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INTRODUCTION OF *i* BOX PICKLING TECHNOLOGY – HIGH PICKLING PERFORMANCE FOR DIFFICULT-TO-DESCALE MATERIAL, ENERGY SAVING AND SUITABLE FOR IMPROVEMENT FROM EXISTING PICKLING TANK[1]

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Abstract

To meet the ever increasing demand of international steel manufacturers for energy saving, compact and high performance pickling system capable for increasing the production of difficult-to-descale strip, various new products e.g. ultra-low carbon steel, high strength steel, electrical silicon steel, has appeared on the market in recent years. In addition, energy saving has been demanded not only by steel manufacturers but also general society. Mitsubishi-Hitachi Metals Machinery Inc., (MH) developed and is distributing ***i* Box** (Immersed Box) pickling tanks to the market, which has even similar high pickling performance by the box turbulence effect. This pickling technology doesn't require continuous acid circulation by electric motor driven pumps as the other circulation type and can save steam consumption by unique designed tank covers. As a result, electrical energy in the pickling tank area is saved by approx. 80% ,and the heating loss from the pickling system is saved by 24% compared with the continuous acid circulation type pickling system of similar production capacity. Since this ***i* Box** can be modified from customers' existing Deep type pickling tank with reusing the existing pickling tank itself, our customer can reduce the shut down term to modify to high performance pickling tank and increasing the line productivity easier. In this paper, MH introduces the ***i* Box** pickling technology based on the pickling theory, and the references of the applications to the actual product lines.

Key words: ***i* Box**; High pickling performance; Energy saving; Difficult-to-descale.

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1 INTRODUCTION

To the fields of automobiles and electric household appliances which are the principal consumers of cold rolled steel strips, recently, there is an increasing demand for ultralow carbon steel, high strength steel with excellent process ability from viewpoint of quality and productivity. To meet this trend steel makers are expanding the production of ultralow carbon steel and High strength steel, but since this steel requires pickling time (de-scaling time) of about two or three times as compared with normal low carbon steel in the conventional deep bath type or normal shallow type pickling tank, the line speed must be lowered to 1/2 to 1/3 in operation. Hence, there has been a problem that the production output has not increased.
Additionally, a part of high strength steel include high content of Silicon which cause the accumulation of sludge in the pickling tank, the sludge impedes the continuous production by pickling tank which is necessary to wash up the external heat exchanger, circulation piping or pumps. The line stop time is increased for maintenance of sludge removal. In addition, steel mills are demanded to save steam and electric energy in order to save the carbon dioxide emission to meet the recent environmental trend.
In order to meet these demands and in replacing the conventional circulation type Mitsubishi Hitachi Metals Machinery Inc., (MH) has developed a ***i* Box** pickling system. In this equipment, the descaling speed can be similar to the Jet pickling tank or Trubulence pickling tank without external acid circulation and external acid heating system. As a result, the heating loss can be reduced by 24% and the electric energy can be saved by approx. 80%.
This paper reports the flow condition inside the pickling tank calculated by numerical simulation and ***i* Box** pickling tank capability against de-scaling speed compared with the Jet pickling tank. In addition, this paper shows the structure of ***i* Box** pickling tank to explain the reason of save the heating loss and save the electric energy.

2 PICKLING EFFICIENCY COMPARED WITH OTHER TYPE PICKLING TANK

As before Hirai[1] made clear the pickling speed theory to explain the relation between heat transfer coefficient and the necessary pickling time. In that paper, the dynamic flow condition in pickling tank was not cleared, since the total flow conditions were not cleared by experimentation in laboratory or actual pickling tank and at that time, software and hardware of numerical simulation had not have enough ability. In this paper, the total flow conditions were simulated by 3D numerical model which is calculated by STAR-CCM+ produced by CD-adapco. The Jet and ***i* Box** pickling tank is compared about the dynamic flow conditions and heat transfer coefficient simulated by the above 3D model and solver. By this comparison, the de-scaling efficiency of ***i* Box** pickling tank is cleared to be similar to Jet pickling tank.
The structure of Jet pickling tank and ***i* Box** pickling tank is mentioned as follows:

2.1 Jet Pickling Tank

This is the pickling tank (Figure 1) which was put into practice in 1990 by the joint development of MH and Kobe Steel.[2] Acid is supplied into a flat square type pickling tank fully by the low pressure slit nozzle at the inlet and the seal slit nozzle at the outlet. Strip path is horizontal and appropriate for high speed running. The

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acid inside the tank is full and is perfectly bound between the tank top and bottom surfaces with no free surface, therefore, relative speed between the steel strip and the acid is maintained even if turbulence is not intentionally injected at a high pressure into the tank with the nozzles at the inlet and the outlet.

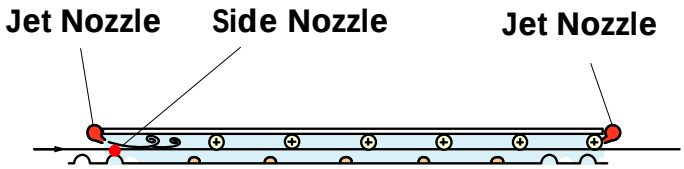

Figure 1. Jet Pickling Tank Model

2.2 *i* Box Pickling Tank

Figure 2 shows the simple structure of ***i* Box** pickling tank. It was put into practice in 1994 at Kawasaki Steel Mizushima Works No.2 pickling line[3] aiming at radical improvement of the pickling speed by modifying the existing deep tank at a lower cost. The principle of promoting the pickling reaction is the same as that of the Jet pickling tank; pickling performance in the same level as the Jet pickling tank can be obtained by installing a flat square tank (box tank) in the upper of the shallow tank. Acid is constantly filled inside the box tank without special slit nozzles at the tank inlet and the outlet and pump circulation system. The acid inside the tank is circulated through the notch at the bottom of the box tank by the running strip. The acid is heated up by the internal steam to acid heat exchanger which is installed inside of the pickling tank. Free surface is closed by the upper side cover, so that acid fume generastion can be reduced. As a result, hydrochloric acid loss and steam loss can be reduced.

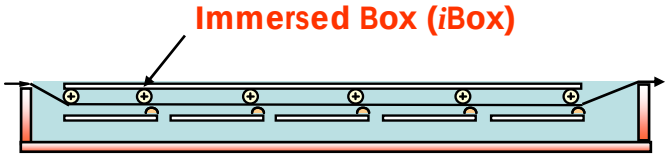

Figure 2. i Box Pickling Tank Model.

2.3 3D Simulation by Numerical Model and Results of Calculation

MH has simulated the flow conditions in Deep bath tank, Jet and ***i* Box** pickling tanks. The flow condition is shown by acid stream line for easier understanding.
To compare , Figure 3 shows the stream line of conventional Deep bath tank in which the stream line near the runing strip is almost similar to the strip speed and along to the strip direction. It is difficult to attack the scale at the strip surface by the fresh acid, because the concentration near the steel strip becomes lower than ***i* Box** pickling tank or Jet Pickling tank. Therefore, the required ickling time becomes longer.
Figure 4 shows the streamline of Jet pickling tank in which the streamline is mixed by the box and dam effect, and it is found that the stream line near jet nozzle is more mixed but in small area. Becasue of the jet nozzle effect, fresh acid is easier to reach to the scale on the strip surface, the pickling speed can be faster than Deep bath tank. The jet nozzle effect, however, is only for the limitaed small area to affect

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the descaling speed, therefore, this effect is not so much affect to the total pickling time.

Figure 5 shows the streamline of ***i* Box** pickling tank in which the stream line is mixed by box and dam effect similar to Jet pickling tank, and whirlpools in the box are occurred by the box and dam effect. The whirlpools are spread to the entire length of the pickling tank. Even though there is no jet nozzle, the turbulence effect is occurred in whole pickling tank.

These numerical simulation for each tank made clear the flow conditions inside the pickling tank and the flow conditions which affect to the pickling time or speed. It means that the pickling efficiency of ***i* Box** pickling tank is similar to Jet pickling tank to be cleared from the flow conditions.

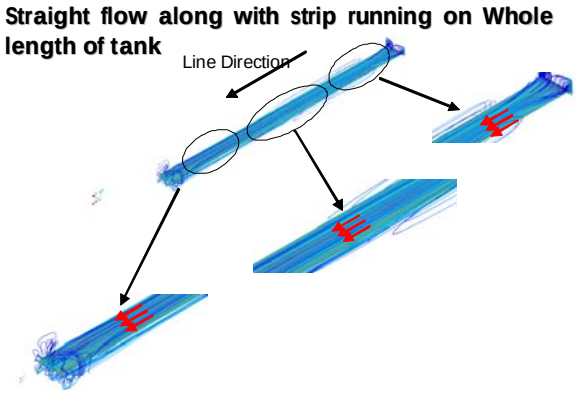

Figure 3. Stream line of Deep bath tank.

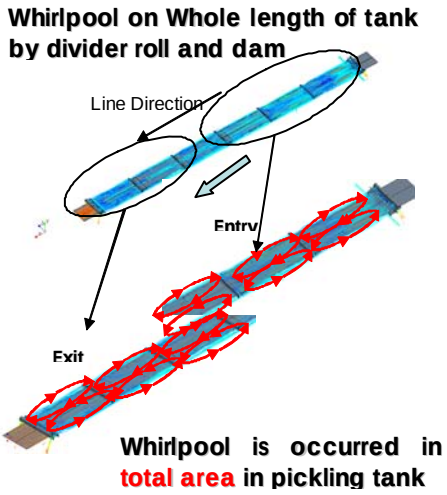

Figure 4. Stream line of Jet pickling tank.

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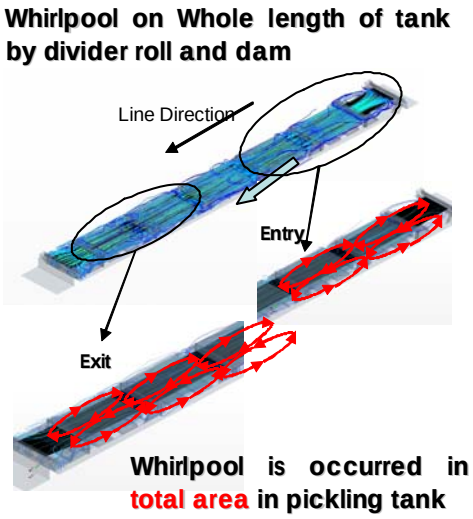

Figure 5. Stream line of ***i*** **Box** Pickling tank.

2.4 Boundary Layer Thickness

Figure 6 shows the typical model examples of the boundary layer thickness which is estimated from the numerical simulation. In Deep bath tank, steel strips to be pickled are immersed in a long tank, which is the conventional method. The acid liquid has free surface and there are no divider roll or dam. Therefore no whirlpool is formed at the middle section of the tank. In Jet pickling tank, the jet nozzle to enhance the acid liquid flow is intensified and the box area is filled with acid with dams installed between the upper and lower levels of the box area, which forms whirlpools in the entire length of the pickling tank. The growth of the boundary layer of the acid on the strip surface is suppressed, and the acid agitation on the surface is accelerated, thereby aiming the promotion of the pickling effect. In the ***i*** **Box**, the strip runs inside the immersed box between the dams installed on the upper and the lower surface, which can form the similar whirlpools in the entire length of pickling tank.

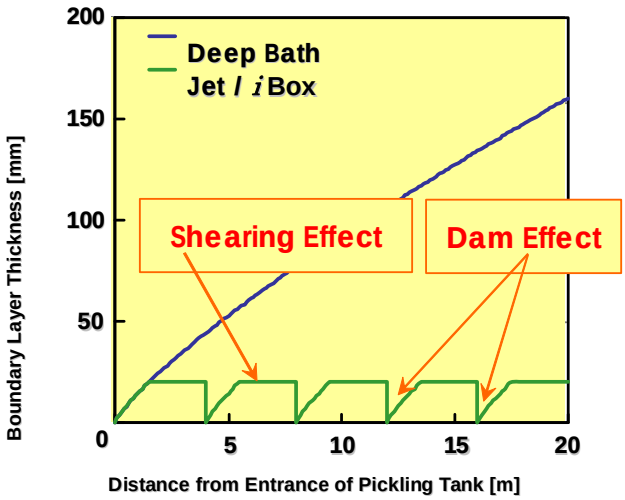

Figure 6. typical model examples the of the boundary layer thickness.

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As the results of these flow simulations, the descaling capability of ***i* Box** pickling tank is cleared which is similar to Jet pickling tank.
By these 3D numerical simulation, it is found that the ***i* Box** pickling tank is much better effect than Deep bath tank and similar effect to Jet pickling tank. As a result, it become clear that ***i* Box** pickling tank can match to the demand of production increase, energy saving and environmentally friendly.

3 MERIT FOR *i* BOX PICKLING TANK

3.1 No Circulation System for Heating

In case of ***i* Box** pickling tank, the steam to acid heat exchanger is installed in the pickling tank as shown in Figure 7. There are acid heat exchangers beside or bottom of box area where the steel strip is running through. Acid solution is circulation by strip running effect and continuously heated up by internal acid heat exchangers. It means that the external circulation system and heat exchanger are not required and as a result, ***i* Box** pickling tank has the following benefits.

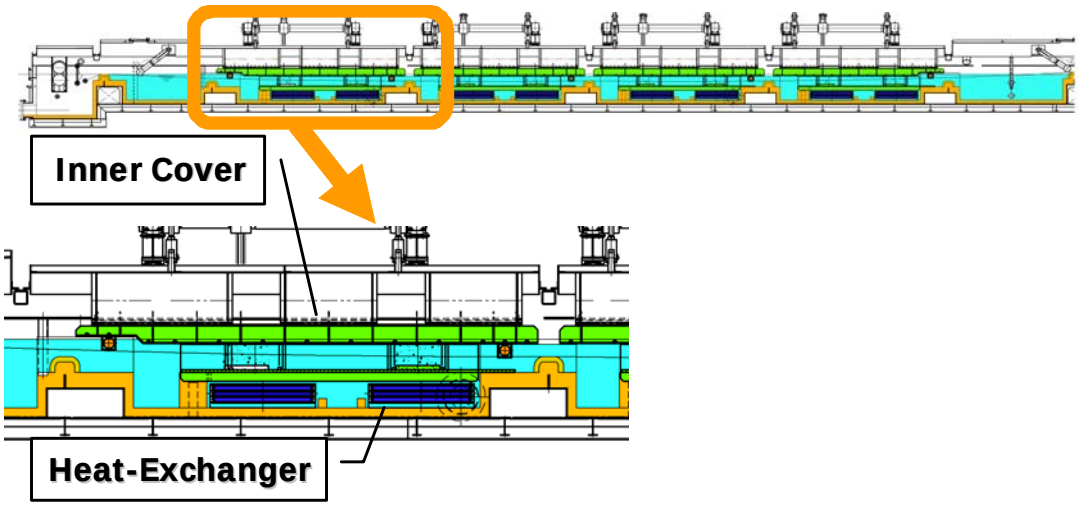

Figure 7. Typical ***i* Box** Pickling tank construction.

Table 1 shows the compared ratio of necessary electric energy and heating loss from pickling system including circulation system between Jet pickling and ***i* Box** pickling tank. During production, we can eliminate the electric energy of pickling circulation pump system. In our calculation, we can reduce the electric energy to approximate18 % of Jet pickling tank.

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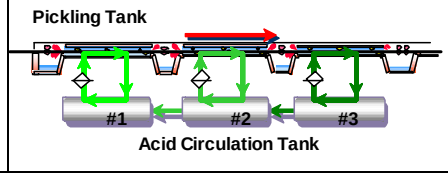
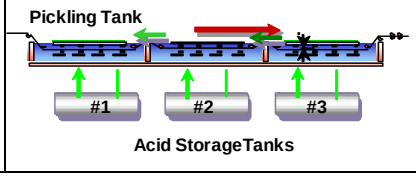
Table 1. Energy loss ratio between Jet and ***i*** **Box** pickling tank

	Description	Circulation type (Jet Type)	***i*** **Box**
0	Pickling Tank Configulation		
1	Electrucal Energy		
	Ave. Power Rate	100:18	
2	Heating loss from circulation system and pickling tank		
	Radiation from pickling tank	100:162	
	Radiation from circulation system	100:0	
	Total heating loss	100:76	

To eliminate the external acid circulation, the heating loss from the surface of the circulation piping system can be reduced. In case of ***i*** **Box** pickling tank, the heating loss is only from the pickling tank itself. As a result of the calculation, the heating loss can be reduced to 76% of Jet pickling tank. This means that steam consumption can be reduced.

In case of high silicon steel production such as electrical steel or high tensile strength steel, SiO_2 sludge is generated in pickling tank which can not be dissolved by hydro chronic acid, and the SiO_2 sludge cause stuck problem of at the circulation piping system and external heat exchanger. In case of processing these steel grades, SiO_2 have to be eliminated by additional filtration system for stable line operation. Such sludge has to be cleaned up or washed out frequently from the piping system and/or external heat exchanger which disturbs the continuous production. In case of ***i*** **Box** pickling tank, since the continuous acid circulation is not necessary, the sludge is flowed out in waste acid or accumulated in pickling tank. Therefore, the sludge does not cause the stuck problem of piping system or frequent line stop caused by clean-up of the external acid heat exchanger or the acid piping system.

3.2 Easy Modification from Conventional Deep Bath Tank

i **Box** pickling tank has another benefit of simple construction and easy to modify to ***i*** **Box** pickling tank from conventional Deep bath tank when increase the production capacity is required. MH have already modified two pickling lines as listed on the **Erro! Fonte de referência não encontrada.** from Deep bath tank to ***i*** **Box** pickling tank and one from MH Shallow bath tank to ***i*** **Box** pickling tank. In the modification from Deep bath tank, the following benefit is enjoyed by our customer.

- Minimize modification area of existing pickling tank even in the case of steel structural pickling tank.
- No modification on civil work is required for line tanks
- No external acid circulation/heating system is required
- No piping, electrical nor drive system modifications is required.
- Minimal line outage for modification and start-up
  (Line outage duration in days, not in weeks)
- No operation condition change is required.

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In the reference of ArceloMittal DOFASCO, ***i* Box** could achieve pickling speed increasing from 130mpm to 200mpm for difficult de-scaling steel grade.

Table 2. Modificaion reference of ***i* Box** pickling tank from Deep bath tank

No.	Customer	Works	Nation	Material	Line Speed (mpm)	Completion	Remarks
1	JFE Steel	West Japan	Japan	Hot Rolled Low Carbon Steel	320	1994	Deep to ***i* Box**
2	DOFASCO	Hamilton	Canada	Hot Rolled Mild Steel	200	2003	Deep to ***i* Box**
3	Ta Ta Iron and Steel	Jamshedpur	India	Hot Rolled Mild Steel	220	2013	Shallow to ***i* Box** Under manufacturing

Table 3 shows the relationship between the number of ***i* Box** pickling tank installation to deep bath tank and the estimated reduction of pickling time for each case which meet various demands of production increase or surface quality improvement

Table 3. Pickling Time Reduction of various case modification from Deep to ***i* Box**

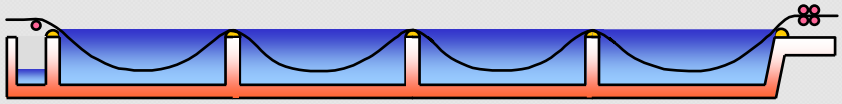
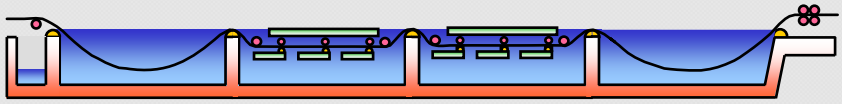
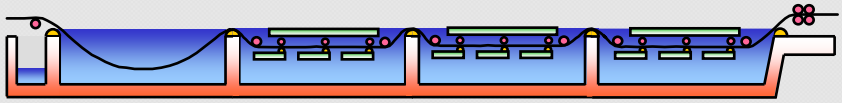
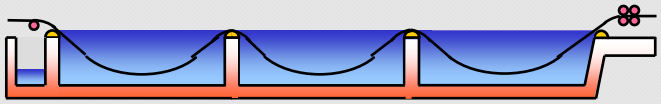
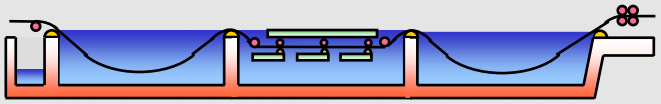
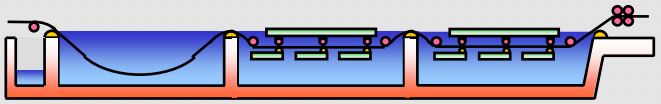
Improvement in pickling efficiency is proportional to the number of BOX tanks added.		**Pickling Time**
4 conventional Deep tanks		**100 %**
2 BOX tanks installed		**64 %**
3 BOX tanks installed		**51 %**
3 conventional Deep tanks		**100 %**
1 BOX tank installed		**72 %**
2 BOX tanks installed		**52 %**

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Figure 8. Overview of ***i*** **Box** pickling tank made of Polypropylene (PP).

4 CONCLUSIONS

The capability of ***i*** **Box** is explained by calculation results by neumerical model simulation. The results of the simulation made clear that the pickling capability of ***i*** **Box** is similar to Jet pickling tank and more effeiency than Deep bath tank. The ***i*** **Box** pickling tank can achieve less maintenace and save electric and steam energy compare with Jet pickling tank of the same production capacity which is intended to find out a compact pickling system capable of increasing the process speed to such an extent as to meet the need for increase in the treating capacity of pickling system, especially to respond for the demands of upgrading existing pickling system. MH's new type of pickling equipment called as ***i*** **Box** will meet the demands for energy saving and less maintenance, with its processing capacity of the same level of high efficiency pickling tanks.

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