

COMPUTATIONAL STUDY OF A TRAILBLAZER MULTI REACTOR TUNDISH (MRT) FOR IMPROVING YIELD AND QUALITY OF STEEL DURING CONTINUOUS CASTING

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Abstract

Increasing the production efficiency of the continuous casting process requires casting longer sequences of ladles without stopping and restarting the caster. As the demand for wider ranges of steel products increases at the same time, the intermixing of dissimilar grades is becoming a problem of growing concern. When high grade dissimilar grade steel intermixed, huge amount of metal is lost from down gradation. With increased usage of steel for critical applications, the demand for cleaner steel has increased. Existing technologies have been improved and new technologies are being introduced all along the process route to minimize the size and quantity of inclusions. The bad effect of inclusion is it creates sliver in the hot rolled coil. To overcome the aforementioned problems a novel multi reactor tundish (MRT) technology has been developed which will decrease the intermixed amount during grade transition. Simultaneously it will increase the quality of steel by removing inclusion by increasing the plug flow and residence time in tundish. A computational study of the newly developed tundish has been done by using Fluent 6.3 computational fluid dynamics software and the results has been compared with two different type of normal tundish used in industry.

Keywords: Tundish, Grade Transition, Inclusion, Yield

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1. INTRODUCTION

To meet the customers' demand for faster delivery of small quantity orders for steel products, the number of castings has been increased with different grades as successive heats in a single casting sequence [1]. Since this successive different grade casting produces undesirable grades of mixed slabs, the steel producers need to know exactly where the mixed region is located that needs to be cut out and to optimize the casting conditions to minimize the costs associated with intermixing different molten steels from different ladles [1]. As the efficiency and flexibility of the continuous casting process improves, it is becoming increasingly common to cast different grades of steel as successive heats in a single casting sequence. Unfortunately, mixing tends to occur during the transition between steel grades. Slabs cast during the transition vary in composition between the grade of the first heat, or "old grade" and that of the second heat, or "new grade," in the sequence. The final product is often referred to as "intermixed steel" and is naturally undesirable since it must be downgraded [2]. The cost can be significant, since each meter of intermixed slab length contains roughly 2 ton of steel. Steel producers need to know exactly where the mixed region exists, in order to cut out and downgrade the minimum amount of steel necessary to satisfy customer product specifications. In addition, casting conditions should be optimized to minimize the costs associated with intermixing [3].

The requirements regarding the improvement of quality of steel and performances achieved in ladle metallurgy lead us to consider the tundish not as a simple liquid steel container but as a real metallurgical reactor capable of appreciably diminishing the inclusion of the molten steel [4]. Inclusions can greatly influence the properties of steel. The requirements for the mechanical properties and chemical composition of steel are constantly increasing. Thus, the strength, ductility, durability, and corrosion resistance of steel have improved over the years to meet the need [5]. This has been achieved partly by making steel cleaner of nonmetallic inclusions, which deteriorate most of the above properties.

The objective of the present research is to minimize the transition period during sequence casting such that less metal loss from down gradation and improve the yield of continuous casting. Not only that the present tundish will improve the quality of steel by removing inclusion from the melt.

2. NOVEL REACTOR

Normal single strand slab casting Tundish consists of a rectangular container with a shroud partially immersed in the liquid steel. Sometimes a weir and dam is introduced as a flow control device. But the novel reactor is consists of two special weir. Within the reactor a dam has been introduced as a flow control device. Multiple of this reactor with dam has been

added in series within the single strand slab casting tundish. The above description has been schematically shown in the

figure 1.

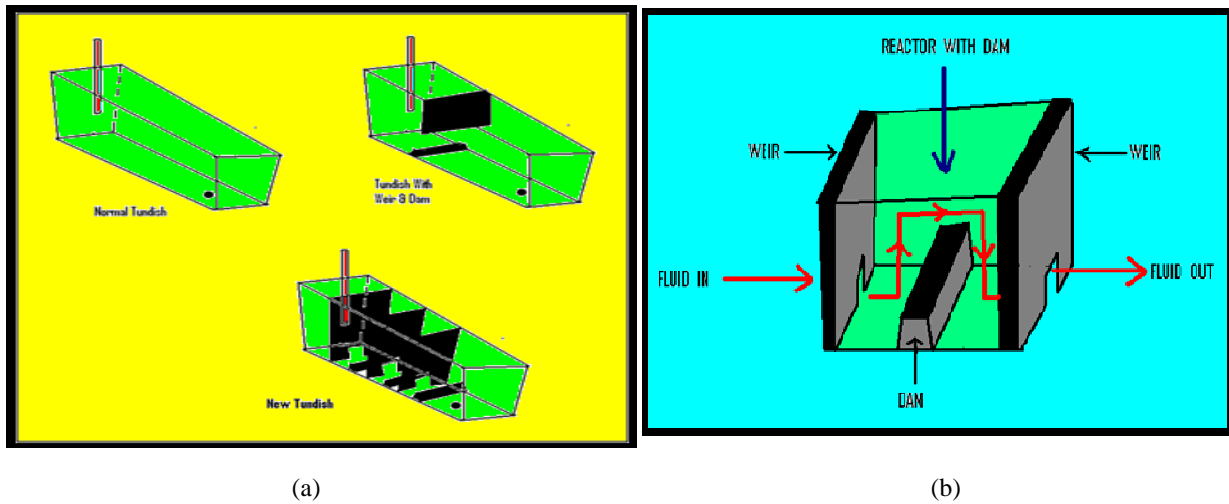
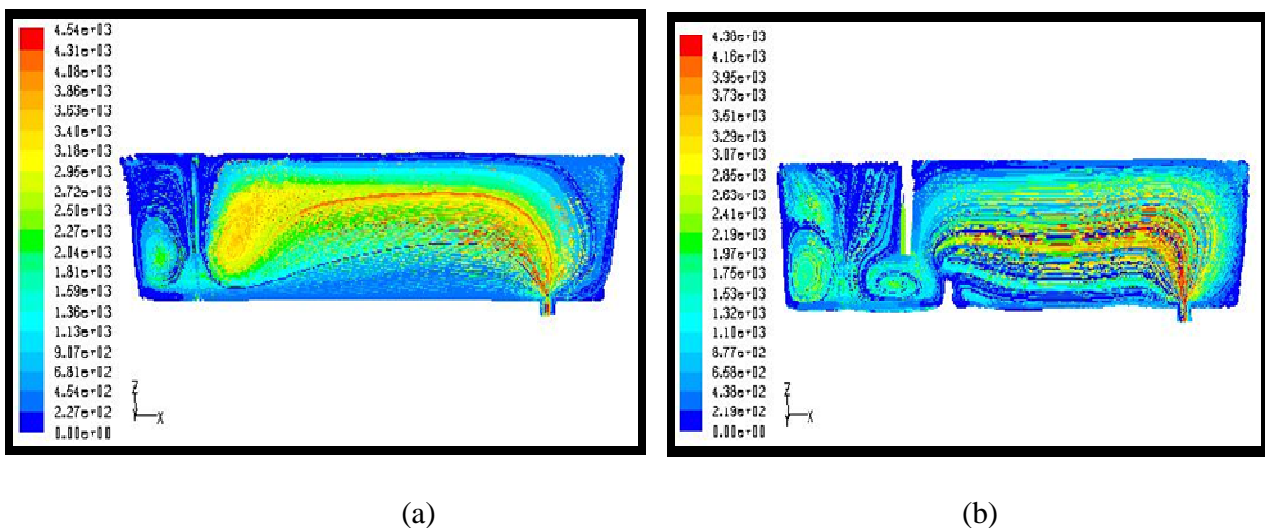


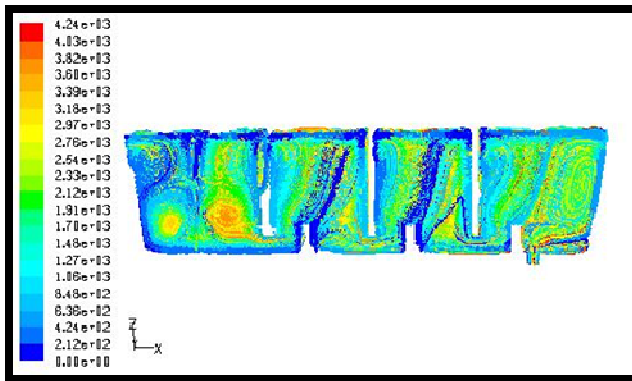
Fig.1 Schematic diagram of (a) normal tundish, tundish with dam-weir and new tundish (b) Novel Reactor with dam

The weir is a special design. At the bottom there is a hole for entering and exiting the fluid. Within the reactor one dam has been placed which act as a barrier to direct transfer of fluid from from one side of the reactor to other side of the reactor. The entering fluid going upward side of the reactor surface to overcome the barrier introduced by the dam. Within the novel reactor different type and dimension of dam can be introduced for flow control. Not only can that semi perforated baffle be introduced for improving the yield and cleanliness of the

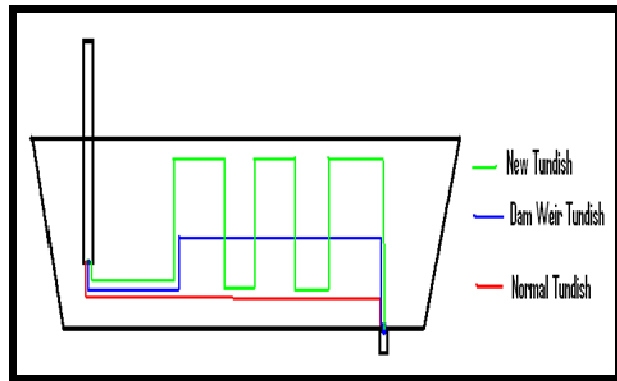
liquid steel. It will help for longer sequence casting with better quality of steel. Gas purging can be introduced within the reactor also for increasing yield and better quality of steel production.

3. VELOCITY PROFILE





(c)



(d)

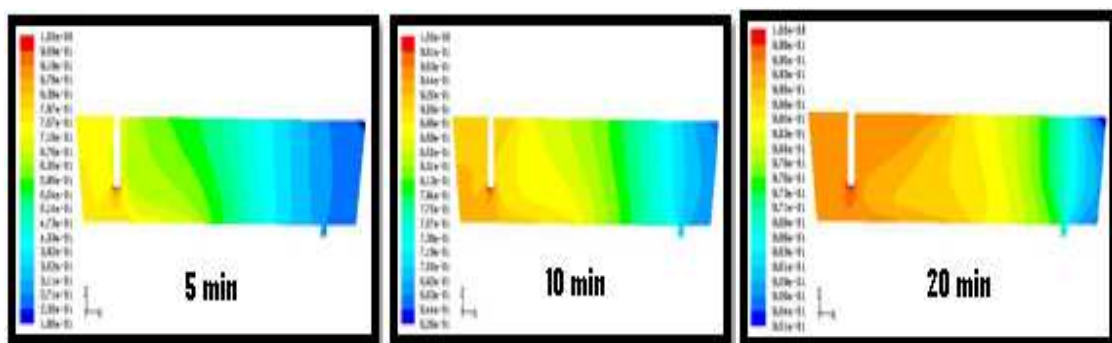
Fig.2 Velocity contours (a) Normal Tundish (b) Tundish with weir-dam (c) New Tundish and (d) Compare Velocity Track of 3 different Tundish.

Velocity profile of the three different tundish has been studied computationally. The velocity contour for normal tundish, tundish with dam-weir and new tundish has been illustrated in figure 2. For computational study a 0.4 scale water model tundish has been investigated. The operating parameters and dimensions of the different portion of the tundish has mentioned in the table1. The dimension of the model tundish was scale down from actual tundish by geometrical similarity criteria and the operating flow rate of water in the model tundish was calculated from Froude similarity criteria. From the velocity track comparison it was found that for new tundish the fluid is travelling more paths compared to the other two tundish configuration. This will indirectly help to less mixing of the liquid within tundish and chances will increase more for production of clean steel.

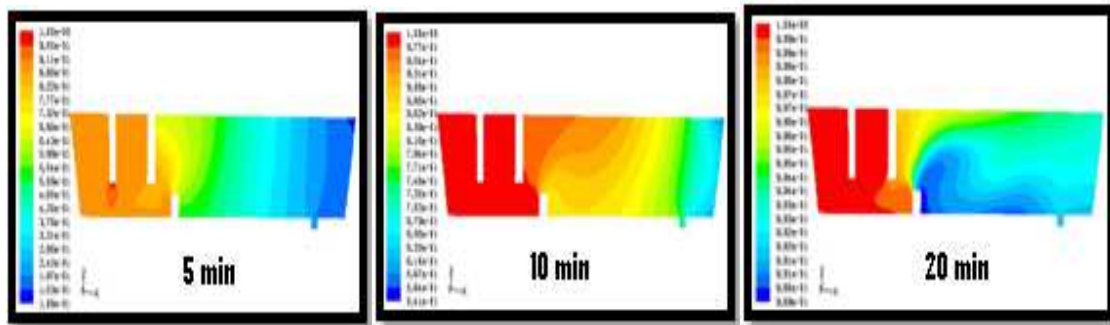
Table1 Dimensions and Operating Parameters used for the study

Parameters	Model
Length (m)	0.179
Width (m)	0.45
height (m)	0.45
Inlet/Outlet Nozzle Diameter (m)	0.004
Shroud Depth of Submergence (m)	0.3
Inlet Velocity (m/sec)	0.667
Turbulent Kinetic Energy (m2/s2)	0.222
Turbulent Dissipation Rate (m2/s3)	0.006

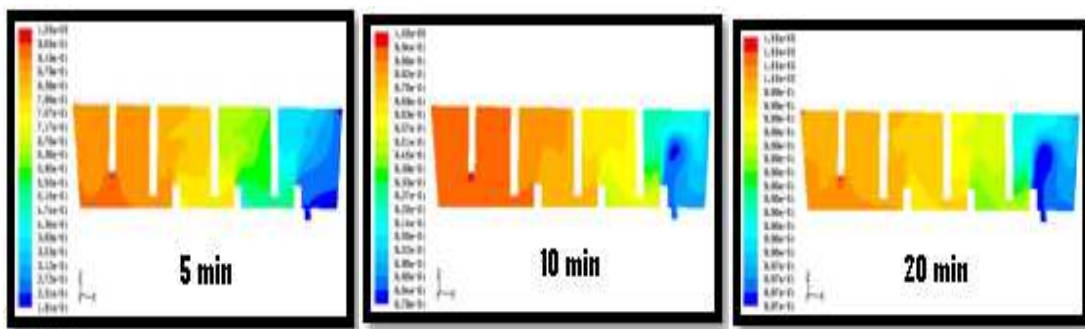
4. RESULTS & DISCUSSION YIELD IMPROVEMENT



(a)



(b)



(c)

Fig.3 New grade concentration over old grade at different time interval for (a) Normal Tundish (b) Tundish with weir & dam (c) New Tundish

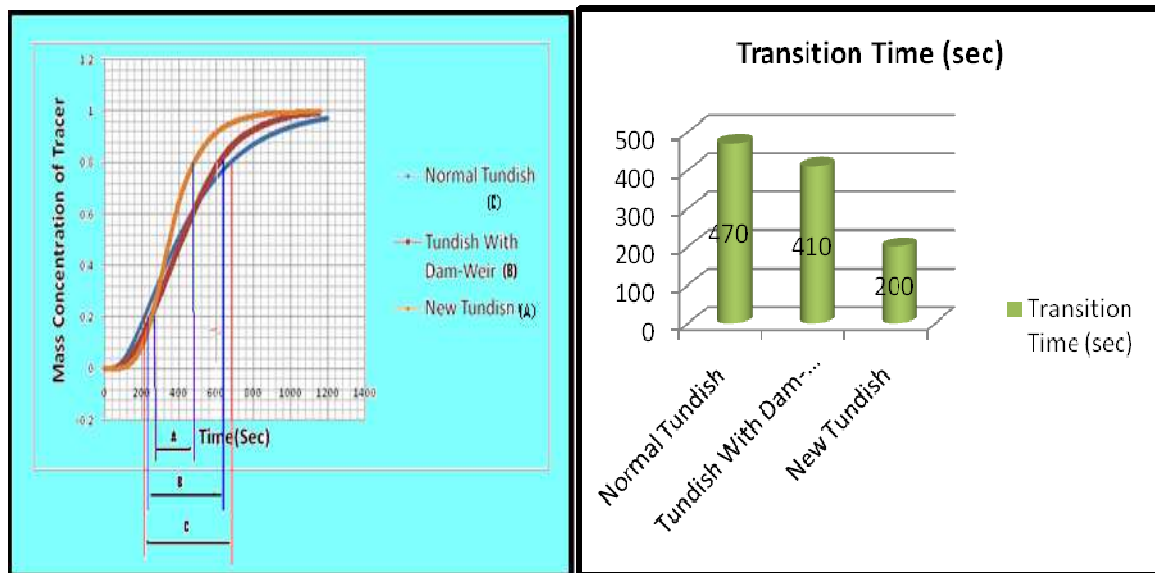


Fig.4 Graphical Representation of Transition Period for Different Tundishes

In recent years yield improvement has got tremendous importance in steel industry. Many researchers are trying to improve the yield by minimizing skull in the tundish. The present approach is to increase the yield of steel by decreasing transition slab formation. For study this phenomena a mathematical modeling investigation was done in three types of tundish i.e. normal tundish, tundish with weir-dam and new tundish. A new grade was inserted over old grade by species transport mechanism. The CFD study of new grade concentration over old grade at different time interval for three tundishes was illustrated in the figure 3. It was observed from the figure that for new tundish the transition period was over within 10 minutes compare to other two tundishes which took a period of 20 minutes.

Figure 4 is a graphical representation of transition period for different tundishes. The change of concentration of tracer has been plotted along the y axis and the time elapsed has been plotted along the X-axis. It is observed from the graph that the transition period (change of concentration from 0.2-0.8) is less for new tundish compared to other two tundishes. For this reason the graph for new tundish is steeper than the graph of normal and dam-weir contain tundish. The transition period for new tundish is 200 sec. But for normal tundish it is 470 sec and it is 410 sec for tundish which containing weir-dam.

4.1 Inclusion Floatation

To judge the cleanliness efficiency of the new reactor compare to other conventional reactor it is important to study the residence time distribution curve of the reactors as a customary basis. The RTD curve is plotted in the figure 5. From the curve it is seen that the new reactor is a plug flow dominated container as indicated by the peak of concentration. Not only that the dead volume will be less as the area under the right portion of the curve less than the other tundishes. The minimum residence time of the new tundish will be more than the other two tundishes as seen from the RTD curve. If it is seen carefully the figure 2 the new tundish flow is more towards upper surface which will help to trap inclusion within the upper slag phase and indirectly will help to make clean steel.

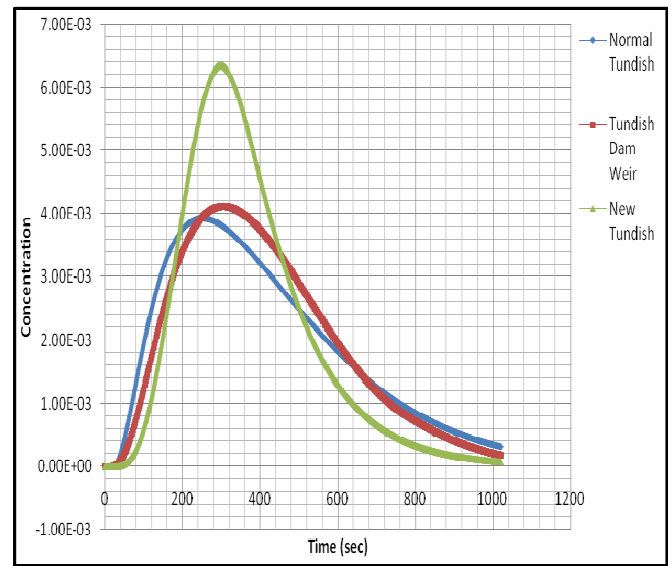
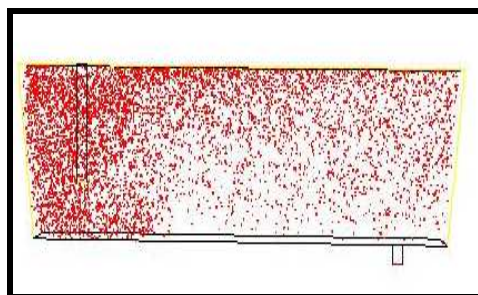
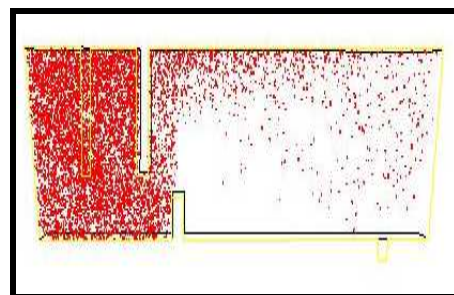


Fig.5 RTD Curve For Different Tundish In Comparison with New Tundish

The cleanliness efficiency of the three types of tundish was investigated by travelling wood particles of diameter 50 μm through the water. The diameter of particle was as chosen as this is the critical diameter of particle for generating sliver complains in the hot rolled coil. In the figure 6 the distribution of non metallic inclusion is shown within the tundish. The Discrete Phase Model was used to track the particles through the water. The top surface and outlet were used to trap the inclusions. It was seen from this study that the normal tundish has highly prone to entrapment of inclusion at the final cast product. Tundish with dam & weir is coming to the next position. The new tundish has high potential to remove the inclusion from the tundish. Here only one particular diameter of inclusion has been studied. It is required further study to find out the effect of other large and small diameter inclusion. Here particle coagulation and its interaction with refractory material has been excluded.



(a)



(b)

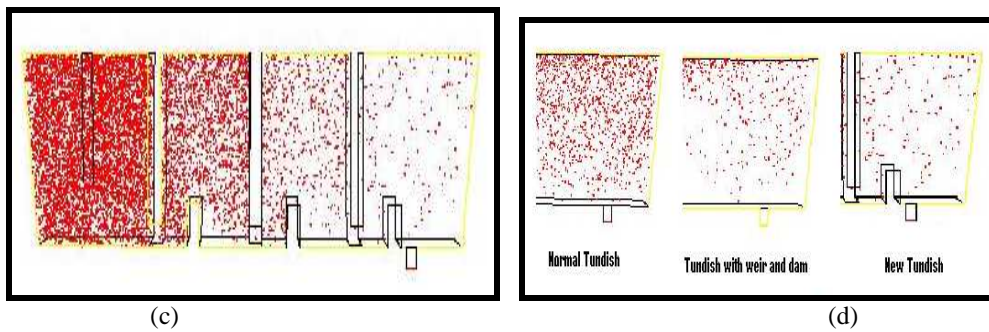


Fig6. Presence of Non-metallic Inclusion of diameter 50 μm in (a) Normal Tundish (b) Tundish With Weir and Dam (c) New Tundish at Steady State (d) Selective Picture at Outlet

CONCLUSIONS

The above study indicates that the new metallurgical reactor is novel in concept and it is highly promising to increase the yield and improve the cleanliness of steel. Not only yield and cleanliness it is anticipated that the new tundish will be able to homogenize the temperature within the tundish itself.

FUTURE WORK

In future a vacuum tank will be incorporated on two consecutive reactors which will act as a suction machine. This will help to increase the inclusion flotation rapidly and will reduce reoxidation. The dissolved gases like H_2 and N_2 will decrease. Finally it will help to discharge a high value quality steel from the tundish. This is schematically shown in figure 7.

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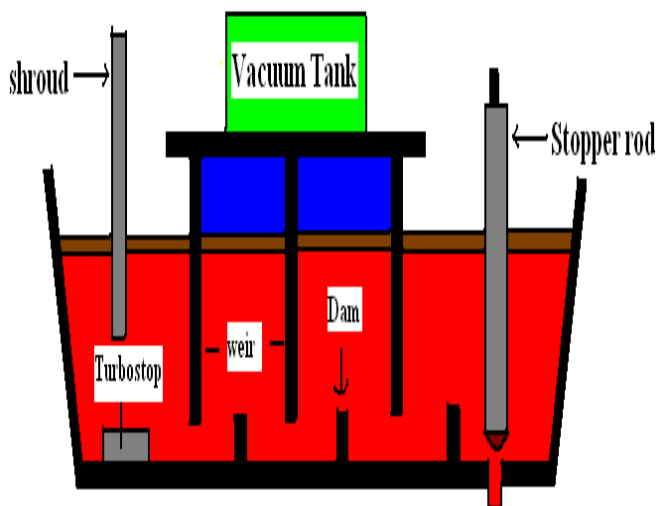


Fig7. Schematic diagram of future work