

CAPACITY MODELLING OF THE COAL VALUE CHAIN AT SASOL COAL SUPPLY

Marthi Harmse
Sasol Technology
Klasie Havenga Road
Sasolburg
Republic of South Africa
marthi.harmse@sasol.com

Johan Janse v Rensburg
CSIR
Meiring-Naudé Road
Pretoria
Republic of South Africa
SvRensbu@csir.co.za

ABSTRACT

Sasol, a petrochemical company in the Republic of South Africa, uses coal to produce oil and chemical products. The coal is mined in the area surrounding the Sasol plants and is transported with conveyor belts to the stockpiles at the gas production plants. The plants must be supplied with adequate coal to sustain production. A simulation model was built to test the feasibility of blending the coal from the mines according to a weekly blend plan.

KEY WORDS

Modelling, coal conveyor simulation

1. Introduction

In 1955 Sasol began producing oil from coal by converting coal into value-added hydrocarbons through Fischer-Tropsch process technologies at Sasolburg in the Free State Province of the Republic of South Africa. During 1980 and 1982, second and third oil-from-coal plants were established at Secunda in the Mpumalanga province. Currently, the Sasol group of companies operates in twenty-three countries on all continents. The group entails diversified fuel production, chemical and related manufacturing and marketing operations, complemented by interests in technology development, oil and gas exploration, and production.

At Secunda, petrochemicals are produced from coal which is mined in the area and transported via a complex conveyor system from the mine bunkers to stockpiles at the two gas production plants. Coal stackers are used to build the stockpiles while coal reclaimers remove the coal from the stockpiles and feed the plants. Since the coal

produced by the mines is of different quality, the coal is blended on the stockpiles to reduce the variation in the quality of the coal that is fed to the plants. Besides the variation in coal quality, the variation in the coal production profiles at the various mines must be managed as well. A coal blend plan is prepared on a weekly basis to reduce these variations while adhering to the coal feed requirements from the plants.

A simulation model was required to determine the feasibility of the coal blend plan in terms of the infrastructure capacity of the mine productions, mine bunkers, conveyor system, coal stackers, stockpile yards and coal reclaimers. The simulation model takes variations into account such as breakdowns, maintenance, infrastructure changes and operational philosophy changes and is based on real-time data.

In section 2 a description of the problem is given after which the structure of the simulation model is discussed in section 3 and some results and experiments of the simulation are reported in section 4. The paper is concluded with section 5.

2. Problem Description

Simulation has been widely used to assist planners with decisions about current and future systems. Sasol is increasingly using simulation because of the benefits previous simulations produced. The following is a small selection of the applications of simulation modelling to the conveyor transport and blending of coal. Walkley and Hutson [1] simulated the supply of coal to the new 2000 MW generating power stations being built for the Central Electricity Generating Board of London. They also found that simulation modelling can lead to other studies or

projects, the results of which are valuable to management. The blending of coal at the Sasol One plant in Sasolburg was studied and simulated by van Nierop et al. [2]. In their study the aim was to blend the coal from five resources and to reduce the variation in ash content. Burý [3] described the use of simulation to optimise the transport and blending of coal in the Czech Republic. In this study the simulation is also used for the quality control of coal blends. Our simulation study is intended to determine if the blending of coal can achieve the desired results.

In Figure 1 the current infrastructure between the mines and the two gas production plants at Secunda is outlined. This infrastructure is simulated by including the coal mines, mine bunkers, overland conveyors, coal chutes, front-end loaders, coal stackers and reclaimers, plant stockpiles and the plants. In the next section each of these areas are discussed in more detail to give a better understanding of how the simulation was structured as well as the challenges posed to the simulation and results required from the simulation.

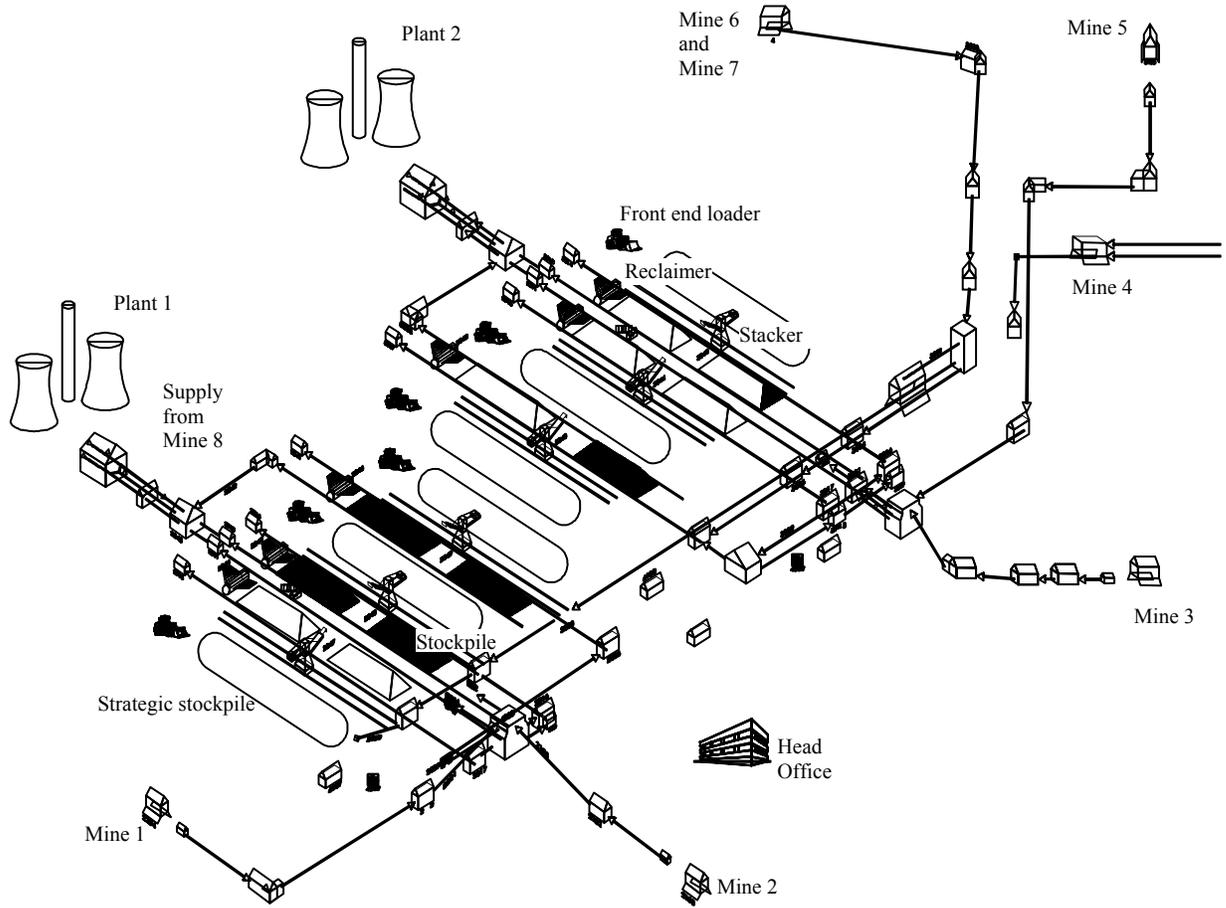


Figure 1 Current coal supply layout at Secunda

3. Model Structure

The main aim of the simulation model is to check whether the weekly blend plans can be achieved in practice. These blend plans are prepared by using other software and are an input to the simulation model. The coal value chain was simulated using the Arena© discrete event simulation software. The simulation model differs from the real world in that the continuous flow of coal is broken into discrete batches of coal. These batches represent the coal that would be transported or moved in a 20-minute

time span. The 20-minute interval was used in other simulations which will be combined with this one to form one simulation model.

3.1. Coal Mines

There are eight mines that can potentially supply coal to the two gas production plants at Secunda. The mines are operated in shifts and coal is not produced during all shifts. The shifts and corresponding coal production are inputs into the simulation model. Seven of these mines are

connected via conveyors to the plants while coal from the eighth mine is transported by trucks to only one plant. The coal from the first seven mines is mined and placed in bunkers at these mines. The bunkers have limited capacity and would fill up if they are not emptied regularly. The excess coal is placed on throw-out stockpiles at the mines which require the service of front-end loaders. The front-end loaders are shared by all the mines and the plant stockpiles. If front-end loaders are not available, the throw-out area at a mine fills up and, when full, the mine must cease operation. The bunkers are the only means to feed the conveyors and therefore the front-end loaders are used to move the coal from the throw-out stockpiles back to the bunkers in times of low production.

Two of the mines are situated a long distance from the plants and utilise a second bunker which helps in the transfer of coal. This bunker can be filled at a higher rate than coal can be transported in the rest of the system. Only if this bunker breaks down coal is transported directly from these mines to the plant stockpiles.

3.2. Conveyors

Overland conveyors transport the coal from the mines to the plants. All the mines are connected to all the stockpiles at the two plants and these connections are called routes. A route consists of a number of conveyors, chutes to change the direction of coal flow, screens for oversized coal particles and ring breakers to reduce these oversized particles into the right size. All possible routes between the mines and the stockpiles were determined beforehand and are an input into the simulation. These routes are also coupled with the direction of coal flow of the chutes on the routes.

The conveying rate of coal for each conveyor is determined by its associated speed and length, which are inputs into the simulation. The weekly blend plan determines the tonnes of coal transported per hour by the conveyors and are managed by the simulation. All the mines and stockpiles vie for the available resources. The first priority is to transport coal from the fullest mine bunker while the second priority is to keep the stockpiles supplied with coal.

The coal transported depends on the available routes between the mines and the stockpiles. The availability of the routes depends on the equipment used in the transfer of coal and the breakdown and maintenance of this equipment. All the equipment can break down or go on maintenance. If a piece of equipment breaks down all the equipment from the breakdown to the plant can function as normal, while the conveyors of the route from the breakdown up to the mine bunker must be stopped to prevent coal spillage.

3.3. Plant stockpiles and stackers

There are three stockpile yards at each plant. The stockpiles on these yards are classified as live stockpiles. At each stockpile yard there are also strategic stockpiles called dead-live stockpiles as well as long-term stockpiles called dead stockpiles. The live stockpiles are those used to feed coal to the plant. The coal is placed on the stockpile by a coal stacker and the coal is removed from the stockpile by a coal reclaimers. A dead-live stockpile is a temporary storage for coal and the coal is placed on the dead-live stockpile by the coal stackers. Coal is removed from the dead-live stockpile by front-end loaders and placed on the conveyors feeding the plant; this operation is called bleed-in. The dead stockpiles are long-term storage of coal and they are prepared to prevent the spontaneous combustion of the coal.

The three live stockpile yards at each plant have a working length where the stackers place coal and the reclaimers remove coal. Coal is placed on the yards in shorter sections called stockpiles or heaps. This allows for the building of one heap by the stacker while the reclaimers can reclaim another heap. One challenge is to build the heaps in such a manner that there will always be a reclaimable heap available. This determines where the stacker will place the coal from the mines on the heaps.

The stackers move at a certain rate and the conveyors transport the coal to the stackers at a certain rate. The stockpiles are built to a certain height namely the stacking height of the stacker, by building horizontal layers of coal from the mines. A minimum heap length is also used to prevent small heaps and short bursts of coal transportation from the mines. A stacker can move over existing heaps and build new heaps in any open space on the yard.

Visual Basic for Applications (VBA[©]) is a component of the Arena[©] software and VBA[©] subroutines are used for the calculation of space to build a new heap.

3.4. Reclaimers

There are three reclaimers at each plant, one per live stockpile yard. Two reclaimers must be scheduled at the same time to supply the plant with coal since coal is extracted from the bunkers at a higher rate than the maximum rate of any one reclaimer. The rates at which the reclaimers work are set depending on the level of the final coal bunkers at the plant. It is essential to keep the levels of these bunkers full to keep the plants working. VBA[©] subroutines are used to schedule the reclaimers.

If two reclaimers cannot be scheduled at the same time, coal is transported directly from the mines to the plants in an operation called prop chuting. If needed the existing transfer of coal must be stopped to make the route available for prop chuting.

The reclaimers reclaim a heap vertically from one side to the other. By reclaiming the coal vertically the horizontal layers of coal from the different mines are blended (mixed). A reclaimer can only reclaim existing heaps on both sides of the reclaimer and are blocked by a heap being stacked. In other words a reclaimer cannot move over existing heaps without reclaiming them.

3.5. Blend plans

Because the mines produce coal of different quality the coal is blended to produce a product of more uniform quality. This is important as the plants cannot operate sufficiently if the quality of one batch of coal differs significantly from another batch. There are various properties of coal that are measured but the most important are ash content and particle size of the coal. These are the only properties tracked in the simulation. Three bands of particle sizes are measured. The transport of coal with conveyors as well as the stacking and reclaiming of coal all reduce the particle size of the coal.

A weekly blend plan is calculated based on the coal production of the mines, the tonnes of coal on the stockpiles and the quality of the coal produced by the mines. There are different blend plans for the two plants and these plans are an input into the simulation. The blend plans specify the percentage of coal from each mine that must be stacked on each new heap on the stockpile yards. They also specify the percentage of bleed-in coal recovered from the dead-live stockpiles.

If a mine bunker is full but the tonnage of coal from the mine on the heap is already equal to the blend plan value, over-blending occurs. A maximum percentage of over-blending is input into the model. VBA© subroutines are used for the calculation of the over-blending of coal. If a mine bunker is full and the plant stockpile heap is already over-blended, the stacker can start building a new heap. If space is not available to start a new heap coal is transported to the dead-live stockpile to reduce the mine bunker tonnage.

In the case where there is no heap to reclaim, a heap still being stacked but bigger than a certain percentage can be classified as a reclaimable heap. If space is available the stacker will start to build a new heap while the first heap is being reclaimed.

3.6. Front-End Loaders

The front-end loaders are a limited resource and are scheduled according to the following priorities: The first priority is to use the front-end loaders to throw out coal at the mines when the mine bunkers are full. The next priority is to bleed in coal from the strategic stockpiles to the stockpiles at the plants, then to transfer coal to the strategic stockpiles. The last priority is to transfer coal

previously thrown out at the mines back to the mine bunkers.

3.7. Gas Production Plants

This simulation only includes the coal processing bunkers at the gas production plants. Another simulation was developed for the gas production plant which is currently being integrated with this simulation model. The coal processing bunkers must be kept full at all times in order to supply the plants with coal. The plants resource their daily planned coal feed requirements, which are an input into the simulation, from the bunkers.

Ultimately the two plants must be supplied with enough coal to keep them in production. This depends on the coal on the stockpiles, the availability of the reclaimers and the final conveyors. Prop chuting is an emergency measure to supply enough coal to the plants directly from the mines without going onto the stockpiles. While coal is prop chuted to a specific plant, no coal can be transferred to one of the stockpiles at that plant and no coal can be reclaimed from these stockpiles.

4. Model Results

At the start of the simulation all the mine bunkers, stackers, stockpiles and reclaimers are initialised with values taken from a snapshot of the mines and plants. The mine productions are based on the planned productions for the week and the plant coal feed requirements planned for the week represents the demand for coal. The weekly planned maintenance is also inputted into the simulation and specifies the day and the length of the maintenance.

Excel© software was used to prepare various reports and graphs of the simulation output which includes the following:

- Level of the mine bunkers every 20 minutes
- Coal transported from the mine bunkers to the stockpiles (Figure 2)
- Prop-chuted coal
- Tonnes and the properties of the coal on the stockpiles
- Coal supplied to the coal processing bunkers as well as the properties of this coal

The root mean square deviation is used as a measure of the deviation of the simulated coal blend plan at the coal processing bunker supply, from the input blend plan (Figure 3). This is one of the most important measures to test whether the weekly blend plans can be achieved in practice.

In validating the simulation, experiments were done for 17 weeks and compared with the historical actual values of the corresponding period. The simulation results

compare favourably with the actual values as indicated for example in Figure 3.

One problem identified with the simulation is that the total tonnes transported from the mines are less than the actual tonnes (Figure 2). This is because the simulation manages the tonnes per hour transported on the conveyors

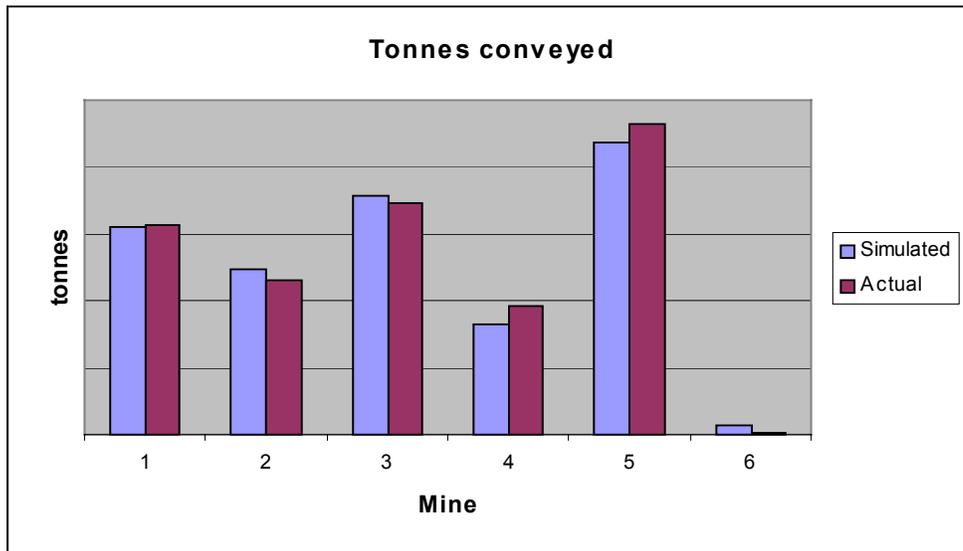


Figure 2 Coal transported from the mine bunkers to the stockpiles

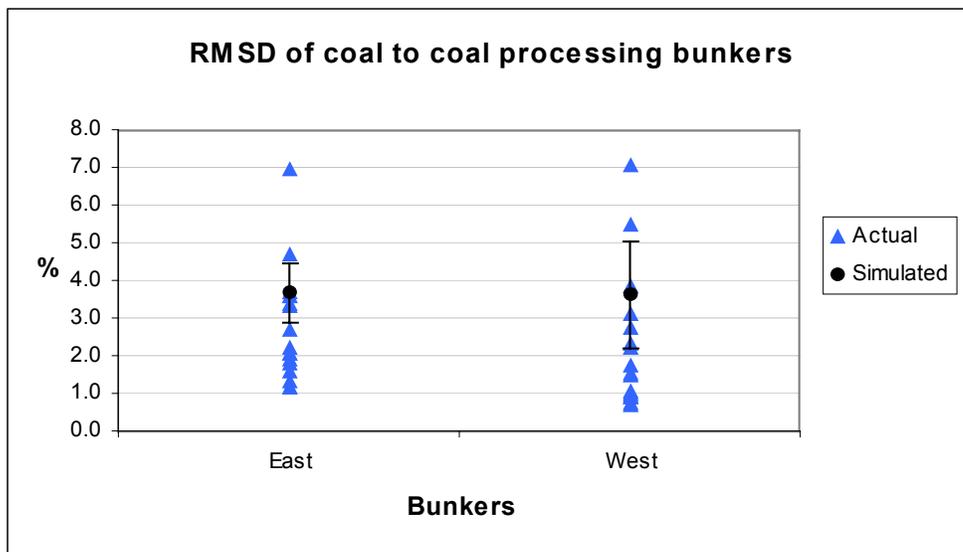


Figure 3 Root mean square deviation of blend plan to coal processing bunkers with 99% confidence intervals

more conservatively since it keeps track of the blend on the stockpiles. In reality the mines furthermore have more leeway in controlling the level of the mine bunkers than the simulation that starts at the mine bunkers.

5. Conclusion

At Secunda, Sasol produces petrochemicals from coal which is mined in the area and transported via a complex conveyor system from the mine bunkers to stockpiles at the two gas production plants. Since the coal produced by the mines is of different quality, the coal is blended on the

stockpiles to reduce the variation in the quality of the coal that is fed to the plants. A coal blend plan is prepared on a weekly basis to reduce these variations while adhering to the coal feed requirements from the plants.

This paper discusses a simulation model to determine the feasibility of the coal blend plan in terms of the infrastructure capacity of the mine productions, mine bunkers, conveyor system, coal stackers, stockpile yards and coal reclaimers. The simulation model takes variations into account such as breakdowns, maintenance, infrastructure changes and operational philosophy

changes and is based on real-time data. The simulation is used on a continuous basis to test the following:

- Feasibility of the blend plan with the current infrastructure and planned production
- Influence of the maintenance plan on the supply of coal to the plants
- Different scenarios, for example if a mine stops production

The simulation results compare favourably with the actual values. One problem identified with the simulation however is that the total tonnes transported from the mines are less than the actual tonnes. The simulation model has also provided some additional benefits, amongst which the following:

- Business processes were mapped and improved
- Operational rules were updated
- Other business systems also benefited

There are also a number of lessons learned from the simulation process namely:

- Never underestimate the complexity of the task
- Verify process flow diagrams and operating rules before building models
- Simulation is a powerful but costly and time consuming process and needs very high quality data

This simulation model will ultimately be combined with a simulation model of the plants to form one complete coal value chain simulation model with which to compare different scenarios affecting the whole value chain operation. Future developments also include using the simulation model for strategic planning as well as using it as a training tool for operators.

References

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