Title: Dense media cyclone models applied to the pre-concentration of diamond ores

Authors affiliation:

M. Cristina Vila (mvila@fe.up.pt), CERENA-FEUP, Department of Mining Engineering, Faculty of Engineering, University of Porto, Portugal

Jelson Damião, Department of Mining Engineering, Faculty of Engineering, University of Agostinho Neto, Luanda, Angola

Extend Abstract

Introduction

Dense media cyclones (DMC) allow a highly efficient separation technique that uses centrifugal sedimentation to separate particles based on the difference in density—having been used since the last century, mainly in coal beneficiation. However, it is also used in iron and diamond ores. The dense medium was first used in diamond processing in 1946 at Premier Mine, South Africa [1],[2], since then its field of application has remained quite stable. Although dense media cyclones constitute an economical and environmentally compatible solution, advances in technology have not kept pace with the speed at which metal ore recovery processes have evolved, for example, flotation or hydrometallurgical processes. Underlying this is the decreasing demand for coal and the rare and localized nature of diamond occurrences.

In the pre-concentration of diamond ores, the dense medium used is commonly suspensions of fine iron-silicon particles, with the efficiency of the process depending on several variables since we have three phases involved (the float - gangue, the sink - concentrate, and the dense medium - of intermediate density). The main factors responsible for the efficiency of DMC separation are therefore feed pressure, the density of the dense medium pulp, granulometry of the dense medium, particle size distribution, particle shapes, density distribution of the ore particles, and the diameter and angle of the conical section of the cyclone [3].

Until the end of the 1990s, the mechanism of particle separation in DMC was not fully understood, relying almost exclusively on empirical models developed for coal separation [4]. DMC internal flow is highly complex and difficult to describe mathematically, even though there has been an increase in recent years in the application of computational fluid dynamics (CFD) to understanding DMC's mechanism [2], [4], [5]. Due to this complexity and the diamond processing specificities, to date, DMC equipment performance has been predicted using empirical equations, derived from the analysis of experimental data including the effect of operational and design variables.

The present work tested the empirical models of Plitt (1976), and Nageswararao and Napier-Munn (1978) to simulate kimberlite diamond ores pre-concentration by DMC. Model results were fitted to experimental data through parameter optimization using the nonlinear optimization generalized reduced gradient (GRG) method.

Methodology

The Plitt model after Flintoff et al. (1987), adapted to density as the cut-property has no dependence on feed density characteristics in any of its equations to determine the four dependent variables: cut-density (*d50c*), volumetric flow split (*S*), pressure drop (*P*), and a sharpness coefficient (*m*). After obtaining d50c, the reduced efficiency (E_{Uc}) can be calculated from the derived Rosin-Rammler function (1), where m is a constant separation parameter:

$$E_{Uc} = 1 - e^{-\ln(2).\left(d_i/d_{50c}\right)^m} \qquad (1)$$

The Nageswararao model (1978) was then tested and selected to be used and adjusted to the diamond ore in the current study since this model assumes a more phenomenological nature than the previous one. Also, unlike the Plitt model, the Nageswararao model, in addition to the laminar flow adjusts to the turbulent flow of the particles, too. The efficiency is then calculated according to equation (2), expressed in terms of overflow recovery (E_{Oa}), being C the cyclone water split to overflow, and α a cyclone efficiency curve shape parameter [6]:

$$E_{Oa} = C\left[\frac{e^{\alpha}-1}{e^{\alpha\, d_i/d_{50c}}+e^{\alpha}-2}\right] \qquad (2)$$

Both models were implemented in a spreadsheet and also in MatLab®. Data published in the literature was used to validate the models and, in a second phase, it was possible to obtain experimental data from a diamond mine in Angola that allowed to calibrate and adjust the Nageswararao model.

Results

The results of a simulation obtained by applying Nageswararao 's model are presented below, with the input data shown in table 1, the partition curves in the graph of figure 1 and the values of the fitted parameters, as well as the quantifier of the quality of the fit, shown in table 2.

Table 1: DMC characteristics, used as model input.

Input parameters	Value	Units
Diameter of the cyclone (D_c)	0.40	m
Diameter of the cyclone vortex finder (D_o)	0.18	m
Diameter of the cyclone spigot (D_u)	0.08	m
Length of the cylindrical section of the cyclone (L_c)	0.23	m
Full cone angle (Θ)	18	degrees

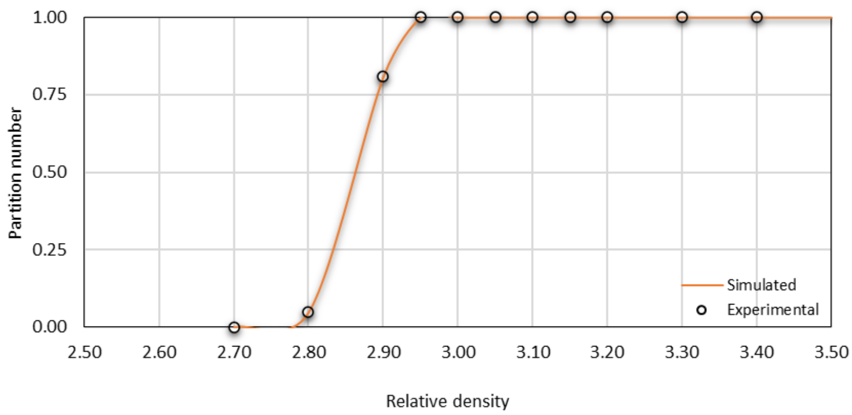

Figure 1 – Obtained partition curve from model simulation (continuous line) overlapped the values calculated from the experimental.

Table 2: Obtained DMC modeling parameters.

Adjusted model parameters	Value
Performance constant (KD_{P0})	3.47
Model parameter affecting the ratio D_u/D_c (a)	1.03
Model parameter affecting the ratio D_o/D_c (b)	1.01
Model parameter related to the drop pressure (f)	0.96
Model parameter affecting the settling factor (g)	1.00
d_{25} and d_{75}	2.82, 2.89
Efficiency of separation E_p	0.033
Quality of the curve fitting, R^2	0.197E-6

The simulated values, after optimizing the sum of the squares of the residuals, show a good fit with the experimental values obtained in tests with indicator crystals, which are carried out periodically in diamond processing plants to ascertain the quality of the dense medium. In the present example the efficiency of the separation, measured by the density corresponding to the middle point between d_{25} and d_{75}, revealed a partition curve close to the perfect partition, represented by a Heaviside step function.

Conclusion

Given the particular nature of diamond ore processing plants, which are eminently discrete, low-grade, and little automated, Nagas' semi-empirical model proved to be a suitable tool for predicting and simulating the behaviour of the dense media cyclone preconcentration operation for diamond ores.

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