COALTECH 2020

Task 4.1

Low-smoke fuels: Test work on devolatilised binderless coal briquettes

By

S J Mangena

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EXECUTIVE SUMMARY

A low-smoke fuel that outperformed anthracite (a natural low-smoke fuel) in terms of particulate emissions has been manufactured by devolatilising binderless briquettes manufactured from Kleinkopje Colliery flotation concentrate. However, due to the poor quality of the feedstock material, the low-smoke fuels had a longer ignition time and a longer boiling time for 1 litre of water. If a better-quality feedstock material can be used, the manufactured low-smoke fuels may be able to compete with anthracite in all respects. A further test will therefore be carried out using a flotation concentrate with a CV of >27 MJ/kg.

1 INTRODUCTION

Various technologies that are used for producing low-smoke fuels in South Africa and a number of other countries worldwide, and the economics associated with some of these technologies, were investigated in 2002. Devolatilisation of coal was found to be the most popular method for producing coal-based low-smoke fuels. Based on this information, a process for manufacturing low-smoke fuel briquettes from ultrafine coal slurry and/or flotation concentrate was proposed (Mangena, 2002).

The proposed process entailed mechanical dewatering of ultrafine coal, thermal drying, binderless briquetting and devolatilisation of the binderless briquettes. This project is therefore directly linked to CoalTech 2020 Task 4.4.1 (*Economic agglomeration of fine coal*).

Laboratory investigations into the devolatilisation of binderless briquettes produced from both the 1 ton/h demonstration plant and the laboratory briquetting press were carried out. The objectives of this report are therefore to outline the results obtained from the laboratory investigations and to compare the performance of the devolatilised binderless briquettes with that of the fuels tested in the national study done by the Department of Minerals and Energy (DME).

2 METHODOLOGY

Two batches of devolatilised binderless briquettes were produced from the laboratory briquetting press and the 1 ton/h demonstration plant, respectively. The briquettes were subjected to various tests. This section explains the methodology used in the test work.

2.1. Binderless briquettes produced in the laboratory

Binderless briquettes produced in the laboratory from the Kleinkopje (KK) flotation concentrate were devolatilised at 500 ^{o}C in a laboratory furnace. The temperature programme used for devolatilising the binderless briquettes produced in the laboratory is shown in Table 1. Proximate analysis was carried out on the raw and the devolatilised binderless briquettes using standard methods. Briquettes produced from the laboratory briquetting press are shown in Figure 1.

Table 1: Temperature programme used for devolatilising the binderless briquettes produced from the laboratory briquetting press

Temperature (^{o}C)	Time
0 – 500	1.4 h
500	5 h

A comparative combustion test was done using the *mbawulas* used in the DME study. About the same volume of raw D-grade coal, raw binderless briquettes and devolatilised binderless briquettes were ignited at the same time in three separate *mbawulas* using a bar of wax-based firelighter. Video clips were recorded 20, 30, 45, 50, 60, 75 and 90 minutes respectively after ignition.

Figure 1: Binderless briquettes produced from the laboratory press (Komarek B100)

2.2 Binderless briquettes produced from a 1 ton/h demonstration plant

As has been mentioned above, the low-smoke fuels project is directly linked to Task 4.4.1. It was therefore decided that a more detailed test should be carried out using the binderless briquettes produced from the 1 ton/h demonstration plant at Kleinkopje Colliery. As with those produced from the laboratory press, the binderless briquettes produced from the demonstration plant were devolatilised in a laboratory furnace using the temperature programme shown in Table 2. Proximate analysis was carried out, using standard methods, on both the raw and devolatilised binderless briquettes produced from the demonstration plant. The briquettes (both raw and devolatilised) were also tested for dry and wet compressive strengths. Figure 2 depicts the devolatilised binderless briquettes produced from the demonstration plant.

Table 2: Temperature programme used for devolatilising the binderless briquettes produced from the 1 ton/h Zemag Roll Press 400 x 140

Temperature (^{o}C)	Time
0 – 500	1.4 h
500	5.5 h

Figure 2: Devolatilised binderless briquettes produced from the 1 ton/h Zemag Roll Press 400 x 140

The Chatillon model UTSE-2 tensile strength testing instrument operated in a compression mode was used for the compressive strength tests. To test for dry compressive strength, the briquettes were sampled randomly and crushed slowly between two parallel metal plates. The crushing load (in kg) was measured on 20 briquettes from each batch and the average value converted to compressive strength (in kPa) with the aid of Equation 1 (Richards, 1990).

$$P = \frac{\text{Crushing load (N) x1 000}}{\text{Cross-sectional area of plane of fracture}} \qquad \textbf{(Equation 1)}$$

To test for wet compressive strength, 20 briquettes from each batch were immersed in water for 2 h and their crushing loads measured immediately after removal from the water. Equation 1 was again employed to convert the average maximum crushing load to compressive wet strength, which was expressed as water resistance.

The devolatilised briquettes were submitted to CSIR M&MTek[1] for a detailed test on their performance. The fuels were tested for ignition time, total solid/particulate emissions and the time taken to boil 1 litre of water.

[1] M&Mtek did the tests for the DME during their national study: *Low-smoke fuels: Standard testing and Verification*.

The same *mbawulas* used during the aforementioned comparative combustion tests were used by M&Mtek to compare the performance of the devolatilised binderless briquettes. LP gas was used to start the fire. The ignition time was determined by measuring the point in time on the temperature graph at which the first sharp temperature increase occurred. Particulate sampling commenced as soon as the fire was lit and ended when the smoke subsided. The particulate emission measurements were done by means of isokinetic sampling, in accordance with the method that is accepted by the Department of Environmental Affairs and Tourism (DEAT) (Le Roux *et al*., 2004).

3 RESULTS AND DISCUSSION

3.1 Binderless briquettes produced in the laboratory

Proximate analyses of the raw and devolatilised briquettes produced in the laboratory are shown in Table 3. As expected, the only significant difference between the chemical properties of both the raw and devolatilised binderless briquettes is the volatile matter, which was about 10% lower in the devolatilised briquettes, thus increasing their fixed carbon content.

Table 3: Proximate analyses of the KK raw and devolatilised binderless briquettes produced from the laboratory briquetting press

	KK flotation concentrate	**Devolatilised binderless briquettes**
CV (MJ/kg)	27.19	27.21
H_2O (%)	2.4	1.7
Ash (%)	15.8	15.6
Volatile matter (%)	22.3	12.2
Fixed carbon (%)	59.5	70.5
Total sulphur (%)	0.67	0.69

When tested for combustion and compared with D-grade sized coal as well as raw binderless briquettes, the devolatilised binderless briquettes did not emit any visible smoke during combustion – see Figure 3. The smoke emissions from the raw briquettes subsided 50 minutes after the fire had started, whereas the smoke emissions from the D-grade coal subsided only after 75 minutes – see Figures 4 and 5.

Figure 3: ***Combustion tests: Comparison of devolatilised binderless briquettes, raw binderless briquettes and D-grade sized coal (photo taken 30 minutes after the fire had started)***

Figure 4: ***Combustion tests: Comparison of devolatilised binderless briquettes, raw binderless briquettes and D-grade sized coal (photo taken 50 minutes after the fire had started)***

Figure 5: Combustion tests: Comparison of devolatilised binderless briquettes, raw binderless briquettes and D-grade sized coal (photo taken 75 minutes after the fire had started)

3.2 Binderless briquettes produced from the 1 ton/h demonstration plant

Table 4 shows some chemical properties of both the raw and devolatilised KK binderless briquettes produced from the 1 ton/h demonstration plant. Again as expected, a significant decrease in volatile matter is observed in the devolatilised briquettes. A slight increase in the ash content is also observed in the devolatilised briquettes – this may be due either to the method used for sampling the briquettes or to slight combustion of the briquettes during devolatilisation.

Table 4: Proximate analyses of the KK raw and devolatilised binderless briquettes produced from the 1 ton/h demonstration plant

	KK flotation concentrate	**Devolatilised binderless briquettes**
CV (MJ/kg)	24.77	24.34
H_2O (%)	2.7	1.9
Ash (%)	21.5	24.6
Volatile matter (%)	20.7	12.4
Fixed carbon (%)	55.1	61.1
Total sulphur (%)	0.79	0.75

Table 5 shows the physical properties of both the raw and devolatilised binderless briquettes produced from the demonstration plant. The dry compressive strength of the binderless briquettes increased from 53 kg to 81 kg after devolatilisation. The wet compressive strength of the briquettes, which is the strength of the briquettes after immersion in cold tap water for 2 hours, increased from 10 kg to 80 kg. The main reason for the increased compressive strength of the devolatilised binderless briquettes is that during devolatilisation, the reactive macerals in coal (i.e. vitrinite, liptinite and reactive inertinite) reach a plastic state at 500 ^{o}C and resolidify during the cooling stage, thus improving the organic bonding of particles in the binderless briquettes (Van Krevelen, 1961).

Table 5: Physical properties of the raw and devolatilised binderless briquettes produced at KK colliery from the Zemag demonstration plant

	Raw binderless briquettes	**Devolatilised briquettes**
Dry compressive strength (kg)	53	81
Dry compressive strength (N)	516	793
Dry compressive strength (kPa)	504	775
Wet compressive strength (kg)	10	80
Wet compressive strength (N)	96	782
Wet compressive strength (kPa)	93	763

The results of a detailed combustion test are shown in Table 6. The temperature profile of the devolatilised briquettes is shown in Figure 6. Table 7 compares the performance of the devolatilised binderless briquettes with that of anthracite, low volatile matter coal and the sized coal that is normally supplied to households.

Table 6: Results of a detailed combustion test of the devolatilised binderless briquettes

Results	**Unit**	**Average**	**1**	**2**	**3**	**Std Dev.**
CV	MJ/kg	24.34				
Batch mass	kg	7.17	7.19	7.20	7.14	0.03
Ignition time	min	43	60	39	30	15.39
Boiling time for 1ℓ water	°C/min	12.00	12.82	12.00	11.18	0.82
Energy per batch of fuel	MJ	174.61	174.93	175.20	173.69	0.81
Total solid emissions	mg/MJ	15.71	17.95	15.90	13.26	2.35

Le Roux *et al*. (2004) determined the ignition time by measuring the point in time on the temperature graph at which the first sharp temperature increase occurs. In terms of ignition time, the devolatilised binderless briquettes compared well with sized coal. Anthracite, a natural low-smoke fuel, performed better in terms of ignition time, followed by low volatile matter coal. This may be attributed to the high CVs of the two fuels, as can be seen in Figure 7.

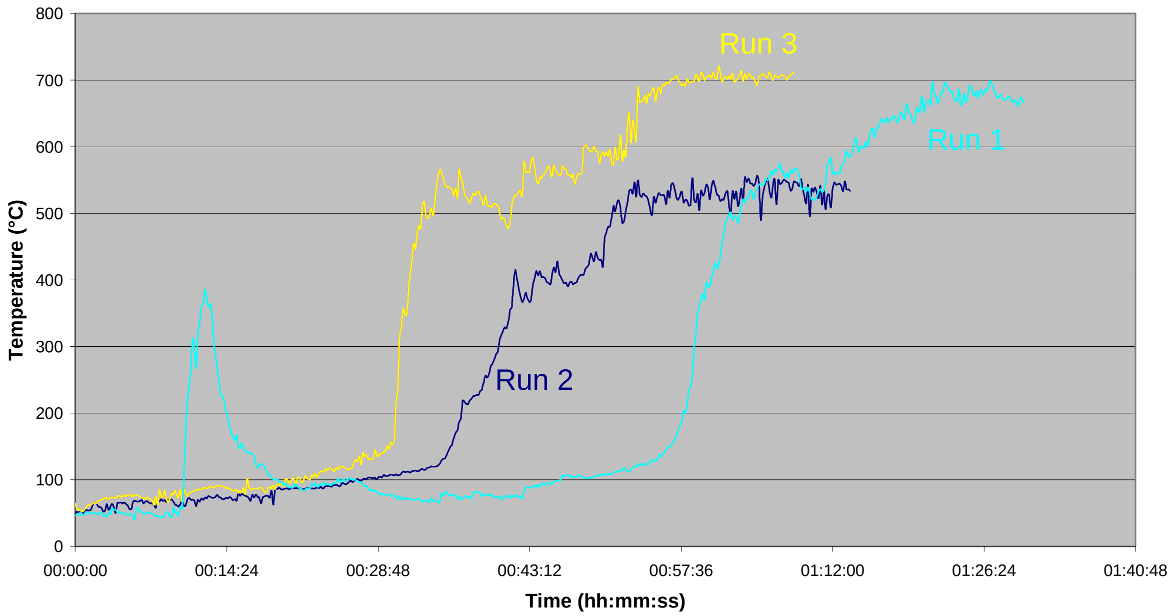

Figure 6: Temperature profile of the KK devolatilised binderless briquettes produced from the demonstration plant

The time taken for 1 litre of water to boil was longer with the KK devolatilised binderless briquettes and once again this may be attributed to its low CV. However, the briquettes outperformed all the fuels tested, including anthracite, in terms of solid or particulate emissions. This was shown previously in Figures 3 to 5 in which it can be seen that during combustion, no smoke was visible from the devolatilised binderless briquettes.

Table 7: Comparison of the performance of the devolatilised binderless briquettes with that of the fuels tested in the national study (Le Roux et al., 2004)

		KK binderless devolatilised briquettes	**Coal**	**Anthracite**	**Low vol. coal**
CV	MJ/kg	**24.34**	25.83	29.87	29.57
Ignition time	min	**43**	41.1 ± 15%	23.7 ±10%	33.2 ± 20%
Boiling time for 1 ℓ water	min:s	**8.18**	4:50 ± 13%	4:17 ± 9%	5:28 ± 17%
Energy per batch	MJ	**174.61**	180.5	179.8	176.6
Total solid emissions (NTP)	mg/MJ	**15.71**	355.1 ± 16%	20.2 ± 19%	135 ± 37%

Given that the coal briquetted and devolatilised was a flotation concentrate, its ash content is supposed to be in the region of ~15 % on an air-dry basis (ad) and its CV in the region of

>27 MJ/kg. It is expected that the devolatilised binderless briquettes produced from this coal will offer formidable competition to anthracite in terms of performance. The binderless briquetting test work at KK is still continuing and briquettes produced from a better-quality flotation concentrate will be devolatilised and tested again for the above-mentioned parameters. More conclusive results can then be obtained.

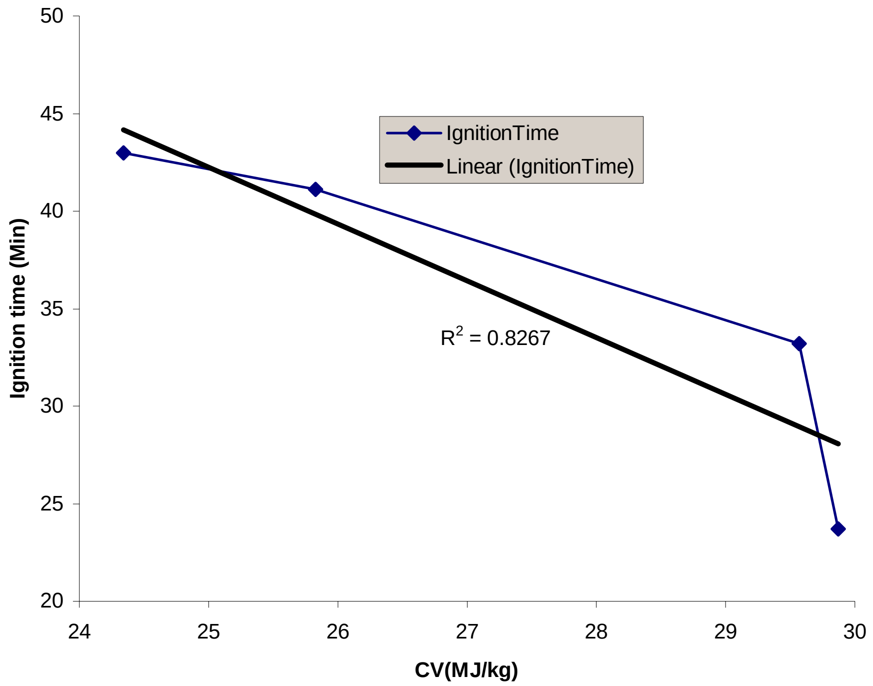

Figure 7: Correlation between CV of the fuel and ignition time

4 CONCLUSIONS

A low-smoke fuel that outperformed anthracite in terms of particulate emissions has been manufactured by devolatilising the binderless briquettes manufactured from Kleinkopje (KK) flotation concentrate.

Due to the poor quality of the feedstock material, the low-smoke fuels had a longer ignition time and took a longer time to boil 1 litre of water. If a better-quality feedstock can be used, the manufactured low-smoke fuels may compete with anthracite in all respects.

It is recommended that a further test be carried out using KK flotation concentrate with a CV of >27 MJ/kg.

5 REFERENCES

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