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DEVELOPMENT OF AN ON-LINE COAL WASHABILITY ANALYZER

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Project Title

DEVELOPMENT OF AN ON-LINE COAL WASHABILITY ANALYZER

Semi-Annual Report
(10/01/1997 - 03/31/1998)

DOE award No. : DE-FG22-96PC96215

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DISCLAIMER

ABSTRACT

Washability analysis is the basis for nearly all coal preparation plant separations. Unfortunately, there are no on-line techniques for determining this most fundamental of all coal cleaning information. In light of recent successes at the University of Utah, it now appears possible to determine coal washability on-line through the use of x-ray computed tomography (CT) analysis. The successful development of such a device is critical to the establishment of process control and automated coal blending systems. In this regard, Virginia Tech, Terra Tek Inc., and Cyprus-Amax Coal Company have joined with the University of Utah and agreed to undertake the development of a **x-ray CT-based on-line coal washability analyzer** with financial assistance from DOE. The three-year project will cost $594,571, of which 33% ($194,575) will be cost-shared by the participants. The project will involve development of appropriate software and extensive testing/evaluation of well-characterized coal samples from three coal preparation plants. Each project participant brings special expertise to the project which is expected to create a new dimension in coal cleaning technology. Finally, it should be noted that the analyzer may prove to be a universal analyzer capable of providing not only washability analysis, but also particle size distribution analysis, ash analysis and perhaps pyritic sulfur analysis.

EXECUTIVE SUMMARY

The primary objective of the proposed research program is to develop a CT-based, on-line coal washability analyzer. A secondary objective will be to demonstrate the capabilities of the analyzer by comparing efficiency data from traditional float-sink tests conducted at three preparation plant sites with efficiency data generated by the washability analyzer. The scope of the proposed research program involves several tasks including (i) the acquisition and preparation of test samples for use in testing and calibrating the analyzer, (ii) the development of appropriate hardware and software necessary to adapt a CT analyzer for use in determining coal washability, (iii) the testing and modification of the analyzer using well-characterized coal samples, (iv) the evaluation of the analyzer's performance under simulated plant conditions, and (v) an evaluation of the technical and economic feasibility of implementing the CT-based washability analyzer on a commercial basis.

Researchers from the University of Utah and Terra Tek Inc. will perform tasks related to the development, calibration and testing the analyzer, while technical personnel from Virginia Tech and Cyprus Amax will provide the required coal samples, evaluate the industrial capabilities of the analyzer, and promote system commercialization.

The main effort during this reporting period was conducted on software development to analyze the coal washability based on 2-D image data sets. Two approaches (namely 3-D and 2-D mass density distribution analyses) were developed to facilitate the separation and classification the density distribution of the coal particle bed. A software package, namely Volume Slicer, was developed for displaying and managing the 3-D data sets.

RESULTS AND DISCUSSION (by task)

Task 1. Project Management

At the beginning of this reporting period, two graduate students (Ataullah Mirza-Baig and Altaf Khan) at the University of Utah were assigned to the project to coordinate the CT scanning for washability analysis, and to develop software and hardware. At Virginia Tech, two additional graduate students (David Brafford and Jaisen Kohmuench) have been assigned to work part-time on this project to acquire coal samples, perform characterization tests and collect field data used to evaluate the industrial applications of the proposed technology.

Task 2. Sample Preparation

In this task, representative samples of run-of-mine coal were collected for use in the calibration and development of the coal washability analyzer. Approximately 10 drums of raw coal were collected from the Lady Dunn Preparation Plant near Charleston, West Virginia. The sample was screened into six size fractions (i.e., (+4, 4x2, 2x1, 1x1/2, 1/2x1/4 and -1/4 inches) and then each size fraction was subjected to detailed washability (float-sink) tests. The following gravity classes used in the washability tests: Float 1.3, 1.3 x 1.5, 1.5 x 1.7, 1.7 x 1.9

and Sink 1.9. Approximately 30 size/density fractions were generated by this procedure. The size/density fractions were then shipped to the University of Utah for use in the development of the CT washability analyzer. Detailed coal analyses (e.g., ash, sulfur, etc.) have not yet been performed the size/density fractions since this is a destructive procedure. These analyses will be performed after all analyzer development and calibration work has been successfully completed.

Task 4. Software Development

To determine the size and mass density distributions, detection of surface boundaries and classification of the particle population is critical. Since the x-ray CT equipment (Philips Tomoscan 60/TX) being used in this study produces two-dimensional images (slices) of a coal particle bed, two methodologies (namely 3-D and 2-D mass density distribution analyses) are being developed to facilitate the separation and classification of particle images in order to determine the density distribution for the coal particle bed.

The first approach, namely 3-D mass density distribution analysis, involves the procedure of stacking the individual 2D slices and generating a three-dimensional data set with the assignment of intensity values to small voxels (volume elements) of the particle bed. Then, the algorithms for 3-D data processing are used to construct the corresponding mass-density distribution. These algorithms include phase segmentation for data reduction, surface extraction (watershed algorithm) to separate contacting particles, labeling for particle classification, and volumetric grade classification for the 3-D data set (as shown in the previous report).

When dealing with a 3-D data set there is always the question of what is the most effective way of displaying this data set in two dimensions, so that the information that needs to be communicated to the viewer is done without complication or confusion. In this regard, a software package, Volume Slicer (Figure 1), was developed for displaying and managing the 3-D data sets. Volume Slicer allows the user to download the sequence of the original 2-D images and to examine the tomographic plane at different positions and from different view points (angles).

Figure 2 illustrates the coordinate system for one of the 3-D data sets for a coal particle bed. Three different cross sections (from a total of 68 sections) along the X-, Y-, and Z-directions as established from the three-dimensional reconstruction of the coal particle bed sample are also displayed in Figure 2. The numbers on the upper left corner of sectioned images indicate the relative position along the corresponding directions (X, Y and Z).

The response time will be significantly reduced if a large CT sampling interval can still provide accurate information for coal washability analysis. Base on early studies, it is expected that the 3-dimensional information can be estimated from sectioned 2-dimensional data with a suitable transformation kernel. In this regard, the second approach involves the development of transformation kernel and algorithms for coal washability information based on non-continuous 2-D images in order to reduce the total response time. In contrast to the approach for the 3-D

mass density analysis mentioned previously, algorithms such as the polygonal approximation and the classification of concavities based on polygons are implemented to enhance the robustness for the separation of particles in contact. A flow chart for the 2-D mass density analysis algorithm is presented in Figure 3. Figure 4 shows the resulting images at different processing steps for the separation of the coal bed particles in contact.

Task 7. Plant Sampling for System Evaluation

The installation and testing of a prototype on-line washability analyzer in an industrial setting is cost prohibitive under the funding constraints of the current project. Therefore, the effectiveness of the analyzer has been evaluated under simulated on-line conditions by collecting data for samples of the feed, clean coal and reject streams for different coal seams. Much of the work performed under this subtask has focused on data from a single plant site due to recent company mergers/buyouts that forced a change in the originally planned test sites. To date, characterization data has been collected for coal feeds from the Hernshaw, Chilton, Upper Alma and Lower Cedar Grove seams. The first two seams are representative of typical steam coal (utility) fuels, while the last two are more representative of metallurgical coals used in coke production. Preliminary evaluations indicate that the conceptual CT washability analyzer can play an important role in optimizing the extensive blending activities currently required to market these particular coals. Future plans call for the collection and shipping of selected samples of these coals to the University of Utah so that comparative analyses can be performed using the CT analyzer.

SUMMARY STATUS ASSESSMENT AND FORECAST

1. Samples of feed coal were collected, sized and subdivided into narrow specific gravity classes for use in the development and calibration of the CT analyzer.

2. Two approaches (namely 3-D and 2-D mass density distribution analyses) were developed to facilitate the separation and classification the density distribution of the coal particle bed.

3. The software package, Volume Slicer, was developed for displaying and managing the 3-D data sets. Volume Slicer allows the user to download the sequence of the original 2-D images and to examine the tomographic plane at different positions and from different view points (angles).

4. The algorithm for the 2-D mass density distribution analysis has been implemented. Test results show that the algorithm works in a promising way. Determination of the relationship between 3-D and 2-D mass density distribution analyses is in progress.

5. Excellent progress has been made on the project and it is expected that the cycle time for the CT scanner and the amount of sample required to achieve a given level of accuracy can be established.

6. Field data have been collected for different coal seams to identify promising commercial applications of the proposed CT washability analyzer. Information obtained to date indicates that the technology may be very useful for the optimization of critical coal blending operations.

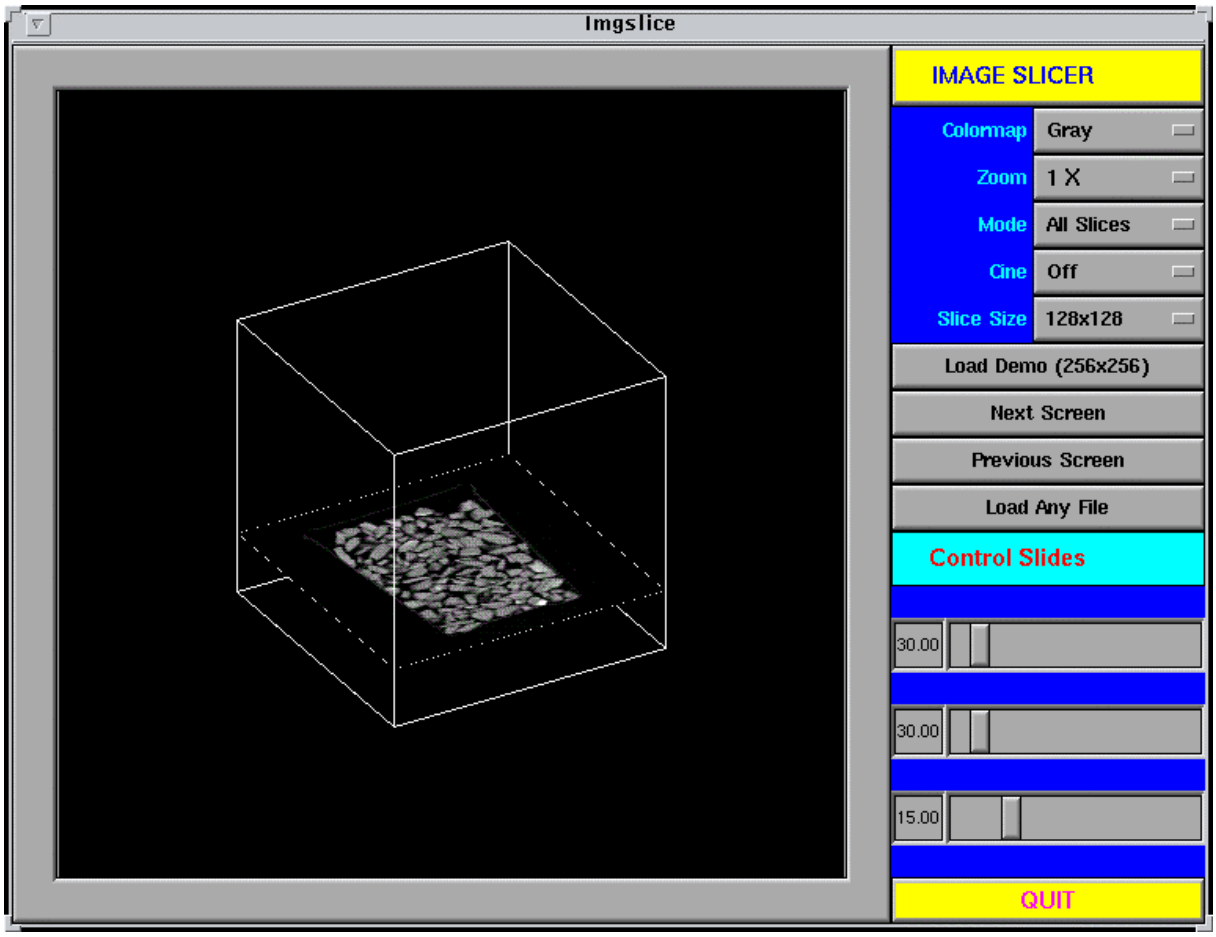

Figure 1. Volume Slicer for displaying and managing 3-D volumetric data sets.

Coordinate System and Cross Sectional Images
at Selected Positions for a Coal Particle Bed

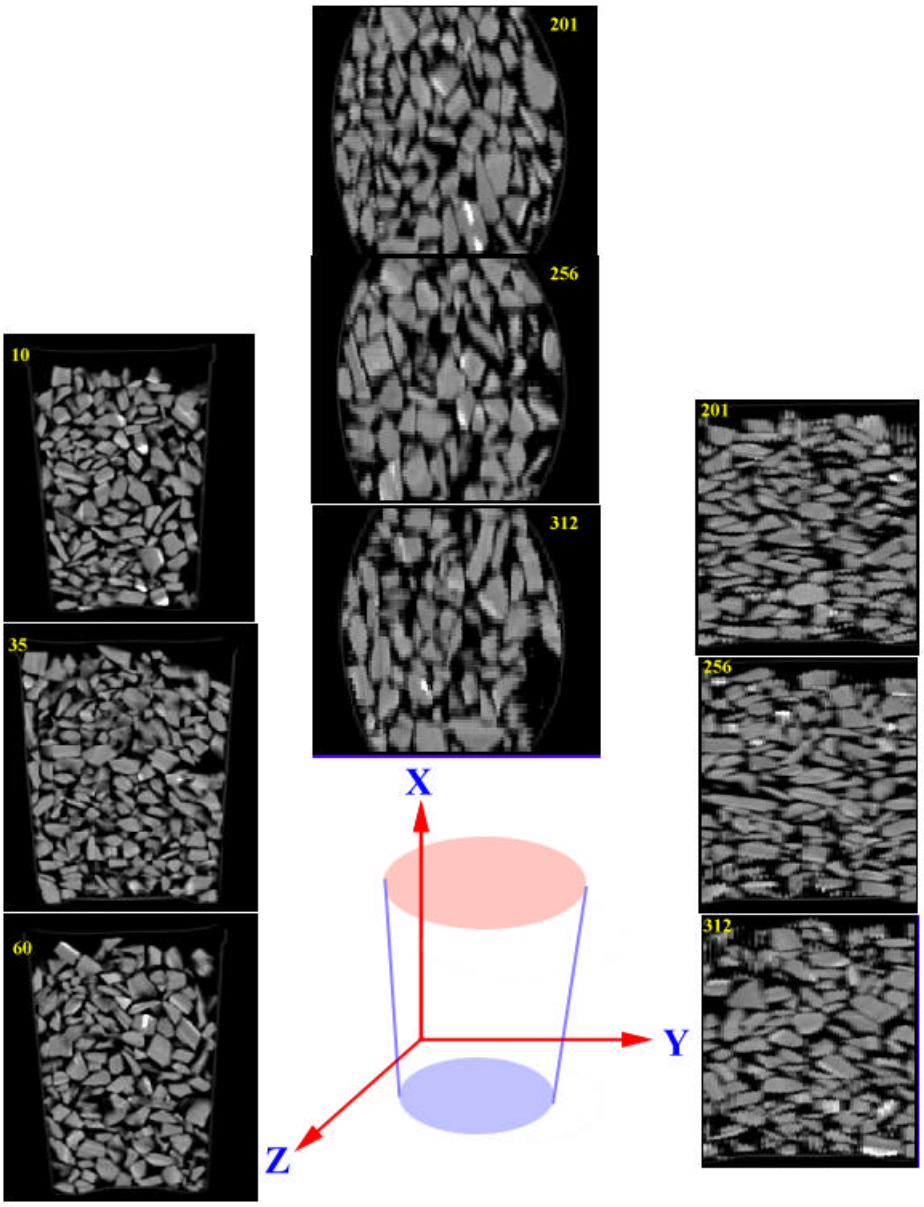

Figure 2. Coordinate system and cross sectional images (perpendicular to indicated axis).

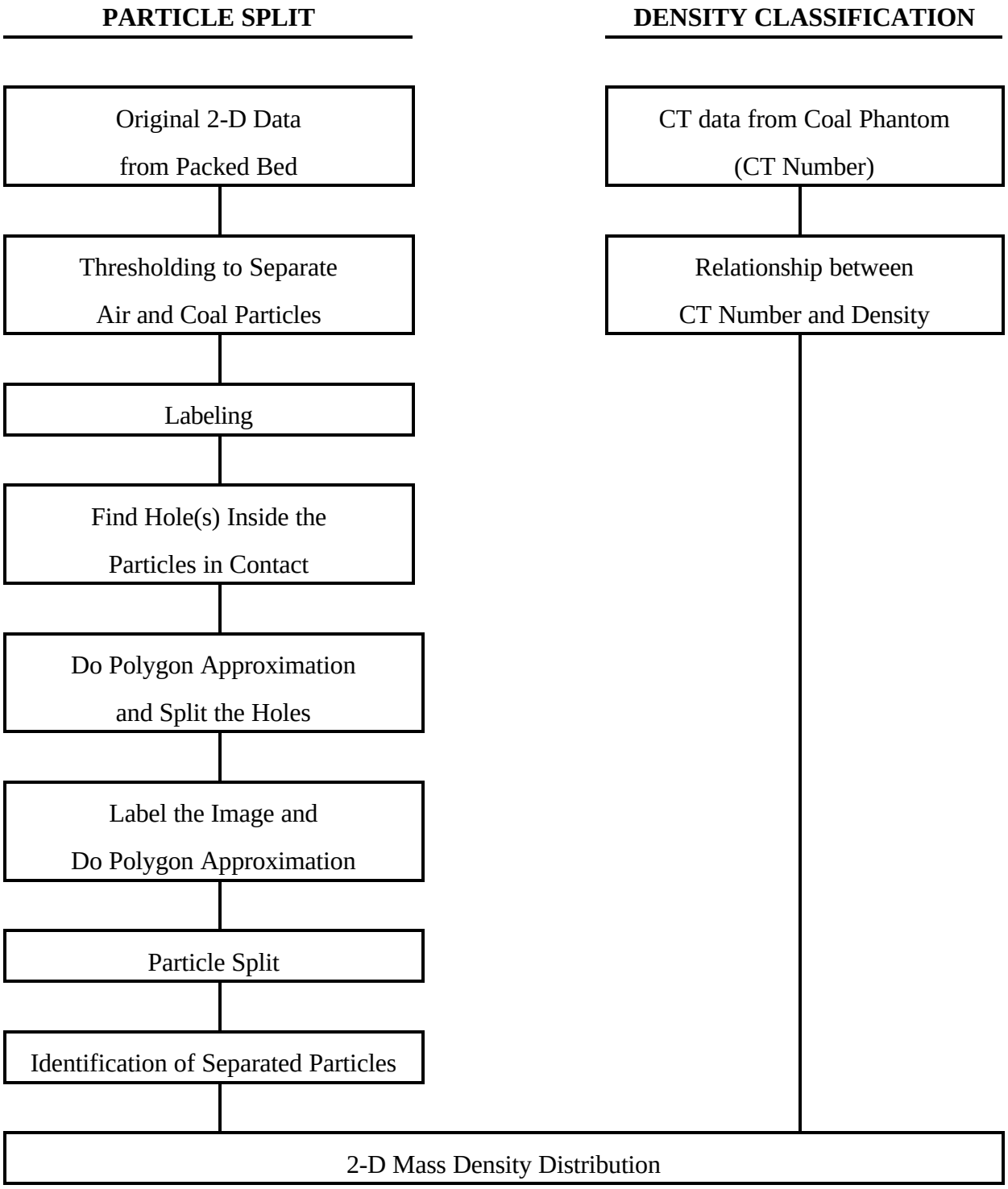

Figure 3. Flow chart for the 2-D mass density analysis algorithm.

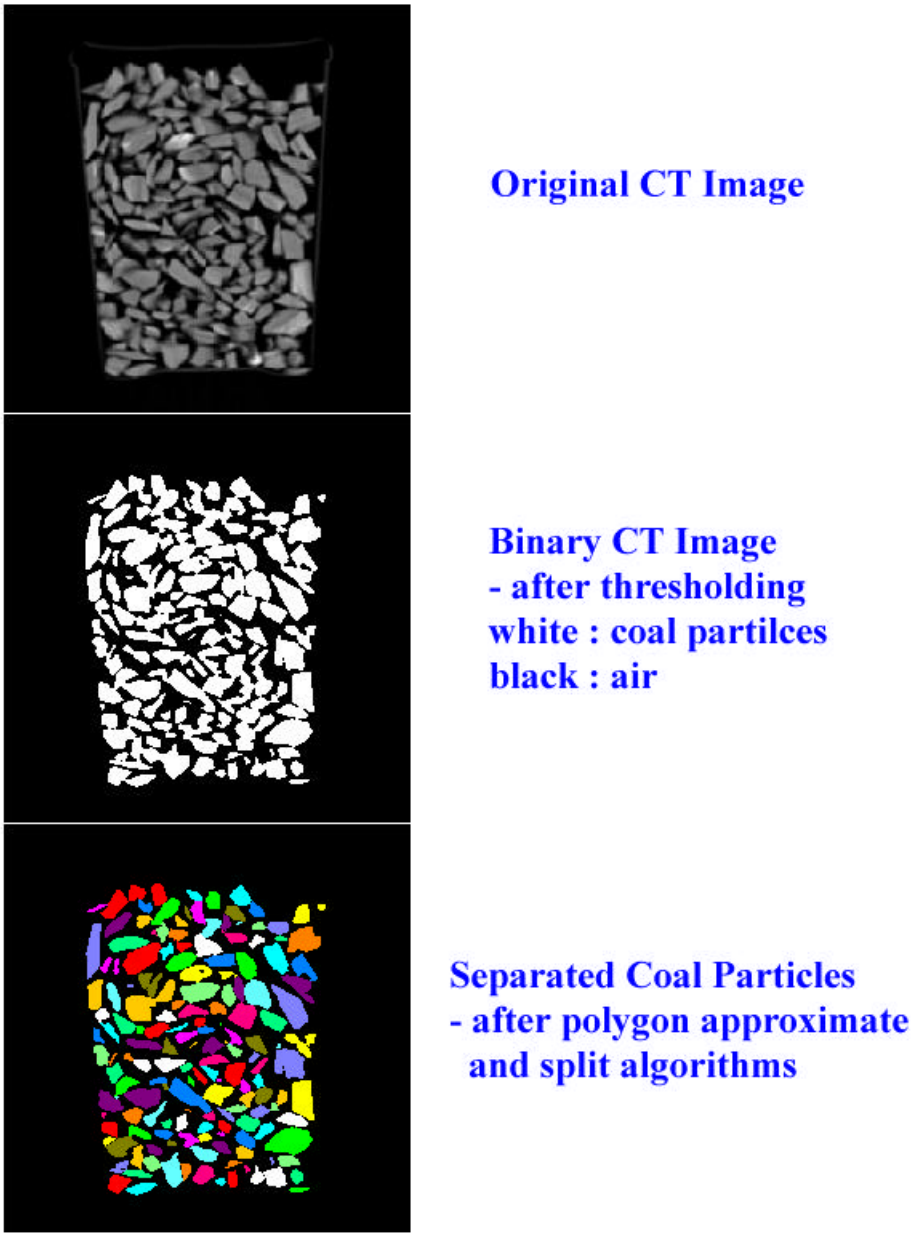

Figure 4. Image sequence shows the results for the separation of coal bed particles in contact using the algorithm for 2-D mass density analysis as shown in Figure 3.