RECOVERY OF UNLIBERATED DIAMONDS BY X-RAY TRANSMISSION SORTING

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Abstract

In May 2009 a test work programme was carried out at the sorting laboratory of CommodasUltrasort in Germany which was aimed at establishing the efficiency of X-ray transmission sorting for the recovery of unliberated diamonds in a size range of +8mm.

A PRO Tertiary XRT belt sorter with a working width of 600mm and a belt speed of ~3m/s was used for the test work.

Dual energy X-ray transmission sorting is a type of sensor-based sorting which uses an X-ray scanning system. The attenuation of the transmitting X-rays is measured at two different energy levels. Thereby it is possible to eliminate the effect of the particle thickness on the measurement result. The effective measurement results in a classification by elemental order based on the periodic table.

Diamonds are mostly composed of Carbon, which has an atomic number of 6. Compared to Silicon with an atomic number of 14, Diamonds show up much lighter on an XRT image than Silica-based gravels (typical DMS sinks material usually has more dense minerals such as Fe, and Mn which shows an even darker X-ray image than Si).

Tests were run with eleven Boart Diamonds in a size range of -15+8mm mixed into 13kg alluvial DMS sinks gravel in a size range of -25+8mm. All liberated Boart Diamonds were recovered at feed rates of 15t/h at average yields of 7.6g per ejected Diamond.

In a second test series the Boart Diamonds were covered in 20% Gypsum by weight and run again at 15t/h. All unliberated Diamonds were recovered at an average yield of 12.2g per ejected Diamond.

The paper outlines the test work results in detail.

1. Introduction

Dual energy X-ray transmission (DE-XRT) sorting has been applied in the recycling industry for several years now, especially in aluminium and electronic scrap recycling. In the mining industry it has been applied in Copper slag, Diamonds and Coal and has been successfully tested for Iron ore, Manganese ore, Gold ore, Cobalt and Nickel slag and Nickel and Copper ore.

The X-ray transmission method works according to the DE-XRT principle. CommodasUltrasort has drawn upon this basic principle and has developed a sensor system suitably adapted to sorting techniques [1].

The broad-band X-ray radiation of an electrical X-ray source is applied to the material to be sorted while it is moved along the scanning area at a rate of ~3m/s. The X-ray sensor system, which works like a line scan camera, picks up the X-rays penetrating the material to be sorted and converts them into digital image data. The sensor system consists of two channels, each capturing the image of material in different X-ray energy spectra. The material to be sorted attenuates the X-ray radiation received, thus decreasing the modulation amplitude of the sensor, so that these image areas appear dark [2]. The image classification process is illustrated in the following image.

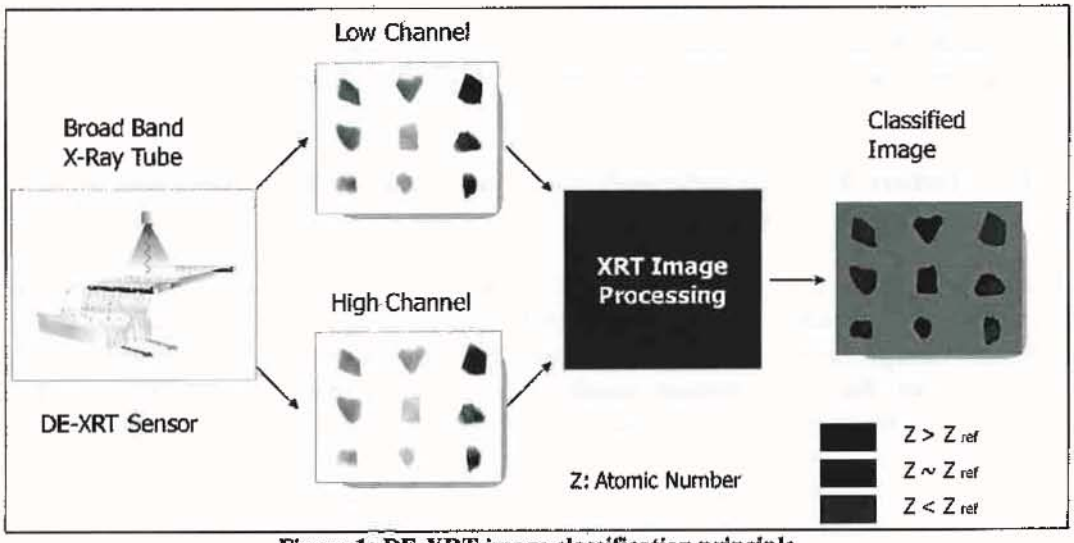

Figure 1: DE-XRT image classification principle

In May 2009 a detailed test series was run at the CommodasUltrasort laboratory in Germany to establish the efficiency of the DE-XRT method for the recovery of Diamonds from gravel.

2. Test Work Procedure

Three different test series were run on a PRO Tertiary XRT belt sorter with a working width of 600mm.

The first test was run with gravel and without Diamonds at a feed rate of 15t/h.

The second test was run with the same gravel and with eleven Diamonds also at a feed rate of 15t/h.

For the third test the Diamonds were covered in 20% by weight Gypsum and run with the gravel at a feed rate of 15t/h.

All tests were repeated three times.

2.1 Feed Preparation

The feed material consisted of 13kg DMS sinks from alluvial gravel in a size range of -25+8mm.

Figure 2: Alluvial DMS sinks

Eleven Boart Diamonds in a size range of -15+8mm were used to test the efficiency of the sorter. The total weight of the eleven Diamonds was 135.5 carats with an average weight of 12.3 carats per Diamond.

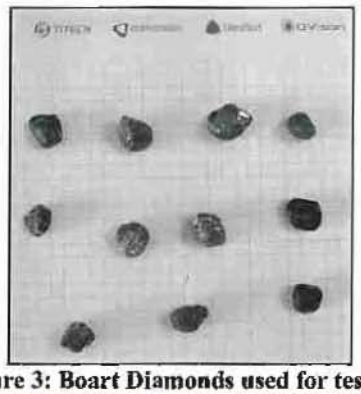

Figure 3: Boart Diamonds used for testing

For the third test series the Boart Diamonds were covered in Gypsum at 20% by weight, effectively covering the whole surface of the Diamonds making them completely non-transparent to any light in the visible spectrum. This would make them unrecoverable by X-ray luminescence sorting, laser sorting, optical sorting (using transparency properties) and any grease methods.

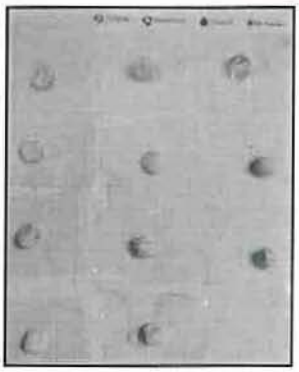

Figure 4: Gypsum covered Boart Diamonds

2.2 Sorter Set-Up

The sorter was set up with a density model and X-ray energy combination that can effectively discriminate between organic and inorganic material. On the DE-XRT classifier Diamonds show up light as organic material (Carbon) whereas gravel shows up dense as inorganic material (typical DMS sinks containing dense minerals such as Fe, Mn etc). An image filter was utilized to suppress faulty pixels around the edges of the particles (dark ring around particles). The following images show samples of classified Diamond and gravel images.

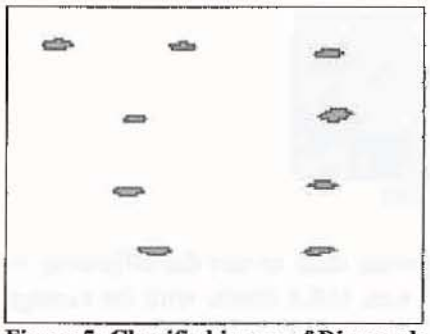

Figure 5: Classified image of Diamonds

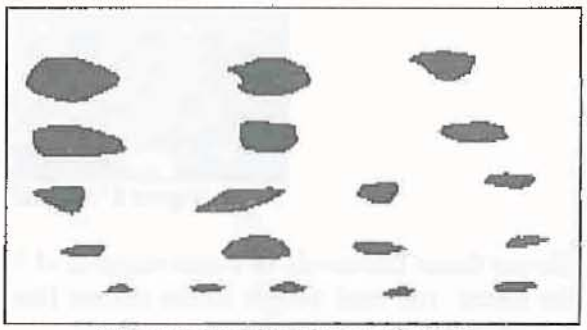

Figure 6: Classified image of gravel

2.3 Test Runs

All of the three test series were run at 15t/h and repeated three times.

The following image shows the raw image (left) and the classified image (right) of pure gravel running at 15t/h on the sorter.

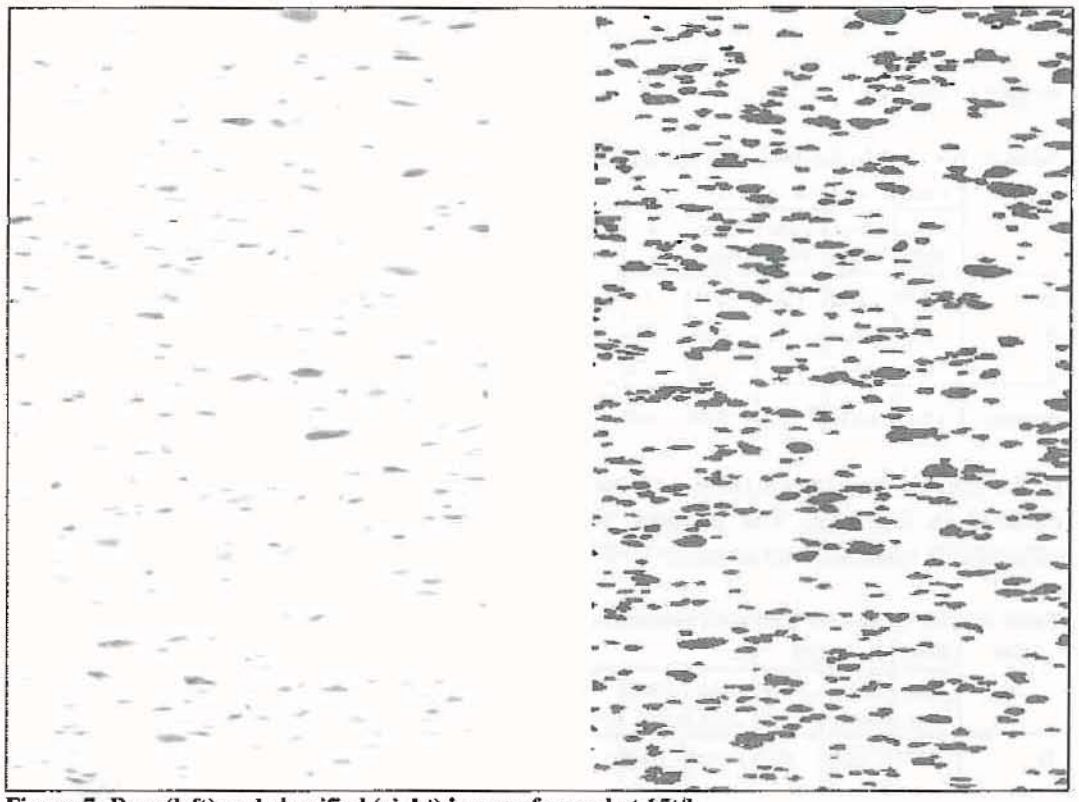

Figure 7: Raw (left) and classified (right) image of gravel at 15t/h

At this feed rate it is noticeable that some particles touch each other and form larger particles on the classified image. But since Diamonds show up as pure organic material the sorter logic was programmed to eject any organic patches, irrespective of any attached inorganic areas. The sorting efficiency is dependent on the feed rate and the size range of the feed material. If sorting at high feed rates and a very wide size distribution smaller stones may be masked by larger ones. In this case, the wide size range may limit the feed rate.

3. Test Work Results

The following table shows the results for the first run with barren gravel at 15t/h.

Table 1: Test results for barren feed

Run	Feed	Reject		Accept						
	Mass [kg]	Mass [kg]	Yield [%]	Mass [kg]	Yield [%]	Gravel Mass [g]	Diamond Mass [g]	Diamond No.	Relative Yield [g/Diamond]	Diamond by Weight [%]
1a	13.51	13.51	100.0	0.00	0.0	0.0	0.0	0	0.0	0.0
1b	13.51	13.51	100.0	0.00	0.0	0.0	0.0	0	0.0	0.0
1c	13.48	13.48	100.0	0.00	0.0	0.0	0.0	0	0.0	0.0
Average	**13.50**	**13.50**	**100.0**	**0.00**	**0.0**	**0.0**	**0.0**	**0**	**0.0**	**0.0**

The sorter did not produce any yield to the accept (concentrate) fraction on all three runs (Table 1).

In the second test series all Diamonds were recovered on all repetitions. The average yield per ejection was 7.6g of gravel. The concentrates averaged 24.7% Diamond by weight (Table 2).

Table 2: Test results for feed with eleven clean Diamonds

Run	Feed	Reject		Accept						
	Mass [kg]	Mass [kg]	Yield [%]	Mass [kg]	Yield [%]	Gravel Mass [g]	Diamond Mass [g]	Diamond No.	Relative Yield [g/Diamond]	Diamond by Weight [%]
2a	13.48	13.38	99.3	0.10	0.7	70.0	27.1	11	6.4	27.9
2b	13.48	13.36	99.1	0.12	0.9	89.0	27.1	11	8.1	23.3
2c	13.46	13.34	99.1	0.12	0.9	92.0	27.1	11	8.4	22.8
Average	**13.47**	**13.36**	**99.2**	**0.11**	**0.8**	**83.7**	**27.1**	**11**	**7.6**	**24.7**

In the third test series all Diamonds were also recovered on all runs although they were covered in Gypsum. The average yield per ejection was 12.2g of gravel and the concentrate contained on average 16.3% Diamond by weight (Table 3).

Table 3: Test results for feed with eleven covered Diamonds

Run	Feed	Reject		Accept						
	Mass [kg]	Mass [kg]	Yield [%]	Mass [kg]	Yield [%]	Gravel Mass [g]	Diamond Mass [g]	Diamond No.	Relative Yield [g/Diamond]	Diamond by Weight [%]
3a	13.46	13.28	98.7	0.18	1.3	147.0	32.7	11	13.4	15.1
3b	13.44	13.28	98.8	0.16	1.2	127.0	32.7	11	11.5	17.0
3c	13.40	13.24	98.8	0.16	1.2	127.0	32.7	11	11.5	17.0
Average	**13.43**	**13.27**	**98.8**	**0.17**	**1.2**	**133.7**	**32.7**	**11**	**12.2**	**16.3**

4. Conclusion

The tests have shown the enormous potential that DE-XRT sorting bears for recovering both clean/free and unliberated Diamonds from gravel at high feed rates and high concentrate grades.

The sorting algorithm discriminates between Diamonds and gravel at a 100% accuracy, even at feed rates of 15t/h on a 600mm working width sorter. The yield of gravel to concentrate is only caused by ejecting the Diamonds. This is purely a function of the dense beltpacking/loading of the feed material at these high feed rates.

The detection of the Diamonds is not affected by covering the Diamonds in Gypsum 20% by weight, making them completely non-transparent to light. The higher yields per ejection are attributable to the higher air pressure used to make sure to recover the unliberated Diamonds.

Reduction of recoveries by masking could not be observed at the feed rate of 15t/h in a size distribution of -25+8mm gravel.

References

[1] Harbeck, H.: Classification of Minerals by the X-Ray Transmission Method. Symposium Sensor-based Sorting, Stolberg, Germany. 2004.

[2] Jong, T. P. R. de, Dalmijn, W. L., Kattentid, H. U. R.: Dual Energy X-Ray Transmission Imaging for Concentration and Control of Solids. Proceedings of XXII International Mineral Processing Congress, IMPC 2003, Cape Town, South Africa. 2003.

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