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Stamped and pressed coal cakes for carbonisation in by-product and heat-recovery coke ovens

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HIGHLIGHTS

- Meaning of the coal compaction in the cokemaking.
- Methods of the coal compaction.
- Energy demand for stamping.
- Model of the densification.
- Assessment of the cake stability.

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ABSTRACT

Coking of coal blends using high volatile coals with poor coking abilities to produce a high quality coke for blast furnace application can be achieved by compacting the coal blend prior to the carbonization process. Here densification up to a relative material density of 80%, i.e. a compact density around 1100 kg/m^3, has proven to be advantageous. Coal is compacted by stamping, if the so-called stamp charging process applied. Compacting of the coal by pressing is used in case of the cokemaking with so called heat-recovery ovens.

Stamped and pressed coal cakes require over the cake volume uniform high density and mechanical stability. Besides the aspects of the coal selection, the efficiency of the process is mainly determined by the operating parameters compacting time and compacting energy for coal cake making and by the sufficient cake mechanical stability to ensure trouble-free charging the ovens.

At the Department for Mechanical Process Engineering & Solids Processing of the Technical University Berlin the two sub-processes of densification and strengthening during stamping and during pressing are theoretically and experimentally investigated using specially developed lab-scale compacting test units for stamping and for pressing and a coal cake strength test device.

Describing cake density in terms of coal properties for a given coal and measured compacting energy input then leads to a compacting equation with the so-called Stampability as the integral model parameter for the stamping process. For the pressing process the cake density can be calculated with the measured compacting pressure and the Compressibility factor, respectively. Investigations were carried out to provide evidence of a significant influence of coal type, coal surface moisture, coal granulometric properties on the densification process.

In order to investigate the mechanical strength properties of the stamped and pressed coal cakes, a specific strength tester has been developed, combining the possibilities of investigating compressive/tensile strength as well as shear strength.

Based on the tests on the densification behaviour and cake strength for a given coal, the stability criterion of a coal cake with the required density and height can now be calculated.

1. Introduction and the objectives of the work

Coking of coal blends using high volatile coals with poor coking abilities to produce a high quality coke for blast furnace application can be achieved by compacting the coal blend prior to the carbonization process. Compacting of coals not only improves the flexibility of the cokemaking by using high amounts of poor and medium coking coals and other low-cost raw materials in blends. Also the oven throughput is increased [1]. Therefore in recent years densification of coals has been introduced even to coals with good carbonisation properties when heat recovery ovens are used [2].

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Nomenclature

B	compressibility factor (–)
c	speed of light in the vacuum (m/s)
d'	RRSB fineness parameter (m)
daf	dry ash free
E	specific stamping energy (J/kg dry coal)
E_0	specific stamping energy for ρ_0 (J/kg dry coal)
F	force (N)
F_{max}	maximum force (N)
g	gravitational constant (m/s^2)
h_c	coal cake height (m)
HGI	Hardgrove grindability index (°H)
K	stampability (–)
n	stamping step (–)
n	RRSB broadness parameter (–)
p	briquetting pressure (kN/m^2)
p_0	reference pressure (kN/m^2)
RRSB	Rosin-Rammler-Sperling-Bennet-distribution-function (–)
s	path (m)
s_0	initial displacement (m)
s_{max}	maximum path (m)
v	velocity (m/s)
VM	volatile matter content (–)
w	surface moisture (–)
waf	water and ash free
wf	water free
w_{opt}	optimum of surface moisture
α	model parameter
β	model parameter (–)
δ	model parameter (–)
ε	dielectric constant A s/(V m)
ε_{cc}	coal cake's dielectric constant A s/(V m)
ϕ_i	inner friction angle (°)
ρ	density (kg/m^3)
ρ_0	initial bulk density (kg/m^3)
ρ_c	coal cake density (kg/m^3)
σ	normal stress (Pa)
σ_{cc}	Compressive strength (Pa)
σ_{cow}	own weight of coal cake (Pa)
σ_z	tensile strength (Pa)
τ	shear stress (Pa)
τ_0	cohesion (Pa)
τ_{max}	maximum of shear stress (Pa)

Here densification up to a relative material density of 80%, i.e. a compact density around 1100 kg/m^3 depending on the true density of the coal, has proven to be advantageous.

Coal is compacted by stamping, if the so-called stamp charging process applied. Stamp charging means coke production in conventional chamber ovens, where the coal blend is previously compacted to a so-called "coal cake" with slightly smaller dimensions than those of the oven and charged vertically standing into the oven on a coal cake charging plate from the battery ram side through the oven door as shown in Fig. 1 [3].

Compacting of the coal by pressing is practised in case of the cokemaking with so-called heat-recovery ovens. In this case the oven charge is compacted to a coal cake with significantly lower height than of the oven and charged horizontally lying into the oven on a charging plate through the oven door [4] (Fig. 2).

The stamped coal cake with dimensions of 0.5 m in width 4–6 m in height 13–16 m in length and the pressed coal cake with typical dimensions of 3–4 m in width 1 m in height 13–16 m in length are used in industrial cokemaking operations [5]. Stamped and pressed coal cakes require over the cake volume uniform high density and mechanical stability. Besides the aspects of the coal selection, the efficiency of the process is mainly determined by the operating parameters compacting time and compacting energy for coal cake making. At the beginning of the densification process the particulate material yields under the stress applied by the compacting equipment, thereby filling the interstitial voids of the particle system with smaller particles. The rearrangement of the particles is supported by the surface moisture which reduces the internal friction. With further strain an elastic–plastic deformation of the particles takes place partly resulting in particle breakage and filling of small pores with the fragments. While the pore volume decreases the pore saturation with water rises causing a damping effect.

Besides the influence of the capillary water on the densification process itself also the mechanical properties of the compact are determined by the surface water as it serves as a binding agent in the formation of adhesive forces. Within the systematic of process engineering the stamp cake can be classed as so-called wet agglomerate which is characterized by the adhesive forces resulting from liquid bridges within the capillary pore system [6].

The following objectives are relevant to the technical compacting process:

(1) The realisation of a certain cake density, homogeneous within the cake volume, in combination with a maximum mass throughput taking account of the carbonisation properties of the coal blend.
(2) The guarantee of a sufficient cake strength in terms of operating safety while charging the coal cake to the oven and

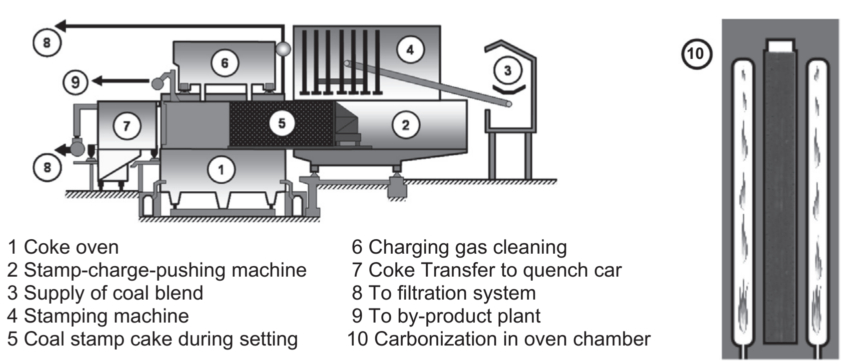

Fig. 1. Principle of stamp-charge coke making process.