IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 8, July 2015.
www.ijiset.com
ISSN 2348 – 7968

Scrap Analysis For Steel Billet Production In Continuous Casting Process

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***Abstract*— Steel scrap is one of the most important raw-materials in steelmaking, which contributes 60% to 80% of the total production cost. Using this steel scrap, by adopting continuous casting process, billets are produced. The quality of the billet is directly related to the steel scrap parameters like scrap source, ingot yield, electrical energy consumption, impurity present in the scrap mix etc. In this process all the metallic scraps are mixed and melted in an electric arc furnace and a sample is tested using spectrometer to find out various elements present in the mix. The aim in the project is to minimize the harmful impurities such as Phosphorus and Sulphur in order to produce quality billet for rolling.**

Scrap are collected from various sources. These scraps are melted together for the required composition. Also the mechanical properties such as yield stress, ultimate strength, nominal breaking stress, actual breaking stress, percentage of elongation in length and percentage reduction in area are found using UTM. Scanning electron microscope analysis are carried out to find out the microstructure of billet as well as the scrap sample

The statistical prediction models are carried out to predict the percentage of the chemical composition, electrical energy consumption and metallic yield of scrap mix.

The investigation reveals that it is possible to produce quality billets as per BIS standard by controlling harmful elements present in the billet. The actual energy consumption for producing quality billets, chemical composition and metallic yield are verified with statistical prediction model and are found comparable.

I. INTRODUCTION

For structural steel production the scrap coming from various industries and imported scrap are utilized. It is a challenge for identifying good scrap for the manufacturers in this contest, the present work is proposed in SAIL-SCL Kerala Limited to produce billets or caterings to the steel ruling industries in and around Calicut. Apart from this scrap available from locally, imported scraps are made available and both the scraps quality are identified, mixing together to obtain quality steel required for structural steel production. Mainly raw materials are available from scrap

The main raw material in Billet Manufacturing process is mild steel scrap which is procured from local and International markets. The scrap is mixed in pre-determined proportions in the scrap yard and fed to the furnaces in charging buckets and melted by Electric Arc using Graphite Electrodes. The molten metal is processed to remove the impurities like sulphur and phosphorous and is subjected to slag off and further refining by adding Ferro alloys and other fluxes to bring it to the required standard specifications. Liquid metal samples are analysed at frequent intervals to ensure quality if the product as per I.S. The molten steel is tapped at the required temperature to the pre-heated ladles. Steel ladles are equipped with latest slide gate opening system. Temperature of the molten metal in the ladle is measured to ensure correct temperature at the continuous casting machine. The liquid metal is then poured from ladle to the tundish and then to the water cooled copper mould on continuous casting machine. There takes place the billet formation by solidification of the molten steel due to water cooling. Billets coming out of the continuous casting machine are cut to the required length by gas cuttingFor structural steel making process the scrap are an important raw material, the coast and quality of final product is mainly depends upon the cost of scrap and scrap quality. The collection of scrap from various sources is an important work during manufacturing of structural steel .The scrap are mainly available locally and foreign countries. The circulating and process scrap is returned to the steel furnace without any deleterious contamination. In particular may be contaminated with non- ferrous metals like tin, copper, nickel etc. Since it is not possible to oxidize these during refining they remain as residuals in steel. The properties of steel are adversely affected by the presence of these residuals. The specifications of steel do to maximum allowable limits. A proper scrap blend is necessary to minimize this problem during steel making. The scrap-based steelmaking process starts by charging the predetermined scrap mix into an electric arc furnace (EAF). Melting a single charge in the furnace is called a heat. When the charge is melted, the uncertainty in the chemical composition of the charge mix cause a risk factor and to essential to find the composition of scrap mix after melting. The objective in scrap charge optimization is to select the most economical scrap mix for each produced steel grade while minimizing the failure risk caused by uncertainties in raw material consistence. Grading of steel scrap is usually in terms of the size distribution, chemistry, density and process methods. The scrap properties can be classified generally in to two categories, physicochemical properties and process related properties. Physicochemical properties are chemical composition and physical properties such as density, specific surface area, size distribution ,melting temperature, specific heat capacity metallic/organic oxides contents.Thease properties can be better determined by controlled experiments in laboratories, on the other hand process related properties like yield ,specific energy consumption, contribution to chemistry of steel and slag, contribution to degree of basket and furnace charging ,contribution to pollution levels depends on both the process condition in the furnace and other materials in the scrap mix this implies that for same shape grade the process related properties may varies considerably for different melt shops .Objective of this work is to estimate the process related for a melt shop through statistical evaluation of the process data collected from EAF. In this section the development of a statistical method in the determination of the constitute elements in scrap, statistical spread on the on the average of elements, metallic yield of the scrap and electrical energy consumption .The idea of statistical treatment of the process data to extract useful information is both natural and simple.

II.EXPERIMENTAL DETAILS

A. Composition analysis

Spectrometer is used in the industry to find out the constituent elements in the sample very easily and accurately within a short time. The inspection of the sample has to be done in 10 minute to check the composition of the melt. This helps to find out about 31 elements in the melt within 10 to 20 seconds. The fine polished like surface is burnt with the help of argon gas and the elements in the surface of the metal is made in to gaseous state and we have length of light in the gas is checked. According to the different elements in the metal composition, and also the percentage of elements contained in the metal, the wave length changes and this is recorded using a computer system. This also shows if the product is coming under the grade or not. Argon gas is used in the spectrometer. A suitable pressure reducer is used for argon supply. Argon inlet pressure to the unit is 7 bars

B. Surface structure analysis

The scanning electron microscope (SEM) is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the shells in atoms that make up the sample producing signals that contain information about the sample's surface topography, composition and other properties such as electrical conductivity. The types of signals produced by an SEM include secondary electrons (SE), back-scattered electrons (BSE), characteristic X-rays, light (cathodoluminescence), specimen current and transmitted electrons (STEM). Generally the most common or standard detection mode is SE imaging. The spot size in a Field Emission SEM is smaller than in conventional SEM and can therefore produce very high-resolution images. Electrons are produced at the top of the column, accelerated down and passed through a combination of lenses and apertures to produce a focused beam of electrons which hits the surface of the sample. The sample is mounted on a stage in the chamber area and, unless the microscope is designed to operate at low vacuums, both the column and the chamber are evacuated by a combination of pumps. The level of the vacuum will depend on the design of the microscope. The position of the electron beam on the sample is controlled by scan coils situated above the objective lens. These coils allow the beam to be scanned over the surface of the sample.

C. Test for reducing the carbon content

Plant follow the BIS quality grade if the carbon percentage in the molten metal is large, commonly used the sponge iron for reducing the level of carbon percentage in scrap mix but now the hike of cost of sponge iron they use the scale present in the billet for reducing the level of carbon in the scrap mix .For improving the percentage of carbon added additional engine blocks in to the furnace and heated .SCL currently manufacturing 100mm square billet of mild/medium/high carbon steel.

III.STATISTICAL ANALYSIS OF STEEL SCRAP

The statistical analysis on scrap give various result and relation of many parameters involving the electric arc furnace process. It is found that many source of scrap are available in the country and to find out the optimum quality of steel scrap. A statistical analysis is attempt to find out the optimum solutions. This may lead to produce and to identify the best scrap lot from this scrap yard for selecting and meeting, and there by the time for selection of scrap is minimize

A. Relation between open carbon content and heating time

Various scrap mix are charged in the furnace and the melting time of various scrap mix are different. Chi square testing method is used to checking the relation between the percentage of carbon in the scrap mix and the melting time.

Table 1

Melting time for scrap mix(hours)	C<0.2	C>0.2	Total
Up to 3	31	9	40
3-4	15	15	30
Greater than 4	20	10	30
Total	66	34	100

H0: The hypothesis that the melting time is independent of the carbon content in the scrap mix

From observed table construct expected frequency table (Ei)

E11= (40*66)/100 =26 approx.

E12= (40*34)/100=14 approx.

E21= (30*66)/100=20 approx.

E22= (30*34)/100=10 approx.

E31= (30*66)/100=20 approx.

E32= (30*34)/100=10 approx.

Table 2

Melting time for scrap mix(hours)	C<0.2	c>0.2	Total
Up to 3	26	14	40
3-4	20	10	30
Greater than 4	20	10	30
Total	66	34	100

$$\chi^2 = \frac{\sum(O_i - E_i)^2}{E_i}$$

χ^2=6.49

The 5% value of χ^2 for 1 degree of freedom is 5.99(the calculated value of χ^2 is greater than this values the hypothesis is rejected. So the melting point of scrap mix is dependent of the percentage of carbon content in the scrap mix.

B. Interval estimation of various elements present in scrap mix

For steel making process the main aim is to minimize the impurities such as phosphorus and sulphur and to maintain the percentage of elements present in the scrap mix within the BIS grade quality range. Confidence interval method is help to predict the maximum and minimum percentage of elements present in the scrap mix.Observing the 50 different heats noted the percentage of elements present in the scrap mix.

Mean of percentage carbon content present in the scrap mix (Ć) =$\frac{\sum C_i}{n}$,

(n is number of observations)

$$S^2 = \frac{\sum(C_i - Ć)^2}{n}$$

S = 0.1101

So the 95%confidence the interval of percentage of carbon present in the scrap mix is ($Ć - 1.96\frac{S}{\sqrt{n}}, Ć + 1.96\frac{S}{\sqrt{n}}$)

= (0.22, 0.28)

Mean of percentage manganese content present in the scrap mix (Ḿ) = $\frac{\sum M_i}{n}$

$$S^2 = \frac{\sum(M_i - Ḿ)^2}{n}$$

$$S = 0.0471$$

The interval of percentage of Manganese present in the scrap mix is

($Ḿ - 1.96\frac{S}{\sqrt{n}}, Ḿ + 1.96\frac{S}{\sqrt{n}}$)

= (0.14, 0.17)

Mean percentage of Sulphur present in the scrap mix (Ś

$$S^2 = \frac{\sum(M_i - Ḿ)^2}{n}$$

S = 0.0471

The interval of percentage of Sulphur present in the scrap mix is

$(\acute{S} - 1.96\frac{S}{\sqrt{n}}, \acute{S} + 1.96\frac{S}{\sqrt{n}})$

= (0.03, 0.07)

Mean percentage of phosphorus content present in the scrap mix (Ṕ) = $\frac{\sum P_i}{n}$

$$S^2 = \frac{\sum(Pi - \acute{P})^2}{n}$$

$$S = 0.0286$$

The interval of percentage of Phosphorus present in the scrap mix is

$(\acute{P} - 1.96\frac{S}{\sqrt{n}}, \acute{P} + 1.96\frac{S}{\sqrt{n}})$

= (0.02, 0.04)

IV RESULT AND DISCUSSION

Various scrap are purchased in the steel plant. Shredded scraps are imported from foreign countries these are consider as the high quality scrap. This type of scrap consist of fragmented old automobile parts, engine blocks etcThe carbon content in the scrap mix is depends upon the melting time and also depend the impurities present in the scrap mix..

A. Combination of scrap

This analysis is carried out using the scrap mix shredded, HMS (high melting scrap) and local scrap in the ratio of 6:3:1.This show that the ingot yield obtained in this scrap mix is around90-93%.which is due to the relatively low metalloid content in their hot metal. Hence it is concluded that from the analysis high yield is recorded as shown below

Table 3.

Total weight of metallic charge	Total weigh Of ingots	Ingot yield (%) *(Yi)*
11900	10800	90.8
11900	10800	90.8
11800	10800	91.5
13100	12300	93.9
13800	12900	93.5
13200	12300	93.2
13500	12600	93.3
13200	12000	90.9
13300	12300	92.5
12000	11100	92.5

B.Daily analysis of scrap

All scrap is checked in every time by spectrometer. For the steel making process using the old metal parts such as automobile parts, ship parts etc. The various scrap are analyzed through spectrometer and listed the percentage of elements

Table 4.

scrap samples	c	Mn	Si	S	P	Cr
Mild steel	0.17	0.15	0.10	0.031	0.016	0.20
Shredded scrap sample	0.18	0.16	0.11	0.030	0.021	0.19
local scrap sample	0.16	0.14	0.10	0.029	0.017	0.17

B. Open carbon test result for various heat

In steel making industries shredded scraps are imported from foreign countries. Most of the scrap imported in India is shredded scrap to compensate the shortage of scrap. Shredded scraps are consider as high quality scraps because the metallic yield obtained from these scraps are around 90%-96.During refining, samples are analyzed in the laboratory and the process is controlled(open carbon testing).Casting is made after analyzing the quality of liquid metal. The final chemical composition of the billet sample as shown

Table 5

Figure 1.Liquid bath metal for open carbon testing

C.Melting time and carbon present in the scrap mix

The relation between melting time and percentage of carbon present in the scrap mix according to the scrap charging experiment given. The meltdown time and carbon percentage in the scrap mix are inversely proportional to each other as shown in figure

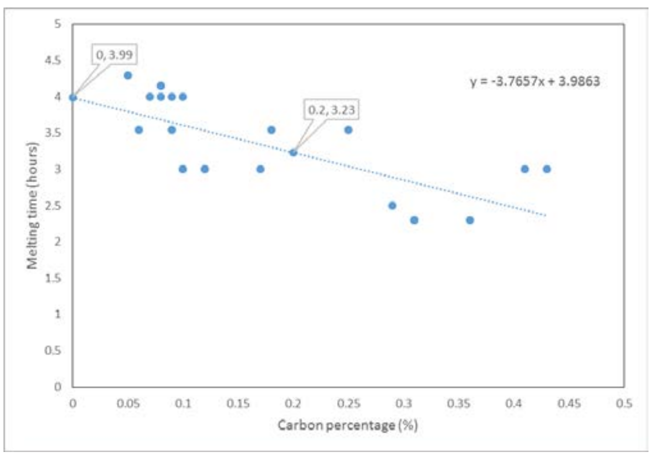

Figure 2. Relation between percentage of carbon and melting time

D. Energy consumption test

The test is carried out to find out the energy consumption for different weight of metallic charge.

No	Carbon	Manganese	Silicon	Sulphur	Phosphorus
1	0.23	0.20	0.008	0.044	0.028
2	0.201	0.55	0.008	0.041	0.031
3	0.21	0.19	0.10	0.045	0.035
4	0.17	0.14	0.13	0.040	0.016
5	0.10	0.120	0.052	0.048	0.0299

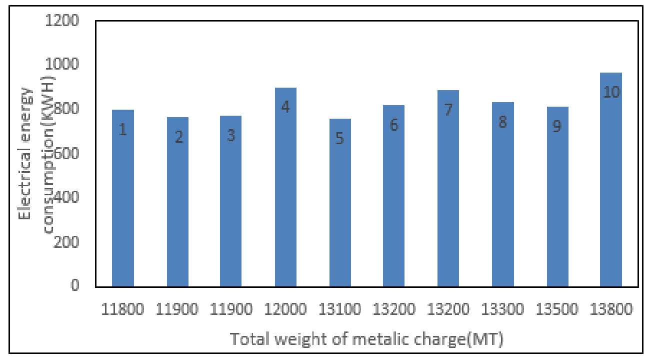

Figure 3.Total weight of metallic charge and electrical energy consumption

E. Weight of scale added for reducing the carbon

Iron oxide mill scale is added for reducing the percentage of carbon present in the scrap mix to reach the BIS standard grade. In this statistical prediction model to control carbon percentage in steel with mill scale addition is found and is given in figure 4.This will be helpful for steel billet producer.

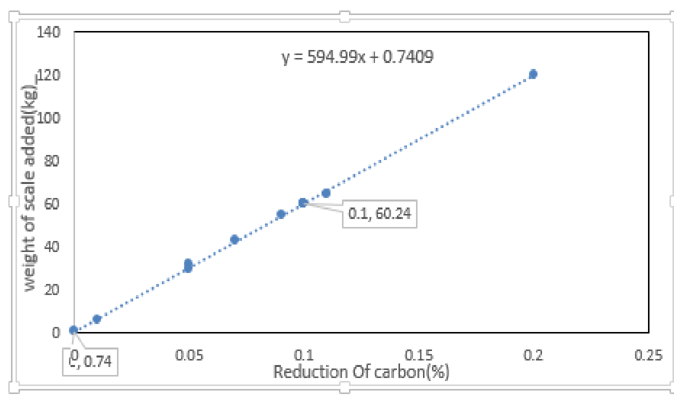

Figure 4.Scale addition for carbon reduction

F. Interval of presence of C, S , Mn and P in the scrap mix

The interval of carbon present in the scrap mix is (0.22, 0.28)

The interval of manganese present in the scrap mix is (0.14, 0.17)

The interval of Sulphur present in the scrap mix is (0.03, 0.07)

The interval of P present in the scrap mix is (0.02, 0.04)

G. UTM result for mild steel

Various mechanical properties of billet bar

Yield stress = 434.9 N/ mm^2

Ultimate strength = 506.85 N/ mm^2

Nominal breaking stress = 502.05 N/ mm^2

Actual breaking stress = 799.6 N/ mm^2

Percentage of elongation in length = 19%

Percentage reduction in area = 37.2 %

H. Scanning electro microscope result

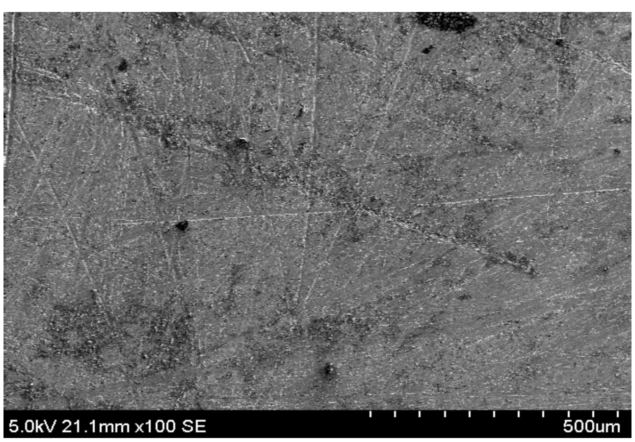

Figure 5.SEM analysis of final billet

From this it is observed that the major matrix is found as ferrite and the pearlite matrix are very much limited showing mild steel scrap structure

V.CONCLUSIONS

From the experiments conducted to study the effect of statistical method of scrap analysis following conclusions are made

- The melt down time of scrap mix depends upon the presence of carbon in the scrap mix and also depend on the impurities present in it
- Shredded scraps are found better than local scrap for ingot yield
- The harmful elements present such as phosphorus and sulphur have been reduced as per BIS standard for producing quality billets.
- The statistical prediction model developed for the project is used to predict the chemical composition, electrical energy consumption and, metallic yield of different scrap mix and the chemical analysis results are found comparable with statistical prediction.

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