

Some experiences in the sintering of iron ores

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AS PART of a 2 m. ton expansion project, the Tata Iron and Steel Company set up an ore-crushing and sintering plant to provide a sized ore plus sinter feed to the blast-furnaces. The sinter plant started operation in late 1959, and the experience gained as a result of plant operation as well as comprehensive laboratory tests is discussed in this paper as it focuses attention on some of the difficulties encountered in sintering hematite ore fines.

THE PLANT

The sintering plant comprises two Lurgi continuous strand machines, each having an effective suction area of 810 ft² over 15 wind boxes with 98 ft suction length. The strand is made up of 85 individual pallets, each of 8 ft 2½ in × 3 ft 3⅝ in. Each strand is rated at a capacity of 2500 tons of sinter per day.

The feed for the sinter strand is prepared in a slowly rotating primary mixing and wetting drum where most of the water needed for the mix is added. The raw mix is then transferred to the sinter building and stored in the single hoppers located above each sintering machine. This is drawn out of the hoppers by a variable-speed trommel feeder and charged into secondary mixing and re-rolling drums. The final mix is distributed in the strand charging hopper along its whole length by means of a shuttle conveyor. The mix is then put on the strand with the help of a trommel feeder by means of a chute which has an adjustable gate by which the bed height can be controlled. Located behind the raw-mix hopper is a hearth layer surge bin from which a hearth layer, composed of +½-in sinter, is laid on the pallets giving a depth of about 1-1½ in.

The ignition hood is situated over the first two wind boxes; the fuel used is coke-oven gas having a calorific value of 490-500 Btu/ft³. The ignited charge travels at a machine speed of 7.9-10.5 ft/min, and the suction is maintained by the sinter fan designed to draw 212 000 ft³/min of air at 177°C and a suction of 40 inwg.

The sinter, discharged from the pallets, goes through a spiked roll crusher to reduce the maximum size to 8 in. The product is hot screened to remove the -¾ in fines for return sinter; the oversize enters the Lurgi coolers. Each strand has an independent cooler having 1 000 ft² of effective cooling area, and a fan capacity of 142 000 ft³/min at 2 inwg at 150°C. The discharge from the cooler is then belted to the screening station, where +½-in fraction is removed for making the hearth layer.

The sinter is then conveyed to either ground storage bins or the blast-furnace high-line sinter bunker.

QUALITY OF SINTER

After some initial trials in the operation of the sintering machines, several attempts were made to standardize on the optimum procedure for making a uniform grade of sinter. In this work, it is first necessary to evolve some

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SYNOPSIS

Plant data on the sintering of hematite ore fines at Jamshedpur are presented to bring out some of the main variables affecting sinter quality. In view of the high gangue content of the dry-screened ore fines, washing and wet-screening has been adopted and the results show a marked improvement in the chemistry of the sinter. The strength is, however, low as judged by either shatter tests or the percentage of fines in the blast-furnace bins. Addition of silica sand improves strength but raises the gangue content. Laboratory tests on other procedures of increasing strength are described. It has been found that mixed-firing produces strong, reducible sinter, and the advantage is specially marked in fluxed sinters which are very weak with conventional ignition practice.

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quick test of sinter quality. In view of the very large number of methods used by others involving shatter, tumbler, impact, and screening, a comprehensive test programme was undertaken to compare the different methods. The results indicated that for the type of sinter produced in the plant, the impact test was too severe; it was not able to distinguish clearly between strong and weak sinters. The screening test was likewise ineffective as a control test at the sinter plant since most of the fines in the sinter charged in the blast-furnace were produced during transit from the sinter plant. The tumbler and shatter tests were found to be quite satisfactory; and of these, the shatter test was adopted as it uses a relatively large sample. A shatter testing equipment was, therefore, installed in the sinter plant near the coolers. The test procedure was the same as that used for determining the shatter strength of coke except for a change in the number of 6 ft drops from four to three. The results of the shatter test are expressed in terms of the percentage of +1.5 and the percentage of -0.5 in fractions produced from +1.5-4.0 in material.

The usual run of sinters made from dry screened iron-ore fines from the Joda East, Badampahar, and Gorumahisani iron mines, gave shatter indices of 27±7% for the +1.5 in fraction and 21±5% of -0.5 in after three drops. Tumbler tests, involving rotation at 60 rev/min, on +1-1.5 in sinter produced about 55±8% +0.5 in after 10 min of tumbling. The results show that the +1.5 in value in shatter and the +0.5 in after tumbling can be correlated satisfactorily.

In determining the optimum operating procedure, three variables were investigated in detail. The first was the moisture content of the sinter mix, including coke breeze and return fines, at the feed roller discharging the mix on the strand. Several tests indicated that the best sinter could be made with about 8% moisture with fluctuation of ±1%.

The second variable examined was machine speed. Typical test data on one run are given below:

Speed, ft/min	7.2	8.2	8.5	8.8	9.2	9.5	9.9	10.2	10.5
Shatter index, %									
+1.5 in	19	23	23	22	21	26	31	35	30
-0.5 in	26	25	22	25	21	22	21	21	24

TABLE I Typical results on the effect of variation in coke breeze input on the quality of sinter

	Coke % of sinter mix	Shatter index, %		Reducibility H ₂ O collected, ml	
		+1.5in	-0.5in		
				60 min	100 min
Series A	5.5	20.0	41.3	13.2	16.0
	6.0	18.8	40.0	10.4	14.0
	6.5	25.5	40.4	14.0	14.5
	7.0	33.0	31.3	11.0	13.6
	7.5	23.9	34.0	10.2	13.2
	8.0	23.0	32.0	10.1	12.9
Series B	7.0	23.9	28.4	9.0	13.4
	7.5	22.5	28.8	10.6	14.6
	8.0	25.0	30.0	10.4	14.6
	8.5	27.5	30.0	10.6	14.8
	9.0	23.8	21.3	10.4	13.0
	9.5	27.5	20.0	9.4	13.4
	10.0	21.3	18.8	8.2	11.0

It is seen that there is a perceptible increase in the percentage of +1.5in material after shatter, but the extent of fines produced, i.e. -0.5in fraction, is little affected. Hence the speed is usually maintained around 9.2 ft/min which gives a steady operation.

The third variable is fuel input, and in this several difficulties were encountered before a proper control could be developed. The initial troubles were associated with the large swings in the discharge of coke breeze from table feeders depending on the moisture content and also the unavailability of automatic weighing. Careful selection and sampling led to a better control over coke breeze feed rate, and pan tests were developed for checking and regulating the fuel/ore ratio. It was found that hourly checks were required for adequate control. The effect of variation in fuel rate on the strength of the sinter is shown in Table I, which also includes some results on the reducibility of the sinters. The reducibility test was developed for iron ore evaluation,² and comprised of passing purified and dried hydrogen over sinter lump samples (75g of $\frac{1}{8}$ - $\frac{3}{4}$ in size) at the rate of 1500 ml/min at 800°C and collecting the water vapour formed by reduction of the iron oxides. The amount of water collected in the first 60 min, i.e. in the linear portion of the H₂O time curve, represents the rate of the reduction and that collected in 100 min is a measure of the extent of reduction. Both these values are, therefore, entered in Table I.

The two different series of data refer to the two different proportions of hard and soft ore fines in the green mix. In both cases, the optimum level of carbon gives the best strength and reducibility. Increase in coke breeze input beyond 9.5% of the mix gives a stronger sinter, but the product is slagged and has a lower reducibility.

The above data on variation of sinter strength as a function of fuel input also suggest the generally low strength of the sinter. If three 6 ft drops on a steel plate can generate about 30% of - $\frac{1}{8}$ in material, the sinter reaching the blast-furnace skip would be obviously sub-size. Typical screen analyses of sinter samples, taken at the sinter plant screens and in the blast-furnace bins, prove this point.

Sample at	Range of screen analyses, %			
	+2in	+1in	- $\frac{3}{8}$ in	- $\frac{1}{8}$ in
Sinter plant	30-50	45-55	10-25	1-3
Blast-furnace bins	0.5-3	5.5-14	18-60	10-20

In addition to the low strength of the sinter, the chemistry was also rather unsatisfactory. The iron content ranged from 57% to 59% and the concentrations of silica and alumina were 9-11% and 7.5-9.4% respectively. This compares unfavourably with the usual composition

TABLE II Laboratory test data on the influence of lime and sand addition on the strength of sinter

Lime, %	Shatter index, %		Sand, %	Shatter index, %	
	+1.5in	-0.5in		+1.5in	-0.5in
0	33.8	37.5	0	32.0	36.8
0.25	33.5	38.4	1	37.3	22.5
0.5	23.0	42.8	2	40.0	20.0
1.0	25.0	43.8	3	38.2	25.2
1.5	28.0	32.5	4	42.1	19.0
2.0	29.9	40.3	5	45.6	16.7
3.0	35.2	42.2			
4.0	32.6	41.6			

of sized ore produced by dry screening, namely 61-62.9% Fe, 2.6-3.5% SiO₂, and 3.2-3.7% Al₂O₃. The high gangue content of sinter arises mostly from the corresponding gangue content in the ore fines and also a 1.6% increase from the ash in coke breeze. To reduce the gangue content of the sinter feed, a scrubbing and wet screening facility was added to the existing ore-crushing and screening plant. The results of the first three months of operation clearly indicate that the desired improvement in quality can be attained. The sinter now analyses 61.5-62.3% Fe with about 6.5-7.2% SiO₂ and 6.8-7.4% Al₂O₃, which is comparable with the analysis of the sized ore. The use of washed and wet screened ore fines can, therefore, remove one of the two major drawbacks of the sinter, the second being the low strength of the product.

The wet ore fines contain about 8-13% moisture, depending on the size distribution of the fines and the nature of the ore. Hard ores, being granular, do not retain very high moistures. The moisture level at the table feeders is about 12-14%, but this is reduced to about 9% by the addition of hot return fines so that the optimum level mentioned earlier is attained. The strength of the sinter is likewise improved as shown by the following data:

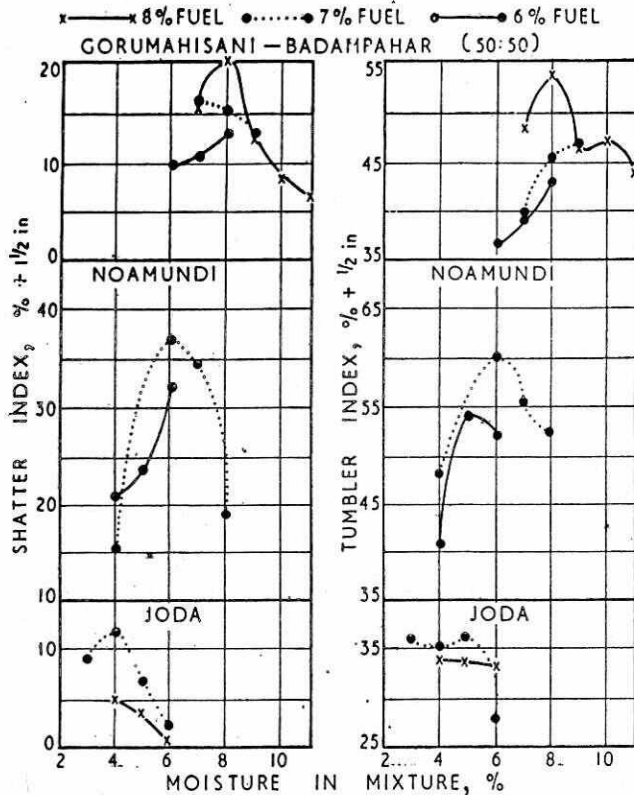
Shatter index	Dry screened fines	Washed fines
+1.5in%	27.8	32.6
σ	7.6	10.6
-0.5in%	21.4	20.8
σ	4.4	5.7

The above improvement is fairly significant and is worth consideration since some doubts were expressed earlier about the sintering characteristics of the washed fines which would be almost free of the -100 mesh material.

Additions of lime and sand

Having discussed the method adopted for improving the chemistry of the sinter, it is interesting to mention the results of some tests conducted in the laboratory and the plant for improving the strength of sinter. Addition of calcined lime and sand was tried. Results of laboratory tests, from a 12in square pot, are given in Table II. The strength values are averages of at least four tests.

Since laboratory tests did not indicate any improvement from the addition of lime, plant tests were conducted only for assessing the effect of sand additions. Extended operation for about three months showed that there was a small but significant rise in strength as judged by the size distribution of sinter at the blast-furnace bins. The amount of - $\frac{1}{8}$ in fraction dropped from about 11% to about 7 and 6% as a result of adding 1.0 and 2.0% of sand respectively; the corresponding values for the - $\frac{3}{8}$ in fraction were 50% before the test and 47.5 and 39.8% after 1 and 2.5% sand additions. The method, though capable of improving strength, is not practised since it raises the total gangue content of the sinter.



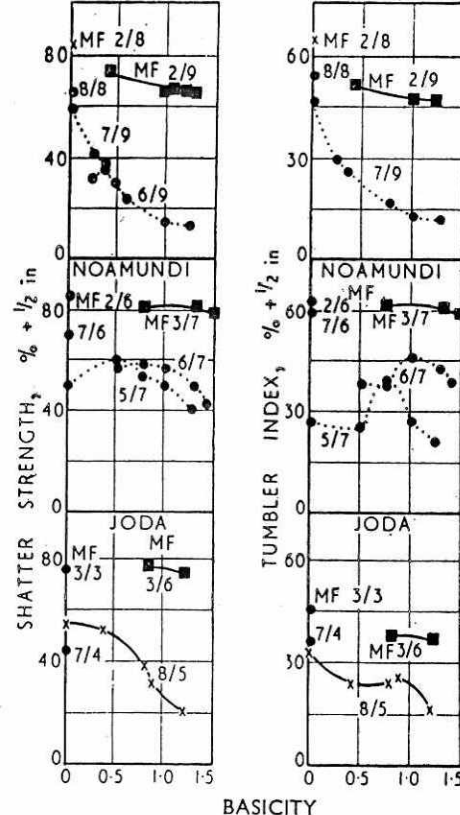
1 Effect of moisture and fuel additions on the shatter and tumbler indices of sinter

FLUXED AND MIXED-FIRED SINTERS

With a view to exploring the possibilities of further improvement in sinter quality, a fairly comprehensive series of tests was made in the laboratory. The sinter pot had a grate area of 1 ft², and 40 lb of sinter could be made in one test. The ore charge was taken from a prepared bed to ensure uniformity, and mixed in a mechanical mixer with the precalculated amounts of return fines, coke breeze, and flux. The charge was fed into the sinter box from a false-bottom container to avoid any undue variations in packing. The procedure for ignition and suction during sintering was also standardized. The product was broken hot to determine the yield of return fines, which was approximately 21–32% for the three different ore mixes. On this basis a return fine addition of 25% to the green ore mix gave a satisfactory return fines balance. The broken sinter, screened over 0.5 in, was cooled and tested for strength and reducibility. Shatter and tumbler tests were conducted according to a standard procedure developed for ore testing,³ and the reducibility index was determined by the test described earlier.² In all cases, duplicate and triplicate sinter tests were made to ensure reliable and reproducible test data. Some additional tests were conducted to evaluate the effect of mixed-firing on sinter strength; for this work, the ignition hood was kept over the sinter pot for 4 to 8 min at reduced gas input after the initial ignition period of 1 min. Coke-oven gas was used as the gaseous fuel.

The overall effects of fuel and moisture additions to the sinter mix are summarized in Fig. 1. A comparison of the results on the different types of ore fines shows that Noamundi fines, containing 49.6–54.4% of $-\frac{1}{8}$ in, gave the best sinters as far as strength is concerned. The fines from the Gorumahisani and Badampahar iron ores contained about 59.1–62.0% $-\frac{1}{8}$ in and this explains why

GORUMAHISANI — BADAMPAHAR (50 : 50)
2/8 INDICATES 2% FUEL AND 8% MOISTURE



2 Effect of flux additions on the strength properties of sinter

the optimum moisture level (8%) is higher than that for Joda ore (4%) containing only 31.2–34% of $-\frac{1}{8}$ in fines. The optimum fuel rate is 7–8%.

Additions of limestone fines, $-\frac{1}{8}$ in, to the sinter mix to produce fluxed sinters lead to a progressive deterioration in strength as shown in Fig. 2, which also includes the results of mixed-firing tests. The drop in shatter and tumbler indices persists up to the highest values of basicity (1.2–1.4) tried in this investigation. The mixed-fire sinters are apparently not affected similarly and are much stronger than conventional sinters. The addition of flux improves the reducibility as normally expected and the mixed-fired sinters are even more reducible. The exact reason for the marked improvement in the quality of sinter resulting from mixed-firing is, however, not clear.

Finally, a mention should be made regarding the general level of FeO contents in the sinter. A series of tests by the Davis tube method, and a special hollow-core transformer equipment developed in the laboratory showed that the sinters contain about 15–21% FeO. This is rather high in view of the hematite ore charge and indicates an insufficient reoxidation. Use of an extended gas hood, as achieved in the mixed-fire tests, lowers the FeO content to about 10–13%, and it appears that better reoxidation of the mixed-fire sinter may develop a better iron oxide bond which might be responsible for the increased strength.

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