# A REVIEW ON STAMPED CHARGING OF COALS[1]

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**Abstract**

The stamped charging of coals, developed in Europe and adopted in China and India, allows the use of high volatile poor coking coals, soft and semi soft coals as well as inerts like petroleum coke and anthracite without impairing coke quality. In this paper the development of the technology is detailed. Different type of equipment for cake preparation and charging are described. The operating aspects are analyzed, including the safety against wall pressure. Blend design as practiced in European, Chinese and Indian coke plants is discussed. Coke quality indexes obtained with this technique are shown. The reasons behind the improvement in MICUM 10 and CSR are briefly addressed. A summary of current research on this process being carried out in Universities, Institutes and Research Centers is presented.

**Key words:** Stamped charging; Blend design; Non-coking coals; Coke quality.

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## 1 INTRODUCTION

The extensive use of pulverized coal injections in blast furnace worldwide, calls for higher coke quality. On the other hand, as coking coals become more expensive, with volatile price and relative availability, coke producers look for the introduction of cheaper coals in the blend. One of the answers to either of these drivers is stamped charging, initially oriented to the use of high volatile poorly coking coals.
Briefly, the technique of charge preparation consists in preparing a cake with the coal blend in a metallic box, then charging it in the coke oven. The higher charge density implies better coke quality when compared with conventional charging. So, depending on the situation, either better coke quality may be obtained, or poorer coking coals may be included in the blend.
The process has been around since the early XX century. It is said that first stamping took place in Poland. Other plants in West and East Europe adopted the technique in Germany, France, United Kingdom, Czech Republic and Ukraine. As an example, Coed Ely coke plant, in South Wales, UK, operated two batteries of 30 ovens each, built by Coppe Company in 1914, 34' long, 8' 6" high and 50' width, with a stamping station located in the space between the two batteries (Figure 1). Straw was used as an aid to cake strength. Straw was used as a binder and a specially designed charger car/ram built to load the charge into the oven from the back. Coke made by the stamp charging process was of a denser and larger variety than that made in other ways, making its use ideal for ironmaking in foundries where strength is an important factor. Another advantage noted was that a much larger range of coals could be coked with the limits of (high) volatility and coking properties much increased.(1)

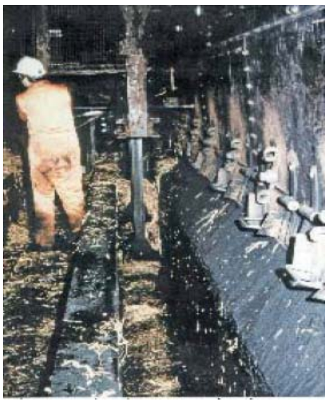


**Figure 1.** Stamping the coal charge at Coed Ely Coke Plant, South Wales, UK. Left: On the right are coal flaps, which are opened to allow the coal to fall into the box; straw on the left was manually forked in on top. Right: The cake is ready and the ram/charger is about to move off. The workman with the bar secures the cake in its raised position.

Modern process development took place in Fuerstenhausen Coke Plant, Völklingen, Germany, focused in the use of high volatile Sarre basin coal. In 1978, after intensive research and development the first 6 meters high cake was produced, overcoming a bottleneck for the economical implantation of this technology. The first plant of this dimension was started-up in 1984, at what is called today ZKS Zentralkokerei Saar, Völklingen, Germany.(2)
The engineering company behind the process development was Saarberg Interplan. This was later absorbed by Koch Transporttechnik. Then Koch was absorbed by FLSmidth, headquartered in Denmark, and became FLSmidth Koch. Later on, VeCon

was founded by a former Koch officer. FLSmidth Koch sealed a joint venture with a heavy machinery Chinese manufacturer, Taiyuan Xingang.
Stamped charging was adopted by Tata Steel in 1989[3] and other plants followed in the same country. During this century, an impressive capacity was built in China, with more than 100 M tpa.[4] The first modern stamp charging plant in the Americas was built in 2010 in ThyssenKrupp Steel CSA, Santa Cruz, Brazil.[5]
In Table 1, a summary of some of the plants adopting this technology is presented. Both conventional slot ovens and non-recovery/heat recovery ovens make use of the technique.

**Table 1.** Some plants adopting stamped charging technology

| Company | Location | Country | Mta | Year | Builder | Oven type |
|---|---|---|---|---|---|---|
| ZKS | Völklingen | Germany | 1.3 | 2010 (#3) 2012 (#1) | Paul Wurth-Saarberg | Slot |
| ISD Alchevsk Coking Plant | Alchevsk | Ukraine | 2.0 | 1993/2006 | Azovintex-VeCon | Slot |
| Shanxi Changzhi | Changzhi | China | 1.5 | | MEPC | Slot |
| Shanxi Zhonghua | Dali Village | China | 1.2 | | SPDCI | Heat-rec. |
| Zhongmei Jingda | Hui'an | China | | | SPDCI | Heat-rec. |
| Jincheng Qinhe | Qinhe | China | | | SPDCI | Heat-rec. |
| Shanxi Sanjia | Jiexiu City | China | | | SPDCI | Heat-rec. |
| Shanxi Luxin Energy Group | Shanxi Prov. | China | | | SPDCI | Heat-rec. |
| Xinjiang International | Urumqi | China | | | SPDCI | Heat-rec. |
| Jiangsu Zhuxi Activ. C. | Liyang City | China | 0.75 | | SPCDI | Heat-rec. |
| Shanxi Fenyang Longquan | Fenyang C. | China | 0.4 | | SPCDI | Heat-rec. |
| Hunan Loudi Xinxing | Loudi | China | 0.6 | | SPCDI | Heat-rec. |
| Qingdao Steel | Qingdao | China | 0.6 | 1995 | Saarberg | Slot |
| Taiyuan Gangyuan | Donggaobai | China | 0.4 | | SPCDI | Heat-rec. |
| Xinggao Coking Group | Gaoping | China | 1.0 | 2000<br>2008 | SPCDI<br>FLSmidth Koch | Heat-rec.<br>Slot |
| Tata Steel | Jamshedpur | India | 2.0 | 1989/2000 | | Slot |
| Sesa Goa | Amona | India | 0.28 | | Sesa Goa | Heat rec. |
| Bla Coke | Arambhada | India | 0.25 | | Bla-VeCon | Heat rec. |
| JSW Steel | Bellary | India | 1.2 | | Sesa Goa-VeCon | Heat-rec. |
| JSW Steel | Bellary | India | 1.5 | 2008 | Sinosteel | Slot |
| JSL | | India | 0.42 | | Sinosteel | Heat-rec. |
| JSPL | Raigahr | India | 0.8 | 2008-2013 | Sinosteel | Heat-rec. |
| SISCOL | Tamil Nadu | India | 0.4 | 2007 | Sinosteel | Heat-rec. |
| Lanco Ind. Ltd. | Rachagunneri | India | 012 | 2005 | Dasgupta-MEPC | Heat-rec. |
| Hoogly Met Coke & Power | Haldia | India | 1.6 | | MEPC | Heat-rec. |
| TK-CSA | Santa Cruz | Brazil | 2.0 | 2010 | Sinosteel | Heat-rec. |

This paper reviews the literature on stamped charging, taking into account that the largest users (China) are those who less write their experiences in English, and that most published research comes from India and Germany which are far behind the Chinese production figures on this matter. Equipment and operation, blend design, coke quality and recent research are discussed separately.

## 2 EQUIPMENT AND OPERATION

Stamping equipment may be located in a building destined to this purpose or in the stamping/ charging / pushing machine (SCP). In Table 2 a summary is presented of reasons given for those supporting SCP. Those supporting stationary stamping as well as separate parallel pushing and charging machine argue that investment cost for machines and foundations is lower.[2]

The stamping process consists in general in introducing the coal blend previously ground at a specific size, within a steel box, as successive layers that are rammed mechanically. It can be applied vertically (Figure 2) or horizontally (Figure 3). Additionally, vibration may be applied to facilitate the accommodation of the particles. A horizontal box is filled with the coal blend, with defined grain size distribution and moisture content, in three equal layers. Compaction and vibration is applied, through 24 plates covering all the surface of the cake, during two minutes for each layer, to support the transfer from the box to the oven. It is said that in this case it is not required as fine grain size as for conventional stamping.[6]

**Table 2.** Reasons to adopt SPC machine instead of stamping station, according to SPC supporters[7]

| | SCP | Stationary |
|---|---|---|
| Maximum oven cycles per day | 120 | <60 |
| Stand-by machines | 50 or 100% possible | Not possible |
| Coal feeding | Long belt conveyor along the machine track | Coal tower with stationary stamping system inside |
| Level of automation | Advanced | Normal |
| Coal cake in one charging | 50 | 44 |
| Investment cost | The same if standard is same | The same if standard is same |
| Production loss | Low | High |

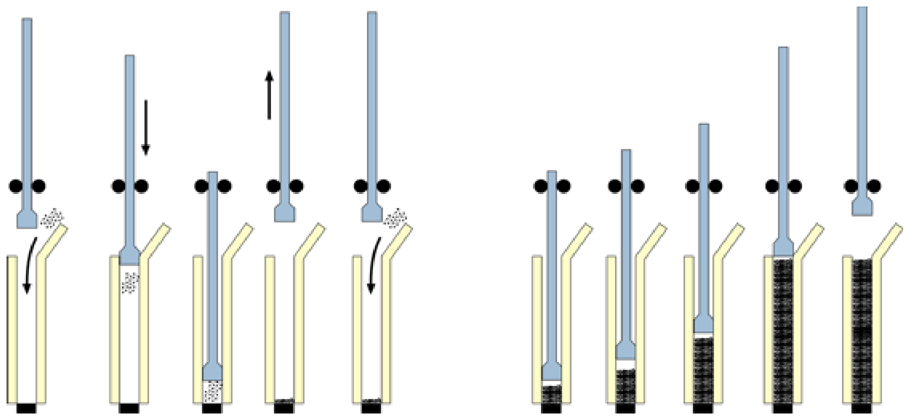

**Figure 2.** Sketch of vertical coal stamping. Left: sequence of charging, pressing and new charging. Right: growing of the cake after each charging step.[8]

**Figure 3.** Equipment for horizontal coal stamping (Met Coke Consultants).[9]

Two aspects have to be taken into account: densification and mechanical properties. Densification is required by the coking process. The denser is the cake, the better is the coke quality, taking into account both cold mechanical strength and behavior at high temperature. Mechanical properties should be enough to support transport of the cake and charge into the oven. This is more critical for vertical ovens than for horizontal.

When the densification starts, coal particles yield under the stress applied by the stamping machine, filling the interstitial voids with smaller particles. The rearrangement of the particles is supported by the surface moisture, reducing 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.[10]

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, i.e. within the systematic of process engineering the stamp cake can be classed as a so-called wet agglomerate which are characterized by the adhesive forces resulting from liquid bridges within the capillary pore system.[11]

Cake density aimed is 1100 to 1150 kg/m$^3$ and depends roughly on moisture and grain size of the coal blend and compacting energy applied. Mechanical properties of coals have an influence, too. In Figure 4, the influence of moisture on wet density is presented for different compacting energy. Wet density grows continuously when moisture increases from 6 to 13%. For higher moisture, the energy applied is use to expulse water out of the cake.

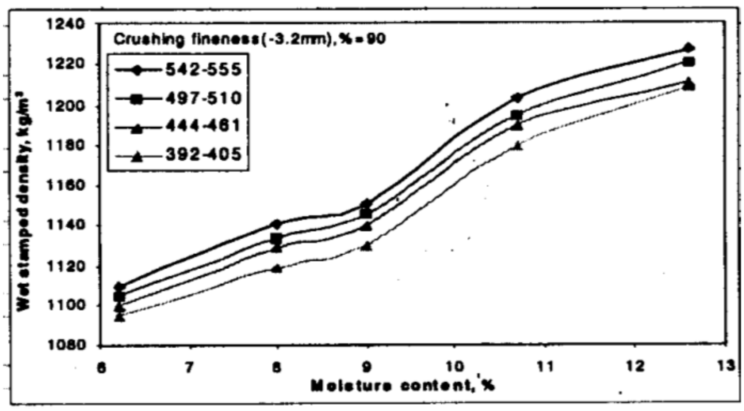


**Figure 4.** Influence of moisture on wet density of cake, for different compacting energies.[12]

Density increases rapidly up to a threshold (around 1000 kg/m3) after which much energy has to be applied to increase density (Figure 5).

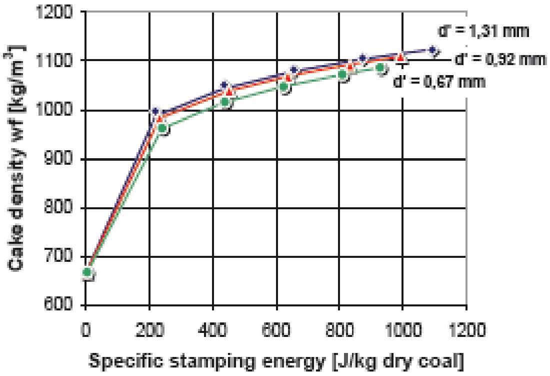


**Figure 5.** Influence of specific stamping energy on cake density, for different grain size distributions.[10]

Generally speaking, regarding the achievement of the strength required for cake transport and charging, two important variables of the coal blend are moisture and grain size; the operating variable is the compacting energy applied and the pertinent mechanical properties are compressive strength and shear strength. An example of the relations between these variables is presented in Figure 6. For a given stamping energy, maximum compressive and shear strength are achieved in this case at around 9% moisture.[13]

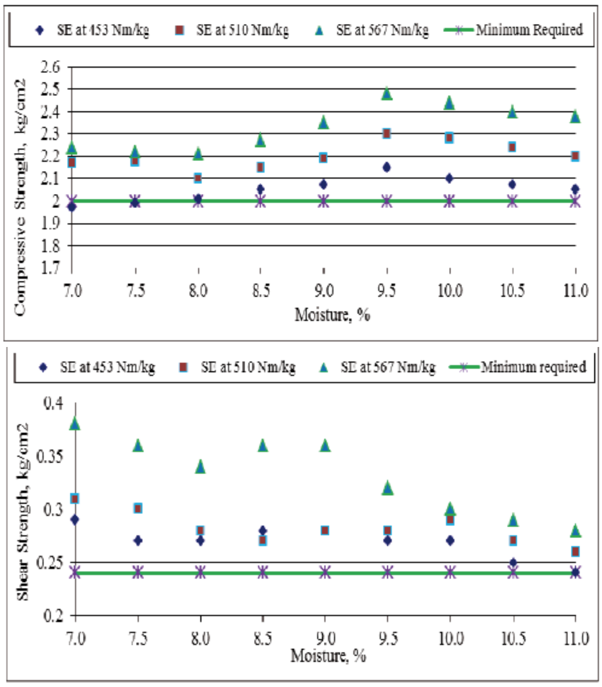


**Figure 6.** Influence of moisture content and compacting energy on shear strength (top) and compressive strength (bottom) .[13]

As discussed before, different equipment may be used for charging the cake: stamping/charging/pushing, charging/pushing machine or just charging machine. Another variation is introduced by the oven design (vertical slot oven or horizontal non-recovery/heat recovery oven. For vertical ovens, cake charging takes place through the pusher side doors (Figure 7). This procedure causes high emissions. In

order to decrease such emissions several systems have been experimented during coal cake charging, especially through the use of sealing frames, nevertheless this intervention only partially reduced emissions sources, without completely eliminating the problem. The solution adopted recently in the new ZKS batteries to decrease emissions sources during the oven charging process has been to create a strong depression in the collecting main during the charging phase: -400 Pa. During the distillation process when no charging process is ongoing, the collecting main is set to a negative pressure of about 0 Pa (current value). The switch to the higher depression set-point is done before starting the pushing series.[14]
For the non-recovery/heat recovery horizontal ovens, charging is also carried out from the front door with a specific machine (Figure 8).

## 2.1 Battery Operation

A concern while using stamped charging is what could happen regarding pressure against how the oven structure behaves under the pressure developed inside the cake, which is higher than in top charging for the same blend (Figure 9). This is critical for vertical ovens but it is not an issue for horizontal ovens. It is interesting to review with two world-class long-timers in stamped charging: ZKS (Dillingen + Saarstahl) and Tata Steel Jamshedpur.

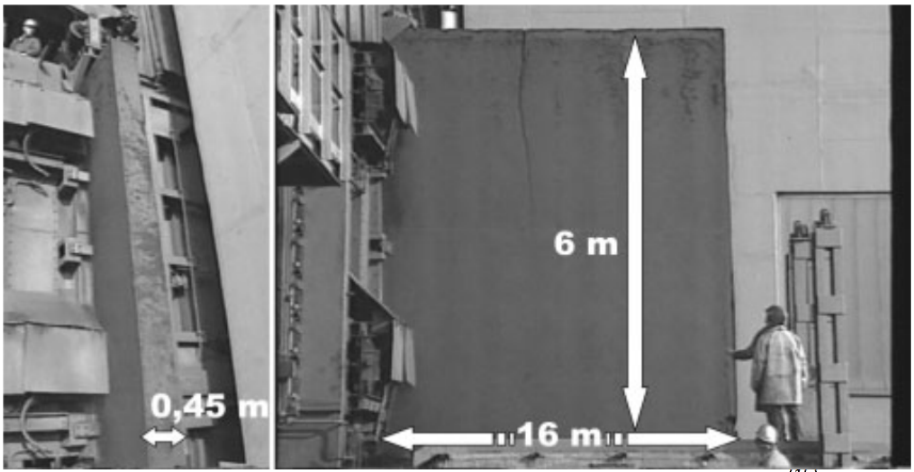


**Figure 7.** Coal cake for charging of conventional slot oven.[15]

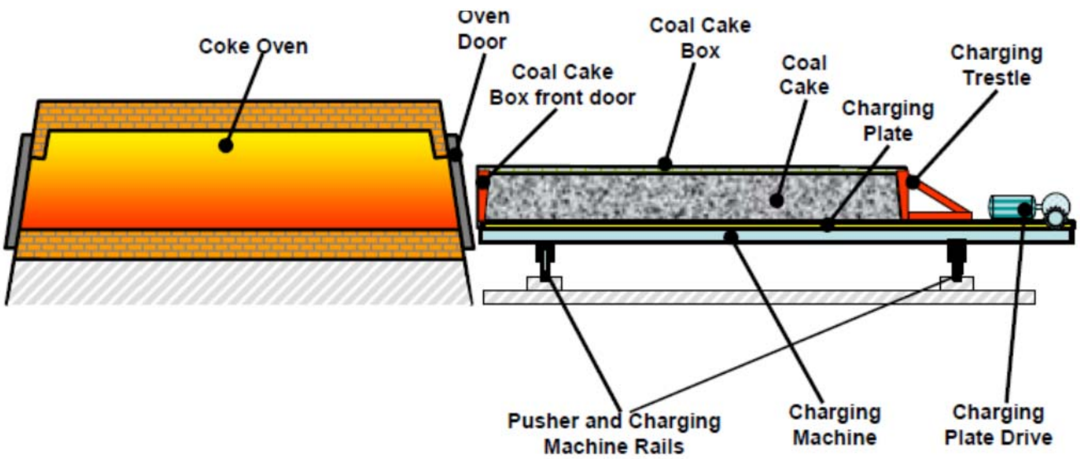


**Figure 8.** Sketch of charging of vibrocompacted coal cake in Sesa Goa.[16]

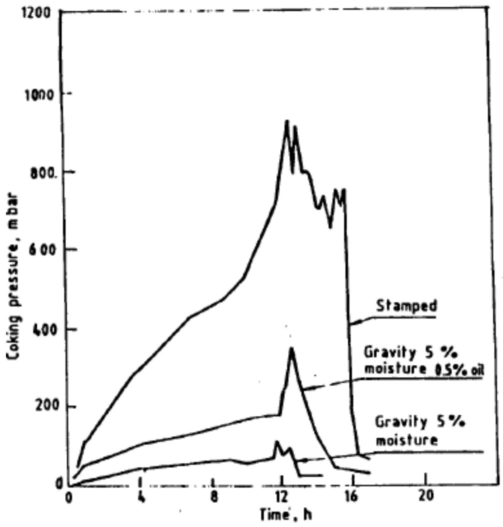


**Figure 9.** Pressure against the wall for stamped vs. top charging the same blend.[12]

ZKS built batteries 1 and 2 by 1984. The designer was Didier; they were the first ever 6.25 m high stamp charged batteries in the world, 40 ovens each.[2] In 2010, battery 3 was built by Paul Wurth, with 50 ovens. Later on, battery 1 was demolished and replaced by a new one, also by Paul Wurth. Battery 2 was said to be shut down after start-up of new Battery 1.[14] So, the batteries worked for almost 30 years. As a comparison, conventional batteries life is in the order of 40 to 50 years.

In the case of Tata Steel Jamshedpur, there are two stamped-charging production units (Table 3). The oldest stamp charged battery is #7, built in 1989.

**Table 3.** Main features of coke oven batteries at Tata Steel Jamshedpur, India[17]

| Technology | Top charge | Stamped charge | | | | |
|---|---|---|---|---|---|---|
| | | Unit 1 | | | Unit 2 | |
| Battery No. | 3 | 5 | 6 | 7 | 8 | 9 |
| Ovens | 54 | 30 | 60 | 54 | 70 | 70 |
| Start-up year | 1975 | 1995 | 1993 | 1989 | 1998 | 2000 |
| Capacity (Mtpa) | 0.32 | 1.0 | | | 1.0 | |

Failures were reported to start by 2005 (Figure 10). Although not all of them relates to the fact of the charge being stamped, one of the main causes was excessive pushing force.[17]

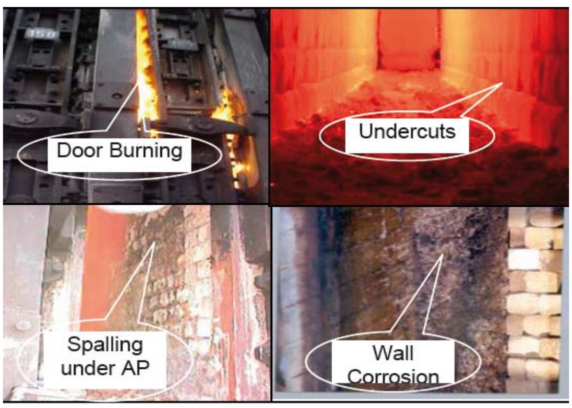


**Figure 10.** Some examples of damage in ovens of battery #7 at Tata Steel Jamshedpur, after 16 years of operation.[17]

Six years of continuous improvement work with changing strategies were required to have all ovens of Unit 1 back on trail (Figure 11).
These two examples suggest that with the technology of the first 6 m high stamp charged batteries built in the middle eighties, working life is around 30 years, shorter than what is expected for top charged batteries. It is worth to mention that for non-recovery/heat-recovery ovens, where pressure against the walls is not an issue, battery life is predicted to be 30 years by SunCoke, one of the most important oven builder and heat-recovery coke producers.[18]
Regarding productivity, the general view is that for the same production level, fewer ovens are necessary. Even though coking time is longer, more coke is produced due to the larger charge. Heat transfer through the coal mass is faster due to the better contact between coal particles.

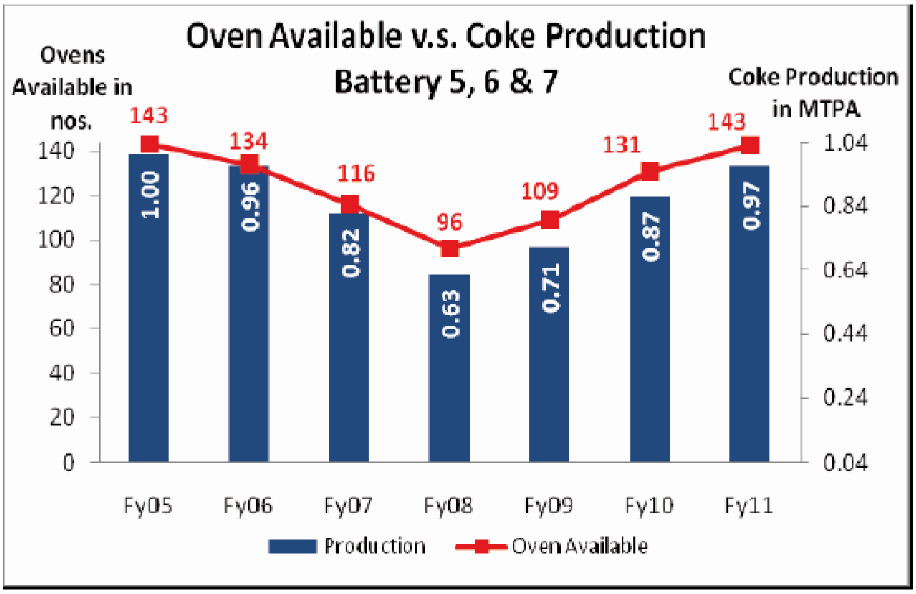


**Figure 11.** Evolution of production and ovens in operation in unit 1 from 2005 to 2011.[17]

## 3 BLEND DESIGN AND COKE QUALITY

It is said that a general specification for coal blends is 25-32% volatile matter (ash free dry base) and a free swelling index of 3 minimum. Nevertheless, there are particular specifications from plant to plant, depending on coal availability and costs. Reported studies on blend design come from one German (ZKS) and two Indian plants (Tata Steel and JSW Steel) and for China as a whole and are discussed separately.

### 3.1 ZKS

The blend includes local high volatile coal, Ruhr and imported low volatile coals and petroleum coke. Main coal features are summarized in Table 4.[6]

**Table 4.** Main features of ZKS stamped coal blend[6]

| | Local coal | Ruhr coal | Imported coal | Pet coke | Blend |
|---|---|---|---|---|---|
| Content (%) | 72 | 5 | 8 | 12 | 100* |
| Volatile matter (%) | 38.6 | 17.3 | 19.1 | 11.8 | 31-32 |
| Dilatation (%) | 100 | -18 | 34 | - | 10 |
| FSI | 8 | 3 | 9 | - | |
| Ash (%) | 6 | 7 | 10 | 1 | 6 |
| Sulphur (%) | 0.72 | 0.80 | 0.80 | 0.85-1.70 | |
| Mean reflectivity | 0.89 | - | 1.4 | - | 1.14 |

** Up to 3% coke breeze is included*

Another stamped charging plant (but with horizontal heat-recovery ovens) that have been using pet coke is TK-CSA in Brazil.

### 3.2 Tata Steel

This plant runs five stamp charging vertical batteries (and one top charged battery). At a certain time, it was specified 29-30% volatile matter and mean vitrinite reflectivity of 1.04 – 1.06%. Under this specification, a blend of 80% of a local high volatile, high ash, poorly coking coal (West Bokaro) and 20% of two Australian low volatile, highly coking coals have given consistent good results along many years. Later on, after testing at pilot and industrial scale, 10% of local high volatile high ash non-coking coal (FSI=zero) has been introduced in two of the batteries, without decreasing coke quality. Less pressure on the side walls was observed.[3]
After that, Tata studied the introduction of Australian semi soft coals in the blend.[16] Following tests at 7 kg and 600 kg ovens, the conclusion was that it was possible to use 30-35% of such coals, complemented with domestic coals, keeping constant the coke quality, with CSR levels of 65-66%. This way, the use of highly coking coals was eliminated, decreasing coke cost. As this plant owns both conventional and stamp charging batteries, blend cost comparison is easy to compare (Figure 12).

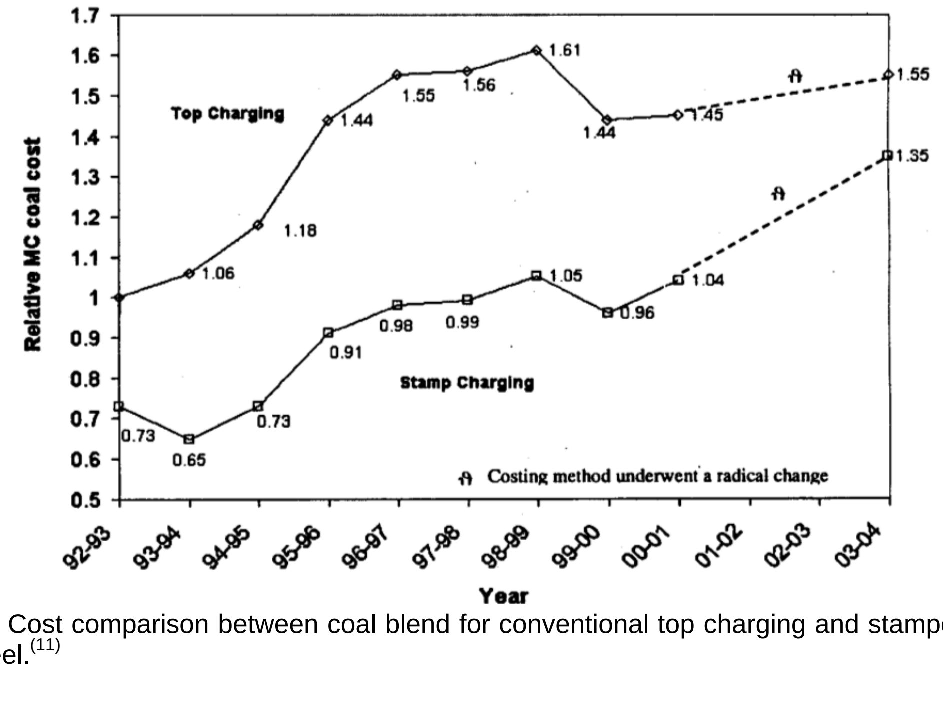


**Figure 12**. Cost comparison between coal blend for conventional top charging and stamped charging at Tata Steel.[11]

### 3.3 JSW Steel

This company operates non-recovery/heat recovery coke ovens with previous vibrocompaction of the charge. In their experience, they have been able to use blends including 10% of semi soft coal and 25% of non-coking coal, keeping CSR between 64 and 66%, CRI between 23 and 25% and MICUM 10 between 4 and 6%.[19] In Table 5 the main properties of the coals in the blend are detailed.

**Table 5.** Main properties of coals taking part in the coking blend of JSW Steel[19]

| Parameters | Coking coals | | Semi soft coals | | Soft/non-coking coals | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | F |
| Volatile matter (%) | 24.8 | 22.7 | 34 | 26 | 26 | 20 |
| Free swelling index | 9 | 8 | 8 | 4 - 5 | 1.5 | 1 |
| Vitrinite (%) | 75 | 57 | 80 | 59 | 55 | 37 |
| V9-V13 (%) | 75 | 57 | 49 | 31 | 14 | 33 |
| Maximum fluidity (ddpm) | 4500 | 1300 | 8000 | 250 | 1 | 1 |
| Mean Max. Reflectivity (%) | 1,24 | 1.28 | 0.84 | 0.88 | 0.93 | 1.17 |

The limiting factor for non-coking coal was reactivity and post-reaction strength, falling below 64% for 30-35% of non-coking coals, while resistance to fissuring and abrasion are still in acceptable values (Table 6, Figure 13).

**Table 6.** Properties of cokes produced through stamped charging, with non-coking coal in the blend[19]

| Coking coal (%) | 100 | 95 | 90 | 85 | 80 | 65 | 65 | 75 | 70 | 65 |
|---|---|---|---|---|---|---|---|---|---|---|
| Semi soft coal (%) | 0 | 0 | 0 | 0 | 0 | 15 | 10 | 0 | 0 | 0 |
| Non-coking coal (%) | 0 | 5 | 10 | 15 | 20 | 20 | 25 | 25 | 30 | 35 |
| Coking time (h) | 62 | 60 | 59 | 61 | 58 | 61 | 61 | 56 | 56 | 62 |
| CRI (%) | 23 | 24 | 25 | 24 | 24 | 25 | 25 | 26 | 26 | 27 |
| CSR (%) | 67 | 67 | 66 | 66 | 65 | 64 | 64 | 65 | 63 | 62 |
| MICUM 10 (%) | 5.6 | 5.7 | 5.5 | 5.8 | 5.3 | 5.3 | 5.7 | 5.3 | 5.9 | 5.7 |
| MICUM 40 (%) | 85 | 86 | 87 | 85 | 88 | 89 | 89 | 87 | 87 | 89 |

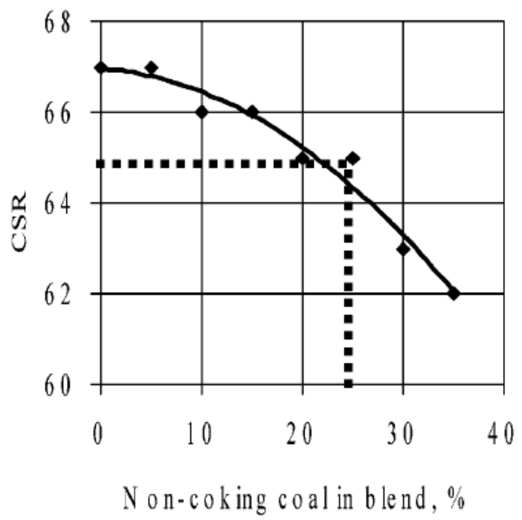


**Figure 13.** Influence of non-coking coal in the blend on post-reaction strength (CSR) of coke.[19]

### 3.4 China

Coals are classified in 12 groups, according to volatile content, agglutination power (measured with index G, a variation of the Roga index); and two values taken from Sapozhnikov dilatometer test, which depends on almost the same variables as the Gieseler plastometer test.[20]

Prime coking coals are so called coking coal (20 to 28% volatile matter and G index > 50, and fat coal (10 to 37% volatile matter and G index > 85. In Figure 14, coal type consumption for 5-year plan 2006-2010 is presented.[4] Consumption of prime coals varied between 51 and 59% in that period.

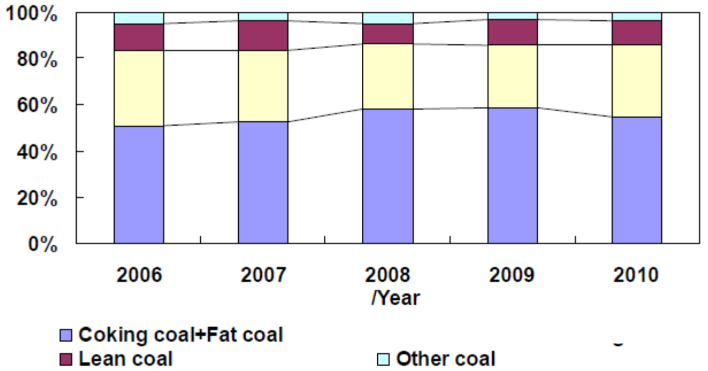


**Figure 14.** Percentage consumption per coal type during 5-year plan 2006-2010 in China.[4]

The Coke and Coal Resources Committee of the Chinese Association of Coke Industry came to the conclusion that with stamped charging, consumption of coking coal and fat coal can be decreased by 14%. SO, emphasis is made on fully using the more than 100 M tpa stamped charging capacity.[4]

The Sinosteel Anshan Research Institute of Thermo Energy carried out research on stamped charging, coming to the conclusion that coke shows lower apparent and total porosity and thicker pore walls than coke from top charged ovens. Regarding high temperature behavior, stamping had no influence on CRI, when the test was carried out with fine coal (Figure 15). In this case, the decisive role was played by the particular features of each coal.

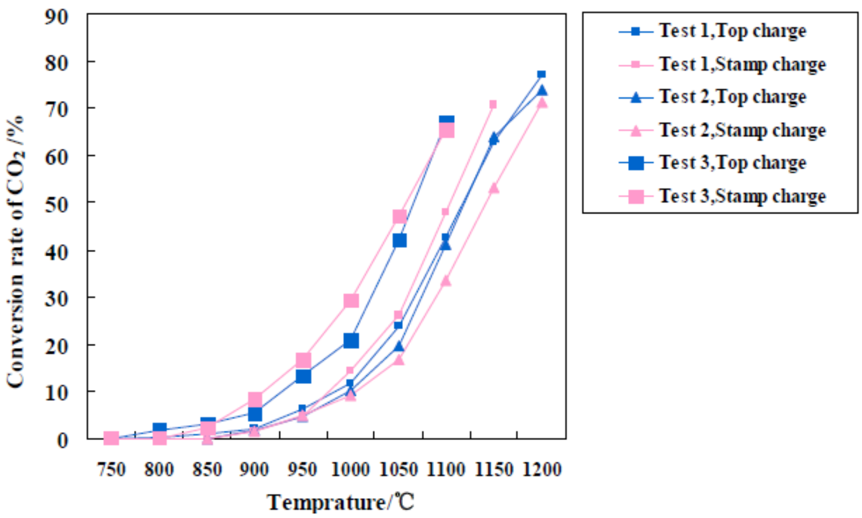


**Figure 15.** Weight loss of fine coke in front of $CO_2$, depending on temperature, for cokes produced through top charging and stamped charging, departing from three blends (blend 3 being the poorest).[4]

Instead, when reactivity was determined on coarse coke, charging type was determinant. The same happened with post-reaction strength. The effect was more important for the poorer blend (Figure 16).

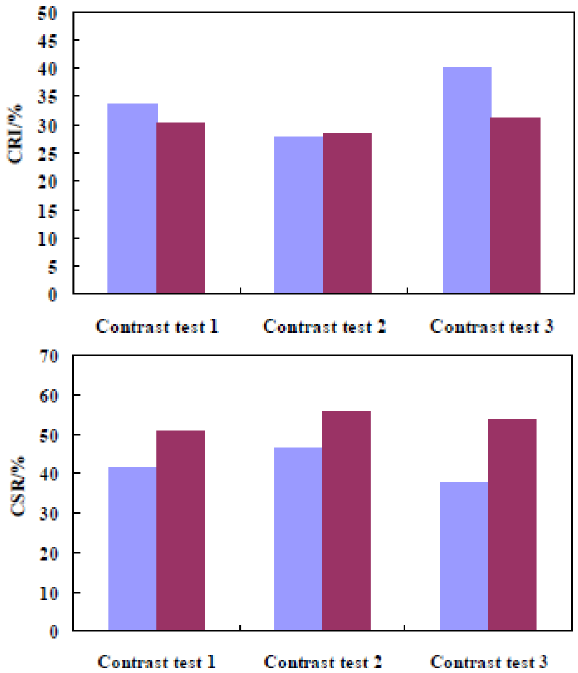


**Figure 16.** CRI and CSR for coarse coke for cokes produced through top charging and stamped charging, departing from three blends (blend 3 being the poorest).[4]

Some Chinese plants are not using coking coal (according to Chinese classification) but 1/3 coking as main coal in the blend; for instance, Shanxi Taiyuan Donsheng Coking Factory.[21] Others specialized in using high percentage of anthracite; generally these plants are equipped with non-recovery/heat-recovery ovens using stamped charging. One of them is Xinggao Coking Group, since 2003, with a production of 0.4 M tpa in QRD 2000 ovens and since 2007 with other line of 0.6 M tpa. Other similar plants are those of Shanxi Sanjia Coking y de Jincheng Qinhe Coking.[21] In Table 7 a typical blend with high anthracite content is presented, with the corresponding coke quality.[7]

**Table 7.** Main characteristics of coal blend and coke quality in an unidentified Chinese plant, using anthracite in the blend, for stamped charging of non-recovery/heat recovery coke ovens[7]

| Coal | Ash (%) | Volatiles (%) | Sulphur (%) |
|---|---|---|---|
| 45% anthracite | 10.2 | 9.3 | 0.41 |
| 20% coking coal | 7.7 | 18.5 | 0.44 |
| 35% 1/3 fat coal | 8.8 | 33.2 | 0.45 |
| Blend | 9.0 | 21.6 | 0.42 |

| Coke | M40 (%) | M10 (%) | CSR (%) | Ash (%) | Sulphur (%) |
|---|---|---|---|---|---|
| | 85.6 | 6.6 | 62.1 | 11.3 | 0.34 |

### 3.5 Summary on Blend Design and Coke Quality

The reported experience on stamped charging reflects a trend in using it when high volatile relative poorly coking coal is available close to the coke plant. This is often the main component of the blend. Low volatile coking coals are usually included. Soft

or semi soft coals are often included, too. Some batteries consume, blended with the previously mentioned coals, low volatile inert carbonaceous materials like anthracite, pet coke or coke breeze.
In some cases, stamped charging is also used as a mean to improve M10 and CSR of coke. This seems to be the case in China's captive coke plants, accompanying a process of growing size of blast furnaces and increased PCI utilization.

## 4 RECENT RESEARCH

In the latest decade, several Institutes, Universities and Technical Centers have been active in stamped charging research:

- Studies on stampability and modeling of stamping operation carried out by researchers at the Technical University of Berlin, Germany;[9,10]
- Lab scale research on use of coal tar pitch or molasses as an additive to the coal blend for improved cake strength and coke quality[12,22] and use of fluid petroleum coke and anthracite to decrease blend cost at Tata Steel R&D;[23]
- Influence of coke structure from stamped charging ovens on high temperature behavior, at Sinosteel Anshan Research Institute of Thermo energy.[4]

These research efforts support the future development of the stamping charging technology.

## 5 CONCLUSIONS

Stamped charging is being used for the production of more than 100 Mt/year of coke. Most of this is capacity has been built in China, where the use of this technology is favored due to its technical and economical advantages. Both vertical slot ovens and non recovery/heat recovery coke ovens take advantage of this technique. Compaction is done either in vertical or horizontal position, complemented in some cases with vibration.
According to the specific situation, the ability to make stamped charging may be used for decreasing coke cost or increasing coke quality.
Recently, research has been carried out in different centers on stampability, use of additives and influence on coke quality.
The adoption of the technology in China and to a less extent in India, suggests that further increase in capacity may take place in the future.

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