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# EVALUATION OF PROPERTIES OF COAL USING VARIOUS NDT METHODS

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## Abstract

The various methods of non-destructive techniques to evaluate the properties of coal are describes in this Paper. Non-destructive techniques have been used almost exclusively for detection of macroscopic defects in existing structures. It is practical and cost effective to expand the role of non-destructive evaluation and can be included in all phases of material production. Quick analysis of coal properties plays an important path in improving combustion efficiency and reducing atmospheric pollution at coal fired power station. Various NDT techniques can be use to analyze coal samples very efficiently. Just by sampling a small amount of coal, the NDT techniques can accurately analyze the calorific value and the percentage of carbon, oxygen, hydrogen, sulfur, water, and ash. Objective of this paper is to make an attempt to study different physical & chemical properties of coal through various NDT techniques & the comparative study of the all the methods has been detailed.

**[I] Introduction**: Today in almost all coal fired power stations, the main problem is to evaluate the coal properties before using it. It is essential to find coal calorific value, moisture content, volatile matter content, ash content and percentage of elements. Till date in many power plants, chemical analysis methods are used to get information about all these parameters which is very time consuming and requires lot of technically skilled persons having detailed knowledge of chemical testing of coal. Besides using the traditional chemical processes many researchers have tried to characterize coal by using various NDT techniques . Non-destructive techniques have been used almost exclusively for detection of macroscopic defects in existing structures. It is practical and cost effective to expand the role of non-destructive evaluation and can be included in all phases of material production. In this paper, we have discussed various techniques that are used to characterize the coal by using non-destructive techniques.

**[II]Measurement Techniques:**

The techniques available for characterization of materials can be categorized in two broad classes, destructive & Non-Destructive Techniques. The destructive techniques cause certain variation in physical shape and material properties, in some cases it damages the materials. Thus there will be degradation of the strength of the material being evaluated. In Non-Destructive evaluation technique there is no physical damage while characterization of the material.

**The common NDT Techniques are as listed below:**

1. Dye penetrant inspection
2. Magnetic Particle Testing
3. Ultrasonic Testing
4. Eddy Current Testing
5. Radiographic Testing

1. **Dye penetrant inspection :**

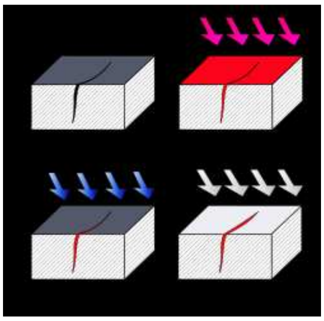

Fig 1: Dye penetrant inspection

is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non porous materials (metals, plastics, or ceramics). LPI is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity leaks in new products, and fatigue cracks on in-service components.

2. **Magnetic Particle Testing**:

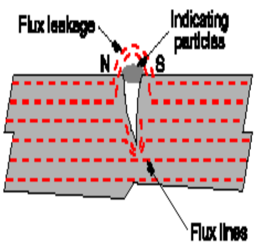


Fig 2: Magnetic Particle Testing

This method is suitable for the detection of surface and near surface discontinuities in magnetic material, mainly ferritic steel and iron. The principle is to generate magnetic flux in the article to be examined, with the flux lines running along the surface at right angles to the suspected defect. Where the flux lines approach a discontinuity they will stay out in to the air at the mouth of the crack. The technique not only detects those defects which are not normally visible to the unaided eye, but also renders easily visible those defects which would otherwise require close scrutiny of the surface.

3. **Ultrasonic Testing:**

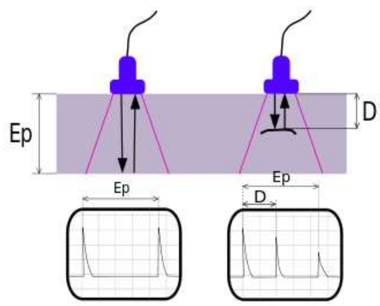


Fig 3 **:** Ultrasonic Testing

In ultrasonic testing (UT), very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are launched into materials to detect internal flaws or to characterize materials. A common example is ultrasonic thickness measurement which tests the thickness of the test object, for example, to monitor pipe work corrosion. Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is a form of non-destructive testing used in many industries including aerospace, automotive and other transportation sectors.

4. **Eddy Current Testing:**

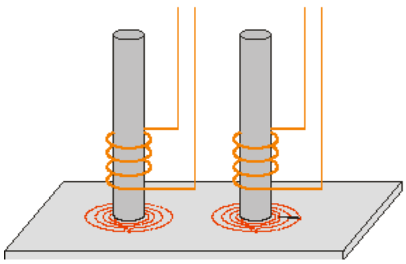

Fig 4: Eddy Current Testing

Eddy-current testing uses electromagnetic induction to detect flaws in conductive materials. Eddy currents can be produced in any electrically conducting material that is subjected to an alternating magnetic field. The alternating magnetic field is normally generated by passing an alternating current through a coil. The coil can have many shapes and can between 10 and 500 turns of wire. The magnitude of the eddy currents generated in the product is dependent on conductivity, permeability and the set up geometry. When a crack, for example, occurs in the product surface the eddy currents must travel farther around the crack and this is detected by the impedance change.

**5. Radiographic Testing:**

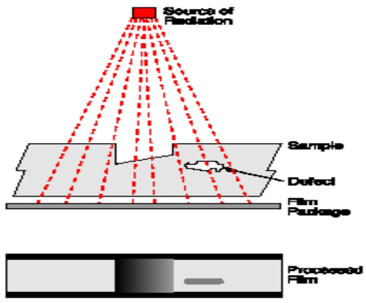


Fig 5: Eddy Current Testing:

This technique is suitable for the detection of internal defects in ferrous and nonferrous metals and other materials. X-rays, generated electrically, and Gamma rays emitted from radio-active isotopes ,are penetrating radiation which is differentially absorbed by the material through which it passes; the greater the thickness, the greater the absorption. Material with internal voids is tested by placing the subject between the source of radiation and the film. The voids show as darkened areas, where more radiation has reached the film, on a clear background.

**[III] Different NDT methods to evaluation of properties coal :**

Desham Gu et.al. [2]. In his work, the pulsed neutron beam bombards the elements in coal samples and interacts with the nuclei of its different atoms. This bombardment induces several different reactions. Among those reactions, the thermal neutron capture reaction [*n, γ* ] and the inelastic scattering reaction [*n, n_ , γ* ] will induce instantaneous *γ* -rays. The elemental analysis of coal, including the coal industrial value analysis, shows that the inelastic reaction cross section of carbon and oxygen are relatively larger, whereas the other elements have larger capture cross sections. The instrument uses the pulsed neutron generator to control the emitting period of pulsed neutron beam to separate the inelastic spectrum induced by fast neutrons and capture spectrum induced by thermal neutrons. After the spectrum separation, the spectrum data to produce the elemental analysis of the coal samples In his work the main controlling parameters were

- Controlling the sampling time precisely with a computer
- Calibrating the *γ* -ray sensors properly
- Applying an appropriate algorithm in data analysis.

Neither one of the [*n, γ]* and [*n, n_, γ* ] reactions can give an accurate elemental analysis by itself because of the cross sectional difference between the reactions on different elements in coal.

Sodium in coal, which causes fouling and slagging, can be measured with an on-line analyzer that uses PFTNA Concerning the neutron generator itself, when it needs replacement, a new one can be shipped by common carrier without special shielding requirements. When de-energized, the radiation emitted from the beta decay of the tritium target is entirely stopped by the rugged stainless steel container in which the (D-T) neutron generator tube is housed. The direct measurement of C and O means that

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Calorific values can be measured without recalibrating for each particular seam analyzed can be done by Vourvopoulos et. al. [3] & also can produce substantial financial savings to a coal-fired power plant. Because of the large amount of coal consumed each year by coal-fired power plants, a reduction of a few percent in fuel cost can result in savings that can easily justify the installation of the analyzer from a financial standpoint

L. Dep et.al. [4]. In his work, Coal flowing in a vertical chute is irradiated by a pulsed neutron generator, producing 14 MeV neutrons in pulses several microseconds wide and with a frequency of several kilohertz. The high-energy neutrons interact with elements such as C and O emitting characteristic gamma rays. In between the neutron pulses, the fast neutrons within the coal bulk lose their energy through scattering with the light elements in the coal, initiating thermal neutron capture reactions. Such reactions measure elements such as H, S, and Cl through their characteristic gamma rays. For the measurement of Na, neutron activation is used, producing isotopes that have longer half-lives (on the order of seconds) than the fast and thermal capture reactions. The gamma rays produced from each category of nuclear reactions are acquired and stored in different spectra. By acquiring the gamma rays in three different time windows, there is a significant reduction of the background as compared with the spectra taken with a radioisotopic source.

The Elemental On Line a analyzer has been built, able to analyze several tons/hour of coal. The main features of the analyzer are self-calibration independent of the coal seam, better accuracy in the determination of elements such as carbon, oxygen, and sodium, and diminished radiation risk. A fast, accurate, real-time method of determining the elemental composition of coal is important to the coal industry for pricing, quality control, and reduction of $SO_2$ emissions. Some of the elements such as C, O, H, and S can be used in an algorithm for the determination of the calorific value (BTU/lb) of coal Continuous control of coal quality can be maintained by blending different types of coal, a method opted by nearly 50% of the coal-fired power plants affected by the Clean Air Act

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Amendments. A real-time method of determining the elemental coal composition can provide the needed information for blending. Nuclear techniques using interactions of neutrons with coal fulfill this need, because the coal is analyzed within minutes as it travels on a conveyor belt or as it falls in a chute. These neutron interactions produce gamma rays that have energies unique to each element In this paper Womble P et.al. [5] discuss a prototype on-line coal analyzer employing the PFTNA technique that we have developed and built at Western Kentucky University & the data from the analysis of a large number of coal samples are presented, and the essential components of the coal analyzer are described.

To monitor the dynamical changes in coals with temperature, an in-situ method must be used, therefore, we have applied single-point-imaging and have carried out the first systematic in-situ variable-temperature NMR(Nuclear Magnetic Resonance) (nondestructive analytical technique )imaging study of coals between 25 and 500・ with our newly developed high temperature imaging probe and systems. It has been clarified that the macromolecular structure of coal is relaxed by the rapid heat treatment and in addition there is a close relation in hydrogen bond and relaxation of molecular structure of coal. The authors [6] developed and built the first system in the world to utilize the molecular-level chemical information provided by NMR imaging to permit not only direct observation of coal .An attempt was made to apply the system to a wide variety of coals and to clarify the behavior of rapidly heated coal during the softening and melting process and the mechanism by which rapid heat treatment improves the coking property. By applying the high temperature in-situ NMR imaging method to coal samples, it has been found that the molecular group domain that is formed by the mobile component at room temperature expands with the rise in temperature and is evenly distributed within the coal grains. By utilizing the molecular-level chemical information provided by NMR imaging, the world's first system was developed and built that enables direct, in-situ observation of the coal softening and melting process without using solvent vapor to swell the coal. With this system, it was possible to clearly grasp the changes in coal at the molecular and molecular group domain levels and the change in their behavior in the heating process

The NMR relaxation has shown potential advantages for the petrophysical characterization of coal in several ways. Firstly, it is a nondestructive technique. NMR does not require special shape or size in sample preparation, and the method does not generally destroy the original pore structure of coal. Secondly, it is the only method that fits well for in situ CBM reservoir. The in situ CBM reservoir is commonly saturated with water that is similar to the measurement condition of NMR. Thirdly, it is an instant detection method and can be easily applied to drill cores in well field. Lastly, with further research it may provide a very promising technique for well logging. This study [7] has shown that pore types of coal can be classified by measuring NMR T distributions. NMR T2 distributions for 100% water saturated samples are commonly bimodal, unimodal and multimodal, with peaks of adsorption pores (<0.1 lm) at 0.5– 2.5 ms, seepage pores (>0.1 lm) at 20–50 ms, and the cleats (or fractures) at >100 ms. The IP and PP values are estimated using NMR data of cores at 100% water-saturated and irreducible water conditions. The PP value of coals is low, in the range of 0.07–4.67%, but more commonly between 0.1% and 2%. PP strongly relates to the developments of cleats and the air permeability of coals. Based on an exponential regression of air permeability and PP, a new NMR-based permeability model is proposed. This model provides significantly better permeability estimations than the classicmodels originally developed for sandstones. In combination with mercury intrusion porosimetry, we also propose a NMR-based pore structure model that efficiently estimates the pore size distribution of coals.

This paper[8] demonstrates capabilities of microfocus X-ray computed tomography (μCT) in characterizing the development of coal porosity and fractures. For the investigated coals, the CT number of minerals, pores and coal matrix are approximately 3000, b600 and 1000–1600 Hounsfield unit (HU), respectively. The total

CT number of analyzed coals mainly relate to the density, coal maceral composition, and proportion of minerals and pores. Although the estimated porosities by segmentation method show some uncertainty, the results correlate well with the analyzed porosities by helium gas method and water-saturated method. The aperture, spacing and spatial distribution of fractures, and mineral morphology are semi-quantitatively evaluated by µCT using a computer-aided design. The slicing analyses of coals demonstrated that distributions of porosity in coals are highly anisotropic. The spatial disposition of pores, fractures and minerals is the most important factor that influences coal porosity and permeability.

Shepard, Phillip W.[9] in his research tried to analyze the anisotropic properties of coal. He has made use of two-path interferometer at microwave frequencies (9GHz) to measure the dielectric constant and conductivity of coal as a function of direction of propagation & polarization of the electromagnetic wave within the coal.

Balinis C.A.[10] developed electromagnetic system to detect and monitor underground coal gasification process. In general, it has been observed that there is a decrease in the values of dielectric constant and an increase in conductivity as the frequency increased.

In electrical power generation there are many problems that may be solved by the application of Image analysis .The presence of non ore gangue material mixed with coal can have impact on combustion efficiency and emission of power plant .Differentiation between coal & gangue is desirable for fuel quality control and yield analysis . Hobson, D.M.[11] in his research work analyse the coal samples through a process of image acquisition and digital processing. Sheen, S.H.[12] used Ultrasonic techniques for measurement of coal slurry viscosity .He used four ultrasonic techniques measurement of attenuation ,acoustic impedancedance ,relaxation acoustic straining and cavitations'.

**[IV]Conclusions:**

The present paper has given the several Non Destructive Test (NDT) methods that are used for the evaluation of Coal properties .Moreover, it has been shown that Non-destructive characterization affords a most promising opportunity during production of materials, devices and structure out of several NDT test. In future the evolution of a variety of technologies will enable NDT to move rapidly ahead and develops. Vastly increased computing capability will enhanced the ability to gather, store and manipulate data and images, and to partially or fully automate NDT techniques. We believe that the NDT techniques are most significant development for characterization and analysis of Coal properties. To evaluate the properties of coal that may be useful to industries which uses boilers and it will be useful in saving the boilers from damaging.

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