

EFFICIENT ENHANCED GRAVITY SEPARATION OF FINE MINERALS USING THE KELSEY CENTRIFUGAL JIG

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ABSTRACT

The Kelsey Centrifugal Jig (KCJ) offers enhanced gravity separation by applying centrifugal force to conventional jigging principles. This enables the KCJ to efficiently separate fine minerals and/or minerals with small differences in specific gravity.

The KCJ was first installed commercially at the Renison Bell tin mine in Australia in 1992 and has since undergone significant development and improvement as well as being installed in a number of mineral sands, tin, tantalum, gold and nickel operations. Other areas of application include tungsten, iron ore, chromite and base metals.

This paper presents information on KCJ principles of operation, KCJ applications and performance figures, and the importance of establishing and maintaining the correct supporting circuit to consistently achieve high levels of separation performance, as well as details of on-going support provided by the manufacturer to maintain the mechanical and metallurgical performance of the KCJ (including a service exchange program to minimize downtime).

Kelsey Centrifugal Jig Principles of Operation

The KCJ is an enhanced gravity separator that incorporates an engineering concept which makes it radically different from conventional jigging technology. The KCJ utilises all the parameters of a conventional jig as well as the additional feature of being able to vary the apparent gravitational field acting on very fine particles and across the ragging bed.

Whereas the dynamics in a conventional jig involve only specific induced movements, the KCJ takes a conventional jig and spins it in a centrifuge. The ability to change the apparent gravitational field by changing the rotational speed results in a major improvement in separation efficiency. This is particularly apparent for very fine minerals, as the enhanced field significantly reduces the effect of forces that hinder fine particle separation. Generation of centrifugal force is achieved by a spinning rotor driven by a variable speed motor. Inside the rotor, a cylindrical screen is spun coaxially together with the rotor. The screen is lined inside with ragging material which is evenly spread by the centrifugal force.

The KCJ is fed through a fixed central pipe and particles in the feed are accelerated towards the ragging bed, due to the apparent gravitational force, while continually rising up the vertical surface of the ragging bed, due to displacement caused by the incoming feed. Pressurised water is introduced into a series of hatches behind the screen and this water is pulsed through the ragging bed, fluidising the ragging particles and facilitating stratification and sorting of the feed material according to particle specific gravity.

This results in particles with specific gravity greater than or equal to that of the ragging passing through the ragging bed via mechanisms of hindered settling and consolidated / interstitial trickling and exploitation of differential acceleration rates, which are magnified by higher apparent gravitational forces. The denser particles pass through the internal screen to concentrate hatches and through spigots to a concentrate launder, while lighter mineral particles are discharged over a ragging retention ring into a tailings launder.

The process of hindered settling within the bed is not only accentuated by the centrifugal force, but also by the pulsing of the ragging bed. The pulsing of the bed is achieved via pulse arms connected to pulse pads which push against the jigs flexible diaphragms (at a frequency and amplitude set by the operator) thus pushing the water contained in the concentrate hutch through the internal screen and dilating the ragging bed. The level of dilation impacts on the level of stratification achieved as well as on the amount of material able to pass to concentrate.

The shock waves produced by the pulses have a twofold effect. Firstly they dilate the ragging bed, as mentioned above, allowing minerals to enter the bed. Secondly they accentuate the different rates of acceleration between particles of differing specific gravities. This phenomenon can be explained in the following way:

- Particles that are subject to a constant force will accelerate at a rate proportional to their mass until they reach a critical velocity
- This critical velocity is also affected by the surface area of the particle
- Therefore particles of the same size but differing specific gravities will separate when placed in a field of constant force, but will slow their separation rate once they reach their critical velocity
- The shockwaves, produced by the pulsing action of the KCJ, continually stop the particles, thus dramatically reducing the time they spend at their critical velocity and thereby approximating to some degree continuous acceleration and maintaining their high initial rate of separation

This phenomenon clearly distinguishes the KCJ from open bowl centrifugal concentrators with no pulsation. Such devices technically separate particles on the basis of mass differential, rather than specific gravity differential, which allows large low specific gravity particles to migrate to concentrate with fine higher specific gravity particles (due to their similar mass) and typically results in poorer separation efficiencies than those achieved with the KCJ with pulsation and a separating medium (ragging).

Operating variables affecting jig performance include: feed rate; feed pulp density & viscosity; feed size distribution; rotational (spin) speed; pulsation frequency & amplitude; ragging type, specific gravity, size distribution & bed depth; internal screen aperture size; and hutch water addition rate.

Figure 1 shows a schematic cross-section of a KCJ. The components shown in red rotate during operation, while those shown in green are stationary and those shown in yellow are moving in a different plane.

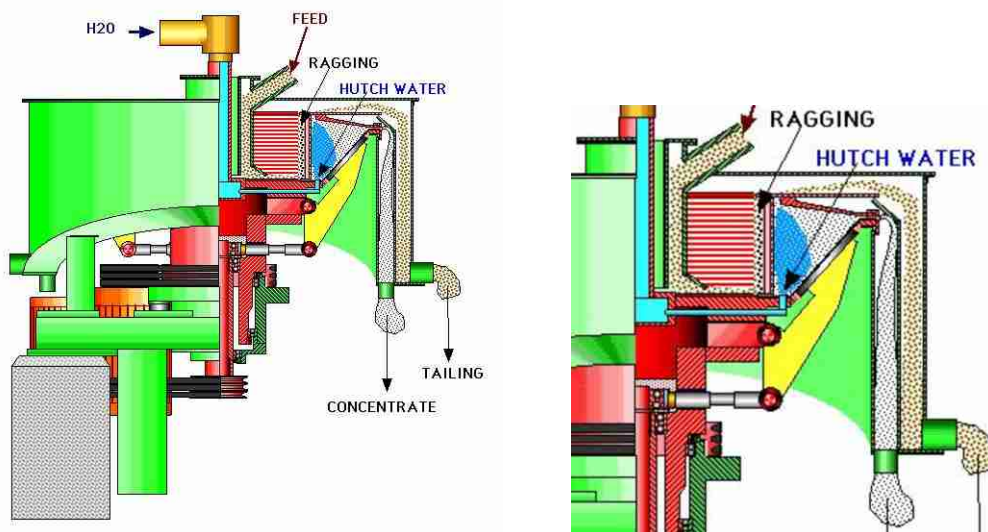


Figure 1: Schematic Cross-Section of a Kelsey Centrifugal Jig

Kelsey Centrifugal Jig Applications

The KCJ has been installed/operated and/or tested on a number of applications, including mineral sands, tin, tantalum, gold, nickel, tungsten, chromite, iron ore and base metals. Given their predominance in India, focus in this paper has been placed on mineral sands, iron ore and chromite and performance data for these applications is presented below.

Mineral Sands

The presence of significant levels of Al/Si minerals, such as kyanite and sillimanite, often compromises the recovery of zircon from titanium mineral concentrates when using conventional separation techniques, due to similar mineral specific gravities and particle sizes. Using its ability to separate minerals with relatively small specific gravity differences, the KCJ can effectively process zircon tailings stockpiles and/or on-line tailings streams to recover zircon minerals.

Depending on processing targets, the KCJ can be used to produce a high (final) grade zircon concentrate at reasonable recovery or to recover maximum zircon into an intermediate grade (say 40-50%) zircon concentrate with commensurate gangue mineral rejection. The latter configuration is generally favoured, as removal of the slightly greater gangue content can be achieved by treating the KCJ concentrate through an appropriate section of an existing plant or an appropriate application-specific circuit.

Table 2 below shows metallurgical results obtained by the KCJ at a mineral sands plant in Australia which has been operating successfully at high levels of mechanical availability since the mid 1990s with two KCJs processing both “Coarse” and “Fine” feed materials. The concentrates from these KCJ stages are fed to coarse and fine spiral circuits for final cleaning.

Table 1: Model J1300 KCJ Plant Performances on Coarse and Fine Mineral Sands

Coarse KCJ	Mass (%)	Grade (%)			Recovery (%)		
		Zircon	Kyanite	Quartz	Zircon	Kyanite	Quartz
Feed	100.0	14.2	36.6	20.8	100.0	100.0	100.0
Concentrate	26.1	45.4	9.1	0.2	83.4	6.5	0.3
Tailings	73.9	3.2	46.3	28.1	16.6	93.5	99.7
Fine KCJ	Mass (%)	Grade (%)			Recovery (%)		
		Zircon	Kyanite	Quartz	Zircon	Kyanite	Quartz
Feed	100.0	47.4	23.8	0.3	100.0	100.0	100.0
Concentrate	45.0	83.1	6.5	0.5	79.0	12.3	74.0
Tailings	55.0	18.1	37.9	0.2	21.0	87.7	26.0

A number of KCJs have recently been (or are in the process of being) installed in the mineral sands industry, mainly in Australia, Africa and India.

Iron Ore

There are a number of iron ore tailings dams and existing iron ore plant tailings streams around the world that contain significant fine iron values. The KCJ offers high separation efficiency and has been shown to be capable of effectively treating these fine iron ore tailings dumps/streams.

Figure 2 below shows the performance of a Model J1800 KCJ in the treatment of a relatively low grade (~13% Fe and ~80% SiO₂) iron ore tailings stream containing some liberated hematite and mainly unliberated iron minerals and predominantly coarser sized silica particles. This material was processed through a KCJ over several hundred hours of operation at an average solids feed rate of 55 t/h and resulted in the production of a concentrate containing ~66% Fe and ~4% SiO₂ at a recovery of ~47% Fe and a rejection of ~98% SiO₂. The data presented in Figure 2 demonstrate the

ability of the KCJ to produce final grade concentrate, across a range of particle sizes and particularly in the very fine (<106 μm) particles sizes, from a low grade, partially liberated tailings stream in a single stage of processing.

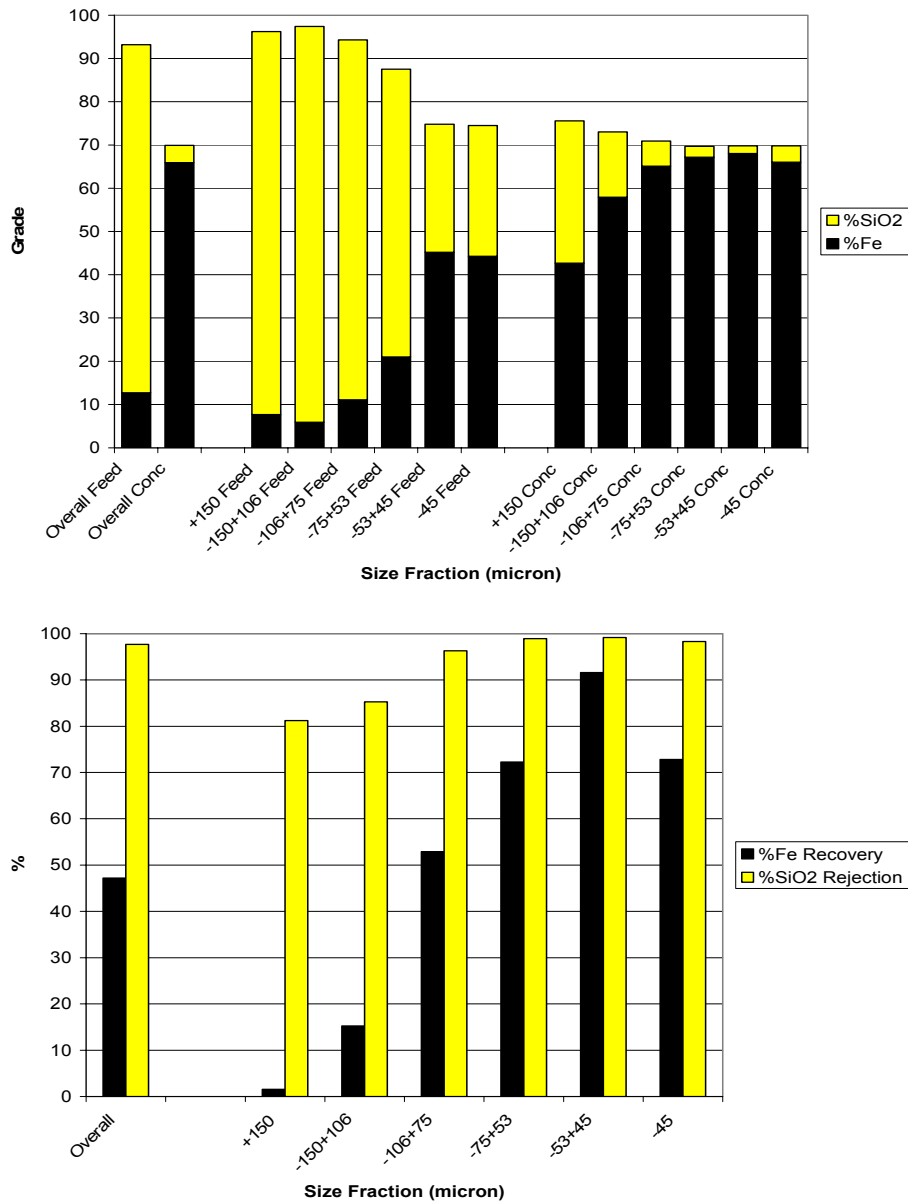


Figure 2: Model J1800 KCJ Performance on Processing Fine Iron Ore Tailings

Chromite

Similar to iron ore, there are a number of chromite ore tailings dumps and streams around the world that contain significant fine chromite values and the KCJ has been proven to be capable of efficiently recovering such fine chromite.

Figure 3 below shows the performance of the KCJ achieved on pilot testing of a sample of chromite plant tailings containing ~30% Cr₂O₃ and having a mass and chromite particle size distribution of approximately 80% <125 μm and 50% <100 μm, indicating that a >42% Cr₂O₃ final grade concentrate can be produced with a 40-50% concentrate mass yield at a recovery of 70-80% Cr₂O₃.

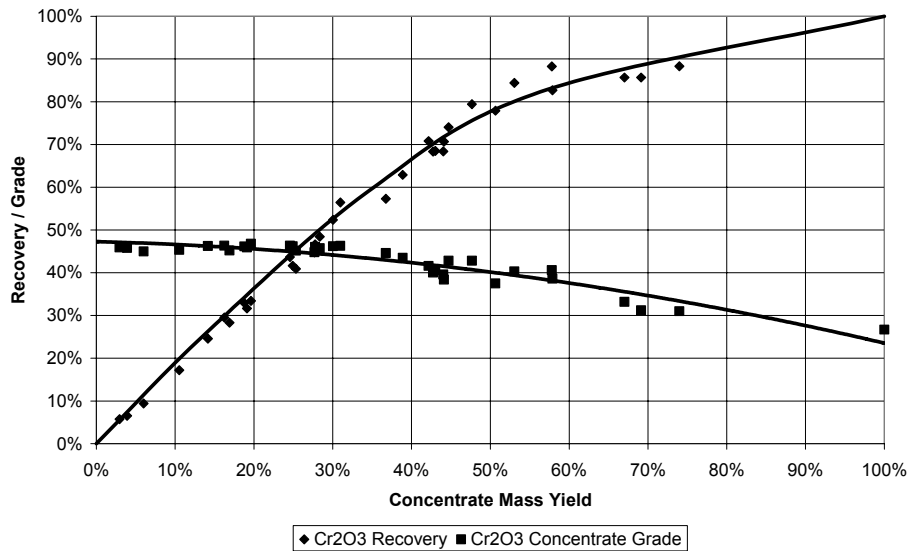


Figure 3: KcJ Performance on Processing Chromite Plant Tailings

Keys to a Successful Kelsey Centrifugal Jig Installation

The key components of a typical KCJ circuit are shown schematically in Figure 4 below and should be incorporated into any successful KCJ installation to take advantage of the excellent metallurgical performance that the KCJ offers.

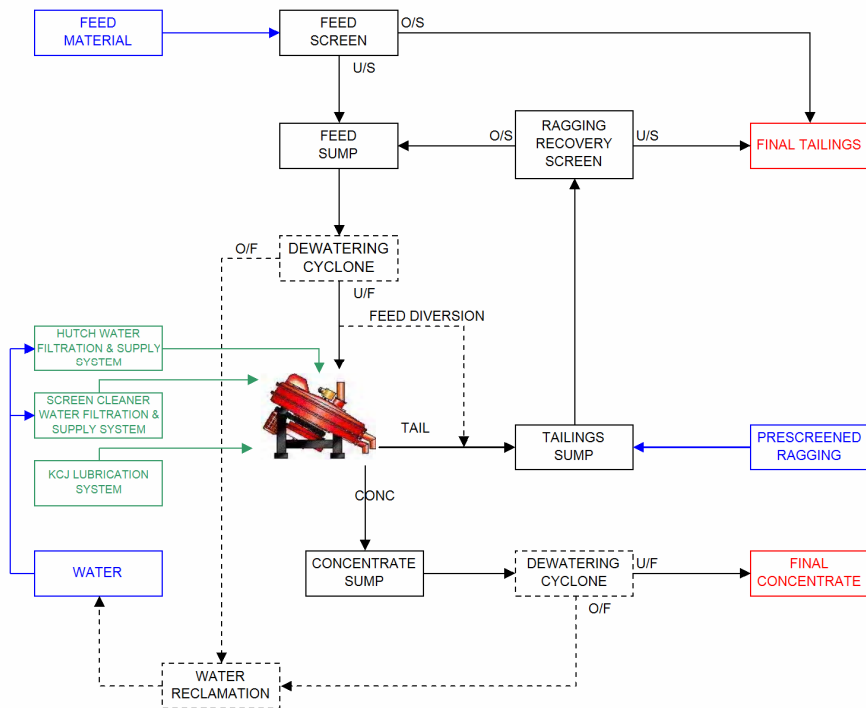


Figure 4: Typical KCJ Circuit Schematic

Successful metallurgical and mechanical performance of a KCJ installation is directly related to the establishment and maintenance of an appropriate circuit of ancillary equipment (including good feed and ragging classification, good hutch water quality, flow rate and pressure, KCJ feed rate control). It is also critically important to the separation performance to ensure that the KCJ internal screen is maintained and cleaned to minimise screen blinding.

The KCJ has standard features, such as an automatic screen cleaner and vibration detection, which help to prevent major damage to the main pulsation mechanism. The manufacturers, Mineral Technologies, also offer a service exchange program, which minimises downtime by enabling overhaul of units off-line after quick exchange with a fully-refurbished unit.

On-going support is also provided by Mineral Technologies to clients to optimise performance of the KCJ, while new applications can be tested at both a laboratory scale and at full-scale, using a purpose-built KCJ Pilot Plant (pictured below). This pilot plant can also be used to treat tailings dumps to recover fine mineral values, generating cash flow and reducing environmental issues associated with these dumps.



Figure 5: Kelsey Jig Pilot Plant

Conclusions

With the addition of centrifugal force to conventional jigging technology principles, the KCJ is able to efficiently separate fine minerals and/or minerals with low specific gravity differentials. Units have been successfully employed and tested in a broad range of fine mineral applications in wide variety of industries including mineral sands, tin, tantalum, gold, nickel, tungsten, base metals, iron ore and chromite.

Continuous improvements in the design and manufacture of the KCJ have led to a robust device which, with appropriate attention to the key elements of circuit design, operation and maintenance, represents often the only solution to fine mineral separation duties which challenge and/or exceed the capabilities of conventional mineral processing equipment.

The manufacturer, Mineral Technologies, offers a full range of services, from laboratory and full-scale testing through to maintenance and service exchange programs, which enable the full benefits of the KCJ to be realised.