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Online washability: Comparison of dual parameter and triple parameter analysis

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Abstract

Growing demand on coal quality leads to the need of enhanced analysis tools for coal parameters. Therefore fast analysis of washability properties becomes a must in coal preparation.

The washability monitor OREGON which was introduced to the coal market in 2012 uses the combination of optical and radiometric methods for the fast determination of the washability curve. The concept of the analyzer is based on the measurement of a sample which will be processed in about 20 to 30 minutes.

The sample is fed through the analyzer on a conveyor belt in a single layer. Each particle is characterized by size and density. The washability characteristics of the full sample are then generated by Statistical evaluation. The method does not utilize any chemicals and the analysis can be performed even by untrained personell.

Basic techniques which are used for analysis were first presented at ICPC 2010. It is obvious that basic combination of radiometric dual energy measurement leads to inaccuracies if ash composition undergoes variations. This effect is well known from dual energies ash gauges.

Therefore the analyzer utilized a combination of dual energy and optical measurements.

The paper discusses the improvements which are achieved by the triple parameter measurement concept in comparison to alorithms based on only two parameters.

Physical Background

Basically the OREGON washability monitor for coal utilizes principles which were derived from the well known dual energy ash analysis. There coal is transmitted by gamma radiation of low and high energy. While the absorption of the low energy radiation is dependent on the layer thickness (or more precisely the mass per area) and the composition of the material the absorption of the high energy radiation is only dependent on the mass per area. Therefore the signal derived with the high energy measuring path can be used to correct the signal of the low energy radiation path in order to produce a signal which is only dependent on the composition of the coal, i.e. the ash content.

Obviously this technique can be also applied on single particles to determine the particle´s ash content. The approximate size respectively mass can be calculated from the signals also and therefore a distribution curve can be generated for washability analysis.

A problem is caused by the fact that the particles to be measured are considerably small. While coal layer on the conveyor belt have typical heights of 150 to 300 mm the particles to be examined for washability have a mesh size of 1 to 100 mm. Consequently the attenuation of the radiation will be much smaller if the radiation energies of the dual energy devices are used. Figure 1 illustrates the low (60 keV, ^{241}Am) and high energy (662 keV, ^{137}Cs) signals which will be measured for an average two different coals with an ash content of approximately 20 % respectively 30 %. Both calculations are done with a bulk density of 0,85 g/cm³ for better comparison.

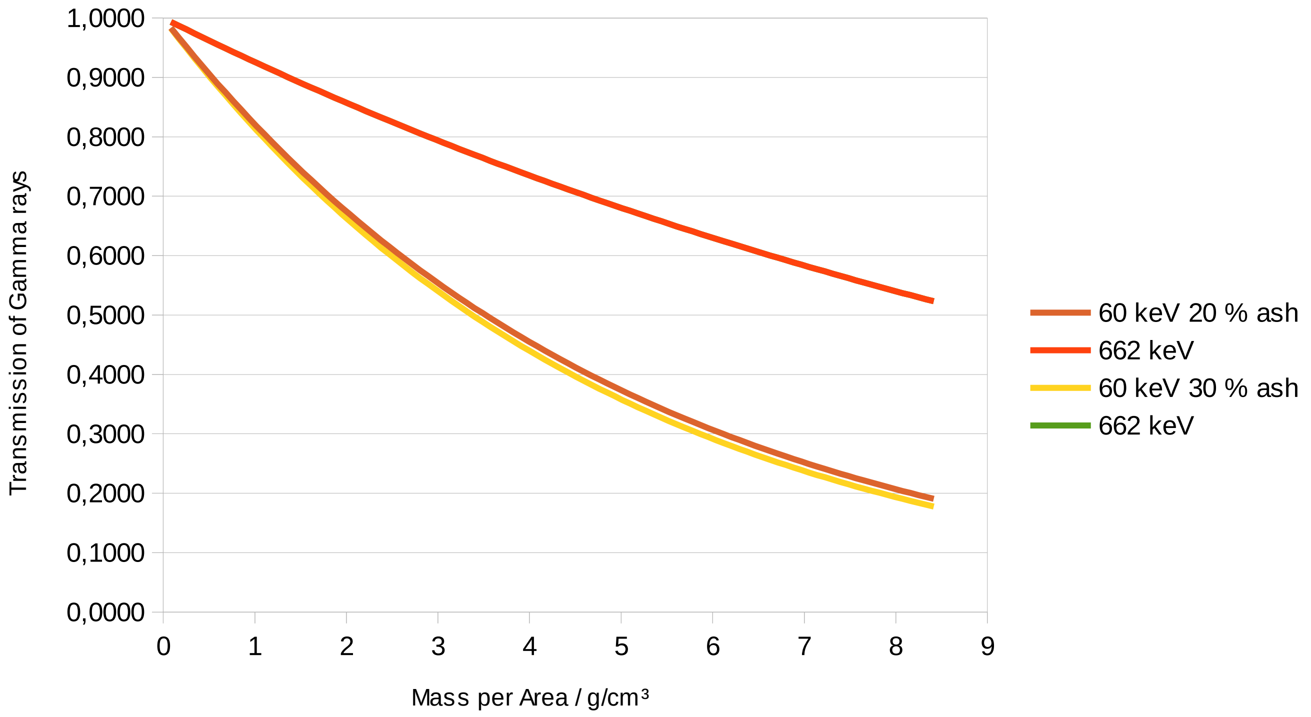

Figure 1: Transmission intensity vs. area weight for gamma radiation of 60 keV and 662 keV

It can be easily seen that the low energy signals can be differentiated with high masses per area but the curves become statistically insignificant by small masses per area. Furthermore, the high energy signal is completely independent of the ash content.

This problem can be overcome by exchanging the energy. While dual energy ash meters are limited to gamma sources which are stable and commercial available the washability monitor utilizes X-rays produced by X-ray tubes. The physics are the same for X-rays and gamma rays but the use of an X-ray tube offers the advantage that the energy of the produced radiation can be defined by the user.

Figure 2 shows the corresponding signals for two X-ray beams of 25 and 40 keV. It is obvious that the derived signals are of better significance and are therefore suitable for washability. This applies especially for the lower mass per area region. However, in the higher mass per area section the 25 keV signals become very weak and cannot be used. This means that the energy of the X-rays needs to be optimized to the particle size if the washability measurement is done in size classes.

At this point it should be mentioned that some non linear effect has to be taken into account; discussion of the physical and mathematical background would exceed the scope of this paper.

Based on this curves it can be stated that the use of X-ray tubes instead of gamma sources is a must for washability analysis. At this point there is no significant difference between the dual energy method for ash analysis and the washability analysis.

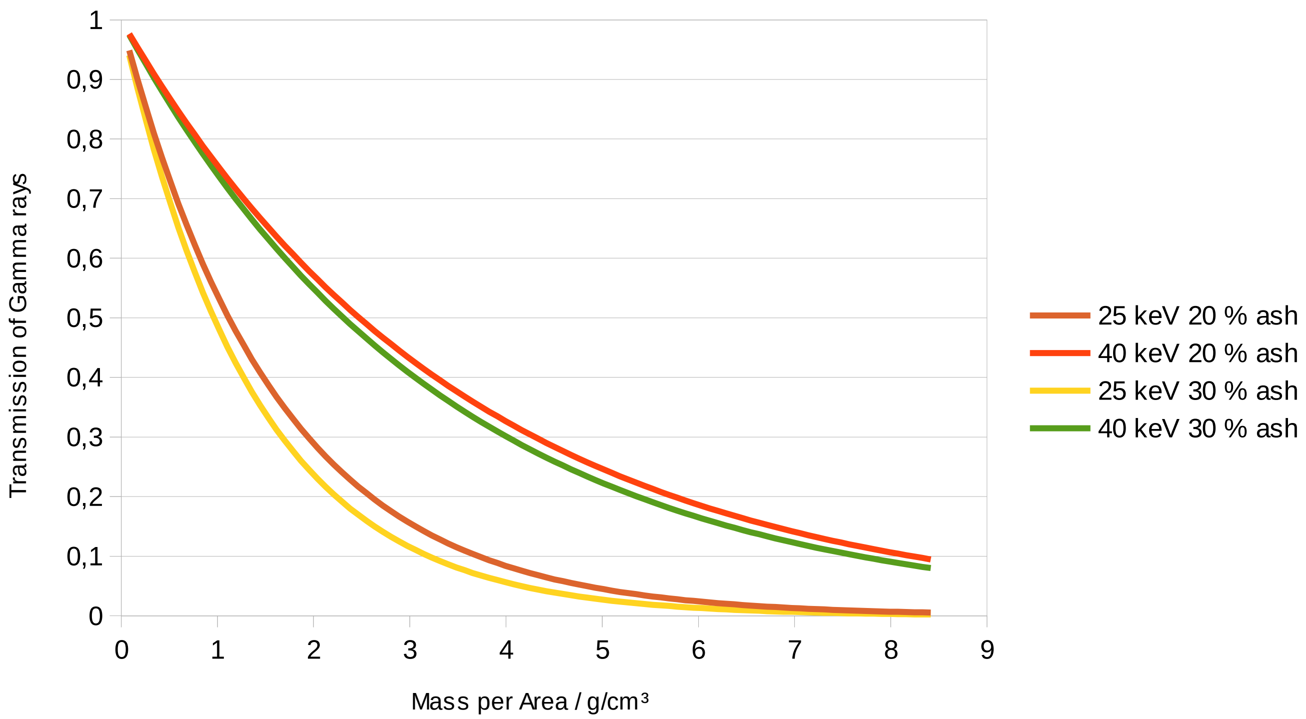

Figure 2: Transmission intensity vs. area weight for X-ray radiation of 25 keV and 40 keV

Unfortunately the dual energy method has a strong drawback which leads to the fact that in modern process control this method does not longer meet the requirements. It works well as long as the ash composition does not vary. However, if ash composition is not constant then these variations will cause a significant error.

Investigations performed by Bachmann [1] show that the relative error caused by a change of 1 % in iron content in the ash is about 6,3 % in ash indication. Figure 2 illustrates the effect for german hard coal. The effect is not as strong if the calcium content changes but even here a change of 1 % Ca causes an error of 2-3 % in ash reading.

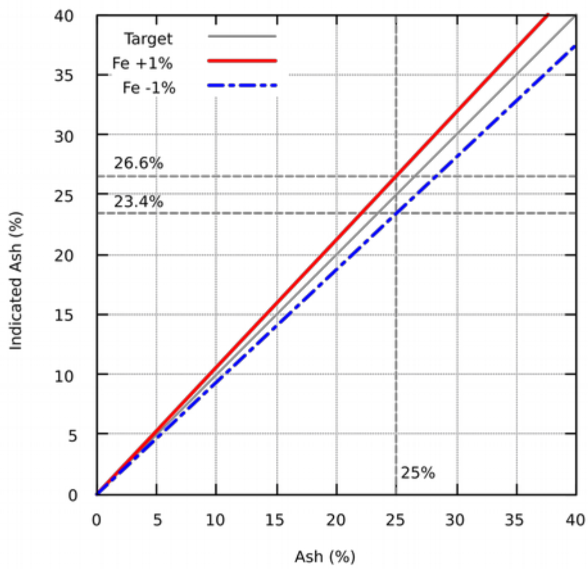

Figure 3: Effect of change in ash composition on indicated ash

This leads to the conclusion that application of the dual energy method is limited to applications where the ash composition does not change. If coal of different origins have to be measured then the accuracy of these devices does not fulfill the requirements. Similar results and attempts to solve these issues were published elsewere [6, 7, 8, 9, 10].

As the physics are the same these drawbacks apply also for low energy X-rays. It even becomes worse. First of all both signals in the low energy range are dependent on the material composition. Secondly, since the absorption coefficients of heavy elements like Iron and Calcium increase strongly with decreasing energy. The correlation between density and ash content depends on the ash composition. This indicates that a washability monitor which is based just on the dual energy principle needs intense recalibration which takes varying ash compositions into account.

Washability Analysis of Coal

Washability analysis requires three steps:

- screening

  different size fractions show different density distributions
- sink float analysis

  this analysis delivers the mass percentage of coal for each density class
- correlation between density and ash

  if this correlation is known then the results can be used to determine the yield.

To sum it up, three basic properties have to be determined for the coal particles: size, density and correlation ash/density. The last point distinguishes the washability analysis of coal from the washability analysis of iron ore. While the correlation between ash and density changes with the genesis of the coal the correlation between density of iron ore and iron content is fairly constant. Therefore the washability analyzer for iron ore utilizes only one X-ray measuring path [5].

The OREGON washability monitor is equipped with an additional optical measurement path which measures exactly each particle´s dimensions. The principle of the optical measurement was already presented in detail at ICPC 2013 [2]. Instead of requiring the high energy X-ray path as a measure of the layer thickness the thickness is therefore known exactly with a resolution of about 100 µm.. After correcting the X-ray signals with the known layer thickness both X-ray signals deliver information about the composition of the material.

The advantage of the use of optical particle characterization is obvious:

- the particle can be scanned in detail;
- the system determines length, width and height of the particle;
- in addition a complete particle´s outline is determined;
- no coal specific calibration is required.

Therefore one term in the washability determination, the size, is measured directly. So the radiometric part is only required for determination of an ash composition independent density; any size related effects can be compensated.

Having two radiometric measuring pathes which are both depending on density and composition pose a system which can be resolved distinctly. Therefore even variations in ash composition are taken into account which allows to use the analyzer without frequent coal specific recalibration. This is an important advantage if coal of different origins need to be characterized.

Conclusions

In contrary to washability determination on iron ore where a stable correlation between density and iron content is established the correlation between coal density and ash content varies with the coal origin. Not only an online analyzer but also laboratory washability analysis is faced with this problem.

The use of an additional X-ray measuring pathes in the originally for iron ore developed washability analyzer OREGON allows to compensate for this effect.

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