Optimization of Liquid Steel grade mix practice in Tundish by using extended shroud.

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Abstract:

Due to stringent market orders and global competition, steel making engineers are confronting the challenge of scheduling and delivery of various steel grades. To overcome this by enhancing the yield and by reducing refractory cost by achieving or increasing sequence length in Tundish , Especially casting managers are involved to plan in advance for mixing different grades in casting . In mixing practice after a ladle close to next ladle opening that results in generating Mixed slabs which will be downgraded or discarded with more quantity of rejection depending upon the width we lose yield due to chemistry change. In our water modelling study carried out to determine the mixing in tundish of different chemistry grades and also studies the length of mixing slab evaluated and same optimization of mixed slab determined and reduces the scrap and aims it for prime grades.

In respect to above study of mixing of steel in tundish prediction based on physical 2/5th scale Water modelling tundish and Numerical simulations have been studied and same implemented in our operation practice by JSW.

JSW steel limited engineers studied the influence of the extended different length shroud design and submergence of different height of steel level in tundish, the Turbostop of impact pad geometry, tundish wall profile and bottom slope design with considering optimizing casting parameters to reduce the mixing zone from 20 T to 6 T of tundish weight and it is by reducing rejection length from 20 mtr down to less than 5 mtr for steel grade with chemistry of 0.08% Carbon and manganese 0.35% to 0.15% Carbon and 0.85% Manganese

Key words: Grade mixing, Tundish, Ladle shroud normal, Extended shroud, Water model

Introduction:-Present task of engineers to reduce the cost of production by increasing sequence length of tundish to improve yield by reducing refractory cost , reduce operation turnaround time delays and casting of scheduled plans of different grades with similar composition of chemistry with in a sequence. The main aim of increasing yield by reducing loses of head and tail with Tundish skull loss and control of time loss by avoiding speed reduction. Once the steel from ladle teemed into a refractory lined steel vessel called as a Tundish, The empty ladle is replaced by next filled liquid steel ladle teemed without interrupting the casting process of sequences. Apart from our study grade mixing occurs when steel has a different chemistry composition needs to be cast one after another. The task of handling different chemistry of steel grades is gaining the importance because of huge demand for variety of steel products increases.

The mixed steel from tundish that is obtained during ladle changeover has to be downgraded are used as a recycle scrap purpose. In order to overcome this by Minimization of mixing zone in tundish will help us to improve the productivity with quality and yield by our present work.

Background:

JSW steel limited making variety of steel grades with different carbon ranges from low to high content with HSLA, Peritectic, microalloy peritectic, IF (Automobile grades) and Electrical steel grades. Such grade orders are handled by JSW through dissimilar grades casting sequences with an competitive cost.

Ways of Casting of different chemistry steel grades quality can be handled as follows:

1) Casting of short sequence of similar grades, past practice casters stopped and restarted after each sequence of casting of grades of similar groups and results no intermixing occurs in tundish and will also not impact on yield , whereas first and last slab are cut and downgraded and same generating more skull in more short sequence casting and need to be segregation of skull and needs more space and same recycled.
2) Grade separator plate practice: When ever the plan of casting of different grades needs to use of separator plate and same will inserted in mold while slowing down of casting speed or even by machine stopping .This prevents the mixing of steel in past semi-finished shell with center liquid core strand but it is very challenging and unsafe practice and sometimes failure happened by way of breakouts.
3) Tundish Fly:A new preheated tundish is positioned over the mold during the ladle change. This prevents the grade mixing in Tundish but past solidified shell of previous heat sequence is down graded and some times we fails because of joint failure after fly which leads to breakouts.
4) Continue sequence with new ladle chemistry steel grades: The new steel grade mixing inside the tundish, inside the mold and inside the semi solidified strand without variation of casting speed. In such a case the rejection of mixing grade cast length depends on rate and extent of mixing between two different chemistry grades in Tundish, mold and in strand, which in turn depends upon the casting parameters and steel flow geometry. Due to more customer demands and orders from customers the above method was commonly adopted but it leads more rejections due to mix chemistry and it impact on quality.

The above practice of mixing of different chemistry will be taking into considerations which impacts on cost effective due to downgrading, scrapping, the production and losing the yield losses.
The effective parameters on the amount of mixed grade in the tundish are reported by previous studies1,2,3 are respectively, liquid steel tundish volume when the new ladle is opened, the casting speed during the grade transition, slab dimensions, tundish refilling rate, the tundish geometry and the type of flow control devices, chemical composition of the initial and subsequent steel grades. It is worthy to notice that both steel grades can have different temperature, therefore the temperature variations inside the vessel will generate additional convective flows that should not be ignored.

Steel grade mixing optimization in tundish has been simulated using 1/3rd scale water modeling experiments. Frouds dimensionless number has been used to ensure the similarity criteria of flow behaviors in the models and actual steel casting tundishes.

To understand the Mixing behavior during a grade change in JSW Vijayanagar casting conditions, 1/3rd scaled plexi-glass tundish water model has been built as shown in Fig. 1. The steel level inside the tundish is around 600mm or 14T above the tundish outlet when the new ladle containing the new steel is opened. To prevent tundish flux emulsification and entrainment of ingress of air from atmosphere, the ladle shroud needs to be quickly submerged to avoid generation of secondary inclusions in tundishes Then the tundish level is raised back to the operating level at 1050mm .

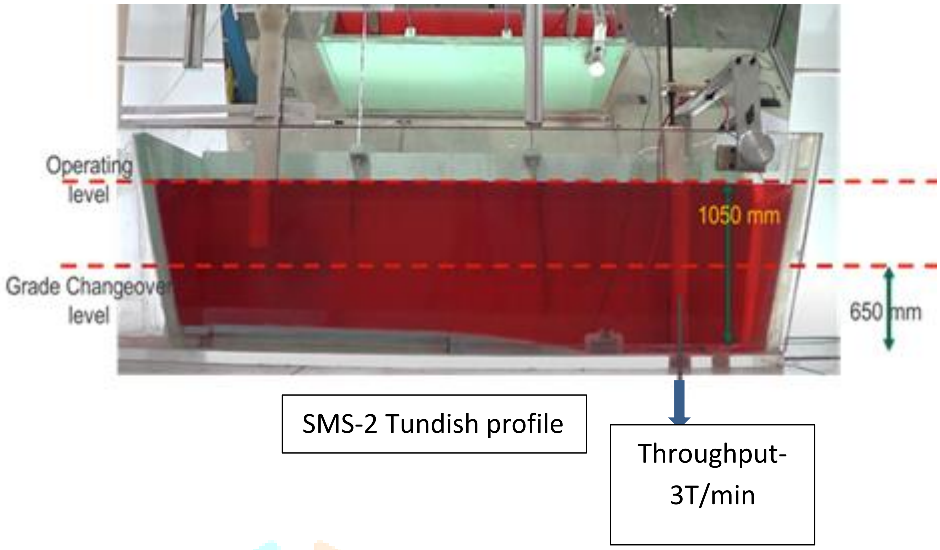


Fig-1 represents the JSW water model of 1/3rd volume and depicts the process summary

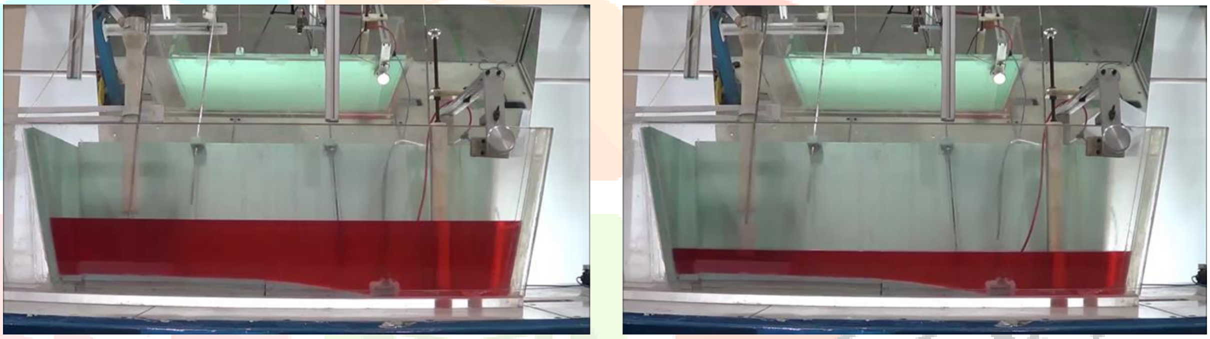
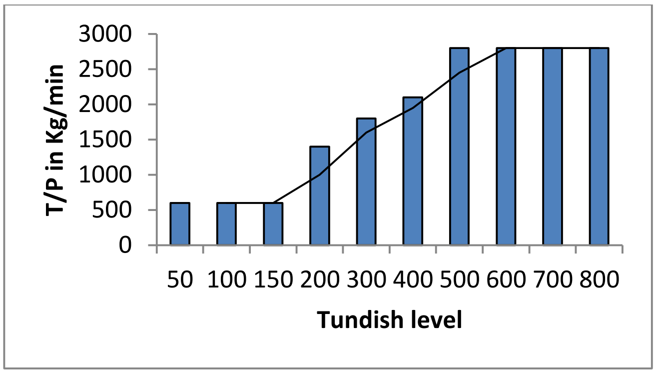
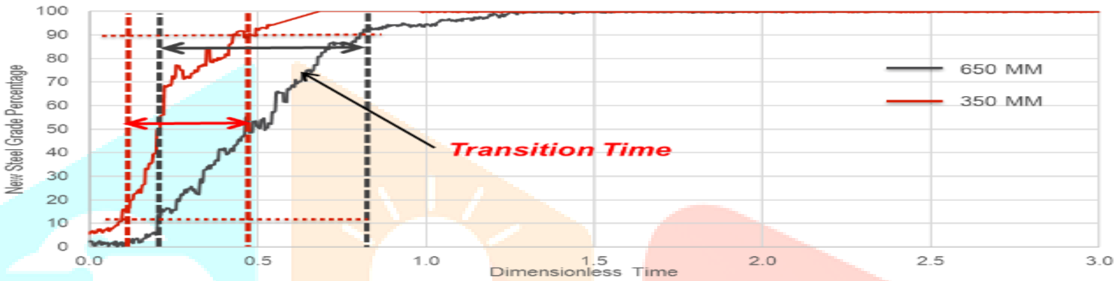


Fig-2 and 3 of JSW water model tundish of 1/3rd scale at 2 different tundish steel levels and figure-2 of 600mm level and fig-3 of 400 mm level.

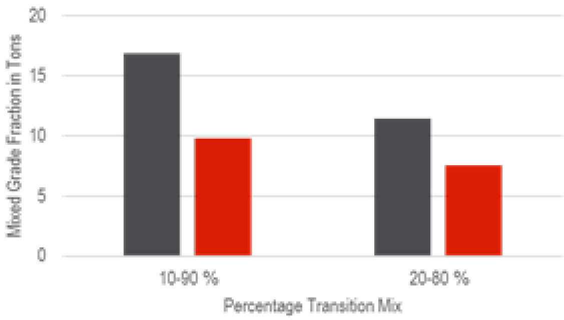
In experimental simulations, different throughput and filling rate have been accounted to study the mixing length reduction. The tundish level before opening of new steel ladle, can be reduced to a level at which rate Vortexing not yet seen or determined. From considered parameters at around 400 mm tundish level no vortexing has been observed while maintaining 2 T/min throughput. Simultaneous experiments with casting speed like through put with different tundish level have been recorded and shown in graph-1



Graph-1 depicts the prevention of vortexing with respect to throughput .



Graph-2 F-curve of two different tundish levels.



Graph-3 depicts the mixing zone at different levels in Tundish

These transition curves or F-curves, showing relationship between the percentage completion of transition and the tons cast on a strand after ladle open, were determined as a function of grade change drain level and refill practice. The grade change drain level is defined as the depth over the outlet strand of residual liquid of the old grade at the moment the ladle containing the new grade is opened.

To illustrate the results of these of experiments, transition curves measured at a simulated grade change drain level of 600mm and 400mm are presented in Graph2, while the results of transition completions at both 600mm and 400mm drain levels is given in Graph.3. The transition results are produced from data of at least three repetitions of each transition test and show the percent completion of transition as a function of tons cast after ladle open for the JSW Vijayanagar tundish configuration.

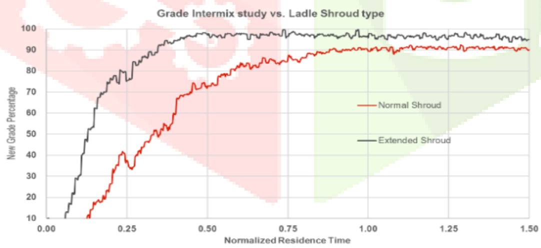
The calculation of the amount of the mixed grade slab in the product as a downgrade steel can be done using different criteria in practice. Selection of the upper and lower limits on the displayed curves identifies the weight of the mixed grade steel. For instance, as shown in Graphs2 and 3, if the lower and upper limits are set to 0.1

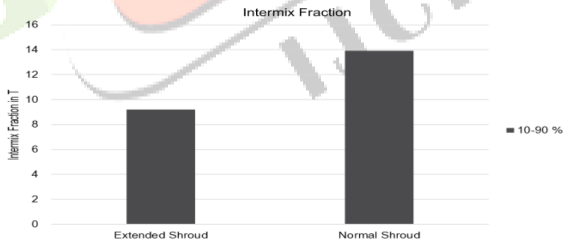
and 0.9 respectively, the weight of the mixed grade steel by the normalized concentration curve will be respectively around 18T and 8T for drain level of 600mm and 400mm.

Figure-4 depicts the immersiom of extended shroud to avoid emulsification in tundish.

In oredr to open new ladle at lower level of tundish weight without generating the emulsification, a new ladle shropud has been considered.After our repeated trials Vesuvious has issued a extended shroud with inside casting insulating material to sustain temperature and also allow it remains in immerse condition to prevent can melting with refractory as shown in figure-4. The elongated shroud allows initially to early submergence at lower level of metal in tundish as shown in fig-4 and after some time can and insulating material washed away and original shroud part remains as usual which used for continue the sequence length of designed length of 1680 mm length.Graph. 4 and Graph.5, compared to a ladle opening at 600mm tundish level with the regular ladle shroud design.

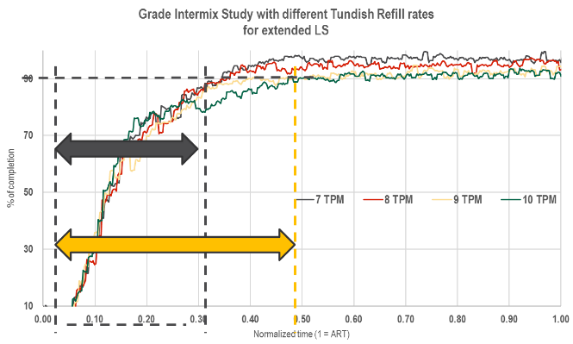
Using a ladle shroud with its extension and opening the ladle at around 350mm with a refill rate of 8 T/min, the intermix transition is reduced by 5.5T, see Graph. 4 and Graph.5, compared to a ladle opening at 600mm tundish level with the regular ladle shroud design.

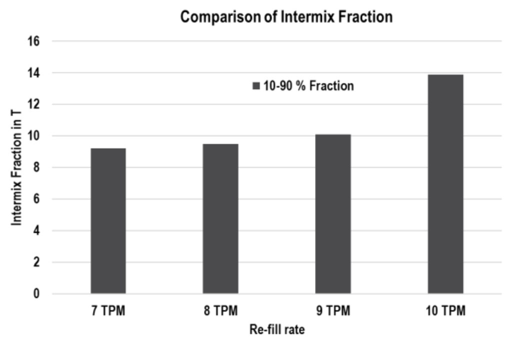




Graph 4: F curves for the normal ladle shroud and with the extension, Graph 5: Transition numbers for a 10-90% grade transition

The refill rate has been increased up to 10T/min without impacting noticeably the intermix volume. This allows a quicker tundish fill to reach the operating level desired for optimal inclusion floatation, see Graph.5 and Graph.6.





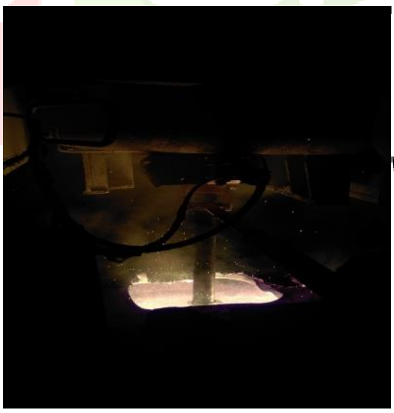
Graph 6: F curves for the extended ladle shroud at different refill rate, Graph 7: transition numbers for a 10-90% grade for different refill rate

JSW Vijayanagar SMS2 grade Mixing results:-

JSW Vijayanagar SMS-2 operation has implemented successfully the optimized parameters determined by physical modeling and has further tuned the operating practices.

The use of the ladle shroud extension and a tundish level around 5T corresponding to 350mm have been considered. The maximum throughput should not exceed 1.8T/min as shown in Graph 1. The refill rate has been increased to 10T/min.

From the tundish floor, the tip of the ladle shroud extension is around 400mm, which corresponds to approximately 100mm above the top surface of the Turbostop® impact pad. To avoid excessive turbulence and tundish flux emulsification, the Turbostop® impact pad position inside the tundish must be checked, Picture 6. The incoming flow from the ladle shroud must hit the inner cavity of the turbulence suppressor; therefore, the length of the extension has to be designed according to the targeted tundish level for the grade transition. Too short, the stream exiting the ladle shroud will entrain tundish flux and air when passing through the flux layer. Too long, an open-eye presence will increase gas absorption rate and thus the re-oxidation of the liquid steel.



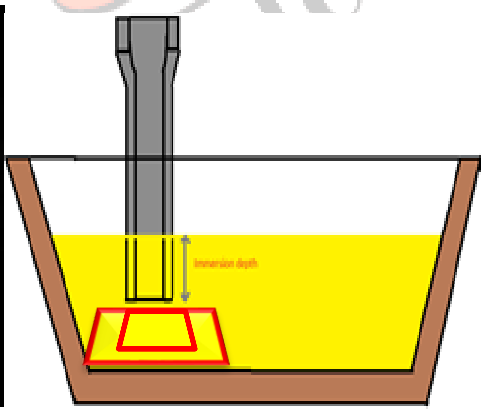


Figure 6,7 & 8: Ladle shroud extension position relative to top of Turbostop®.

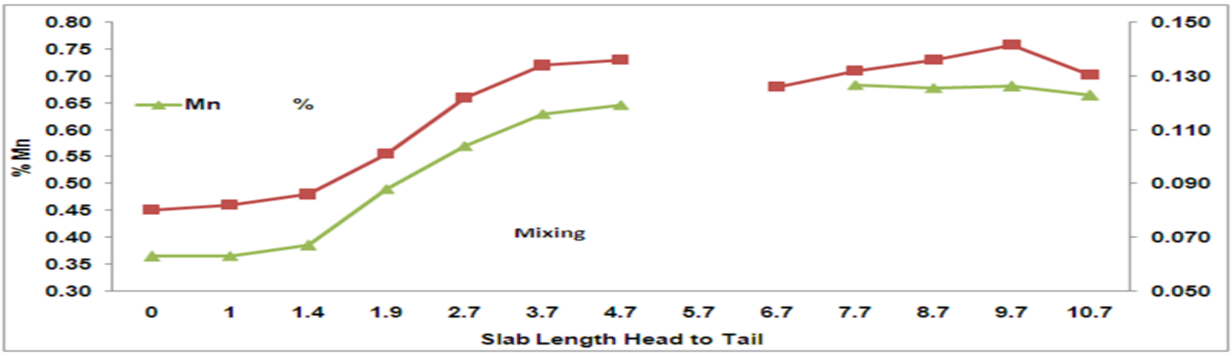
Figure-9 & 10 depicts the different grades mixed during trial of 0.06% C , 0.35% Mn to 0.15 % C & 0.8% Mn and silicon from 0.015 % t0 0.16 %.

Figure-11 To track the steel grade mixing or transition phase , steel samples are cut from the cast slab, near the narrow faces of 1 mtr interval in such a way that the slab can be processed downstream without additional rework

Figure-11 Mixed slab taken for analysis of mixed or transition part identification and cut it into 1 mtr interval

The key factor studied during this practice was to optimize the casting throughput during draining of tundish before new grade is poured into the same tundish and rate of tundish re-filling was optimized at the same time casting through put was gradually increased within a time frame. The re-oxidation and tundish flux entrainment are limited thanks to the quick submergence of the new ladle shroud with its extension. JSW has automated this ramp down and ramp up procedure after several trials based on the cast width and the grade severity factor to help the operators to focus on stabilizing the casting operation.

Steel samples collected on the cast slabs are highlighting the significant intermix reduction from more than 30m down (prior to any optimization) to less than 4.5 m. Graph.8, 9, 10 and table-1 show that only 1.5m has to be downgraded when applying the suggested draining level, refill rate with the ladle shroud extension

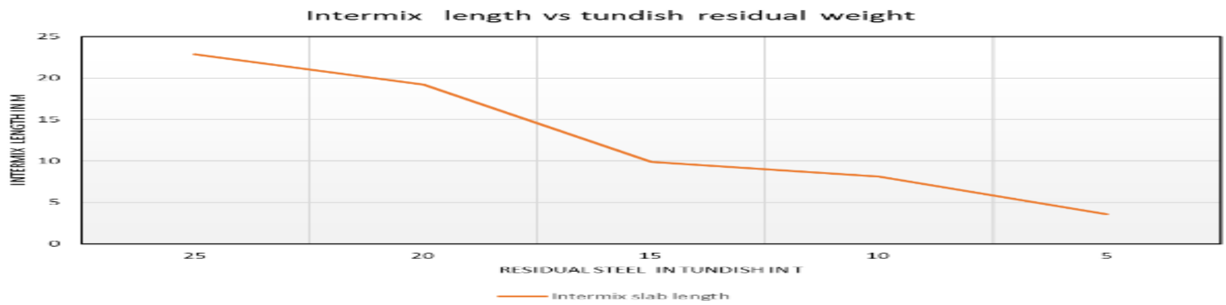


Graph-8 Chemical analysis of mixed slab

Trial	Sample position 'mtr'	C %	Mn %	S %	P %	Si %	Alt %	Cr %	N i %	Cu %	Nb %	V %	Ti %	Mo %	B %	Sn %	Ca%
Extended shroud trial	0	0.080	0.37	0.011	0.016	0.015	0.049	0.009	0.011	0.006	0.001	0.001	0.001	0.001	0.0001	0.001	0.0003
Extended shroud trial	1	0.082	0.37	0.013	0.016	0.016	0.049	0.007	0.012	0.006	0.001	0.001	0.001	0.001	0.0001	0.001	0.0001
Extended shroud trial	1.4	0.086	0.385	0.014	0.015	0.018	0.0458	0.009	0.01	0.006	0.001	0.001	0.0009	0.001	0.0001	0.001	0.0002
Extended shroud trial	1.9	0.101	0.49	0.011	0.016	0.042	0.040	0.009	0.010	0.006	0.001	0.001	0.001	0.001	0.0001	0.001	0.0002
Extended shroud trial	2.7	0.122	0.57	0.008	0.019	0.055	0.038	0.010	0.010	0.008	0.001	0.001	0.002	0.001	0.0001	0.001	0.0002
Extended shroud trial	3.7	0.134	0.63	0.006	0.018	0.069	0.036	0.010	0.010	0.007	0.001	0.001	0.002	0.001	0.0001	0.001	0.0001
Extended shroud trial	4.7	0.136	0.65	0.006	0.016	0.082	0.035	0.009	0.012	0.006	0.001	0.001	0.0013	0.001	0.0001	0.001	0.0001
Extended shroud trial	5.7			Sample rejected													
Extended shroud trial	6.7	0.126		0.006		Sample is very small not possible to do other elements											
Extended shroud trial	7.7	0.132	0.68	0.006	0.015	0.087	0.0353	0.008	0.013	0.006	0.001	0.001	0.0014	0.001	0.0001	0.001	0.0004
Extended shroud trial	8.7	0.136	0.68	0.007	0.016	0.088	0.0365	0.008	0.013	0.006	0.001	0.001	0.0015	0.001	0.0001	0.001	0.0003
Extended shroud trial	9.7	0.142	0.68	0.009	0.018	0.095	0.035	0.009	0.012	0.006	0.001	0.001	0.001	0.001	0.0002	0.002	0.0002
Extended shroud trial	10.7	0.130	0.66	0.005	0.016	0.091	0.036	0.010	0.012	0.005	0.001	0.001	0.001	0.001	0.0001	0.001	0.0005

Table-1 Steel slab analysis of 1 mtr interval distance

Graph-9 chemical analysis with respect to C, Mn and Si



Graph-10 Tundish weight w.r.t chemical analysis

Additional physical modelling and numerical simulations are being considered to further reduce the intermix grade length by profiling the yield enhanced tundish profile, by using also a tundish gas diffuser. Furthermore, the mold flow behaviour is under investigation to also reduce steel grade mixing5.

Grade transition software should be considered to concentrate the intermixed grade region within a slab standard length for downgrade market.

CONCLUSIONS

During the process of casting the quantity of steel remaining in tundish strongly approaches the mixing occurring in tundish

Water model experiments have been used to determine improved grade transition practice for JSW Vijayanagar tundish. A quicker dilution of the old steel grade along with low casting speed at low tundish level is beneficial to reduce intermixed volume. The grade transition is performed at low tundish level, at around <5 T, in combination with a ladle shroud with an extension to prevent tundish flux emulsification and re-oxidation prior to its submergence.

Such change over practice allows JSW steel plant to maximize the productivity of the caster and reduce yield losses from 30m intermix slabs to less than 4.5 m as shown in Graph.10.

Planning should be optimized to reduce mixing losses, stringent grades should always be cast first there after plan critical grades change should be avoided and overlapping mixing phase overlapping planned to correspond to one full length slab.

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