Highly Efficient Enhanced Gravity Separation
The Kelsey Centrifugal Jig

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Abstract

The Kelsey Centrifugal Jig is an enhanced gravitational separating device which utilizes the principles of the conventional mineral jigs but has the additional feature of being able to vary the apparent gravitational field.

Mineral jigs for many centuries have been used by the mining industry to extract coarse liberated particles from a wide range of minerals. Chris Kelsey has revolutionized the mineral jig industry by designing and manufacturing the only enhanced gravity jig on the world market to date.

The Kelsey Jig has proven over a wide range of commercial installations its ability to conduct extremely efficient separations of minerals with a broad size distribution.

Introduction

This paper identifies the separation efficiency achievable using enhanced gravity concentration in the Kelsey Jig on a number of industrial applications. It also shows the potential of this device with the new range of units available on opening markets.

The commercial introduction of the Kelsey Jig into the mineral industry came in 1992 when the Renison Tin Mine in Tasmania, Australia began installing units to replace the existing classification and tabling circuit.

Mechanical availability exceeds 95% world wide with particular plants recording 98% availability. The recent commercial release of a new series of jigs will increase this excellent record to even higher levels of achievement.

The Kelsey Centrifugal Jig

The concept of the Kelsey Centrifugal Jig 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, in a conventional jig, the dynamics involve only specific induced movements, the Centrifugal Jig takes a conventional jig and spins it in a centrifuge. The ability to change the apparent gravitational field, up to 50 times gravity, results in a major improvement in separation efficiency, particularly of very fine minerals, by significantly reducing the effect of forces that hinder fine particle separation.

Generation of the centrifugal force is achieved by variable speed control of a spinning rotor. Inside the rotor, a screen of parabolic shape is spun coaxially together with the rotor. The screen is lined inside with ragging material which is evenly spread by the centrifugal force.

The feed pulp passes down the fixed central pipe and is distributed over the base of the ragging. The particles in the feed are accelerated towards the ragging bed, due to the apparent gravitational force, while continually rising up the bed, due to the vertical displacement caused by the incoming feed.

Those particles whose specific gravity exceeds or equals that of the ragging material will be allowed to settle in the ragging bed. Having penetrated the ragging bed, the particles then go through the processes of hindered settling and consolidated trickling. The heavier minerals pass completely through the ragging retention screen and into the concentrate hutches where they ultimately pass as slurry through concentrate spigots and into the concentrate launder. Lighter minerals that are not able to settle will be discharged over the top of the screens ragging retention ring and into the tailing 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 pads to work against the jigs flexible diaphragm. Water contained within the concentrate hutches presses against the diaphragm, at a frequency and amplitude set by the operator, thus dilating the ragging bed. The level of dilation impacts on the amount of material able to pass to concentrate.

The shock wave 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 terminal velocity. This terminal velocity is mainly linked to 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 terminal velocity. The shockwaves, produced by the pulsing action of the jig, continually stop the particles, thus limiting their time at their terminal velocity and maintaining a high rate of separation.

Metallurgical Performance

The Kelsey Centrifugal Jig has been shown over the years in several mineral applications to be metallurgically and economically superior to other processing options. The ability of the jig to upgrade material substantially with minimal losses, especially in the fines region, makes this device ideal for low grade, high value streams like those found in a tin or mineral sands plant.

Many papers have been written over the years by plants operating or evaluating the Kelsey Centrifugal Jig and the metallurgical results have always been very impressive. The commercial release of the new series of Kelsey Jigs has now made the device much more amenable to processing high tonnage streams economically.

Tin Separation Efficiency

The separation of valuable tin minerals from low grade streams has always been a niche market for the Kelsey Centrifugal Jig. The ability to achieve high upgrade ratios with minimal losses is crucial to the success of tin processing plants. The jigs presence in this industry has resulted in all new units entering the mining industry being installed by tin operations first.

Typical Shaking Table and Kelsey Jig Comparison

Stream	Kelsey Centrifugal Jig			Shaking Table		
	Wt%	Sn%	Dist'n%	Wt%	Sn%	Dist'n%
Feed	100	13.5	100	100	13.6	100
Conc	21.5	61.1	97.5	25.8	49.2	93.5
Tail	78.5	0.4	2.5	74.2	1.2	6.5

"When compared to shaking tables and electrostatic separators, the jig was less sensitive to changes in feed grade and had a much higher capacity per square foot of floor space".[1]

Typical Size Distribution Curve from a Kelsey Jig in Operation

Size	***Feed***		***Concentrate***		***Tail***		***Rec.***
μm	Wt%	Sn%	Wt%	Sn%	Wt%	Sn%	%Sn
300	3.14	3.96	0.17	48.90	6.25	2.37	42.29
212	9.04	9.34	2.75	46.90	10.94	4.19	60.55
150	8.19	17.3	5.96	56.30	9.01	4.09	82.34
106	15.52	18.8	12.61	59.70	16.41	3.48	86.53
75	21.49	18	17.13	55.40	23.32	3.38	86.58
53	15.98	22.7	19.02	56.80	17.13	4.74	86.32
38	13.53	32.3	21.46	57.80	9.06	9.53	84.41
-38	13.11	44.1	20.90	61.50	7.88	18.90	82.49
Total	**100**	**21.96**	**100**	**56.43**	**100**	**5.49**	**83.10**

Comparison of Devices on Spiral Feed

Equipment	Mass Rec. (%)	Sn Rec. (%)
Kelsey Jig	3.79	84.15
Falcon	49.03	76

It is quite clear from the independant comparison that the Kelsey Centrifugal Jig with its jigging action is able to reject a vast amount of material to tailings and yet maintain a high recovery, especially the fine valuable minerals.*(Silva, 1999)*[4]

Typical Kelsey Jig Results from around a Tin Circuit - Conducted at CVRD

Sample	Objective	Mass Recovery (%)	Tin Recovery (%)	Enrich-ment Ratio
Tables 1 and 2 combined tailings	Max recovery	1.02	56.90	55.81
	Max grade	0.44	26.13	60.00
Table 3 tailings	Max recovery	13.91	83.16	5.98
	Max grade	8.40	77.86	9.27
Scavenger of table 3 tailings	Max recovery	2.21	56.60	25.66
	Max grade	2.21	56.60	25.66
Tables feed	Max recovery	5.64	89.99	15.95
	Max grade	4.13	80.39	19.47
Spirals feed	Max recovery	3.79	84.15	22.21
	Max grade	3.33	82.94	24.93
Fine fraction of spirals tailings	Max recovery	14.58	89.32	6.13
	Max grade	14.58	89.32	6.13

The main conclusions from this particular test work are outlined below (Silva, 1999)[4]: The success of the application of the centrifugal jigs for this particular ore is mostly due to its ability to concentrate fine cassiterite particles (less than 50 μm). In the previous flow sheet, these particles could not be concentrated by tables in an efficient way and had to be recovered by flotation, which was expensive and still not very efficient. With the usage of centrifugal force combined with bed classification of the Kelsey Jig it was possible to concentrate all size ranges with high recoveries.

From the results tabled it is quite clear why the Kelsey Centrifugal Jig has such a dominant presence in the tin industry, the enrichment ratios and recoveries achieved on various streams are not obtainable by any other gravity device in single pass.

Zircon Separation Efficiency

The separation of Zircon and Kyanite has always been a problem for the mineral sands industry. The aluminum containing minerals have resulted in high amounts of zircon being rejected to tails to meet market requirements.

In 1994 the first jig was installed into this application. Ti West in Western Australia who operate two units on different applications within the Zircon Circuit.
Iluka Resources own and operate the largest number of units in various plants around the world and have benefited most from the Kelsey Centrifugal Jig.

Typical Zircon Recovery from a Non conductor Wet Circuit Tailings

Stream	%Free Qtz.	%Rutile	%Zircon	%Kyanite
Kelsey Feed	8.0	0.8	34.2	24.5
Kelsey Conc.	0.1	1.6	86.1	2.8
Kelsey Tail	12.7	0.4	3.3	37.4
Recovery	0.4	71.0	93.9	4.4

Similar results have been posted in other papers.[2]

The results above again show the ability of a production scale unit to obtain high upgrade ratios whilst maintaining high recovery. No other device in the industry can obtain this metallurgical performance with the same tonnage and floor space.

Iron Ore Separation Efficiency

This data is from plant trials and lab scale work. Geo Logics intends to dominate gravity recovery of fine iron ore with the recently released Model J1800 Kelsey Centrifugal Jig.

Work with the J1800 to date on final tailings streams around the world has seen the metallurgical performance of this large unit confirmed.

Table 1 - Size Distribution from a Kelsey Jig Operating in Iron Ore

Size	*Feed*		*Concentrate*		*Tail*		*Rec.*	*Reject.*
µm	Wt%	Fe%	Fe%	Si%	Fe%	Si%	Fe%	%Si
300	4.63	13.2			13.2	76.83		
212	19.71	8.39			8.4	86.89		
150	24.93	6.06	42.7	32.86	5.9	92.34	3.06	99.85
106	21.78	5.92	57.9	15.1	5.1	92.69	15.17	99.74
75	11.76	11.11	65.1	5.81	5.8	90.82	52.46	99.38
53	5.63	21.03	67.2	2.51	7.7	84.95	71.58	99.15
45	4.55	45.15	68	1.78	10.6	71.6	90.65	96.38
-45	7.00	44.33	66	3.8	21.8	57.64	75.90	93.58
Total	**100**	**12.71**	**65.87**	**4.00**	**7.39**	**88.19**	**47.14**	**99.55**

As can be seen from Table 1, the rejection of silica in single pass and the high recovery of liberated fines would not be achievable from any other gravity device in single stage.

Table 2 – Plant Tails from a Magnetic Plant

Stream	**Iron Recovery**	**Concentrate Grade %Fe**	**Concentrate Grade %Si**	**Weight Yield to Concentrate**
Plant Tails	68	65.6	3.4	23.8
Plant Tails	64.5	67.4	1.8	21.6

The above results show the ability of the Kelsey Centrifugal Jig to recover with a high separation efficiency fine hematite from plant tailings and generate a concentrate with a P_{80} of only 52µm.

Conclusion

Kelsey Centrifugal Jigs are dominant in the Tin and Zircon processing industries. Recent advancements such as the addition to the product range of the Model J1800 Kelsey Centrifugal Jig will see many other mineral processing plants such as iron ore and base metals utilise the Kelsey jigs in the same manner.

References

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