Fines Briquetting — Improving the Economics and Closing the Material Loop at Direct Reduction Plants



Authors

Alexander Fleischanderl (top row, left)
technology officer upstream, vice president iron and steelmaking, head of ECO solutions, Primetals Technologies Austria GmbH, Linz, Austria
alexander.fleischanderl@primetals.com

Christian Brunner (top row, right)
process and safety engineer, Primetals Technologies Austria GmbH, Linz, Austria
christian.a.brunner@primetals.com

Jörg Schwelberger (bottom)
senior sales manager, Primetals Technologies Austria GmbH, Linz, Austria
joerg.schwelberger@primetals.com

At direct reduction (DR) plants, a significant amount of byproducts are generated as pellet fines, DR sludge and various dusts from material handling. The most economical way to close the material cycle is to agglomerate these byproducts in a fines briquetting plant applying a binder system that allows feeding the briquettes to the reduction shaft. Primetals Technologies has installed a first-of-its-kind briquetting plant at voestalpine's Midrex plant near Corpus Christi, Texas, USA. The plant was successfully commissioned in 2017. A status report will be provided and results including performance impact and economic feasibility on the Midrex operation will be discussed.

The fines generated in direct reduction (DR) plants and downstream facilities, such as steel plants and rolling mills, are typically seen as a problem to be solved, considering that the amount of undersized material results in a reduced iron yield and additional costs for handling of these byproduct fines. Reutilization of such materials in the process is therefore highly beneficial in reducing operation costs. In some cases, these fines can be used directly, up to some limit, e.g., in sinter plants. However, in many cases, in locations where DR plants are operated, there is no sinter plant available nearby.

The options for the destination of byproduct fines is summarized in Table 1.

Around the world, government regulations and restrictions of depositing, transport, and use of dust, sludge and slag generated in the iron- and steelmaking process are becoming more stringent, and the pressure on the direct reduced iron (DRI) or steel producers higher.

With this scenario, where depositing becomes more difficult, byproducts such as iron-containing dust, sludge, oxide fines, mill scales and slag may be turned into a valuable resource and recycling may become a profitable activity within a plant.

Table 1

Options for Use of Byproducts

Option	Advantages and disadvantages
Deposit/storage	Space/cost/regulations
Export/sale	Profitability/transport cost
Processing in dedicated plant	High investment cost/process reliability
Integrated plant: a. Addition to sinter plant — blast furnace route b. Briquetting and addition to blast furnace or basic oxygen furnace	Restriction for chemical composition a. Zn, Alkalis b. Less restriction in basic oxygen furnace, Zn needs to be taken care of
Direct reduced iron/electric arc furnace: Briquetting and processing in existing plants	Low investment cost/agglomeration process/influence on existing plant

This article is available online at AIST.org for 30 days following publication.

Table 2

Typical Quantities of Byproducts Produced in Direct Reduced Iron (DRI)-Based Plants

	Specific generation (kg/t DRI)			Annual generation for 2-million-tpy DRI/HBI (kt/a)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Oxide fines	30	54	44	61	109	87
DR sludge	17	45	25	33	90	49
DR fines	8	20	14	17	40	27
DR dust	6	26	16	13	52	32
EAF dust	8	18	11	16	35	23
Scale	13	16	14	25	31	28
Others	2	8	5	4	15	10
Total	84	186	128	169	372	257

The percentage in mass of the total steel output generated as byproduct such as dust, sludge and mill scale is very high, on the order of 10% in weight of the total steel produced, and these byproducts have an iron content ranging from 50% to 65%, similar to that of iron ore.

Typical quantities, from a representative sample of plants, for byproduct generation for a direct reduction plant producing DRI or hot briquetted iron (HBI) are listed in Table 2.

In recent years, iron ore prices have risen to levels above US$100/ton (currently around US$70–90/ton), and the current DR pellet price is US$120–140/ton. The high raw material cost and the high quantities of byproduct fines with high iron content make it a logical choice to reuse these materials as a partial substitute for iron ore pellets. The reuse of these byproducts in DR plants was not practiced until recently, due to the lack of the appropriate agglomeration technology and know-how.

During the early stages of the voestalpine direct reduction project in Corpus Christi, starting in 2013, Primetals Technologies, in cooperation with voestalpine, did comprehensive studies and tests for cold briquetting of iron-containing byproducts, in order to develop the appropriate method to produce briquettes from byproduct fines that are suitable for use in direct reduction plants.

In order 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") were performed and proved to be successful. Based on these developments, the first commercial, full-scale briquetting plant with direct charging to the DR plant was built.

Cold Briquetting: Development and Process — The goal was to develop a process for the production of briquettes including most or all of the generated byproducts that may be used for integrated recycling in existing primary production units. The process steps to achieve this goal were investigated in detail and the parameters necessary to produce the briquettes with the appropriate properties were determined.

In the first step of the cold briquetting process, the byproducts are collected in a material handling and storage system. The process includes pre-treatment of the residues, including drying and screening, if necessary. The byproducts are dosed in a defined proportion and mixed while adding the binders. The selection of the binder system is dependent on the desired metallurgical route and application of the respective recycling product. 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% of 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, blast furnace or a DR plant. Critical for the process is producing briquettes that can withstand the handling, the conditions in the DR shaft, and that the iron oxide can be reduced with high efficiency.

Cold Briquetting: Laboratory and Field Tests — For the development of the Primetals Technologies 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 Fig. 1, the baskets of oxide briquettes before and after passing the DR shaft under reduction gas atmosphere are shown. These tests confirmed that the briquettes are stable under the reduction conditions. The basket test results agreed well with the laboratory test results

Figure 1

(a) (b)

Briquette basket before reduction shaft (a) and after reduction shaft (b).

(e.g., RDI tests), so that conclusion from the laboratory tests can be applied to actual plant conditions.

Basket tests have been made with several material combinations and show a typical metallization degree of the briquettes of 90% or even higher.

Cold Briquetting: Industrial-Scale Installation — The recycling concept for byproducts generated in DRI plants had not yet been used until recently in an industrial scale. Based on the technology developed by Primetals Technologies, the first plant of this kind was implemented by voestalpine Texas LLC in Corpus Christi, Texas, USA.

This plant produces briquettes from the byproduct 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 byproduct fines. The major part of the byproduct 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). Fig. 2 shows a view of the briquetting plant.

The plant is located near the iron oxide pellet day bins and the conveyor that transports the oxides to the Midrex shaft. The design allows a direct transport of oxide fines from the pellet fines silo. The dewatered sludge is generated in the nearby water treatment plant. The transport distance by the front loaders of the filter cake is only approximately 50 m.

The materials can be charged into dosing hoppers that can handle and dose the filter cake with a humidity of around 20%. The filter cake is stored in a covered storage area and is then transported and dumped into the dosing hopper, then dried to humidity levels below 4%.

The briquettes are produced from the mix of available materials with a precisely defined recipe including oxide fines, dried DR sludge, miscellaneous fines and dusts, and binder. The briquettes are then screened and the fines from the screen recycled to the briquetting process, so that no net fines are produced. After the screen, the briquettes are transported to a curing bin and from there charged onto the iron ore pellet conveyor as addition to the raw material mix. Alternatively, the briquettes can be stored in an intermediate storage yard.

The plant is designed to process approximately 160,000 t/a of byproduct fines. The plant data is summarized in Table 3.

Being the first industrial plant of this kind, during the first months of operation only a small amount of briquettes were charged to the DR plant, amounting to approximately 1% of the oxide charge.

During the first charging of the briquettes to the pellet feed system, the stability of the briquettes was monitored at different points in the charging system. It could be observed that the briquettes remained intact during the transport into the furnace (Fig. 3).

Figure 2

A cold briquetting plant for byproducts as an integrated part of a DRI plant at voestalpine Texas LLC.

Table 3

Key Design Parameters for Fines Recycling Plant at voestalpine Texas LLC

Feed material	Pellet fines, sludge, HBI chips and fines, miscellaneous 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	January 2017	

Figure 3

Oxide briquettes being charged to the DR plant.

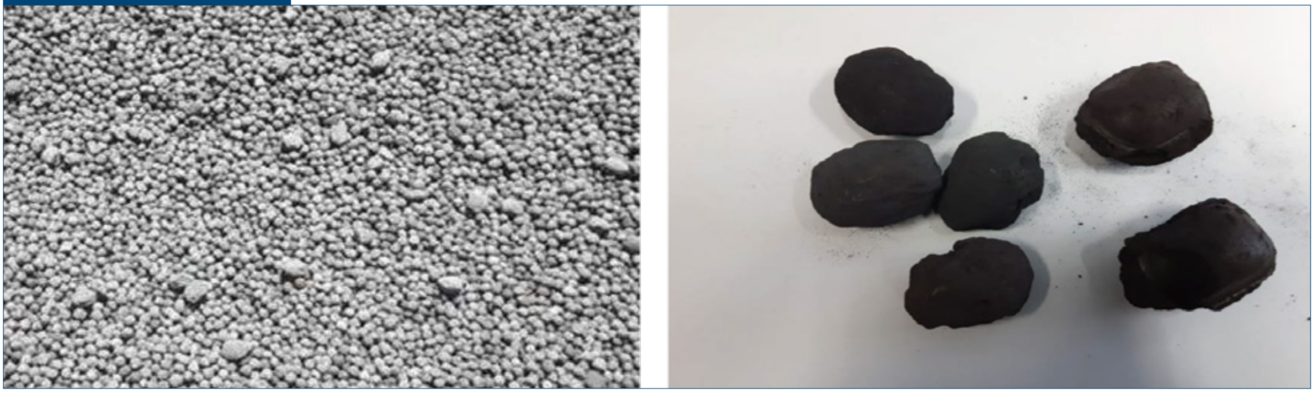
During the initial test runs, no influence on overall product quality, HBI metallization or carbon content could be observed.

Compared to DR plants producing DRI, at the HBI plant in Corpus Christi it is not feasible to recover test baskets. In order to get an indication of the metallization of the oxide briquettes separately from the reduced pellets, the analysis was made with the Remet produced. The analysis and evidence of the briquettes in the Remet again confirm that the oxide briquettes are stable in the reduction shaft (Fig. 4) and show a metallization rate similar to the one of the pellets.

Cold Briquetting: Economics for Typical DR Plant Cold Briquetting Operation (example, not related to the voestalpine plant) — In order to show the economic impact of a fines recycling plant within a DR plant complex, an example of a cold briquetting plant with an annual capacity of 200,000 t/a is analyzed.

The economic advantage of a briquetting plant results due to the fact that the fines are available for free, and the conversion cost to produce proper cold briquettes is significantly lower than the purchase cost of pellets. In Table 4, the possible economic benefits are shown.

Figure 4



Oxide briquettes after reduction in the DR plant.

Table 4

Comparison of Costs of Cold Briquettes and Pellets and Economic Advantage

	Briquettes	Pellets
Fe content	62%	66%
Metallization	93%	94%
Fe in DRI as % of charge material	58%	62%
Required input material (compared to 100% pellets to produce same amount of reduced iron)	107%	100%
Capacity (briquetting plant output/equivalent pellets)	200,000	186,480
OpEx	US$3,605,800	—
CapEx (interest + depreciation, 10 years)	US$1,800,000	—
Specific cost per ton	27	130
Annual cost of briquettes (equivalent pellets)	US$5,405,800	US$24,242,360
Annual gain by recycling fines	US$18,836,560	—

The basis for the comparison was made on typical costs (electricity, utilities, manpower, pellets, investment) and should illustrate a case study. The numbers demonstrate a very short payback time for an installation of a cold briquetting plant.

Conclusion

Considering the evidence from the laboratory tests and the first test results from the industrial plant of voestalpine Texas LLC, it can be concluded that the recycling of byproduct fines in DR plants is possible and recycling by cold briquetting is, from an economical point of view, the best solution for handling byproduct fines.

The main advantages after installation of a fines recycling plant include:

- Reuse byproducts such as fines, dust, sludge, scales, etc.
- Reduce or eliminate handling and shipping costs of the fines.
- Reduce the environmental impact.
- Reduce operating costs due to substitution of costly primary raw materials (e.g., DR-grade pellet).
- Increase productivity and yield.

A solution for the recycling of fines, similar to the installation of voestalpine Texas LLC, can be implemented in almost all direct reduction plants and other similar integrated steel plant applications. ✦

AISTech

This paper was presented at AISTech 2018 — The Iron & Steel Technology Conference and Exposition, Philadelphia, Pa., USA, and published in the Conference Proceedings.