Evaluation of the Briquettability of hot DRI from different Direct Reduction Technologies and various Ores

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1. Introduction

Around the globe, a large number of direct reduction plants that utilize different reduction technologies are operating successfully. Additional installations are being planned or are already in different stages of construction [1].

If the DRI (Direct Reduced Iron) is not directly used in an integrated steel mill, the production facilities are called merchant plants. The highly reactive material from these works must be passivated prior to its storage and distribution to distant consumers. The level of passivation depends on the method and distance of transportation. The most reliable passivation is obtained if the still hot DRI is immediately densified. This technique which is required by the IMO for overseas shipment also allows the intermediate storage, transshipment, and distribution of the product to brokers and unrelated users.

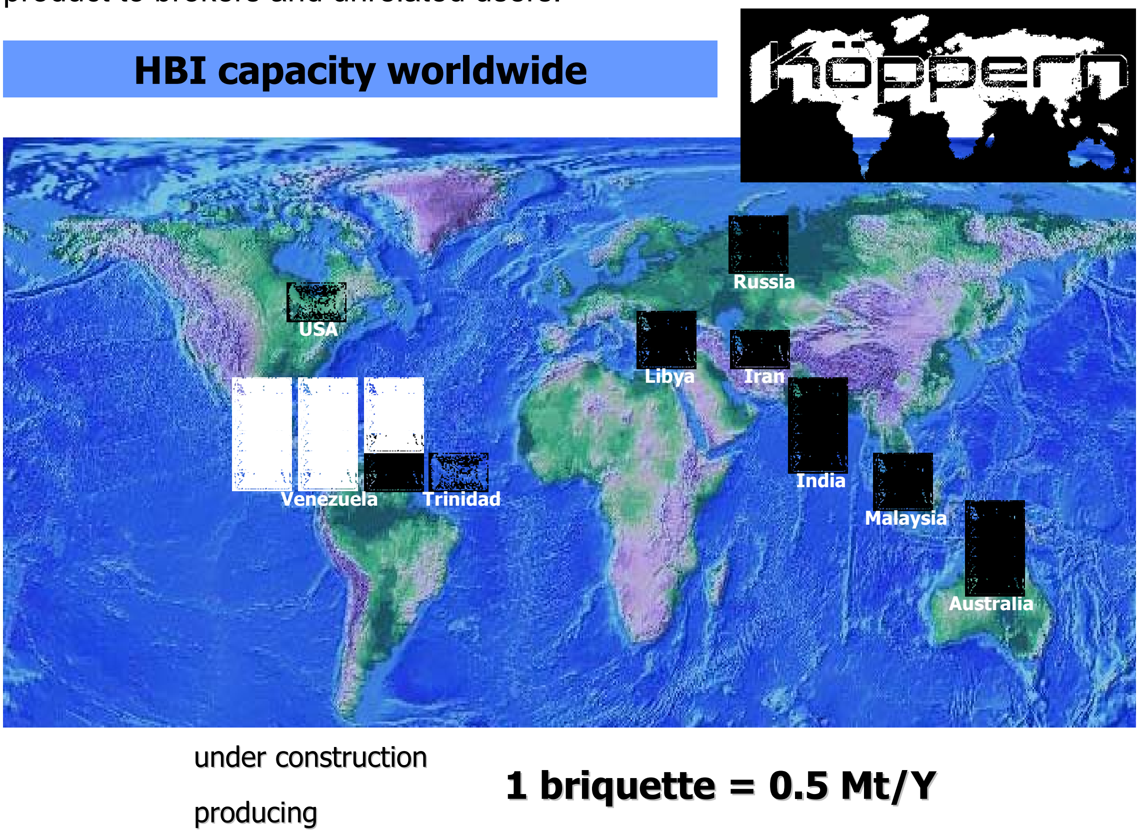

Figure 1: HBI production capacities worldwide (Status 07/00)

In all plants with hot densification that are in operation and being planned today, the process is carried out in specially designed roller presses that produce Hot Briquetted Iron (HBI). The large specific surface area of untreated DRI which causes the high reactivity of this material is so much reduced in the briquettes, that an effective and lasting passivation is realized. Details of the hot briquetting system will not be presented in this paper. For further information on this technology the literature should be consulted [1].

Figure 1 shows the locations of direct reduction plants with hot briquetting. Facilities that are already producing HBI as well as those under construction are depicted.

For the development of new HBI projects, questions arise as to how easily specific ores can be reduced with a particular direct reduction process and how well the resulting hot DRI can be briquetted. This is of particular importance if modified or new direct reduction technologies are considered.

The most reliable method to test direct reduction and briquettability is the design, installation, and operation of a pilot plant. Pilot plants that included hot briquetting were used in the development of US Steel's Nu-Iron (later called HIB), Thyssen's Purofer, and Esso's FIOR processes. Midrex also operated a temporary HBI pilot plant prior to this company's engagement at Opco and Venprecar in Venezuela and HYL routinely tests ores and the hot briquettabilitiy of the resulting DRI at a pilot system in Monterrey, Mexico.

For evaluating the briquettability of hot DRI, other methods are now available for obtaining basic information which, in comparison with the scale of a pilot plant, require only a small amount of material and effort. The present state-of-the-art in this field is the topic of the following discussions.

2. TESTS FOR THE DETERMINATION OF BRIQUETTABILITY

KÖPPERN carries out general hot briquetting tests for quite some time already. For the determination of parameters influencing the production of HBI, two methods are available. The selection and application of either or both of these depends, among other criteria, on the amount of sample that is available for testing. Table 1 is a summary describing the methods.

	Laboratory	Test Facility
Size of DRI Sample required	20 kg	600 - 800 Litres: 3 - 4 trials each 200 Litres
Test Equipment	Punch and Die Press	Roller Press
Test Result	Relative Quality (qualitative)	Press and System Design (quantitative)

Table 1: Summary of two test methods that are available for evaluating the briquettability of hot DRI

The laboratory tests are carried out at the University of Freiberg, Germany, in cooperation with a staff that has many years of experience in the field of agglomeration and briquetting. The test facility is located at KÖPPERN in Hattingen/Ruhr, Germany.

2.1. LABORATORY TESTS

At the beginning of a project, often only a small sample of the reduced iron ore is available. By selecting the punch and die press only 20 kg of material are sufficient for a complete series of tests. Results may be:

- a first survey regarding briquettability of DRI from a modified or new direct reduction process
- a first evaluation of the DRI from a new ore source
- investigation of the influence of specific parameters on hot briquetting.

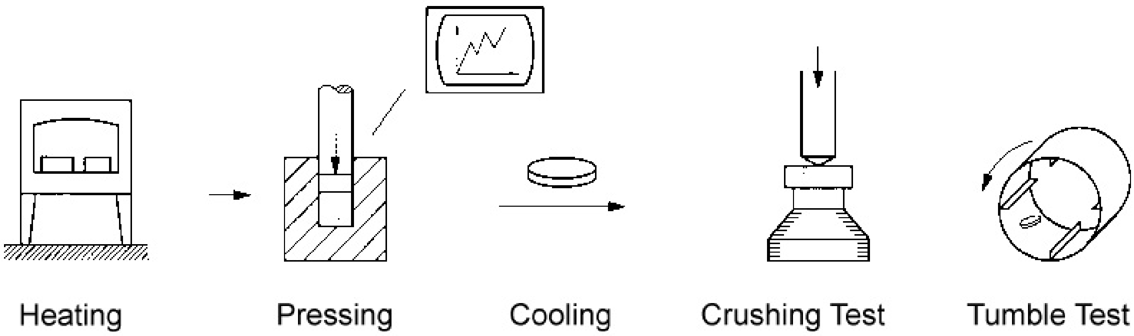

Figure 2: Schematic representation of laboratory testing procedures.

Typically, the sequence of testing is as follows:
- Heating of the sample
- Densification in a punch and die press (including recording of the pressure/ densification plot)
- Cooling of the compact
- Crushing test
- Determination of the abrasion resistance (tumble test)
- Additional testing such as chemistry, porosity, etc.

Figure 3: DRI samples from pellets and fine ore and corresponding compacts produced in the punch and die press

Normally, for each material, the investigations are carried out at different temperatures and compaction forces. To avoid errors by random results, several tests are evaluated for each condition. Figure 3 is a photograph showing two DRI samples (in this case from pellets and from fine ore) as well as corresponding "tablets" that were produced in the punch and die press. The goal of the investigations is to compare compacts in relation to each other.

The parameters, characteristics, and results that are determined during the evaluation of new materials are ranked in comparison with those obtained by the same test method from materials which are already being processed in existing industrial plants. This yields a relative statement as to whether the higher, similar, or lower quality may be expected from a large scale facility. Figure 4 is a schematic presentation of how this procedure works.

Because of the small amount of material that is required for a single test, in addition to the parameters of briquetting (pressing force and temperature), the influence of DRI characteristics on briquettability can be investigated with this laboratory method. For this purpose, individual reduction parameters are varied during a laboratory reduction test and their influence on compact quality is determined.

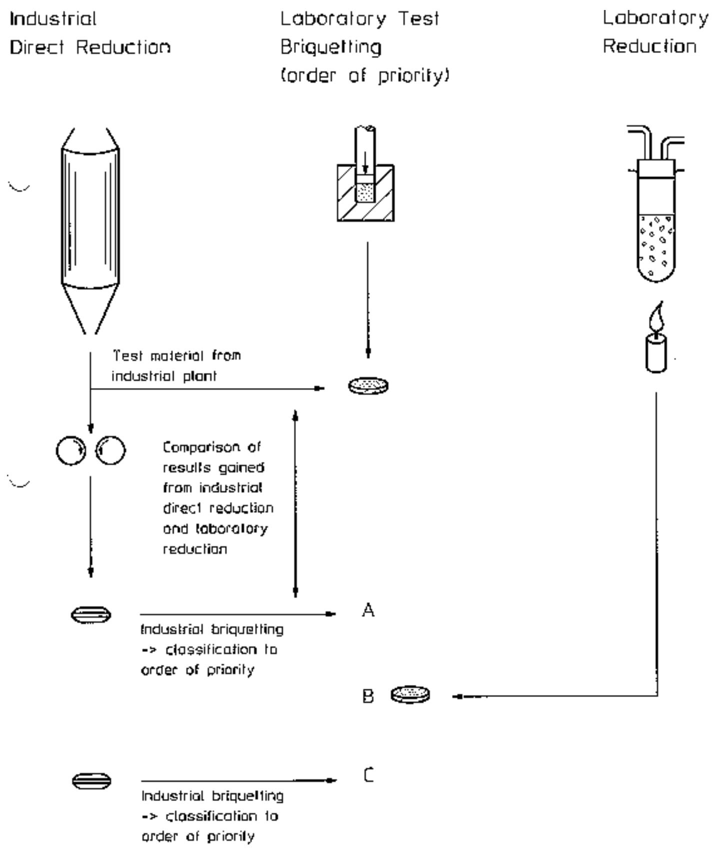

Figure 4: Schematic representation of the ranking procedure used to compare the results of tests on new materials with those already processed in industrial plants.

2.2. TRIALS USING A ROLLER PRESS IN THE TEST FACILITY

In the test facility trials are carried out on a commercial sized, highly instrumented roller press (Figure 5).

Figure 5: Large scale instrumented roller press at KÖPPERN's test facility.

Roller diameter	1,000 mm
Roller width	140 mm
Max. drive power	400 kW

Also available is an electrically heated furnace with controllable athmosphere for the heating of the sample (Figure 6).

Because of the commercial size of the equipment (Figure 5), approx. 200 Liters of DRI, corresponding to approx. 300 kg at a bulk density of 1.5 kg/liter, are required for each test. To eliminate the influence of random deviations, at least 3 to 4 trials should be carried out, this corresponds to an approx. amount of 600 to 800 Liters of DRI that is required for operating the test facilitiy. Only if these trials are conducted, scale-up considerations are possible for the design of an industrial briquetting system.
While the optimal temperature depends to a great extend also on the direct reduction process, the required pressing force and drive power, among other parameters, are determined. Product quality is determined by means of appropriate tests providing apparent density of the briquettes as well as drop (shatter test) and crushing (compression test) strengths.

Figure 6: Electrically heated furnace at KÖPPERN's test facility during the extraction of a hot test sample.

3. Some typical results

In the following, some results of the laboratory evaluation are presented first. The possibilities also the limitations of these tests will become evident.

Figure 7 illustrates the influence of temperature on the apparent density of the compact from different DRI-products at constant pressing force. The graph shows that up to a temperature of approx. 450 °C the apparent compact density changes only little and, for some materials, levels out above 800 °C. Although not depicted in Figure 7 and without going into a more detailed discussion, it should be mentioned that an insufficient apparent density observed at a low temperature is difficult to be compensated by applying a higher pressing force.

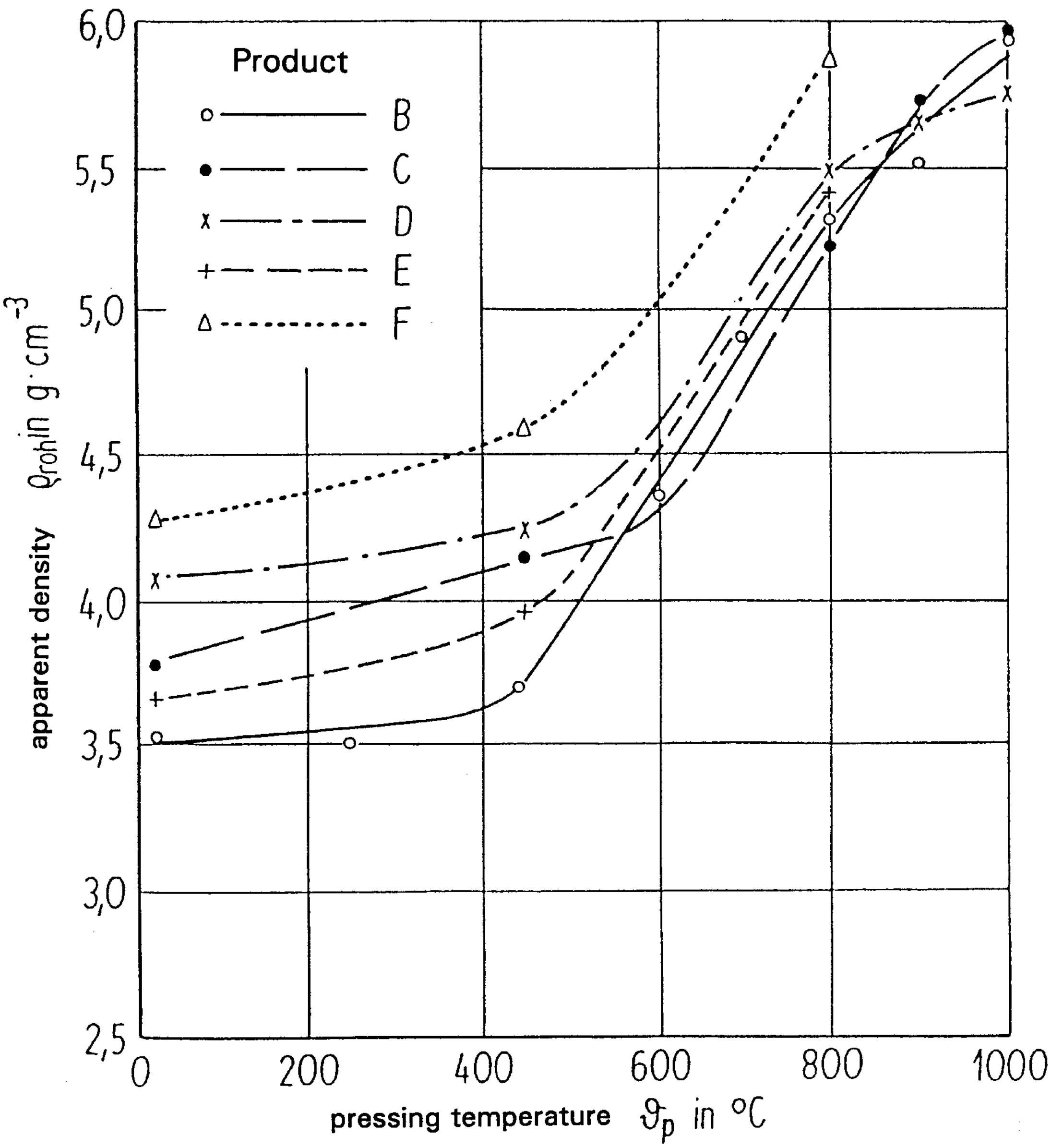

Figure 7: Diagram showing the influence of temperature on apparent density of the compact at constant pressing force for different DRI products.

Other measures of quality, for example the abrasion resistance of hot compacted DRI, show a similar influence of temperature (Figure 8).

As mentioned before, the main purpose of roller press trials in the test facility is to obtain data for the selection and design of industrial equipment and systems. Figure 9 shows, for example the plot of pressing force and torque versus time that was recorded during such a test. The stable operation during approx. 20 seconds between an initial peak at the beginning and the drop of both parameters when the feed was consumed is used to evaluate the briquetting behavior.

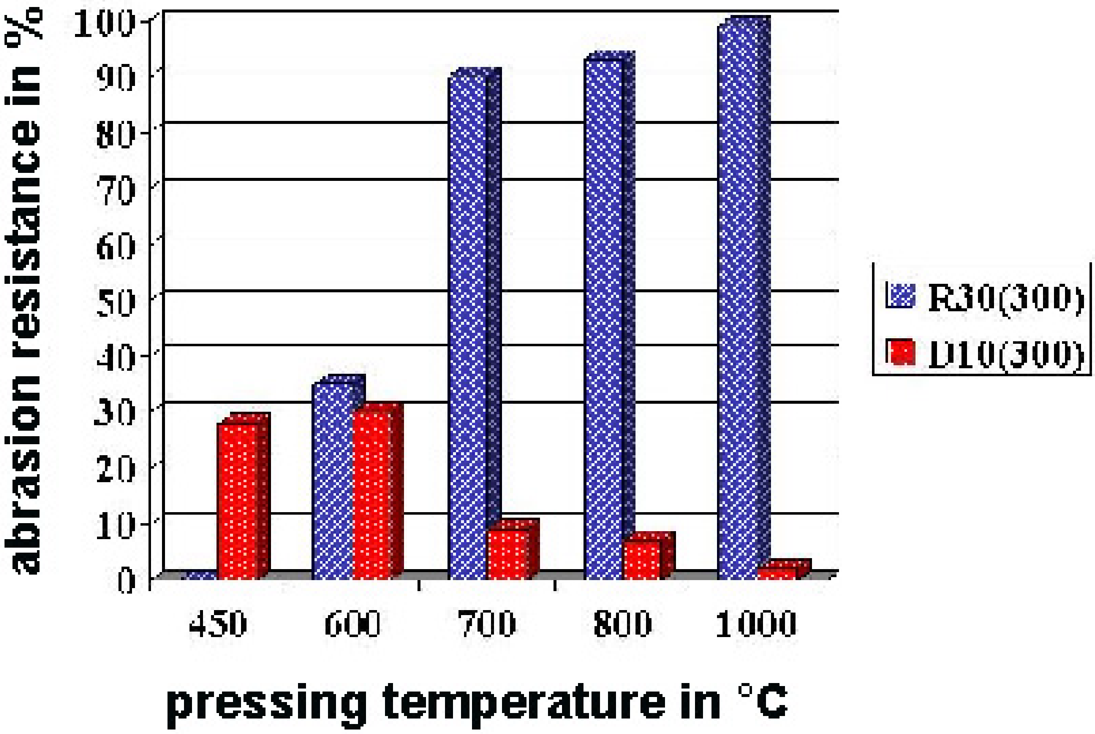

Figure 8: *Influence of the temperature on the abrasion resistance of hot compacted DRI.*
R30 (300): Amount retained on a 30 mm screen after 300 revolutions of the tumble drum.
D10 (300): Amount passing a 10 mm screen after 300 revolutions of the tumble drum.

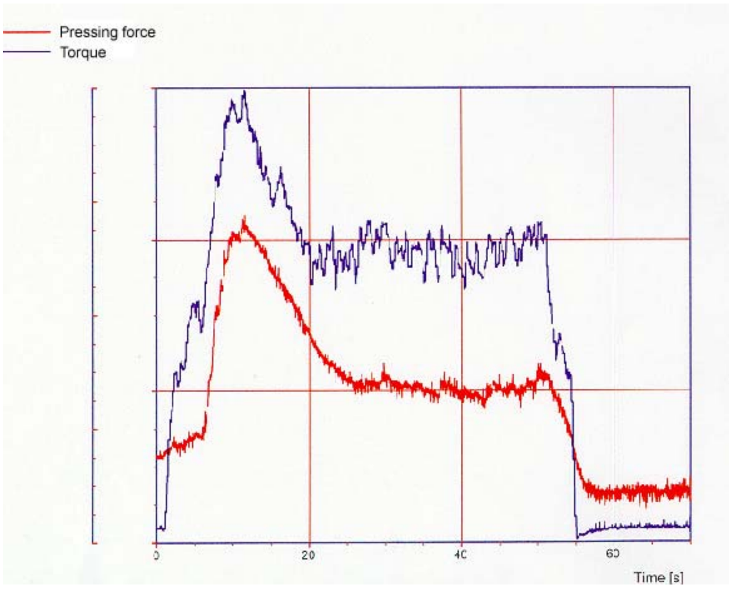

Figure 9: *Record of pressing force and torque as a function of time during a test in the roller press at KÖPPERN's facility.*

4. Conclusions

The best theory is never as good as the practical test.

Therefore, in cooperation with the University of Freiberg, Germany, KÖPPERN has developed test methods for the investigation of hot briquetting of DRI. Results, including comparative ratings, have been collected for quite some time.

These data are an excellent basis for evaluating the briquettability of products from modified or new direct reduction processes and/or new ore sources.

For the final design and lay-out of an operating system, commerically sized roller presses are available at KÖPPERN's test facility in Hattingen/Ruhr, Germany. Using these machines, further trials with larger amounts of material are carried out.

Information relating laboratory and test center data with experiences from the field are available and are continually supplemented.

5. Reference List

1. W. Schütze, HBI - A proven Product for Growing Markets, Simposio Siderurgico, Ciudad Guyana 1997
2. MIDREX World Direct Reduction Statistics 96