A Study of Pinched Sluice Concentrator

by

MR. B. JEYADEVAN (C.I.S.I.R.)

Abstract : The pinched sluice concentrator is a device for the separation of heavy minerals particularly beach sands. They come in a variety of sizes and shapes and have been used extensively overseas in the beach sand industry for over a century.

Previous work to study the mechanisms of separation of these units have been of a purely empirical nature and thus required experienced and skilled operators to achieve acceptable level of separation. More recent work has shown that the performance characteristics of a pinched sluice could be analysed using the established theories of fluid mechanics and mineral processing.

This paper outlines the work published up to date and also the progress of research in this field at the Department of Mining and Mineral Engineering, University of Moratuwa.

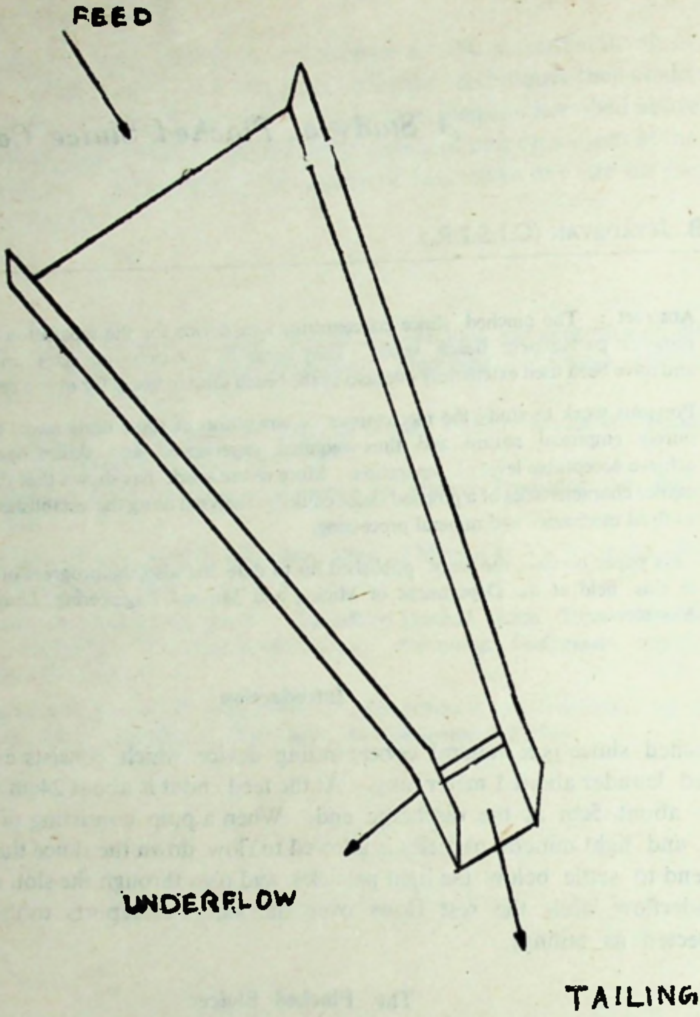
1. Introduction

A pinched sluice is a mineral concentrating device which consists essentially of a inclined launder about 1 meter long. At the feed end it is about 24cm wide, narrowing to about 5cm at the discharge end. When a pulp consisting of a mixture of heavy and light mineral particles is allowed to flow down the sluice the heavy particles tend to settle below the light particles and pass through the slot and collected as underflow while the rest flows over the slot and reports to the tail end and is collected as tailings.

The Pinched Sluice

Although the pinched sluices have been used for the concentration of heavy minerals, especially in the beach sand industry for over a century, the segregation mechanism involved has not been fully understood. Even then the high degree of separation that could be achieved in a pinched sluice had lead to the invention of new devices such as Reichert Cone Concentrators.

The Reichert Cone Concentrator is an extension of pinched sluice in that its conical shape is essentially a number of sluices without walls joined together side edge to side edge. These units are being used for some years in the field of mineral processing and are becoming one of the standard tools in the beach sand industry. They are being extensively used in Australia, to process ilmenite, rutile from the beach sand and it can handle a few million tons per year.



However, the device in such configuration is not capable of producing a clean concentrate in a single operation. Therefore an assembly of these units is used to get a final concentrate. Design of these assemblies and the determination of their optimum condition correspond to the performance of the basic unit pinched sluice. In an attempt to study the segregation mechanisms of pinched sluice a project has been initiated by the Ceylon Institute of Scientific and Industrial Research in collaboration with the Department of Mining and Mineral Engineering, University of Moratuwa.

2. Previous Work

Most of the earlier work on pinched sluices had been of an empirical nature where the grade of the product (underflow) is correlated to the operating variables by way of regression analysis using a large number of operating data covering a wide range of operating conditions.

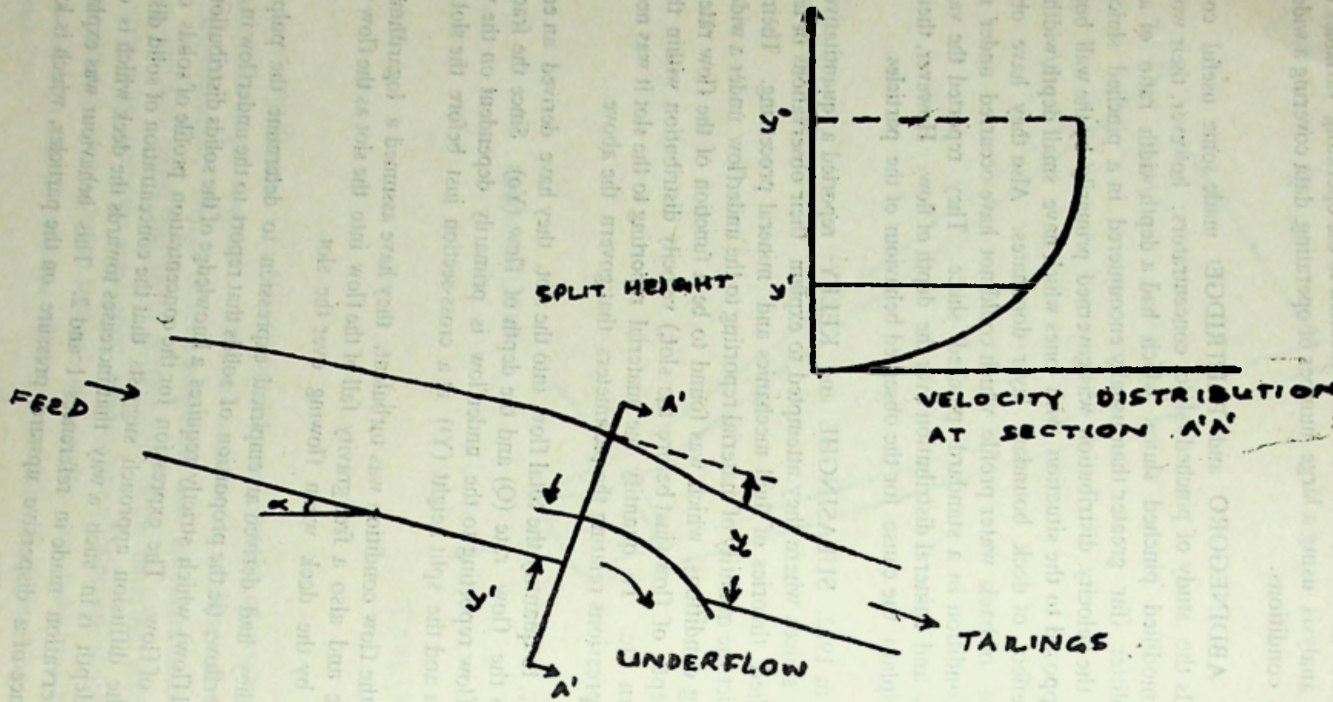
In 1979, ABDINEGORO and PARTRIDGE[1] made some useful contributions towards the study of pinched sluice concentrators; however, their work was done on a modified pinched sluice, which had a depth/width ratio of about 6 near the splitter (far greater than usually encountered in a pinched sluice). In their sluice, the velocity distribution was governed primarily by the wall boundary layers, as opposed to the situation with ones which have small depth/width ratio, where the effect of deck boundary layer dominates. Also they have observed the existence of back water profile which could not have occurred under normal operating condition in a standard pinched sluice. They reported the variation of flow rates and mineral distribution over the depth of flow. However, their work does not explain the cause for the observed behaviour of the particles.

Later, in 1982, SUBASINGHE and KELLY[2] reported a quantitative study on pinched sluices where they attempted to explain their observations in terms of the established theories of fluid mechanics and mineral processing. Their work was to predict the quantity of material reporting to the underflow under a wide range of operating conditions, which was found to be a function of the flow rate, angle of slope, depth of flow (just before the slot,) velocity distribution within the flow flow pattern etc. To quantify the material reporting to the slot it was necessary to have expressions relating the parameters that govern the above.

Firstly, to quantify the total flow into the slot, they have derived an equation relating to the flow rate (Q) and the depth of flow (Yo). Since the fraction of the total flow reporting to the underflow is primarily dependent on the velocity distribution and the split height (Y^1) at a cross-section just before the slot.

Since the flow condition was turbulent, they have assumed a logarithmic velocity profile and also a free gravity fall of the flow into the slot as the flow was not supported by the deck when flowing over the slot.

Also they had derived an empirical expression to determine the pulp density of the underflow, (ie the proportion of solids that report to the underflow in relation to the total flow) which strictly requires a knowledge of the solids distribution across the depth of flow. The expression for the concentration profile of solids obtained by using the diffusion approach suggests that the concentration of solid distributed over the depth is in such a way that increases towards the deck which is contrary to the observation made in references 1 and 2. This behaviour was explained by the existence of a dispersive upward pressure on the particles, which is known as BAGNOLDS stresses.



longitudinal X — section through the enterline of sluice.

Finally, they have derived an expression to quantity the proportion of the heavy particles to the light ones in the underflow. (ie. the grade of the underflow) by arguing that the charge from the initial completely mixed state to the segregated steady state could be described by a first order rate equation.

3. Summary of the results

3.1. It has been shown that the relationship between flow rate (Q) and depth of flow (Y_0) takes the form,

$$\frac{Q}{B \,\mathrm{Sin}\, \alpha \,\frac{1}{2}} = a\, Y_0^{\,b}$$

Where, a and b are constants

α — inclination
B — width of sluice (just before the slot)

The above relationship will give us the depth of flow (just before the slot) for a given flow rate, width of sluice, and inclination. By assuming logarithmic velocity profiled and a free gravity fall, it is possible to evaluate the split height Y' which in turn enables the determination of the total flow through the slot.

3.2. Concentration of solids in the underflow is expressed in terms of the concentration of feed, grade of feed, the angle of slope and takes the form,

$$\frac{C_u}{C_f} = \frac{0.28}{(\mathrm{Sin}\alpha)^{1.7}} + 1.5 g_f - \frac{0.06\, C_f}{(\mathrm{Sin}\alpha)^{3.1}}$$

Where, Cu — concentration of the underflow
C_f — concentration of the feed
g_f — grade of feed.

3.3. The grade of underflow has been given as follows:

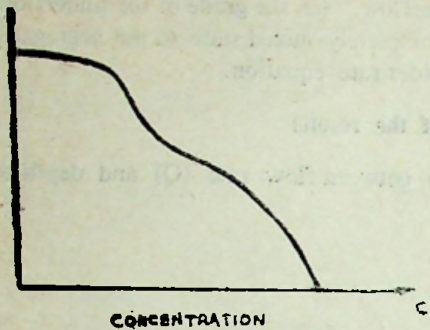
$$g_u = g_f/\phi$$

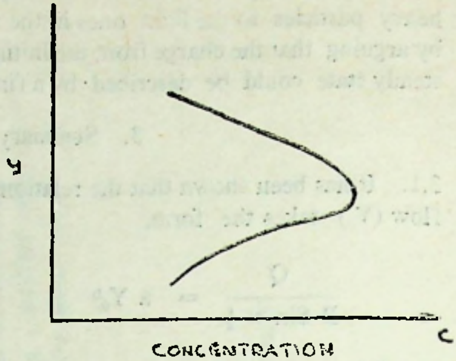
Where, $\phi = (1 - \phi)^e - t/T + \phi$
g_f = grade of feed
t = residence time
$\phi = g_f/g_u$
$\phi = \phi = g_f$

4. Present Work

Present work is an extension of the above work. It is intended

1. To verify whether the concentration profile of solids over the depth of flow complies with the theory of BAGNOLDS dispersive shear or that of diffusion theory.





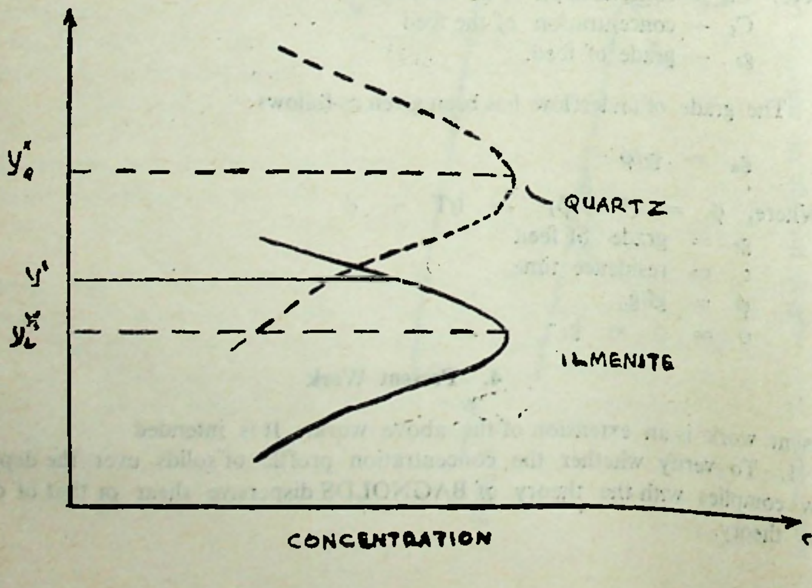
Solid Concentration Profiles

Although the observed results may be explained quantitatively by BAGNOLDS THEORY, their complete quantitative analysis will not be possible until more work is done.

The particle distribution over the depth in a pinched sluice shows that the concentration increases as the distance from the base of the sluice increases up to a certain depth beyond which the concentration decrease.

The solid distribution over the depth will decide on the amount of solids that report to the slot and is dependent on the split height, velocity distribution and the slot width.

2. To study the particle distribution of different minerals over the depth under a given set of conditions, and also to determine the depth as which maximum concentration occurs.



As shown above different minerals will have maximum concentration at different depth. So if we are to separate iron sand. the split height at which we should operate is Y'.

3. To study the effects of particle size on the grade and recovery of the underflow product.

References

1. Sujipto Abdinegoro and Antony C. Partridge — 1979. Flow Characteristics of a Pinched Sluice. The Aus. I.M.M. Conference.
2. Subasinghe and Kelly — 1983. Modelling of a Pinched Sluice Concentrator. Thesis for the degree of Doctor of Philosophy to the School of Engineering, University of Auckland, New Zealand.
3. G. K. N. S. Subasinghe and Kelly — Control '94. Mineral/Metallurgical Processing Organised by the AIME of NY 1984.