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ADVANCED GRAVITY SEPARATORS - A REVIEW OF STATE OF THE ART TECHNOLOGY

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ABSTRACT

A comprehensive review of various types of industrial advanced gravity separators (AGS) is presented. The discussion focuses mainly on enhanced gravity separators and teetered bed separators. Enhancement of settling velocity of fine and ultrafines particles is discussed. The principle of separation, application and its separation performance of each device are reviewed. Details of the variables involved and the respective advantages and disadvantages of the separators, along with explanatory diagrams illustrating the processes have been discussed.

Keywords : Enhanced gravity separation, Principle, applications and performance, Tectrered bed separator.

INTRODUCTION

Recovery of valuables from natural ores by gravity concentration process is one of the oldest techniques. This technique is widely used in mineral beneficiation practices for its low cost, ease of operation, and eco-friendly nature. Differential settling velocity of the particles is the basis of such processes. The settling velocity of particle is governed jointly by weight, buoyancy and drag force.

Application of gravity processes is still questionable for concentration of fines and ultrafines particles because of their poor settling characteristics. Gravity force is not sufficient to create the differential mobility on the particle for fines and ultrafines. However, significant advancement is made in the field of gravity separation by introducing several advanced gravity separators. In some of these techniques centrifugal field is applied to enhance the gravity. Separators, where centrifugal field is employed, are called enhanced gravity separator (EGS). In certain instances, autogenous heavy medium is created when they are called teetered bed separator (TBS). These EGSs and TBSs are capable of concentrating fines and ultrafines particles. In the present review, the following advanced gravity separation methods are reviewed with emphasis on the separation principle and potential applications :

– EGS : (a) Knelson concentrator, (b) Falcon concentrator, (c) Kelsey Jig, (d) Multi-Gravity Separator (MGS) and (e) Water-only Cyclone (Stub Cyclone)

– TBS : Floatex Density Separator

PRINCIPLE OF ENHANCE GRAVITY SEPARATORS

Settling velocity of an individual particle is determined from its physical properties namely size, density and shape along with the fluid-particle and particle-particle interactions. Particle dynamics may be expressed by the following equation.

$$m_p \frac{du_p}{dt} = F_g - F_b - F_d \qquad (1)$$

where m_p and u_p are mass and velocity of a particle respectively, t is time, F_g, F_b, F_d are gravitational force, buoyant force and drag force respectively, acting on the particle.

Particles having higher specific gravity settle faster than those having lower specific gravity, and thus differential mobility is generated. For better separation a minimum difference in settling velocity between different minerals is essential. To ensure a minimum difference in settling velocity concentration criterion is defined [1-2] as follows.

$$C_c = \frac{\rho_h - \rho_m}{\rho_L - \rho_m} \qquad (2)$$

where, ρ_h, ρ_L and ρ_m are the specific gravity of the heavy mineral, light mineral and fluid respectively and C_c is concentration criteria. A value of C_c above 2.5 gives viable separation in conventional gravity separators. Newly developed various EGSs systems are used for concentration for materials having concentration criteria below 2.5.

Fine particles possess small mass and higher surface area which leads to lower particle momentum and higher surface energy. Hence, the settling characteristics of fines and ultrafine particles are less influenced by their density and size along with other interacting forces. Gravity is enhanced by application of centrifugal field to cause economic separation. Settling velocity of a particle in a centrifugal field can be expressed by the following equation (3).

$$m_p \frac{du_{pr}}{dt} = F_c - F_b - F_d \qquad (3)$$

where, u_{pr} is the particle radial velocity and F_c is the centrifugal force acting on the particle.

Under steady state condition particle settling in Stokes flow regime under centrifugal field could be expressed by the following correlation [3].

$$u_{pr} = \frac{(\rho_p - \rho_f)d_p^2\omega^2 r}{18\mu} \qquad (4)$$

where, ρ_p and ρ_f are particle and fluid density respectively, ω is particle angular velocity, r is radius of circulatory motion, d_p is particle diameter and μ is fluid viscosity. Influence of centrifugal field on particle settling velocity can be described by equation (4). Luttrell et al. [4] have discussed the influence of centrifugal field on settling velocity of coal particles (Fig. 1). In their discussion, particles of varying size and density were considered. The enhancement of settling velocity is the basis of EGSs. Salient features of different EGSs are presented in Table 1.

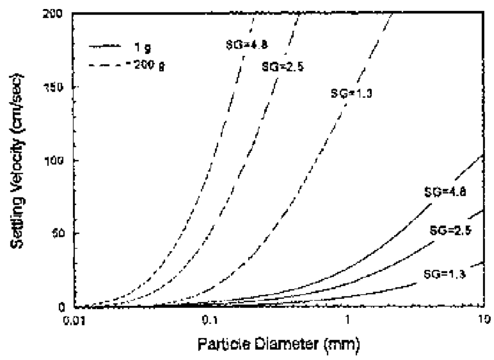

Fig. 1 : Effect of centrifugal force on particle settling velocity [4]

Teetered Bed Separators (TBS)

Proper selection of operating parameters lead to generation of autogenous, dense medium in this type of separators. Hindered settling is the mechanism of settling. Particles settle and accumulate inside the unit forming a bed. Particle bed extends into a state of teeter by action of fluidizing water. This bed acts as an artificial heavy medium. The apparent viscosity and density of suspension increase due to this.

Table 1 : Salient features of different EGS

EGS	Salient Features	Disadvantages	Applications
Knelson Concentrator	– About 60g is achievable – Misplacement is minimized using wash water – Both semi-batch and continuous units are available	– Huge amount of fluidization water is required	– Alluvial gold
Falcon Concentrator	– About 300 g is achievable – High capacity – No wash water – Both semi-batch and continuous units are available – Good metallurgical performance – Able to treat particle size down to 15-20 micron – Mechanically simple and robust – Low operator attention required	– Requires feed to be screened to less than opening size of concentrate orifices to prevent blinding	– Coal, iron ore, lead, zinc, copper etc.
Kelsey Jig	– About 60 g achievable – High capacity – Much finer particle could be separated – Narrow specific gravity difference required	– Complex system – Relatively high capital and operating cost	– Tin, chromites, iron ore, gold etc.
Multi-Gravity Separator (MGS)	– About 25 g is achievable – Able to handle very fine particles (-75+10 micron) – Excellent metallurgical performance	– Low capacity – Mechanically complex – Unsuited for treating coarse materials – Require operator attention	– Zinc, lead, copper, tin, gold etc.
Water Only Cyclone	– About 40 g is achievable – Very simple operation – High capacity	– Larger diameter units are inherently inefficient.	– Fine coal cleaning