BRIQUETTING OF FERROUS AND COAL FINES – SAVING RESOURCES, CREATING VALUE*

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Abstract

One of the global trends that are constantly challenging the iron and steel industry is related to the generation of fines, slurry, sludge and scales, summed up as ferrous by-products. The recycling of those by-products is commonly practiced in many steel plants. These materials normally cannot be used directly in the primary processes. The most common application is to add ferrous by-products which are suitable concerning chemical composition and grain size distribution to the sinter mix. Besides addition of fines to the sinter plant, other solutions exist.

Primetals will present latest developments in the field of cold briquetting of ferrous by-products. Giving examples and results of executed project(s) of cold briquettes directly fed to the DR shaft, and other solutions for integrated steel mills.

Coal briquetting on the other hand is based on coal fines which often originate from wear during coal transport from mine to plant. These fines can be used to produced briquettes designed either for the use in a smelting reduction process (COREX®/FINEX®) or for enhanced coke oven operation in the traditional blast furnace route.

Primetals coal briquetting targets at the production of coal briquettes superior in mechanical properties and hot strength. Their application aims at an increase in productivity and reduction of costs. In the paper, Primetals will show different scenarios and solutions for coal briquetting technology.

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Keywords: Briquetting, Cold Briquetting, Coal Briquetting, Fines Compacting, By Products, Fines, Coal, Direct Reduction, DR, DRB, Direct Reduced Briquettes, Blast Furnace, Coke Oven, COREX, FINEX.

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1 INTRODUCTION

Government regulations around the world concerning environmental care are becoming more stringent, also including regulations and restrictions of depositing and use of dust, sludge and slag generated in the iron and steelmaking process.
With this scenario, by-products such as iron containing dust, sludge, oxide fines, mill scales and slag, become a valuable resource and recycling a profitable activity within a plant. Up to ten percent in mass of the total steel output are dust, sludge and mill scale by-product materials with an iron content ranging from 50% to 65% for fines.
At the same time, during the last years, iron ore prices have risen to levels above 100 USD/t (currently around 70 to 90 USD/t). Also the price for coking coal, and therefore for coke has gained momentum on the international markets.

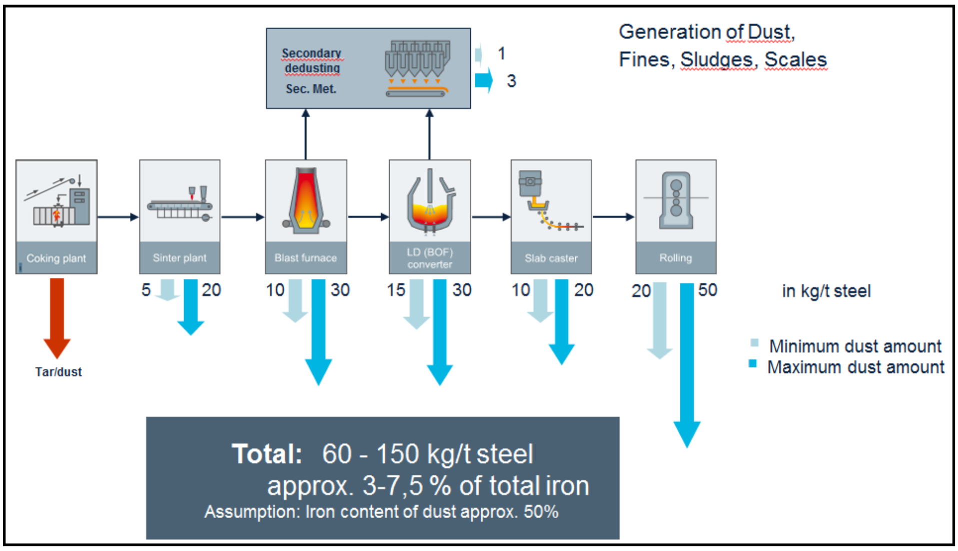

Figure 1: Typical by-product generation in an integrated steel plant

With this scenario, by-products such as iron containing dusts, sludges, oxide fines and scales as well as for example lime dusts and coal fines become a valuable resource and recycling a profitable activity within a plant. In DRI based plants a large amount of oxide fines, DRI sludge and DRI fines are generated in the process or during material and product handling.

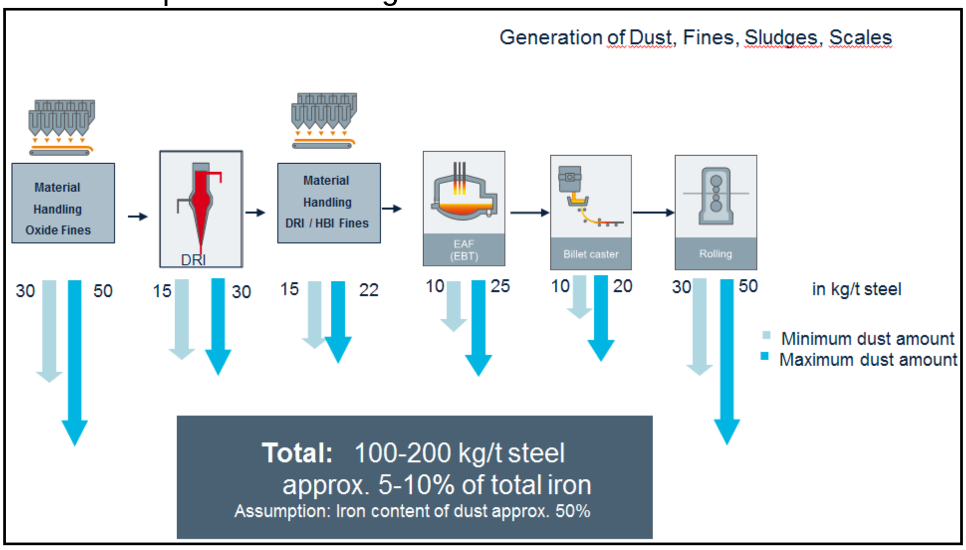

Figure 2: Typical by-product generation in a DRI based steel mill

In many cases, these by-products may be utilized in sinter plants where this is easily possible without further processing, or sold at low value in order to avoid the space consuming and sometimes costly option of depositing the materials in- or outside the plant. In certain cases the addition of mainly unconditioned by-products is possible, in some cases with a negative impact on the plant operation, such as increase generation of fines and reduction of productivity, and leaving still a large amount of by-products unused.
However, in many DRI based plants there is no sinter plant available for recycling and the most effective way to make use of the materials is in the direct reduction plant as partial pellet or lump ore substitute. The reuse of these by-products in DR plants is currently not common.

Primetals, in cooperation with voestalpine did comprehensive studies and tests in cold briquetting of iron containing by-products. To verify the physical stability and chemical reducibility of the briquetted material, extensive laboratory tests (e.g. static reduction test) as well as field tests – so called “basket tests” have been performed and proved to be successful. Furthermore, the first commercial, full scale briquetting plant with direct charging to the DR plant has been built by voestalpine Stahl, in Texas, US, together with Primetals as technology provider.

On the other hand coal briquetting is one of the oldest applications of agglomeration and aims to bring coal fines from mining or transportation to good use. Its development and application dates back to the 19th century and has since then been subject to constant further development. Whereas the first coal briquettes were produced by piston presses and mainly used as fuel for domestic/industrial heating, double roller presses nowadays allow for production of high capacities under good economic conditions and the application of coal briquetting in all sorts of industrial fields.[1,2]
Primetals Technologies has an over 30 years lasting tradition of developing coal briquetting for the iron and steel industry with the main fields of application being the use of coal fines for the Corex®/Finex® process [3] and the utilization of briquettes in coking plants [4].

2 DEVELOPMENT

Cold Briquetting

In order to include most or all of the generated by-products, cold briquetting of various dusts and sludges allows integrated recycling within existing primary production units. After pre-treatment of the residues, including drying, screening and mixing, binders are added and following the mixture is briquetted using roller-type presses. The selection of the binder system is dependent on desired metallurgical route for the respective recycling.

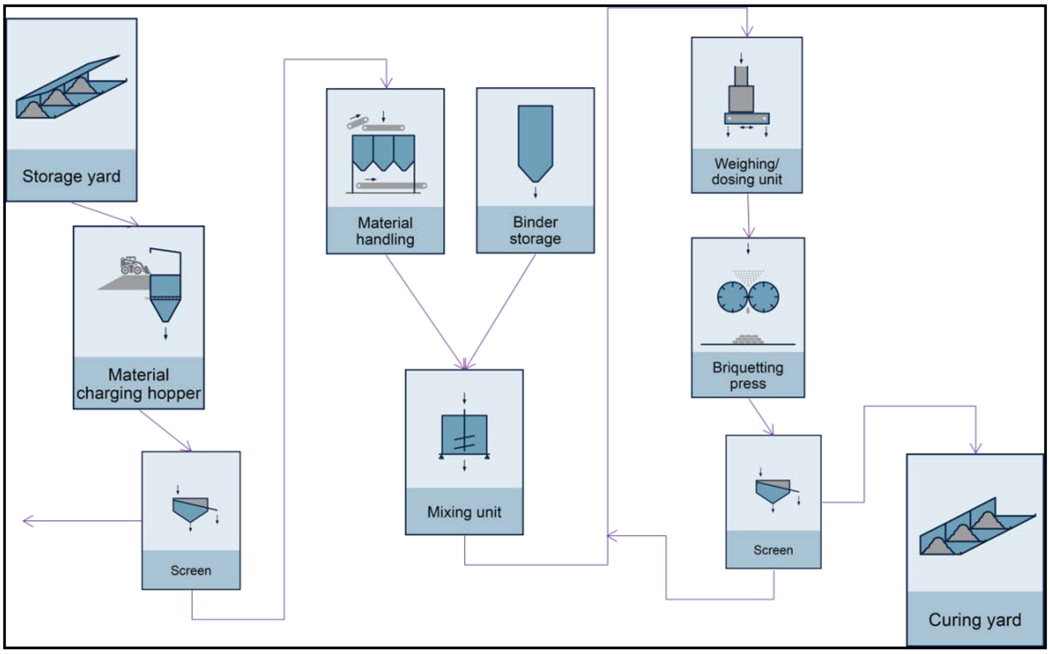

Figure 3: Block diagram of a cold briquetting process

In the first step of the cold briquetting process the by-products are collected in a material handling and storage system. The by-products are dosed in a defined proportion and are mixed while adding the binders. Afterwards the material is fed to a briquetting press. In a final step the product briquettes are screened and then conveyed to the curing and storage yard. Approximately 10% fines are internally recycled after the screening. Final product screening may be done just before charging the material to the process, e.g. a BOF converter or Blast Furnace or a DR plant.

An important issue when recycling by-product fines in the primary process is the limit on certain elements that may be harmful to the main process. This is mainly the case for Zinc, which is limited in the addition in the blast furnace. If recycled in the BOF converter, the content of Zn in the dust or sludge is significant and the Zn content increases as the material is recycled in the process. After several recycling steps the Zn content may increase from an initial value of below 3% to values above 20%. Measures have to be taken to limit the Zn content in the recycling process. This can be accomplished by measuring the Zn content online and separating the Zn–rich fraction. The Zn-rich fraction is then taken out of the recycling loop and may be used as raw material for Zn-production (e.g. in a Waelz process). The schematic of the separation of the Zn rich dust in a BOF converter process is shown in

Figure 4.

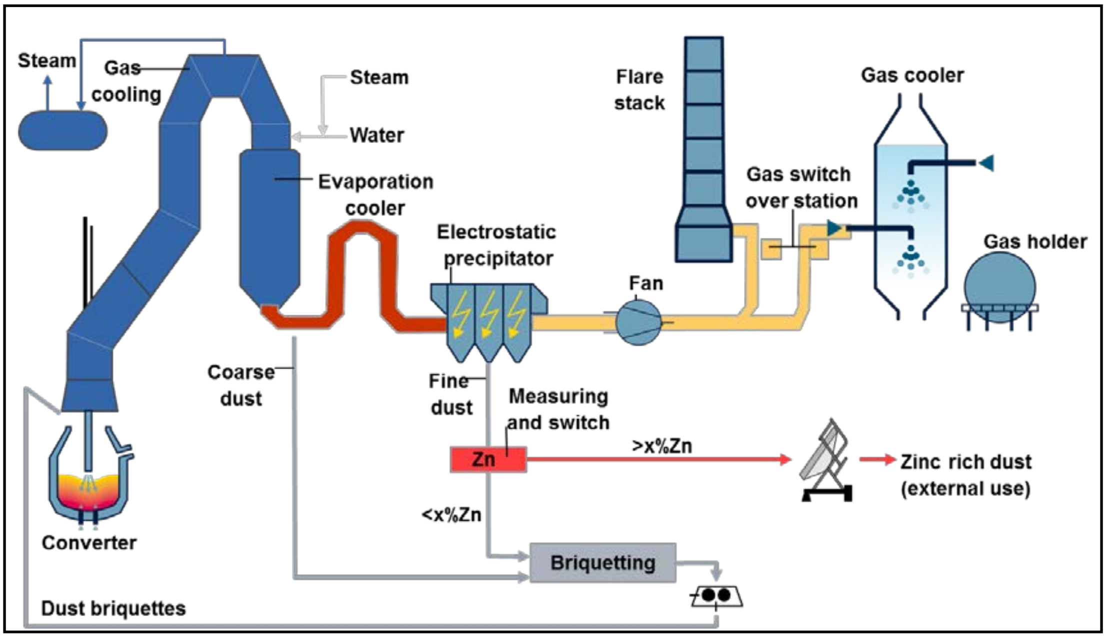

Figure 4: LD (BOF) recycling of briquettes with separation of Zn-rich dust

In DRI based steel mills there is normally no agglomeration plant such as a sinter plant available which would offer the possibility to recycle the generated fine by-products without agglomeration. Commonly only DRI fines (iron fines) are briquetted for charging in an electric arc furnace, while the oxide fines and other by-products rich in iron oxide but with low metallic iron content are not reused. In many cases it is not economical or generates little added value to sell and transport the materials to other plants for recycling. For these plants, the best recycling concept is to agglomerate the by-products, which may reach approximately 10% of the quantity of the produced DRI capacity.

The recycled materials may be blended with iron containing dust from the material handling systems, oxide fines, HBI fines and DRI slurry and can be recycled by cold briquetting with an inorganic binder system. The cold briquetting process itself is similar to the process shown in Figure 3. The produced briquettes are directly fed into the direct reduction plant (e.g. MIDREX or HYL) and replace expensive ferrous materials such as iron ore or pellets in the reduction shaft. The great economic value of such a project is determined by the high iron ore and pellet costs, compared to a relatively low operating cost and investment cost for a cold briquetting plant.

Coal Briquetting

The basic principle of coal briquetting is illustrated in Figure 5: Coal is sized and if necessary dried, then the binder is intermixed either in dry powdery form or as solution or a combination of both. Water, steam or other additives may be added according to the briquetting recipe. After pressing the briquettes, the curing process adds to briquette stability and strength.

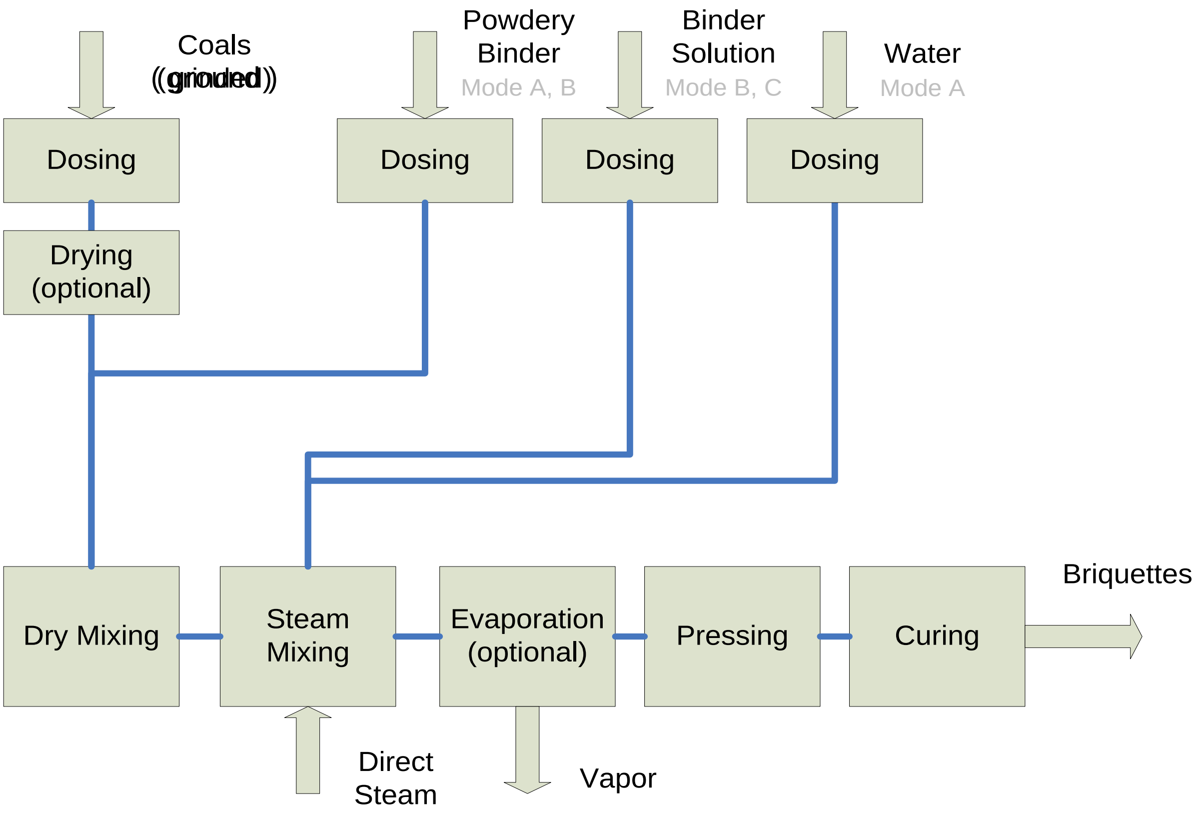

Figure 5: block diagram of coal briquetting with three different modes:

Mode A: solid (powdery) binder, dry mixing, water addition to adjust moisture, steam mixing
Mode B: solid (powdery) binder partially substituted by binder solution - added instead of water before steam mixing
Mode C: addition of binder solution before steam mixing step

Coal Briquetting for COREX® /FINEX® plants

COREX® and FINEX® have established themselves as commercially successful smelting reduction processes in the last decades [5, 6, 7]. The major reductant for COREX® /FINEX® is non-coking coal. The aim of coal briquetting lies within the utilization of otherwise hard-to-use coal fines and the substitution of lumpy coal. Target is the production of coal briquettes with low reactivity (when attacked by reducing gases) and good mechanical properties to support the burden in the fixed bed of the melter gasifier. (Figure 6)

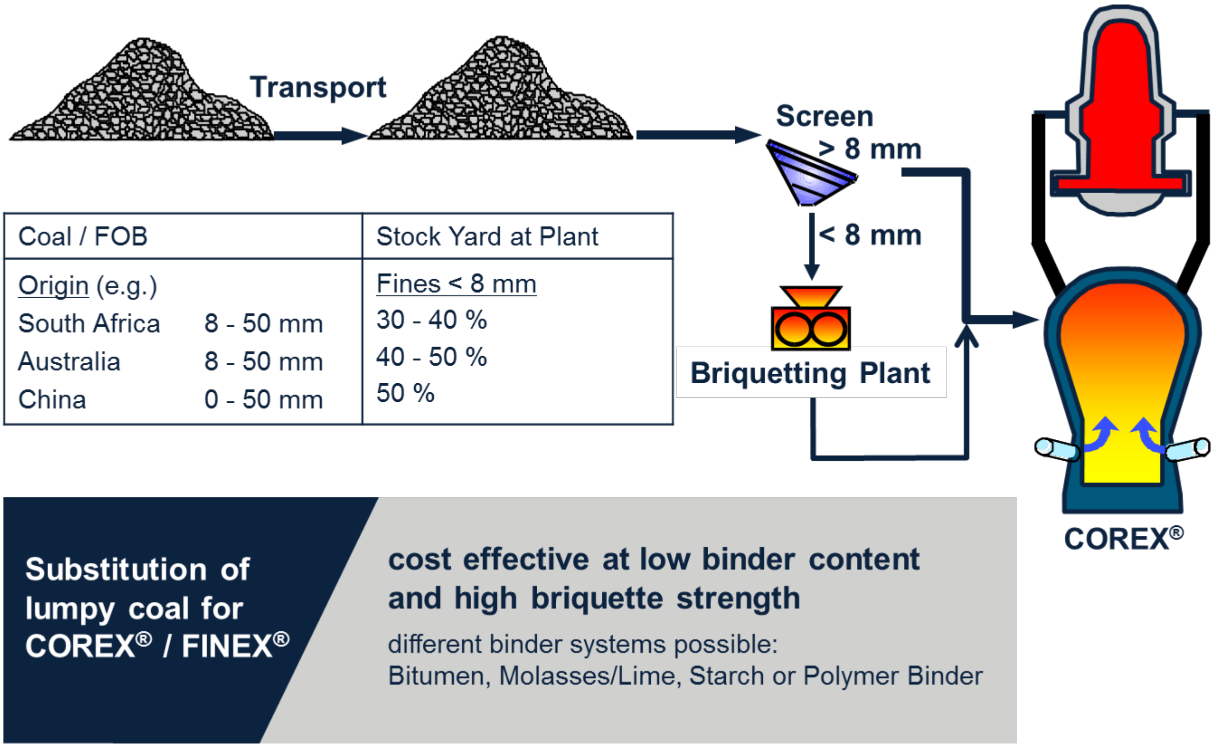

Figure 6: coal briquetting as a means of coal fines recycling and substitution of lumpy coals for COREX®/FINEX®

Coal Briquetting for Coke Oven Plants

Coal briquettes have been used in a number of coke oven plants in history (Table 1). The reasons for the individual plants vary, but it is clear that the technology offers different opportunities for the plant operator:

- an effective use of resources with coke of equivalent or even better quality
- reductionofproductioncostsor
- enhanced of coke oven plant productivity

Using the standard coal blend for partial briquetting with e.g. tar or pitch leads to enhanced coke quality due to higher density of coal feed. This was an objective at e.g. ISCOR Vanderbijl Park and Newcastle, S.A in 1991, using partial briquetting with up to 30% briquettes: “The introduction of partial briquetting has resulted in a marked improvement in coke quality. The improved coke quality in turn has resulted in much better blast-furnace operating conditions, and the productivity has increased” [4]. On the other hand, the use of lower-grade coal mixtures offers the possibility to save operation costs without the loss of coke quality. [8]

Company	Start-up / Operation	Type of briquetting	Briquette Amount [%]	Binder
Völklingen (1)	1959	Total blend (only 25% of briquettes remained stable)	25	no binder
Nippon Steel (Yawata/Kimitsu/Oita) (2)	1971/1975/1976	Partial briquetting	30	with binder
Nippon Kokan (2)	1970's	Partial briquetting	30	with binder
Sumitomo Metal Industries (2)	1970's	Separated briquetting	30-35	with binder
ISCOR (3)		Partial briquetting	30	pitch/crude tar
Krivoy Rog (4)	1987			Bitumen
Nippon Steel Oita Works (2)	1992	Partial briquetting (DAPS)	30	no binder (only fines < 0,3 mm are briquetted)
Nippon Steel Oita/Nagoya Works (2)	2008/13	Partial briquetting (SCOPE 21)	30	only fines are briquetted)
Kansai Coke & Chemicals/Kakogawa (2)	1977-1987	Partial briquetting		PDA (Propane Deasphalting asphalt)
JFE Steel Corporation/Fukuyama (2)	in operation	Partial briquetting		
JFE Steel Corporation/Keihin (2)	in operation	Partial briquetting		
Sumitomo Metal Industries/Wakayama (2)	in operation	Partial briquetting		

Table 1: industrial application of coal briquetting for coke oven plants
(1) Germany, (2) Japan, (3) South Africa, (4) Ukraine

Results

Coal briquetting – Study

Voestalpine Stahl GmbH intends to increase the coal throughput of their coke ovens to boost productivity by use of a coking feed with higher bulk density. For that purpose, the coking plant shall be charged with up to 30% briquettes in the coal feed. This measure is expected to lead to a coke production increase of up to 13%.
Voestalpine Stahl GmbH has conducted numerous research activities in the last years to investigate the influence of partial briquetting of their coking coal feed on the coke production and to determine optimum briquetting parameters such as briquette size, choice of binder and mechanical press parameters. The crushing strength of briquettes with crudetar as binder were low for green briquettes, while the shatter index was comparable to briquettes using bitumen or molasses or other binder, but seemed to be sufficient for further handling.
Based on voestalpine's preliminary examinations, Primetals Technologies developed an optimized plant concept for a coal briquetting plant at voestalpine's Linz site and carried out a study on the technological viability and feasibility of the implementation.
The plant concept includes careful drying at temperatures sufficiently low in order not to affect the coking characteristics of the coal blend, admixing of crude tar, pressing and cooling of the briquettes. A chips/fines recycling loop from after the roller presses

has been deemed unnecessary as well as bunkering the final mechanically weak briquettes.
Small-scale and semi-technical coking tests with coal blend – briquette mixtures showed good results for the chosen setup. Further tests are projected to examine the influence of the increased bulk density on coking time, gas and wall pressure in the coking chambers, strain on oven machines and life expectancy of the whole coking plant.

Cold Briquetting – Laboratory Tests

For the development of the Primetals Fines Compacting Technology, several test campaigns were conducted. The briquettes produced in the test campaigns were charged in soft baskets in reduction plants to verify their stability and metallization behavior under real production conditions. In Figure 7the oxide briquettes after passing the DRI shaft under reduction gas atmosphere are shown. The results fulfill the requirements of a direct reduction shaft concerning the low temperature disintegration behaviour (at 550°C). These results confirmed that the briquettes are stable under the reduction conditions. The basket tests results agreed well with the laboratory tests results (RDI tests), so that conclusion from the laboratory tests can be applied to actual plant conditions.

a)

SAMPLE ID-	T - 10	T - 14	T - 18	T - 19	T - 23
CHEMICAL ANALYSIS (%)					
Total Iron as Fe	78.45	81.31	78.03	77.5	81.97
Metallic Iron as Fe	66.88	74.65	71.83	72.41	80.41
Metallization	85.25	91.80	92.05	93.43	98.11
FeO	14.88	8.57	7.98	6.54	2
Carbon as C	2.76	3.27	3.36	3.41	3.43
Sulphur as S	0.0097	0.0043	0.0062	0.0043	0.0072
Phosphorus as P	0.052	0.045	0.056	0.063	0.068

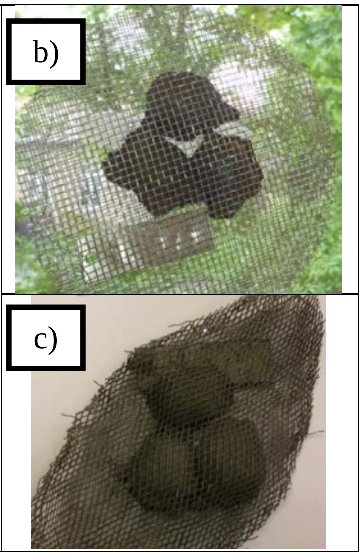

Figure 7: Soft basket tests in reduction shaft a) results of test campaign b) fresh baskets before test c) deformed soft baskets after test

Cold Briquetting – Industrial Scale Installation

The recycling concept for by-products generated in DRI plants has not yet been used until recently in an industrial scale. Based on the technology developed by Primetals the first plant of this kind was implemented by voestalpine Texas LLC in Corpus Christi.

This plant produces briquettes from the by-product fines such as pellet fines and dust, DRI sludge, HBI fines and miscellaneous dusts generated in the plant, which can be recycled directly in the main DRI process in the same location, without necessity of long transportation and avoiding manual handling of the by-product fines. The major part of the by-product fines generated in the process are either transported directly from the collecting silos to the briquetting plant (oxide fines) or have a very short transport distance (DRI sludge), as shown in figure 4.

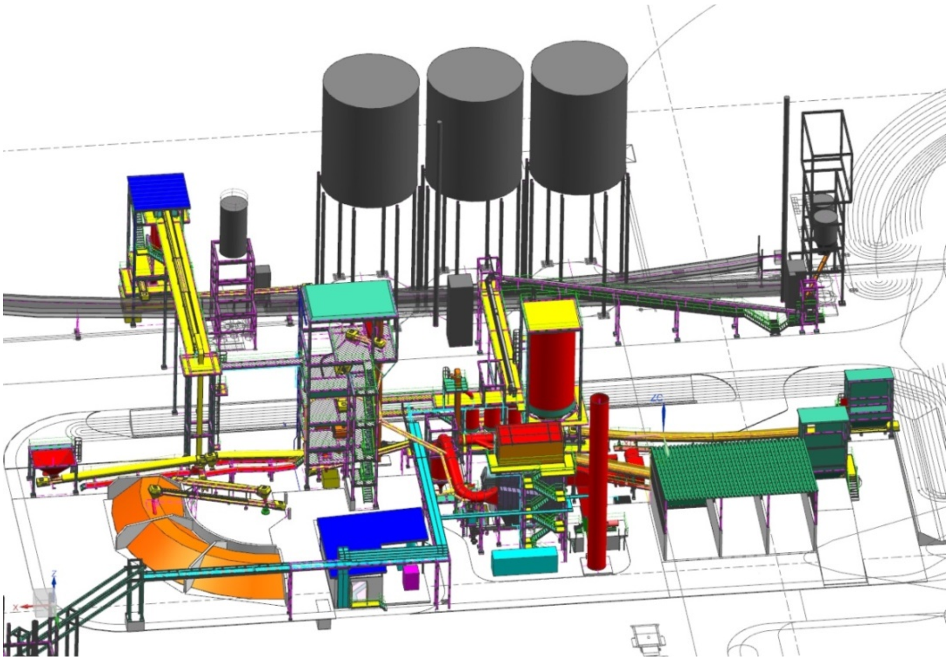

Figure 8: 3D View of a cold briquetting plant for by-products in a DRI plant with direct recycling of briquettes in the main process.

Figure 9: Picture of a cold briquetting plant for by-products as an integrated part of a DRI plant at voestalpine Texas LLC; start up 01.2017

Fines Recycling Plant		
Feed material	pellet fines, sludge, HBI chips and fines, misc. dust	
Annual Capacity	approx. 160.000	t/a
Design Capacity	24.6	t/h (briquettes)
Binder system	inorganic binder	
Briquette size	approx. 5	ccm
Start Up	01.2017	

Table 2: plant data of Fines Recycling Plant, voestalpine Texas LLC

3 CONCLUSION

Briquetting, indeed, is a very smart solution to

- Re-use by products such as fines, dust, sludge, scales, etc.
- Reducethereforeenvironmentalimpact
- Reduce operating cost due to substitution of costly primary raw materials (e.g. DR grade pellet)
- Increaseproductivity
- Increase quality or keep quality with worse input material

With many tests (industrial & laboratory) and a full scale industrial plant, the benefits of briquetting have been shown.

Acknowledgments

We would like to thank Voestalpine Texas LLC and Voestalpine Stahl GmbH for the cooperation on this work

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