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Engineering

EFFECT OF BRIQUETTING AND COAL MOISTURE CONTROL PROCESSES ON COKE QUALITY

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ABSTRACT Recently issues faced by cokemakers connected with availability of resources, coal quality and price, and environmental concerns have led to the development of coal pre-treatment. Aiming the use of semi-coking coal, technologies for increasing bulk density have been applied such as briquetting and coal moisture control (CMC) which have proved their benefits on manufacturing of a strong metallurgical coke. This work showed coke with high quality regarding bulk density, CSR, DI and coke % > 25 mm was produced from addition of briquettes 20% in the coal blend. For those cokes produced from CMC, coke containing moisture 4% in coal blend presented better properties than cokes with excessive moisture. It was disclosed the effect of briquettes 20% on coke quality is equivalent to produce coke with moisture 4%.

KEYWORDS : metallurgical coke, coke quality, briquetting, coal moisture control

INTRODUCTION

In the current context, most of the coking plants in the worldwide have faced a series of adversities regarding the availability of hard-coking coals, the price of coal that has risen considerably over the past few years, the deteriorating of coal quality, the age of coke oven batteries and the demand for reduction of CO_2 emissions [1].

Faced with these problems, industries especially Japanese, have been concerned with developing of environmentally friendly alternatives that aim at the best use of resources, i.e., increase in the blending ratio of low rank slightly caking (or semi-soft) coal, consequently making the blend cheaper. Technologies to increase semi-soft coals presume the 1) increasing density, 2) optimizing the level of coal crushing or 3) adding additives to increase coking property [2].

Coals set as hard-coking have as feature sufficient dilatation during the pyrolysis, thus when the expansion of the coal grains is larger than the volume of voids between them, they fuse with each other in large contact areas producing a strong bonding, therefore the coke strength is high [3]. As semi-soft coal has inferior caking property than hard-coking [1], the increasing on bulk density reduces the particle-particle distance compensating its lack of dilation and yet producing a high-strength coke, explaining the theory to increasing density.

This research is focused in technologies to increase density such as briquetting and coal moisture control (CMC). The briquetting concept introduced and patented in 1948 by William Easby and applied by Japanese industry in the 70s in cokemaking, consists in applying pressure to fine coal with a binder (coal-tar, pitches, petroleum pitch, asphalt, oil, biomass etc) by roll press under relative low pressure [4]. On the other hand, Coal Moisture Control (CMC) was applied for the first time at Oita Works in 1983 [5] with the purpose to reduce the coal moisture content from 8-11% (typical range) to 5-6% before its charging into the coke oven.

The present research intents to show improvements on coke quality manufactured from these processes and define from results, the ideal amount of briquettes and moisture content in the coal blend. Additionally, is shown the overlapping of results between them.

CASE STUDY

In the present study, effect of partial addition of briquettes (0, 10, 20, 30 and 60%) and the moisture content (2, 4, 6, 8, 10, 12 and 14%) in the coal blend (characteristic as shows Figure 1) on coke quality regarding coal charge bulk density, coke strength after reaction with CO^2 (CSR) (ASTM D5341, 2014) [6], drum index (DI) (JIS K2151, 2004)[7] and particle size of coke > 25mm (metallurgical parameter for using in blast furnace) were investigated.

TABLE – 1: Coal blend used for briquettes and coal moisture control processes.

Coal (%)		**Particle Size of coal used in briquettes**	**w%**
EUA	18	>2	28.61
CAN	10	2>x>1	32.83
AUS	10	1>x>0.355	35.8
COL	37	1>x>0.149	2.74
EUA	5	<0.149	0.02
BRA (pet coke)	20	**Total**	100
Petrographic (%)			
Vitrinite	60.2	Reflectance	1.14
Proximate analysis of the blend (%)		**Rheology**	
Volatile matter	23.46	Maximum fluidity (log)	2.5
Ash	7.57	Softening temperature (°C)	309
Moisture	8.00	Maximum temperature of fluidity (°C)	360
Sulphur content	0.81	Solidification Temperature (°C)	382

The coking experiments were performed in a pilot oven of dimensions 455mm width x 930mm length x 830mm height, load capacity of 255 kg (dry basis) and 750 kg /m3 bulk density. The oven heating is done by 72 resistors of silicon carbide which reach a temperature approximately of 1100°C. After 20h of carbonization, the coke is quenched by water and exposed to a drop impact of 2m in height, three times, using a shatter tester. Subsequently, the coke quality parameters were assessed.

Coal blend with partial addition of briquettes has the contraction and coking pressure evaluated through the Sole-heated-oven according to ASTM D2014 (2010)[8].

RESULTS AND DISCUSS

As the amount of briquettes in the blend increases, the bulk density increases as show the Figure 1 - A. This fact was expected once the particle-particle distance decreases, resulting in increasing of coal mass, consequently increasing the bulk density which has a positive impact on enhancing the productivity. Observing the impact of briquettes % on strength parameters, i.e, CSR, DI and on the coke % > 25mm, there is a maximum value on briquettes 30% (Figure 1 – B – C - D). Beyond this value, the effect of briquettes adding on those parameters is not totally effective due to increased free space between coal particles and briquettes supersaturation, causing cracks in the coke mass that lead to a smaller size and a weaker coke [9].

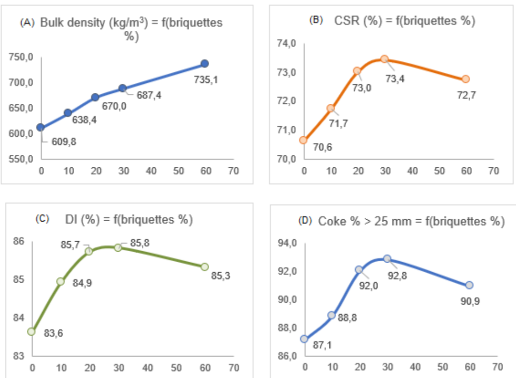

Figure 1: Effect of adding briquettes on (A) bulk density, (B) CSR, (C) DI and (D) coke % > 25mm.

However, taking account the results interconnected to the coke oven preservation from Sole-heated-oven experiments, although the coal blend with briquettes 20% presents value within the specification for the contraction/expansion test (Figure 2 - A) whose target value is between -7 to -15, the value for the pressure test is out the specification, whose the maximum target value is 1.0psi (Figure 2 - B).

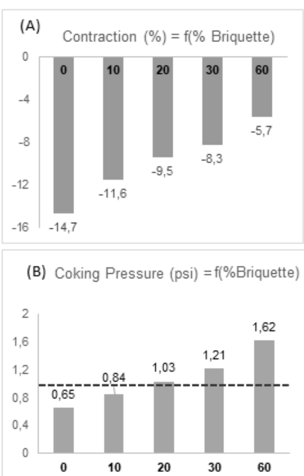

Figure 2: A) Contraction and B) coking pressure results.

Thereby, the ideal amount of briquettes in the coal blend considering the results above is 20%. Comparing the coke without addition of briquettes regarding briquettes 20% there is an increase on bulk density of 10%, CSR of 2,4%, DI of 2,1% and coke % > 25mm of 4,9%. The variation of the coal burden bulk density regarding the moisture content is shown in the Figure 3 - A, which reaches a maximum for dry coal (2%-moisture content), decreases to a minimum between 10 and 12% moisture, and increase again with the addition of moisture. Initially the density decreases because of the replacement of 1,4g/m^3 coal by 1g/cm^3 water and due the hydrophobic particles of coal that cause repulsion between the coal particle increasing the free space. In contrast, with a high moisture content, water behaves as a binder, making particles to adhere with each other forming pseudo-particles. Thus, the agglomeration effect leads to a decreasing the void fraction explaining the increase on density again.

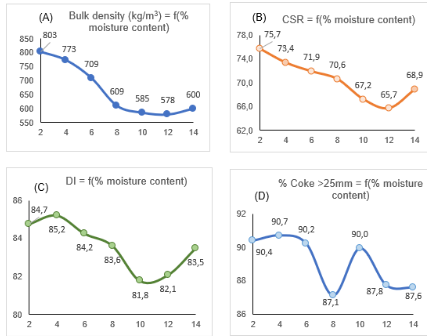

Figure 3: Effect of moisture content on (A) bulk density, (B) CSR, (C) DI and (D) coke % > 25mm.

As the moisture present in the blend decreases, improvements on CSR, DI and % coke > 25mm (Figure 3 – B – C – D) were found as resulted of increasing density. For safety reasons and to maintain the integrity of the furnaces, we excluded the result of 2% moisture once it has high bulk density value, and consider working with coal blends with moisture 4%, whose DI and % coke >25% values were better. Thus, considering the coal blend with 4% moisture, regarding to the 8% moisture blend (typical value for cokemaking), it can be observed an increasing on bulk density of 27%, on CSR of 2,8%, on DI of 1,6% and on coke % > 25mm of 3,6%.

Finally, it is shown the overlapping of briquetting and CMC results (Figures 4 – A - B - C - D) to find which moisture content would produce the equal or approximately the same result on coke quality to addition of briquettes 20% - ideal amount of briquettes found previously- in the coal blend. Analyzing the Figure 4 - A, moisture 6% has bulk density value the nearest to briquettes 20%. For all other plots from Figure 4 – B – C - D, moisture content of 4% presented values the closest to briquettes 20% for CSR, DI and coke % > 25%.

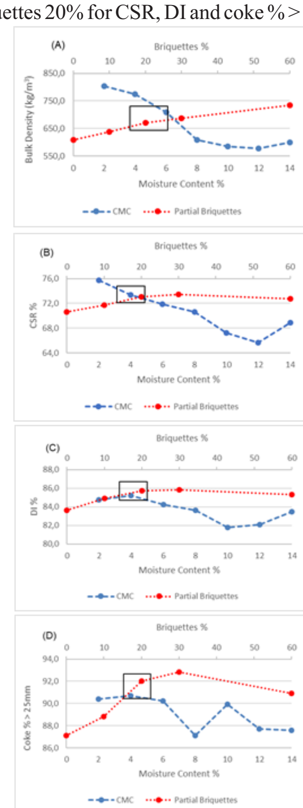

Figure 4: Overlapping of (A) bulk density, (B) CSR, ©, DI and (D) coke % > 25mm for briquetting and CMC results.

CONCLUSIONS

Technologies of increasing density as briquetting and CMC have proved their impacts on enhance of coke quality. Regarding briquetting process, it was found that the ideal amount of briquettes is 20% and this promoted an increasing on density of 10%, on CSR of 2,4%, on DI of 2,1% and on coke % > 25mm of 4,9%.

On the other hand, for CMC technology, coke with moisture 4% had the highest benefits on coke quality and produced the following effect of increasing: on bulk density of 27%, on CSR of 2,8%, on DI of 1,6%, on coke % > 25mm of 3,6%.

Overlapping the results of coke quality parameters for both technologies, it was disclosed that briquettes 20% produce proximately the same result that coke manufactured from coal blend with moisture 4%.

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