OF NECESSITY TO ALTER SINTER STRENGTH TEST STANDARDS[1]

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Abstract

The sinter testing results in standard test drum would depend to a large extent on the sampling place. The farther is this place from the sintering strand, the higher will be strength index for one and the same batch of sinter. This is accounted for by the fact that there is a dwindling of defects number in the sinter yield structure as it is being transported to the ironmaking shop. The determination of sampling place and methods are not unified at steel plants at all. Therefore, the methods of testing applied today cannot be used for comparative analysis of sinter characteristic made at various steel plants under different conditions in terms of production and raw material. In report a method is suggested for research and testing of sinter, based on a model which describes extensive desintegration of sinter. This method does not call for developing new designs of equipment or testing technique, it will be necessary only to modify the testing procedure and to use computers more widely.

Key words: Sinter; Strength; Extensive disintegration; Blast furnace.

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1 INTRODUCTION

As is known, sinter as treated in screens and transported over junction to the iron making shop, would undergo considerable mechanical loads, thus being degraded with a considerable quantity of fines. As it happens, fines that have been screened off sinter would go as returns to the charge and undergo sintering again. It is obvious that the sinter degradation process is a component of the sintering technology as it would effect it through the variations in returns sinter regime.

For that reason it is suggested in this paper to study the sinter degradation process and develop criteria for assessing sinter quality.

2 DISCUSSION

It is shown in the S.B. Bazilevitch's work [1] the degradation of sinter which takes place on the track of from the sinter plant to the iron making shop can be well modeled by testing samples of sinter in the standard drum. It is also shown that the level of mechanical loads upon sinter at different critical points of the track may be estimated with reference to the degradation time of sinter in the standard drum. It is customary to assume as equivalent the time of testing in the drum, when the quantity of fines generated from sinter becomes equal to the quantity of fines generated on the track in a corresponding spot. These loads, as expressed by the sinter degradation time in the standard drum are named by S.V. Bazilevitch as "drum equivalent".

The authors of this work [2] suggest to describe the sinter degradation time in the standard drum by equation:

$$F = b * T * \frac{dF}{dT} \tag{1}$$

Where: F – yield of fines, size – 5 mm during the tests in the standard drum, p.u.

T – period of testing in the standard drum, min.

dF/dT - sinter degradation rate

"b" – proportionality factor

Solving the equation (1) one gets the sinter degradation equation as:

$$F = a * T^{b} \tag{2}$$

Where: "a" and "b" are the parameters that determine the sinter strength attributes, "T" – the period of sinter sample testing in the standard drum.

Through a double testing at T_1 and T_2 time and by solving the system of equations (3) one can determine parameters "a" and "b" and get the degradation equation for a concrete sample of sinter and then determine the yield of fines "F" depending upon the testing time "T" in the standard drum.

$$\begin{aligned} F_1 &= a * T_1^{b} \\ F_2 &= a * T_2^{è} \end{aligned} \tag{3}$$

However, under operating conditions, to plot the equation of sinter degradation it is necessary to know the level of mechanical loads, affecting sinter when it reaches the sampling point. These loads at the sinter sampling point should be reduced to the equivalent testing time in the standard drum – T_0. Then the equations system (2) will assume the form of (4):

$$F = a*(To+\Delta t)^b \tag{4}$$

Here Δt_1 and Δt_2 –sinter testing time in the standard drum, $T_0 + \Delta t$ – a summary duration of sample test with reference to the mechanical loads upon sinter on the way to the sampling point.

It is clear that T_0 value is a drum equivalent at the sampling point, which is independent of the sinter properties, but a constant value, which depends on the rigidity of the sinter feeding track. Therefore, T_0 value can be determined for once only. The repeated determination of T_0 may be needed only if some changes have taken place on the sinter feeding track.

Theoretically it may be possible to determine T_0 value a triple testing of sinter with the preset testing intervals in the standard drum, by solving the equation system (5), which consists of three equations with three unknowns “a’, “b” and T_0.

$$\begin{aligned} dF_1 &= a*(To+\Delta t_1)^b - a*To^b \\ dF_2 &= a*(To+\Delta t_2)^b - a*(To+\Delta t_1)^b \\ dF_3 &= a*(To+\Delta t_3) - a*(To+\Delta t_2)^b \end{aligned} \tag{5}$$

In practice an analytic solution of equations system (5) seems to be unfeasible due to unavoidable errors in experiments, therefore the simple way for solving this task would be statistical methods. While taking them, it is expedient for the sake of accuracy to increase the number of tests at intervals Δtn.

Aiming at verifying the idea, i.e. the determination of mechanical loads effect upon sinter as it is traveling of the track to the sampling point we conducted experiments at the sinter plants of Novolipetsk Steel. Two samples were purposely taken on different dates so that sinter of various qualities would be tested. The tests results are given in Table 1. As can be seen from Table 1, each sample of sinter underwent 5 tests at intervals of 3 minutes. The results are given in relative values.

Table 1. The tests results

Date of testing	Intervals of testing time - Δti, min	The results of testing, Fines generation - ΔFi, д.е.	
		Sample №1	Sample №2
Experience №1 18.02.2012 Experience №2 22.02.2012	2	0,1666	0,1467
	5	0,0867	0,0867
	8	0,0400	0,0467
	11	0,0267	0,0267
	14	0,3333	0,0267
Cold Strength on GOST ,%		66,3	69,3

Below there is a method given for plotting the sinter degradation equation. Initially a system of equations (6) was plotted. These equations were used for determining the accretion of fines yields dF1 as by the method of sinter samples were taken at Δti intervals.

Figures 1 shows an explanatory diagram, which contains the values we were dealing with while determining the parameters of sinter degradation.

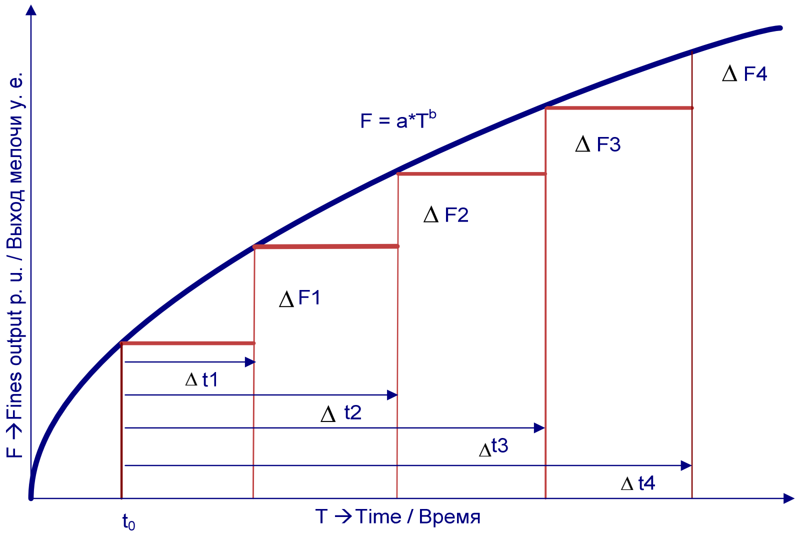

Figure 1. Sinter degradation curve.

Initially, the starting values “a”, “b” and T_0 values were preset in equations (6), correspondingly at 0.1; 0.1 and 0.5 minutes, and dFi values were determined.

$$\begin{aligned}
dF_1 &= a^*(T0+\Delta t1)^b - a^*T_0^b \\
dF_2 &= a^*(T0+\Delta t2)^b - a^*(T_0+\Delta t_1)^b \\
dF_3 &= a^*(T0+\Delta t3)^b - a^*(T_0+\Delta t_2)^b \\
dF_4 &= a^*(T0+\Delta t4)^b - a^*(T_0+\Delta t_3)^b \\
&\ldots\ldots\ldots\ldots\ldots\ldots \\
dFi &= A^*(T_0+\Delta ti)^b - A^*(T_0+\Delta t(i-1))^b
\end{aligned} \tag{6}$$

After that the difference Ci between the estimated values, dFi values and experiments values - ΔFi was determined with the help of equations (7).

$$\begin{aligned}
C_1 &= \Delta F_1 - dF_1 \\
C_2 &= \Delta F_2 - dF_2 \\
C_3 &= \Delta F_3 - dF_3 \\
C_4 &= \Delta F_4 - dF_4 \\
&\ldots\ldots\ldots \\
Ci &= \Delta Fi - dFi
\end{aligned} \tag{7}$$

After that the sum of deviations squares was calculated by formula (8):

$$\Sigma Ci^2 = C1^2 + C2^2 + C3^2 + C4^2 + \ldots\ldots Ci^2 \tag{8}$$

Then by the method of consecutive and cyclic itineration of “a”, “b” and T_0 values in equations (6) ΣCi^2 in equation (8) was minimized to 3-4 figures after the dot. The last values of “a”, “b” and T_0 were assumed as the parameters of the degradation equation for further calculation of sinter strength.

In this case it becomes possible to determine the sinter standard strength at each and every spot on the sinter transportation track. The following formula can be used for this purpose (9):

$$St = \frac{(1 - a*(To+8)^{b})}{(1 - a*To^{b})} \tag{9}$$

The numerator in formula (9) is the residue of large size fraction of +5mm after the testing of sinter in the standard drum for 8 minutes, the denominator is the residue large size fraction +5, which reaches the sampling point on the transportation track. As can be seen from equation (9), the strength is determined of the sinter which has been preliminary stabilized on the transportation track and is equivalent to the testing time in the standard drum. For that reason this strength would depend essentially on the parameter “T”, which may vary at different steel works. It is obvious that for the sake of analysis of the furnace performance it is desirable to measure the strength of skip sinter immediately before charging it into the furnace. Under the conditions, prevailing at NLSW, as per our approximate evaluation, the level of mechanical loads on sinter at the sampling point of skip sinter would be as per equivalent “Tsk” roughly 5 minutes.

However, the evaluation of skip sinter strength is hardly eligible for assessing the performance of a sinter plant, because by large this strength is predetermined by mechanical loads on sinter, which sustains them as its is mechanically treated on the track from the sintering machine to the blast furnace. In our opinion, the evaluation of the sinter strength should be in direct relation with the initial strength of the product which is caked on the sintering machine, its ability to resist degradation. For this we suggest to use the method, similar to that adopted in nuclear physics, which consists of determining the half-life period for sinter when it is tested in the standard drum. For that by transforming the sinter degradation equation (2) we can obtain an expression to calculate the sinter half-life period – Thd (10).

$$Thl = (\frac{0,5}{a})^{\frac{1}{b}} \tag{10}$$

Here, 0.5 means that the relative amount of fines F, which is generated during the period of half-decay, is equal to 0.5.

The assessment of adequacy of the sinter degradation equation can be made by calculating the standard deviation of the measured accretion of fines – Δfi as compared with the estimated values – dFi by formula (11).

$$\sigma = (\Sigma Ci^{2}/n)^{0,5} \tag{11}$$

The calculation results of the parameters of sinter degradation equation and its strength characteristics are given in Table 2.

Table 2. Parameters of the equation and samples test data at NISW

Sample Sr. No.	To	a	b	St,%	Sto,%	Thl, min	σ
Sample No.1	0.165	0.192	0.337	81.27	68.17	16.86	0/014
Sample No.2	0.149	0.185	0.329	83.08	70.03	20.53	0.0085

As it can be seen from Table 1, the estimated attributes of sinter samples 1 and 2 did not differ from each other much. Sample 2 showed bigger strength. The standard strength of Sample 2 was 83.08 and it exceeded the strength of Sample 1 by 2% in magnitude. Let us remember that the strength index St was determined as a skip sinter with its drum equivalent under Novolipetsk conditions being 5 minutes. Therefore its strength is substantially bigger that that determined at the sinter plant (see Table 1). The estimated strength of sinter samples at the sampling point Sto was 68.17 and 70.03 respectively, which is quite in conformity with the practical data from Table 1. Here the following salient feature should be noted. In case of a standard test, the strength of sinter is determined by one test. But if the same estimated strength is determined by the sinter degradation curve, the number of tests will be not less then three. Therefore it is possible to ascertain that the strength of sinter which has been estimated by the degradation curve, will be more accurate as compared with the one determined by a standard method.

Cake strength test – Thl (the sinter half-life period immediately after sintering) for samples 1 and 2 was 16.6 and 20.53 minutes respectively. The relative difference in assessments is:

$$\Delta Thl\% = 100*(20.53 - 16.6)/20.53 = 19.14\%$$

At assessing the strength of the same samples by a standard formula, the relative difference in strength assessments was:

$$\Delta Sto = 100*(70.03 - 68.17)/70.03 = 2.66\%$$

So, the suggested method for assessing the strength of sinter produces a bigger value of variability in data which is one more advantage of assessment by a sinter half-life period .

Figure 2 shows graphically the curves of first and second samples degradation. It is significant that the estimated values of To for both the curves practically coincide, as the difference in time is only:

0.165 – 0.149 = 0.016 minutes

This result testifies to the fact that the suggested method determines quite accurately the level of mechanical loads upon sinter at the sampling point. In Figure 2 graph it can be seen that the curves of samples degradation would practically intersect at these points.

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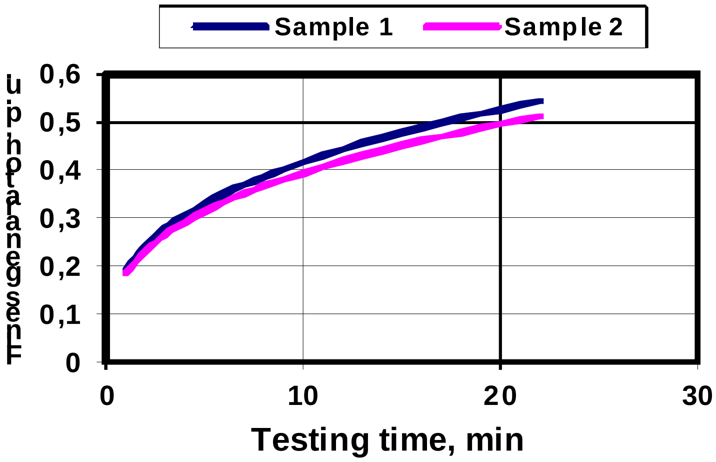

Figure 2. Sinter disintegration diagram.

The half-life periods of samples that are determined graphically, would also coincide with the estimated data.

3 CONCLUSIONS

A method has been developed for testing sinter, which makes it possible to design the sinter degradation equation. For the sake of comparative analysis of different grades of sinter , made out of different grades of raw material, it is suggested to assess the strength of sinter by estimation its half-life period in a standard drum. This assessment would reflect not only the effect exerted by the raw material, but also the effect of process-related factors upon the sinter strength.

It suggested to calculate the assessment of the strength of sinter which is charged into the blast furnace, with reference to the sinter sample with preceding level of mechanical loads, that are equal to the mechanical loads, experienced by sinter as it is transported from the sintering machine to the blast furnace. Such an assessment would reflect a real strength of sinter at the moment it is charged into the blast furnace.

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