Computer-Aided Design and Fabrication of a Dry Wind-Sifter Separator

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ABSTRACT: In this study, the simulation of a newly designed wind-sifter separator for dry beneficiation was deployed to upgrade $-6.7 + 3.36$, $-3.36 + 1$, and $-1$ mm coal. The wind-sifter principle is very effective for particle separation as it is based on the separation of lighter particles from heavier ones. First, the study entails computer simulations by utilizing the Lagrangian particle tracking method to observe the effectiveness of the wind sifting principle in separating particles based on their density in an air stream. From the three particle size fractions used, the simulation test results show that at a cut-point of 1.5 RD, yields of 29.1, 54.3, and 99.4% were attained at different optimum velocities for $-6.7 + 3.36$, $-3.36 + 1$, and $-1$ mm, respectively. The effect of operating parameters such as the mass flowrate and air velocity on yield, ash content, and calorific value were determined using the fabricated separator. A preliminary experimental study showed that the separator was effective in upgrading the feed coal with 30.28% ash content and 21 MJ/kg calorific value to clean coal with 18.94% ash content and 26.8 MJ/kg calorific value. A laboratory-scale wind-sifter separator was fabricated based on the results from the simulation test, which served as the first applied prototype in the field of dry coal beneficiation.

1. INTRODUCTION

South Africa is the seventh-largest coal producer, and the sixth-largest exporter of coal with ~245 metric tons of coal produced annually.1 Coal contributes about 77% of South Africa’s primary energy; therefore, the need to utilize coal efficiently is of utmost importance to South Africa. Coal is abundant in South Africa; the estimated reserves indicate that enough coal remains to last more than a century, assuming that the current rates of usage and production remain the same.2 Coal is extremely heterogeneous in nature and contains both organic and inorganic matters. It is extremely important to always remove these impurities (inorganic matter) from the coal before combustion. The principal coal beneficiation technique has been the water-based wet beneficiation process due to its excellent separation efficiency. However, owing to its high operational costs associated with ancillary items such as flotation reagents, thickeners, cyclones, filtration machines, and centrifuges, along with environmental concerns, dry coal beneficiation is progressively becoming a significant alternative approach.3–6 Although dry coal beneficiation processes (which are rapidly evolving) have seen different techniques come to light with improvement in existing technologies, little to no information on the use of the wind-sifter technique in coal processing is available or recorded in dry beneficiation of coal in South Africa (SA).

Dry beneficiation of coal is a clean coal technology (CCT) option that separates organic coal from its inorganic minerals without utilizing water. Dry coal processes rely on the physical properties of coal and its minerals. Numerous studies have been conducted on dry coal beneficiation based on the physical properties of coal such as shape, size, density, electrical conductivity, and magnetism.7–9 The effective utilization of a gas–solid fluidized bed for the beneficiation of the $-6$ mm coal fraction has led to studies in upgrading this fraction using gas-vibro fluidized bed, the air dense medium fluidized bed technique, and many other applications.6,10 In this research, we seek to upgrade the quality of $-6$ mm high-ash coal, as this proportion is generated in millions of tons due to mechanized mining in South Africa. Given the possibility of implementing carbon tax in South Africa, more stringent regulations constraining CO$_2$ and SO$_2$ and water usage may be imposed on the coal industry; therefore, the industry is obliged to develop a dry coal process suitable for the available coal in the country. The coal quality present in the South African coalfields is of moderate to poor grades, with many lying in remote locations and of too low quality to be of economic value to be mined and beneficiated using wet techniques. With the best quality of run of mine (ROM) coal being mined out, it...
is paramount that cutting-edge dry beneficiation techniques and principles are adapted to suit the nature of South African coal in terms of its quality and near-gravity particle attribute. Recently, the principle of air jet used in other industries is now being adapted in the beneficiation of fine coal particles. The principle had found application in air ventilation, particle dewatering, solid waste treatment, metal smelting, aircraft industry, coal beneficiation, and many other areas. The same principle was used by Nihot recycling technology in designing a separator for segregating municipal solid waste, construction, and demolition waste. Yang et al. also applied this principle to design a novel planar air-jet separator for the dry beneficiation of −6 + 2 mm fine coal. The result of this study shows that clean coal with an ash content of 16.61% and yield of 56.75% can be obtained from feed coal of 26.9% ash. On this premise, this study also reviews the application of wind-sifter technology, which has been successfully implemented in the separation of municipal solid waste, opal sandstone, mica, food, and other organic materials. From the investigation conducted by Goran the wind sifting principle was used in designing a rotating type of separator for the effective transportation and separation of pulverized materials. Redemann et al. also applied the same concept in designing a different configuration of wind-sifter separator for managing ash production in the circulating fluidized bed combustors firing refuse-derived fuel (RDF) and coal. Eichert et al. conducted a study using a zigzag wind sifter for separating electronic waste and electrical equipment from dust and other lighter materials. In addition, Krüger et al. also deployed the use of zigzag wind sifters in waste treatment through the sorting of wastes and removal of impurities to achieve a better quality of refuse-derived fuel. A recent investigation conducted by de la Fuente et al. likewise applied the principle, integrated with a chipper and a fractioning machine to separate contaminants such as gravel and stones from wood chips. The effectiveness of this technique for coal beneficiation will depend on the extent to which the coal minerals within the coal matrix can be liberated from the organic material during the crushing and grinding processes.

The proposed principle applied in the present design is based on wind sifting, which uses forced draft air through an air-jet inlet into the separator, to facilitate the separation of lighter (clean) coal from its denser particles. The principle likewise separates particles based on the differences in their sizes, shapes, and relative densities. The separator designed for this study was adapted from an existing luchtscheiding wind-sifter separator made by Trenenso Technik for other materials. The Trenenso wind sifter has a zigzag configuration, which facilitates the bouncing off the particles differently and separates them according to their density, with the lighter particles transported by the air stream into the cyclone section and the heavier particles fall into the designated collection bin in this section. The newly fabricated separator used in this study differs in terms of configuration and modification made to chamber 1 and the newly designed chamber 2. The means of recovering the coal products and the numbers of product grades that can be obtained from this innovation made it different from others, and it should be appreciated. Chamber 1 from the Trenenso’s wind sifter and other designs separated particles or feed into one bin (product) using a cyclone in their chamber 2 to cut just a single product grade. In our design, the concept used in chamber 2 “diffuser section” facilitates the separation of inherent particles within the coal to attain their settling velocities and be separated into four (4) bins as a clean coal product(s) based on their relative densities (RDs). This chamber is integrated with a filter connected in tandem with it to filter coal dust particles along with the air exiting the separator. The other novel feature of the invention is set forth in Figure 3 (chamber 2), which will become apparent to those knowledgeable in the art upon examining the illustration provided.

The schematic representation of this design and the fabricated separator was in accordance with the simulation results obtained from three different particle sizes (−6.7 + 3.36; −3.36 + 1, and −1 mm) as the simulation tests were carried out to investigate the effect of air velocity on the above-mentioned three particle size fractions as well as individual particles in each particle size fraction.

2. EXPERIMENTAL SECTION

2.1. Geometry Design and Simulation. As earlier stated, the Lagrangian particle tracking method was used for the simulation test runs in this study; however, the fluid body of the wind-sifter separator was first generated using AutoCAD Inventory 2017 and exported into Star CCM+ for the simulation process. Factors such as the air-jet angle, velocity of the air stream, density and size of the particle, buoyancy, drag force, gravity, and friction on the wall of the separator were considered during the design of the separator.

While Figure 1 shows the full separator assembly, Figure 2A,B indicates the individual chambers and their respective flow boundaries.

![Figure 1. Full separator assembly.](https://doi.org/10.1021/acsomega.1c02192)
used were a surface remesher and a prism layer mesher. The surface remesher meshing model was used to improve the overall quality of an existing surface and optimize it for the volume mesh model, which is the polyhedral mesher, as used in this study. The polyhedral mesher is a volume core mesh model that provides a balanced solution for complex mesh generation as it uses arbitrary polyhedral cell shapes to build the core mesh. The polyhedral mesher was utilized in this design as it is straightforward and requires no further surface preparation, unlike the tetrahedral mesher models. It is very effective for the analysis of the simulation and contains \( \sim 5 \) fewer cells when compared to the tetrahedral mesher model. The prism layer mesher model was also applied with the core volume mesher (polyhedral mesher) to generate an orthogonal prismatic cell next to the surfaces of the walls of the separator. This type of mesh allows for significant and precise results during the simulation test, even with only a few prism layers, as shown in Figures 3 and 4.

The continuum used in this study was air, which was used to separate the particles while the \( k \)-omega turbulence model and the Boussinesq eddy viscosity model were used to account for turbulence for the Reynolds average Navier–Stokes (RANS) turbulence model category in the separator. The particles were fed into the separator using gravity and Lagrangian models. For the gravity model, values of \((0, -9.81 \text{ m/s}^2, 0)\) were used in the \((x, y, z)\) dimension, respectively, to ensure proper action of gravity in the “negative” \( y \) direction in the separator. For the Lagrangian model, the material of the particles selected in the simulator was raw coal with with seven sets/fractions of the particles representing RD of \( 1.3–1.9 \text{ g/cm}^3 \) at an interval of 0.1. The particles were then fed into the computational geometry (separator) via the coal inlet boundary (chamber 1) for the separation process. Figure 5 depicts the generated volume mesh of the two separating chambers, while the following assumptions were made regarding the simulation test runs.

(I) The particle relative densities are equally represented in terms of mass.

(II) Each relative density (RD) within the coal was represented in the simulator and assigned a size (mm) to simplify the simulation, and this can be seen in Table 1.

(III) Normal and tangential restitution coefficients of the boundary for the wind-sifter separator were assumed to be 0.7. This was to account for the inner section of the separator that was lined with Linatex rubber HDS 60 from Weir Minerals to prevent the breaking of the coal as it is being transported in the air stream.

2.2. Mathematical Model. The gas phase was treated as a continuous phase with the equations below providing the guiding model used for describing the forces experienced by the particles at any location in the separator. The basic equation used arises from the Euler equation that is written below.

\[
\frac{dp}{dt} = -\rho \nabla \cdot u \\
\frac{du}{dt} = -\nabla \left( \frac{P}{\rho} \right) + \mu \nabla^2 u + g \\
\frac{de}{dt} = -\frac{P}{\rho} \nabla \cdot u
\]  

(1) (2) (3)
equal zero. The temperature of the air is assumed to be

When explained, the equation becomes

\[ \rho \frac{dU}{dt} = -\nabla P + \rho g - F_{ap} \tag{5} \]

where \( \rho \) is the fluid density, \( u \) is the fluid velocity, \( e \) is the specific energy of the fluid, \( P \) is the pressure of the air, \( t \) is the time, \( g \) is the acceleration due to gravity, and \( F_{ap} \) is the total force of the interaction between the fluid and the particles per unit volume of the fluid (air). The expression of \( F_{ap} \) is given in eq 3 as

\[ F_{ap} = \sum_{n} \frac{f_{ap,j}}{V} \tag{6} \]

where \( \alpha \) represents the fluid (air), \( p \) represents the particle “\( j \)”, \( n \) represents the number of particles considered, \( V \) represents volume of particle “\( j \)”, and \( f_{ap,j} \) is the force of interaction for individual particles, which is shown in eq 4.

\[ f_{ap,j} = F_{B} - F_{W} - F_{D} \tag{7} \]

According to eqs 5 and 6, \( F_{B} \) is represented as the buoyant force, \( \rho \) is the density of the fluid (air), \( V \) is the displaced body volume of the fluid (this is also the volume of the particle since it is fully immersed in air), and \( g \) is the acceleration due to gravity.

\[ F_{B} = \rho V g \tag{8} \]

\[ F_{W} = m \times g \tag{9} \]

For eq 7, \( F_{W} \) represents the weight of the particle, \( m \) is the mass of the particle, and \( g \) is the acceleration due to gravity.

\[ F_{D} = (C_{D} \times A \times \rho \times u^2) / 2 \tag{11} \]

In eq 8, \( F_{D} \) is the drag force on the particle, \( C_{D} \) denotes the drag coefficient of the particle, \( A \) is the cross-sectional area, \( \rho \) is the density of the fluid (air), and \( u \) is the flow velocity relative to air.

When \( F_{B} > F_{W} + F_{D} \), the particles are being transported in the air stream, and when \( F_{B} = F_{W} + F_{D} \), \( f_{ap,j} \) is zero, the particle velocity in the air stream terminates, and the particles fall.

2.3. Numerical Model. The initial conditions for the simulation process gas into the separator were a temperature of 20 °C and a pressure of 101.325 kPa. The acceleration due to gravity was acting in the negative “\( y \)” direction, and the time step for air was 0.001 s and that for the particle was 0.006 s. The boundary conditions were the inlet air velocities, which was 6.0–6.6 m/s for (−6.7 +3.36 mm), 4.2 m/s for (−3.36 + 1 mm), and 1.7 m/s for −1 mm, and mass flowrates of 420 g/min. Velocity outlet was adopted for the outlet boundary, while
the outlet velocities for all cases were determined by the simulation process. At the air inlet section, "phase impermeable" was selected to make sure that only the air was entering into the chamber at that boundary, while the velocity of the particles being there via the "coal inlet" boundary was (0, 0, 0). This enables the coal to fall freely into the chamber without additional energy. The normal restitution and tangential restitution of the coefficient were both at 0.7 to account for the inner lining of the separator, and a "no-slip boundary condition" was assumed for the wall of the separator. The mesh sensitivity analysis/mesh dependency test was conducted for four mesh sizes at 5, 10, 15, and 20 mm, and it was observed that at 10 mm, the accuracy was optimum with 673,665 cells. The simulation result showed that the velocity at the outlet of chamber 2, which is also the same as the outlet of chamber 1, was found to be 28.0 m/s. This was also validated by the experimental result of ~28.0 m/s. Table 2 gives information of the mesh sensitivity analysis.

Table 2. Results of the Mesh Sensitivity Analysis

| mesh size (mm) | number of cells | velocity range (m/s) |
|---------------|----------------|---------------------|
| 5             | 1472,323       | 27.9–28.0           |
| 10            | 673,665        | 27.9–28.0           |
| 15            | 476,732        | 27.7–28.1           |
| 20            | 332,549        | 27.2–27.8           |

2.4. Experimental Apparatus. The wind-sifter separator separates lighter particles from heavier ones and the separator is fabricated from mild steel, with a footprint of 4000 mm length, 1670 mm height, and 770 mm width. The separator (Figure 6) has two chambers, with the first chamber having two inlets and an outlet; the top inlet serves as an inlet for coal (no. 7), and the other inlet serves as the channel for the air stream into the first chamber (no. 6). The air is supplied into the separator with the aid of 1, as the air is drawn into the system through 2, travels through 4 and 5, and enters the first chamber through 6. Number 3 serves as a safety relief valve to depressurize the separator assembly from excessive pressure buildup. The air stream travels through 9, 12, 13, and 15 and, in so doing, separates the lighter particles from the heavier ones and transports them into the second chamber. The particles transported into the second chamber are separated into four different bins (14) after attaining their settling velocities, while the heavier particles fall through 9 to the coal bins at the base of the wind-sifter section.

The concept of separation is for the lightest of the clean coal particles (1.3 RD) to fall into the furthest bin (bin 1), followed by 1.4 RD in bin 2, while particles with 1.7, 1.8, and 1.9 RD are expected to fall into bins 5, 6, and 7 in the first chamber.

2.5. Materials and Methods. In this investigation, run of mine (ROM) coal from the Witbank coalfield with 30.28% ash content was screened and sized into two particle size fractions (−6.7 + 3.36 and −3.36 +1 mm) for the preliminary dry beneficiation study according to ISO 13909:2016. Both size fractions (500 g) were then fed into the separator at each of the optimal velocities attained from the simulation. The air stream velocity was varied for both −6.7 + 3.36 and −3.36 +1 mm to observe the influence of the air stream velocity on the quality of the clean coal product. The ash contents (%) for the ROM and clean coal products were then determined from proximate analysis in accordance with ASTM D5142 using the equipment Leco TGA 701, while the calorific values of the samples were determined in accordance with ASTM D5865-04 using a Leco AC 500 bomb calorimeter.

3. RESULTS AND DISCUSSION

The influence of factors such as the air velocity and particle size on the separation efficiency of the separator was studied at a particle feed rate of 420 g/min (the feed rate of each particle’s relative density of 60 g/mm). The mass feed rate of the particles for the −6.7 + 3.36 mm size range using the optimal velocity can be pushed up to 2100 g/min while still maintaining the dilute phase, following a study by Santos et al.,29 who utilized a dilute phase of 6 g of particles in 11 g of air. The mass flow rate can be obtained from eqs 9 and 10.

\[
\text{mass flowrate of air} = \rho_{\text{air}} \times u \times A
\]

(12)

particle mass flow rate

\[
= \text{mass flowrate of air} \times \frac{6 \text{ g of particles}}{11 \text{ g of air}}
\]

(13)

where \( \rho_{\text{air}} \) is the density of air at 20 °C, \( u \) is the velocity of air entering into the separator, and \( A \) is the cross-sectional area (with a diameter of 100 mm). Following the conditions above,
the mass feed rate of the $-3.36 + 1$ and $-1$ mm size distribution can still be pushed up to 1300 and 526.2 g/min while still maintaining the dilute phase. The density of air used is 1.204 kg/m$^3$ as the air is assumed to be at room temperature ($20^\circ$C). The formula for determining the separation efficiency of the separator is stated below

$$\text{yield (\%)} = \frac{M_O}{M_I}$$  \hspace{1cm} (14)

where $M_O$ is the mass of the lighter particles that flow from chamber 1 to chamber 2 and $M_I$ is the mass of the particles fed into the separator through the particle inlet. The separation efficiencies for the three particle sizes ($-6.7 + 3.36$; $-3.36 + 1$, and $-1$ mm) for this study were found to be 35.6, 39.6, and 49.5%, respectively.

3.1. Effect of Air Velocity. To determine the optimal velocity so that the optimal yields and separation efficiency for each particle size distribution could be achieved, different air inlet velocities were used with other parameters remaining constant. At 10 m/s for the $-6.7 + 3.36$ mm particle size fraction, it was observed that all of the particles were carried off in the air stream without dropping into the designated bins according to their relative densities, and this denoted no separation. Similar results were obtained at 9.5 and 9 m/s and upon reducing the velocity further; an optimal velocity

Figure 7. Effect of air velocity and optimal velocity determination for the $-6.7 + 3.36$ mm size fraction.

Figure 8. Mass yields from the three particle size fractions at their respective optimal velocities.

Figure 9. Mass yield(s) of individual particles at a particle size distribution of $-6.7 + 3.36$ mm.
between 6.0 and 6.6 m/s was attained for the −6.7 + 3.36 mm size fraction, as seen in Figure 7. A similar process was also conducted for the other two size fractions (−3.36 + 1 and −1 mm) until optimal mass yields at velocities of 4.2 and 1.7 m/s were attained, respectively. Simulation test runs were also conducted for all of the particle size fractions at a relative density of 1.6, as shown in Figure 8, using their respective optimal air velocities. The overall results showed that at the cutoff density of 1.6 g/cm³, the −1 mm size fraction has the highest recovery of 47.2%, and as the size fraction increased, the yield was seen to decrease.

3.2. Effect of Individual Particles within a Particle Size Distribution on the Yield. Further study was also carried out on the simulator to determine the effect of individual particles within the particle size distribution on the separator efficiency while varying the relative density and keeping the velocity constant. Figure 9 depicts the yield obtained from the individual particles present within the −6.7 + 3.36 mm size range at different relative densities (RDs) and a velocity of 6.6 m/s. As the individual particle size increased from 3.36 to 6.7 mm, the yield decreased from 99.6 to 23.6% at the constant velocity. The same trend was also seen for all of the cut points (RD), as at 1.9 RD, the yield for the 3.36 mm particle size was decreased to 0 from 6.35 to 6.70 mm. Figures 10 and 11 also depict the yield obtained for individual particles at particle size distributions of −3.36 + 1 and −1 mm. At an RD of 1.3−1.6, a yield of 100% was achieved for the −1 mm particle size, while at 0.1 mm size, 100% recovery was attained for all of the RDs tested. These results show that particle size and density play a role in the transportation and separation of particles in an air stream as they influence the drag force and buoyant force.
experienced by the particle. This is not the case for some dense medium separation processes like the float and sink method that partitions coal or particles based on their relative densities, following Archimedes’ principle once the condition of the medium-to-ore ratio is adhered to.

3.3. Particle Misplacement in the Separator. The simulation results for the $-6.7 + 3.36$ mm particle size fraction and 1.3–1.6 g/cm$^3$ RD are depicted in Figures 12–15; however, similar results are obtained for the other two particle size fractions. This separator had shown great flexibility to cut at a specific relative density and particle size; however, particle misplacement (the phenomenon of particles settling in undesignated bins) was noted as a major drawback and this was observed in the simulation of all of the three particle size fractions. This phenomenon occurs in both separation chambers, and in this paper, the misplacement obtained for the $-6.7 + 3.36$ mm particle size fraction is presented. According to Figure 12, the particle misplacement observed in bin 5 and bin 6 of chamber 1 of Figure 14 might be because of gravity and the constraint in determining an appropriate air-jet angle for effective transportation of all 1.3 and 1.4 particles, respectively into chamber 2. However, for the 1.3 RD, the lighter particles traveled farther in the air stream compared to that for 1.4 RD, as seen in chamber 2 in Figures 12 and 13. This is because of the delay in the particle attaining its settling velocity as it enters the diffuser chamber, but its kinetic energy reduces, causing it to expand and making the particles misplace as they settle in the undesignated bins.

At a cut density of 1.6 RD in Figure 15, the misplacement observed in bin 3 might be a result of the delay in the settling velocity of the particles as they enter chamber 2, and with a decrease in the kinetic energy causing it to expand, some particles are seen settled in undesignated bins.

Figure 13. Particle tracks for the $-6.7 + 3.36$ mm size fraction at an RD of 1.4 in both chambers.

Figure 14. Particle tracks for the $-6.7 + 3.36$ mm size fraction at an RD of 1.5 in both chambers.

Figure 15. Particle tracks for the $-6.7 + 3.36$ mm size fraction at an RD of 1.6 in both chambers.
The degree of misplacements in chambers 1 and 2 can be observed in Figures 16 and 17, respectively, for the −6.7 + 3.36 mm size distribution. It can be observed from Figure 16 that bin 6 recovered the highest particle of all particle RDs that fall into chamber 1. This occurred following an ineffective air-jet angle for effective transportation of the lighter particles as stated earlier. In Figure 17, it can be observed that bin 4 has the highest recoveries for each particle RD. This occurs as the air stream transporting the lighter particles begins to expand upon entering chamber 2, which makes the particles to quickly attain their settling velocities and fall into undesignated bins. It can be observed that for bin 1, only the designated 1.3 RD particles fall into it, whereas bin 2 obtained some 1.3 and 1.4 RD particles. This also occurs in bin 3 and bin 4, where 1.3–1.5 RD and 1.3–1.6 RD particles are collected, respectively.
The same trend also occurs for both $-3.36 + 1$ and $-1$ mm particle size fractions.

### 3.4. Preliminary Beneficiation Studies Using the Wind-Sifter Separator

A preliminary beneficiation study was carried out using the separator for both the $-6.7 + 3.36$ and $-3.36 + 1$ mm particle size fractions; however, the study for the $-1$ mm particle size fraction was suspended. This was because the very fine particles were sticking to the walls of the separator owing to the absorption of moisture by the fines, and this will be accounted for in further investigations.

ROM feed coal with an ash content of 30.28% was screened for two different size fractions, and 500 g of each particle size fraction was fed into the separator on different occasions. The samples were subjected to varying air stream velocities of 6.0 and 4.5 m/s for $-6.7 + 3.36$ mm and 4.2 and 2.5 m/s for the $-3.36 + 1$ mm size fraction. The results show a similar trend in ash content and yield reduction in both cases when the air stream velocity is reduced according to Figures 18–21. Figure 18 shows that for the $-6.7 + 3.36$ mm size fraction, at 6.0 m/s, the cleanest coal with a cumulative ash content of 21.95% and a heat content of 26.4 MJ/kg was achieved in bin 1 (which collects the clean coal product). However, as the velocity was reduced to 4.5 m/s, as shown in Figure 19, the cleanest coal with a cumulative ash content of 18.94% ash, a heat content of 26.8 MJ/kg, and a cumulative yield of 5.20% was attained in bin 1. For the $-3.36 + 1$ mm size fraction, Figure 20 shows that at...
an air stream velocity of 4.2 m/s, the cleanest coal with a cumulative ash of 25.82%, a cumulative yield of 59.60%, and a heat content of 25.8 MJ/kg was achieved. However, when the airstream velocity was reduced to 2.5 m/s, a clean coal product of 21.43% ash, cumulative yield of 27.98%, and a heat content of 26.2 MJ/kg was achieved in bin 4 as observed in Figure 21. Overall, it could be seen that a reduction in air stream velocity had a significant effect on the ash content and calorific value for both particle sizes. As the air stream velocity decreases, the ash content and the heat content increase.

4. CONCLUSIONS

The separation of particles within the wind-sifter separator chambers was found to be influenced by parameters such as the air stream velocity, particle size, and particle density. According to the simulation test runs, mass recoveries of 35.60, 39.60, and 49.50% were achieved for the three particle size fractions (−6.7 + 3.36, −3.36 + 1, and −1 mm), respectively. The influence of drag force also plays a vital role, as observed in Figure 9, where percentage recovery of particles at 1.3 RD and 6.7 mm was found to be higher than that recovered at 1.9 RD and 3.36 mm. For different particle size fractions and at RD 1.6 and optimal air velocities, the overall results show the highest recovery of 47.2% for the −1 mm size fraction.

The preliminary experimental studies show that air stream velocity is the major operating parameter influencing the separation process, and it was observed that the novel wind-sifter separator in this study can effectively beneficiate ROM coal from the Witbank coalfield. The separation results show that reducing the air velocity greatly influences the grade and the yield of the product. It was observed that for the −6.7 + 3.36 mm particle size fraction, a cumulative yield product of 58.38% and a cumulative ash content of 21.95% (chamber 2) were realized at an air velocity of 6.0 m/s. As the air stream velocity was reduced to 4.5 m/s, a product yield of 30.68% with a cumulative ash content of 20.56% was recovered. With the designed separator adhering to the principle of wind sifting and achieving different product grades, it is evident that the present configuration can also be applied to separate other minerals or ores with little modification and adjustment.

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Notes
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