International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 5, Issue 6, June 2016)

Development and Implementation of Nozzle Clogging Index at Continuous Caster to Improve Length of Casting

Rajendra. T[1], Rachappa Kadli[2], Anil Kumar. S[3]
[1]DGM, [2]Sr. Mgr, [3]Asst Engr, JSW steels

***Abstract*- In the current practice at slab caster shop of JSW Steel, there is no tool available which can correctly quantify the nozzle clogging during casting operation. As a result, operators roughly estimate the extent of clogging by monitoring the stopper rod position during casting. In light of above, a model has been developed which helps the operator to take effective action to either release or avoid clogging which would further improve the length of casting by allowing more heats in tundish.**

***Keywords*-- Clogging, Tundish, Clogging index, Flushing, Stopper position**

I. Introduction

Clogging is formation and accumulation of non metallic inclusions on the well block and the SEN in tundish . This will restrict the passage of molten steel and limits the production i.e., limits the length of casting .

Clogging can be reduced by dislodging the accumulation on the Well block by flushing manually by means of stopper rod operation but if the accumulation exists in the SEN then it is unavoidable to dislodge, which would make inevitable to end the casting . But to identify the accumulation of non metallic inclusions in SEN or on well block is a herculean task , and so we have developed a model which would allow us to identify at the earliest the location of clogging and its intensity .This would help us plan accordingly either to continue casting or improve cast by flushing or to end casting .

II. Definition Of Clogging Index And Modeling

Clogging index may defined as the ratio between Diff between theoretical lift of stopper in tundish and the actual lift of stopper in tundish to the Maximum lift of the stopper at that speed.

$$\text{Clogging Index} = \frac{\text{Actual lift of stopper} - \text{theoretical lift of stopper}}{100 - (\text{theoretical lift of stopper} + \text{Zeroing})} \quad \text{----------(1)}$$

A. Calculation of actual lift of stopper:

The calculation of actual stopper lift is the difference between the actual stopper position and the zeroing position the stopper.

Stopper Lift=Stopper Position- Zeroing value of that stopper

Stopper position, is the opening of the stopper in the tundish which controls the metal flow from tundish to mould. The Actual stopper position values are available in the data acquisition system ,from where the online stopper position values and history of same can be tapped and can be used for analyzing .

Zeroing is the preset value or the tolerance value set for stopper in the mechanism to increase the operating range of stopper, to compensate if the same erodes with span of casting. This value can also be tapped online or from the data acquisition system.

B. Calculation of theoretical lift of the stopper:

The theoretical lift is the lift of the stopper required to permit adequate quantity of metal required at that particular speed of the casting. Many researchers have calculated the Theoretical lift and Through put by using basic trigonometric and geometrical principles. But we preferred pragmatic approach to find the same. In order to calculate, We have used SOLID edge software , where we have modeled the physical part of the Stopper and the Well block of Tundish and the same was assembled the Lift of the stopper was calculated which is described below. Researchers have calculated the theoretical opening by using Bolger formula developed in late 90's as posted below :

$$A = \pi l \sin\left(\frac{\alpha}{2}\right).\left(l \tan\left(\frac{\alpha}{2}\right) + D_b + R_s\left(1 - \cos\left(\frac{\alpha}{2}\right)\right)\right)$$

A= Area of stopper and SEN gap (mm^2)
α=angle of conical head
D_b= SEN bore diameter (mm)
R_s= radius of SEN seat (mm)
l=stopper lift (mm)

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 5, Issue 6, June 2016)

Although this formula gives base for working or calculating but we wanted to validate this further by modeling. Stopper lift or its orientation can be represented by either of two directions, either vertical or horizontal. By modeling it was concluded that for vertical lift of 2.98mm, the horizontal or slant lift was found to be 1 mm, and the slant ht was further resolved along vertical and horizontal coordinates . From the figure it is clear that the horizontal span resolved is of prime concern in permitting metal flow and varies linearly with lift of stopper.

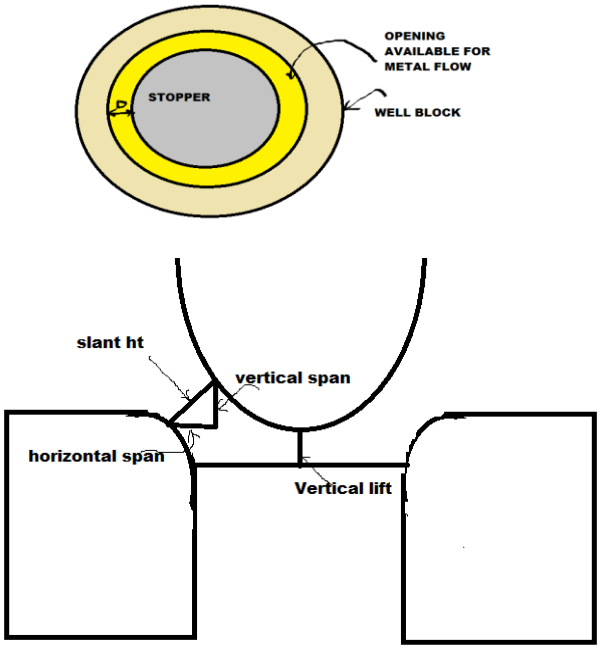

Fig 1: Top and front view of Stopper and well block assembly

In the above figure the portion painted yellow is the opening portion for metal flow, and this can be calculated once the width D, by the formula:

$$A(y) = \pi\left(r^2 - y^2\right)$$

A-Area of opening in mm2

r–Radius of the stopper at that instant in mm(obtained from Cut section in Solid edge)

y=r+D Sum of width D in the fig and Stopper radius in mm

C. Obtaining Dimensions of D from Solid edge:

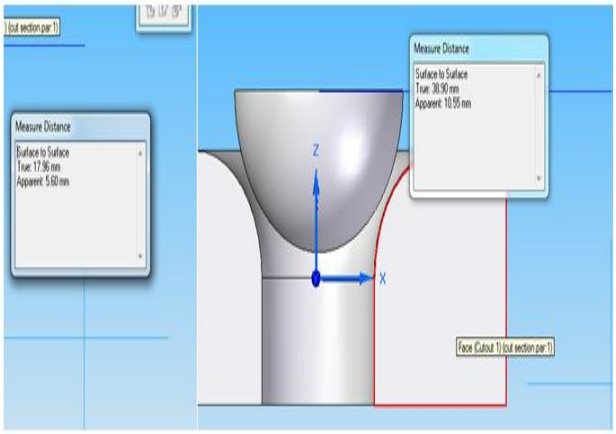

Fig 2: Stopper and well block assembly in Solid edge software

The dimensions of stopper and SEN parituclars were obtained by physical measurement using calipers and the same were used to build a assembly in solid edge. The assembled part were lifted by defined mm and the respective like D was measured by using Smart dimension techniques as shown in the above figure .

Later the Values were used to calculate the area of opening by equation (3) and the same was interpolated to all integral values of opening and the same was extrapolated as shown in the figures below

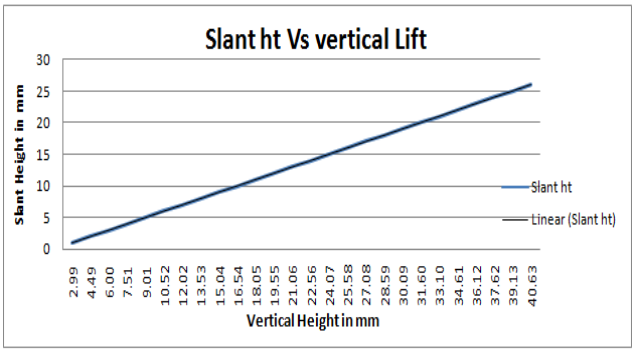

Figure 3: Graph showing relationship between Slant ht and stopper(vertical) Lift

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 5, Issue 6, June 2016)

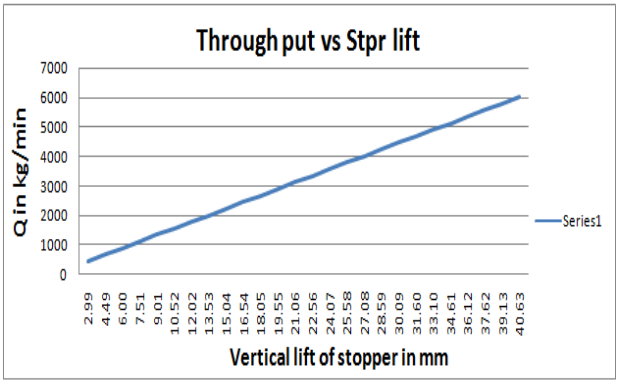

Fig 4: Graph showing relationship between Through put and Stopper lift

After finding the relation between Vertical and horizontal lift of stopper in mm, a clogging model in excel was developed which is displayed below. All domain values like stopper position, section, speed and zeroing position needs to be entered in the white boxes which will automatically display the percentage of clogging, thickness of clogging in the SEN (Sub entry nozzle) and clogging if run at different casting speeds.

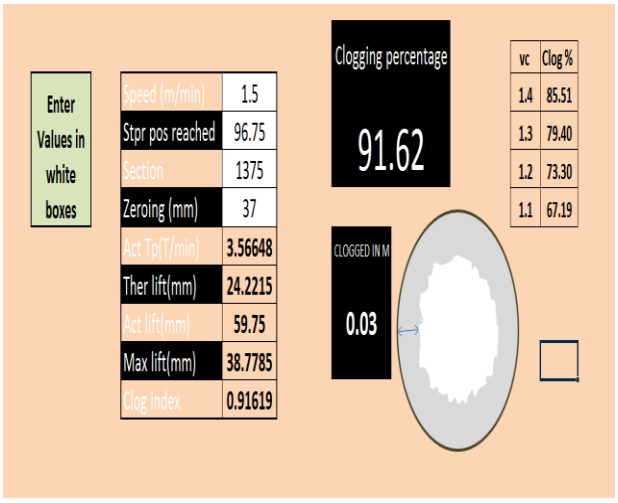

Figure 5: Clogging model framed

III. Calculation Of Clogging Index

Let us consider an example of real time process:

Ex.1: If the details are as below, what is the clogging index ?

a) Stopper position =78 mm
b) Stopper zeroing = 38mm
c) Casting speed =1.3mpm
Actual lift of = Stopper position – Stopper zeroing

the stopper (78-38=40 mm)

Actual = 3.9Tpm (tonnes per minute)

through put

Theoretical stopper lift= (22.5*3.9)/3.313 = 24.68mm (by interpolation technique from the graph, for a lift of 22.5mm, 3.313 tpm is the TP)

$$\text{Clogging Index} = \frac{\text{Actual lift of stopper} - \text{theoretical lift of stopper}}{100 - (\text{theoretical lift of stopper} + \text{Zeroing})} \quad \text{----------(1)}$$

Clogging Index = (40-24.68)/(100-24.68-38)= **0.4456**

Clogging percentage = 44.56%

It means that 44.56% of SEN is clogged which is compensated by lift of (40-24.68=15mm) than theoretical lift 24.68mm required at that through put and speed

Figure 6: Clogging showing 40% in actual and our model predicted 44.56 %

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435(Online) Volume 5, Issue 6, June 2016)

IV. Results And Discussion

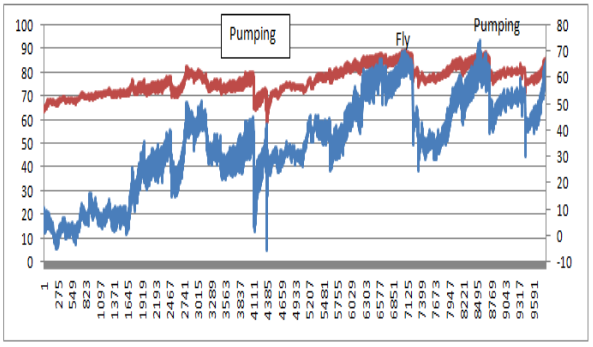

Figure 7: Application of clogging index/percentage on real time data obtained from LVL 2

In the above figure the red line indicates clogging index in percentage and the blue line indicates stopper position. As the stopper position increases the clogging index also increases as they are linearly related . After number of trails we arrived to a platform that once the clogging index crosses beyond 40% effective action like Pumping or enabling Oscillation of stopper would release the clogging deposit and this release could be seen with the drop in clogging index in the above figure.

As discussed two actions Pumping and Oscillation are very crucial as enabling them at the right time would allow us to take more heats in tundish.

Pumping is a mechanical action of fully closing the stopper and reopening the same to required level which would flush the clogged deposit on the well block. This is clearly represented in the figure above.

Oscillation of stopper is another mechanical action which is gradual as compared to above when enabled, it would oscillate by said position say maximum of +-2 mm based on oscillation frequency. This would not immediately flush the deposit but would gradually break the clogged deposit and will release the same with time.

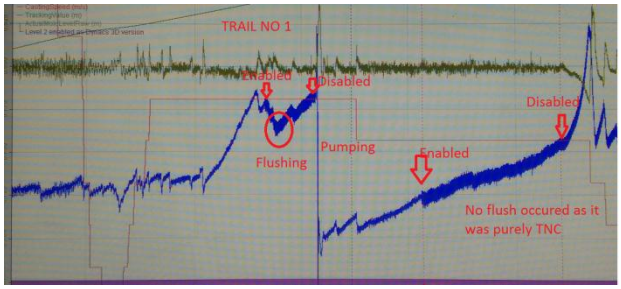

Figure 8: Auto flushing when stopper oscillation was enabled

Decision like pumping or Oscillation of stopper is not recommended further, if the clogging index does not drop by initial pumping or Oscillation of stopper for said span, which clearly indicates the deposit is inside the SEN (Sub entry nozzle). SEN change or Tundish change is advised if one is facing the above situation.

V. Conclusion

The clogging index indicator has been useful to take the decision of manual flushing/ pumping or enabling stopper oscillation and minimizes the unnecessary pumping and flushing during operation. Also by the help of this model the operator can take suitable action like SEN tube change or tundish change in appropriate time. This results in reducing casting abnormalities such as biased flow and tundish nozzle clogging and the tundish life can be enhanced.

Most of the times the clogging deposit occurs on the well block, enabling pumping or oscillation of stopper at the right time would clear the clogged deposit. This right time would be indicated by the model predicted by us.

So this model would be more helpful if is made available online on the HMI (Human Machine interface) screen so that the operator could take necessary action once the Index crosses said limit.

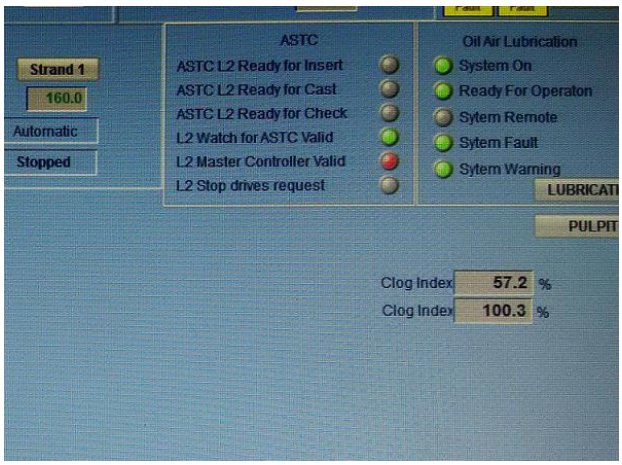

Figure 9: Online monitoring of clogging index in HMI(Human Machine Interface screen)

The model was made available online and was proved to be as useful tool in predicting clogging more specifically and enabled operator to take effective action to increase the length of Casting.

REFERENCES

[1] B. Bergman, N.Bannenberg, R. Piepenbrock, "Castability assurance of Al-killed Si- free steel by calcium cored wire treatment", *1st European Conference on Continuous Casting*, 1991, p. 1.501-1.508

[2] Girase, N.U., S. Basu, and S.K. Choudhary, Development of indices for quantification of nozzle clogging during continuous slab casting. Ironmaking and Steelmaking, 2007. 34(6): p. 506-512.

[3] D. Bolger, Stopper rod and submerged nozzle design and operation in continuous casting", Steelmaking Conference Proceeding, 1994, p. 531-537.

[4] Yuan, F., et al., Online forecasting model of tundish nozzle clogging. Journal of University of Science and Technology Beijing, Mineral, Metallurgy, Material, 2006. 13(1): p. 21-24.