Use of Online XRF Analysis for Improvement of Coal Quality by Blending

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Abstract

Increasing environmental demands and upcoming legislation have strong influence on the coal quality requirements in domestic power plants. This means that domestic coal needs to be blended with imported coal. Conventional ash meters like dual energy gauges utilizing Americium and Cesium sources for determination of ash content cannot be used for blending purposes due to their dependency on ash composition.

X-ray fluorescence analysis is well proven and widely used in the laboratory. This technique was transferred to an online device for use directly on the conveyor belt by the company J&C Bachmann. This analyzer called TEXAS measures the composition of the coal but not only the ash content. Having an analyzer in place allows to realize a blending strategy. That way fuel with minimized quality variation on ash, moisture, CV and sulphur can be provided. Simple approach will be control of the blending relation between domestic and imported coal while the most sophisticated approach will be control of stacking and reclaiming in order to optimize the coal quality. The TEXAS analyzer feeds quality information directly to the control software where the control is realized according to the customer’s requirements. Basic control strategies are discussed in the presentations.

Physical Background

Online measurement of ash in coal is mostly done using the interaction between electromagnetic radiation and the coal constituents. Different physical interactions can be used:

- gamma ray backscatter
- gamma ray absorption
- X-ray fluorescence.

Backscatter

Measurement of the backscattered radiation of a low energy (241Am) or high energy (137Cs) gamma source is the eldest online analysis method for ash in coal which was first used about 1965. These systems were widely used in countries like Germany and the former Soviet Union. However, due to the fact that measurement requires a sufficient measuring volume under constant conditions this method could be used only if a subsample were taken automatically and continuously from the main product stream (241Am) or inside of coal trucks (137Cs).

Dual energy absorption

Measurement of the gamma ray absorption in a transmission setup using two measuring paths with different energies (i.e. 241Am and 137Cs) overcomes the requirement of constant volume.
Basic measurement principle is very similar to the well known X-ray examination in medicine. The human flesh can be seen as dark matter. X-rays are absorbed weakly by flesh. On the other side bones are identified as bright areas since bones absorb much stronger than flesh. Chemically, flesh is close to coal (burnable matter) while bones can be compared to ash. So the amount of absorption indicates the ash content.

The layer thickness of coal on conveyor belts may vary strongly. It is obvious that higher layers of coal will absorb more radiation than small layers. Therefore it is necessary to compensate for layer thickness. This is done by using two measurement beams with radiation sources of different energies. So the influence of varying layer thicknesses can be compensated.

Analyzers utilizing this method are produced by various companies and in multiple configurations. There are devices available with separate high and low energy radiation sources and detectors which are mounted in line along the conveyor belt as well as devices with combined high and low energy radiation sources and an energy discriminating detector which measures both radiations.

![Exemplary dual energy ash analyzer](image)

This method ("Dual Energy method") 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.

This leads to the conclusion that application of Dual Energy ash meters 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.
X-ray fluorescence

When materials are exposed to short-wavelength X-rays or gamma rays, ionization of their component atoms may take place. Ionization consists of the ejection of one or more electrons from the atom, and may occur if the atom is exposed to radiation with an energy greater than its ionization potential. X-rays and gamma rays can be energetic enough to expel tightly held electrons from the inner orbitals of the atom. The removal of an electron in this way causes the electronic structure of the atom to get unstable, and electrons in higher orbitals “fall” into the lower orbital to fill the hole left behind. In falling, energy is released in the form of a photon, the energy of which is equal to the energy difference of the two orbitals involved. Thus, the material emits radiation, which has an energy characteristic of the atoms present. The term fluorescence is applied to phenomena in which the absorption of radiation of a specific energy results in the re-emission of radiation of a different, but characteristic, energy (generally lower) /2/.

The advantage over a dual energy device is that instead of looking at bulk absorption for only two specific wavelengths X-ray fluorescence analyzes the atomic composition of the material. Therefore changes in composition will be seen right away and do not disturb the measurement.

If this measurement is applied to coal then the generated spectrum can be used to derive measures like ash content and calorific value. Basically, the intensity of the radiation caused by each elements (which is identified by radiation energy) corresponds to the concentration of the element in coal. So the components can be easily identified and the composition is calculated based on calibration parameters.

This method is utilized by the elemental analyzer TEXAS from J&C Bachmann. There an X-ray tube irradiates the coal while an energy dispersive sensor monitors the fluorescence radiation. The generated spectrum is then analyzed.

The typical way of material transportation is the use of conveyor belts. If the belt setup ensures that the material is conveyed with a fixed layer height and a fixed profile then the XRF analyzer can be installed directly above the material. This way a fixed geometry is realized.
Typical application of this setup are variable speed belts under silos. These belts are always filled with material; the profile is defined by the chute outlet. Belt speed defines the amount of material fed on the conveyor. Measuring the quality there allows to control feed according to quality parameters.

If the material layer on the conveyor varies between 0 and 100 % and even the profile varies then a fixed geometry cannot be obtained by a static installation of the analyzer. In these cases the analyzer has to be installed on a sled which floats above the material stream.

![Fig. 3: Online X-ray fluorescence analyzer mounted on sled](image)

The sled design works with a parallel support structure which ensures that the sled is always parallel to the conveyor belt. If no material is present then the sled is hanging freely above the empty belt without touching it. As soon as material is fed on the belt the sled will swing in direction of belt movement and it ensures constant geometry between sensor and material.

A counter weight is used to adjust the force the sled applies to the material. Therefore material spill as well as strong wear and tear of the sled plate can be avoided.

**Representativity**

It may be noted at this point that the representativity of the measurement is a vital factor for quality control especially in blending applications. None of the devices for coal analysis are measuring the whole coal stream with identical representation of all particles. Dual Energy devices measure only in the center of the belt; X-ray fluorescence scans the coal surface. Therefore both methods need material homogenization and therefore they should be installed behind a rectangular belt transfer point. The neutron source based PGNAA devices transmit the whole belt including the material due to the high energy of the neutrons. For this reason these devices need a minimum volume of material for the neutrons to interact. If this volume is not present then the accuracy will decrease.

**Blending Strategies**

When it comes to blending material streams from two or more sources together there are multiple ways to utilize quality parameter measurement with different benefits and cost. In this chapter some of the available options are discussed.

**Reactive Blending**
When blending reactively quality parameters of the material stream are usually determined right before or right after the blending position. The different strategies are used in either feedforward and feedback control circuits.

If a feedforward control shall be established then knowledge of composition and mass flow of the material used for blending is required. Blending of imported and domestic coal requires installation of two online devices which derive information on these products. If more material sources are available then in turn one analyzer for every additional stream is required which increases the investment to be made.

A feedback circuit requires only measurement of the final - blended - product. This method is recommended if the blend is done using just two products and one product has a uniform composition. However, if the quality of more than one product varies the system needs to operate without knowledge about which component changed and thus can operate poorly under these conditions which may result in strong quality variations.

The complete control strategy can be achieved if single products and blended product are monitored. Then even small deviation in quality can be addressed.

All three strategies allow blending with a certain target (i.e. ash content or calorific value). If targets for multiple quality parameters have to be met in narrow limits a compromise between different parameters has to be made. These parameters may be moisture content, sulfur content, sodium content (ash fusion temperature), mercury or arsenic content (SCR catalyst). This can involve hard limits for certain parameters and weights defining the importance of meeting specific target values closer than others in case of a compromise. If all material blend combinations exceed hard limits the current material has to be either deposited for later blending, dumped as waste material or an additional high quality material source has to be added to the stream.

Another disadvantage of all of these strategies is the missing planning reliability. Since the material is only measured when it arrives at the blending point the next hours and days can not be planned ahead or plans can not be met on irregularities.

**Proactive Blending**

Proactive blending tries to solve the main drawbacks of reactive blending:

1. Homogenization of multiple quality parameters
2. Planning reliability for the blended product

This is achieved by measuring the input material quality before stockpiling and tracing the stockpiling process. Using this method the complete material distribution within the stockpile is known and can be utilized to derive a precise model for the material quality output from the reclaim system.

*Figure illustrates a feedforward and feedback control system for reactive blending*
Doing this for all material sources the optimally blended material stream for the given stockpiles can be produced. But even with only a part of the material being stockpiled (e.g. imported coal) proactive blending allows a more reliable blend with domestic coal. While the domestic coal can be fed directly the complete knowledge about the stockpiled material allows ideal blending within the quality parameters of the stocked material. While avoiding waste material this strategy minimizes fluctuations in the product stream and improves overall homogenization of the material.

Additionally a position control system for the stacker can provide improved homogenization during the stockpiling process by distributing the material by the measured quality reactively. This way the material of different quality can either be distributed more evenly over the stockpile or even be split by different quality measures into separate smaller stockpiles. This provides the ability to reclaim material with specific properties for balancing fluctuations in the directly fed material using only one stacker and reclaimer system (e.g. if using as bucket wheel reclaimer).

**Fig. 5: Illustration of a feedforward and feedback control system for proactive blending**

**Conclusions**

The reliability expectations of power plants are very high. To meet these expectations, not only the power generating part of the plant has to operate in a very narrow parameter band but also the coal quality has to meet a narrow band. This is especially true for India where the demand for power nearly doubled in the last decade. Keeping up with this demand while also meeting the coming, stricter environmental limits poses a significant challenge for Indian power plants.

By decreasing the variation in coal quality to the absolute minimum a reliable boiler performance and thus a maximized power output can be achieved.

**References**

/1/ Bachmann, Claus: Untersuchung des Absorptions- und Streuverhaltens von Gamma-Strahlung an feinkörnigen Steinkohlen und an Kohleträuben auf Grund des Photo- und Comptoneffektes im Hinblick auf die Asche- und Feststoffgehaltsbestimmung, Thesis, RWTH Aachen, Germany, 1985
