with Mill Power Characteristics of Alternative Controller ...	78

LIST OF REFERENCES

1. Hogg, R. and Fuerstenau, D. W. "POWER RELATIONSHIPS FOR TUMBLING MILLS". A.I.M.E. Transactions, Vol. 252, Pages 418 - 423. December 1972.

2. "I.B.M. APPLICATION PROGRAM: C.S.M.P." Users Manual, January 1972.

3. Hinde, A. L. "CONTROL OF MILL CIRCUITS FOR CONSTANT PARTICLE SIZE OF PRODUCT". Progress Report, Metallurgy Laboratory, Chamber of Mines of South Africa, unpublished paper, December 1975.

4. Hinde, A. L. and King, R. P. "REPORT ON MINIMAL VARIANCE CONTROL STRATEGIES FOR WET MILLING CIRCUITS". Chamber of Mines of South Africa Research Report No. 103/76, December 1976.

5. Lynch, A. J. and Rao, T. C. "MODELLING AND SCALE UP OF HYDROCYCLONE CLASSIFIERS". 11th International Mineral Processing Congress, Cagliari, 1975.

6. Flitt, L. R. "THE ANALYSIS OF SOLID-SOLID SEPARATIONS IN CLASSIFIERS". CIM Bulletin, 64, pages 42 - 47, 1971.

7. Hinde, A. L. "CONTROL OF MILLING CIRCUITS FOR CONSTANT PARTICLE SIZE". Note for the Record, Metallurgy Laboratory, Chamber of Mines of South Africa, unpublished paper, 15th March 1976.

8. Herbold, R. J. "THE USE OF CONTINUOUS SIMULATION IN ESTIMATING PARAMETERS IN SYSTEMS OF DIFFERENTIAL EQUATIONS". Proceedings of Conference on Applications of Continuous System Simulation, June 1969.

9. Flitt, L. R. "A MATHEMATICAL MODEL OF THE HYDROCYCLONE CLASSIFIER". CIM Bulletin, December 1976.

10. Webber, C. B. and Diaz, L. S. "AUTOMATIC PARTICLE SIZE AND ROD MILL TONNAGE CONTROL AT CRAIGMONT MINES LTD." Canadian Mineral Processors Annual Meeting, Ottawa, Ontario, January 1973.

11. Dart, P. W. and Sand, J. A. "BENEFITS TO BE EXPECTED FROM A REAL-TIME MEASUREMENT OF PARTICLE SIZE". Conference of Metallurgists, Canadian Institute of Mining and Metallurgy, Quebec City, August 1973.

12. Klimpel, R. R. and Austin, L. G. "THE BACK-CALCULATION OF SPECIFIC RATES OF BREAKAGE AND NON-NORMALIZED BREAKAGE DISTRIBUTION PARAMETERS FROM BATCH GRINDING DATA". International Journal of Mineral Processing, Vol. 4, Pages 7 - 32. 1977.

13. Tauté, W. J., Meyer, P. and Austin, L. G. Proc. IFAC Symposium on Automatic Control in Mining, Mineral and Metal Processing, Sydney, Pages 11 - 19, 1973.

14. Austin, L. G. and Luckie, P. T. "METHODS FOR DETERMINATION OF BREAKAGE DISTRIBUTION PARAMETERS". Department of Material Sciences, Pennsylvania State University, unpublished paper, January 1971.

15. Bailey-McEwan, M. "PROGRESS REPORT NO. 2". Unpublished paper, April 1976.

16. Gueurro, P. K. and Arbiter, N. "TUMBLING MILL POWER AT CATARACTING SPEEDS". A.I.M.E. Transactions, Vol. 180, October 1970.

17. Stanley, G. G. "MECHANISMS IN THE AUTOGENOUS MILL AND THEIR MATHEMATICAL REPRESENTATION". S.A.I.M.M. Journal, November 1974.

18. Himmelblau, D. M. and Bischoff, K. B. "PROCESS ANALYSIS AND SIMULATION: DETERMINISTIC SYSTEMS". Chapter 4, John Wiley and Sons, Inc., New York, 1968.

19. Herbst, J. A., Mika, T. S. and Rajamani, K. "A COMPARISON OF DISTRIBUTED AND LUMPED PARAMETER MODELS FOR OPEN CIRCUIT GRINDING". Zerkleinern, European Symposium, Nuremberg, 15th - 17th September 1975.

20. Bradburn, R. G., Flintoff, B. C. and Walker, A. "PRACTICAL APPROACH TO DIGITAL CONTROL OF A GRINDING CIRCUIT AT BRENDA MINES LTD." Brenda Mines Ltd., Peachland, British Columbia, November 1975.

21. Jaspan, R. K., Kropholler, H. W., Mika, T. and Woodburn, E. "AN ANALYSIS OF CLOSED CIRCUIT WET-GRINDING MILL CONTROL CHARACTERISTICS BY SIMULATION". Zerkleinern, European Symposium, Nuremberg, 15th - 17th September 1975.

22. Lees, M. J. "EXPERIMENTAL AND COMPUTER STUDIES OF THE DYNAMIC BEHAVIOUR OF AN INDUSTRIAL GRINDING CIRCUIT". Ph.D. thesis, University of Queensland, 1973.

23. Birch, P. R. "AN INTRODUCTION TO THE CONTROL OF GRINDING CIRCUITS CLOSED BY HYDROCYCLONES". Minerals Science Engineering, Vol. 4, No. 3, July 1972.

24. Olsen, T. O., Berstad, H. and Danielsen, S. "AUTOMATIC CONTROL OF CONTINUOUS AUTOGENOUS GRINDING". 2nd IFAC Symposium on Automation in Mining, Mineral and Metal Processing, Johannesburg, 13th - 17th September, 1976.

25. Ragot, J., Roesch, M. and de Goul, P. "TRANSIENT STUDY OF A CLOSED GRINDING CIRCUIT". 2nd IFAC Symposium on Automation in Mining, Mineral and Metal Processing, Johannesburg, 13th - 17th September, 1976.

Author Rabins R
Name of thesis Simulation of Multiple closed loop milling circuits 1977

PUBLISHER:
University of the Witwatersrand, Johannesburg
©2013

LEGAL NOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed, or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page) for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.

Author Rabins R
Name of thesis Simulation of Multiple closed loop milling circuits 1977

PUBLISHER:
University of the Witwatersrand, Johannesburg
©2013

LEGAL NOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed, or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page) for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.