HIGH PRODUCTIVITY IMPROVEMENT IN JFE FUKUYAMA NO.1 HOT STRIP MILL

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Abstract: Productivity improvement technologies we developed at Fukuyama Hot Mills are, high accuracy temperature tracking from entry side of reheating furnaces to finishing mill, automatic reheating furnaces control system, and mill pacing control. Although applied technology is conventional, theoretical model calculation by latest industry computer improves productivity dramatically.

Keywords: Steel industry, Computer application, Productivity, Prediction, Difference equation, Heat transfer function.

1. ABSTRACT

Conventional productivity analysis and improvement method is described in Chapter 2.
In Chapter 3, each technology refinement is described in detail. Although the conventional improvement in productivity is mainly based on the improvement in capability of hardware, the key device of this scheme is software. In Chapter 4, the enforcement effect is given. Comparison with the former is shown about various control performances and operation indices. Finally a conclusion is described.

2. CONVENTIONAL PRODUCTIVITY IMPROVEMENT METHOD

The bottlenecks of the efficiency of a hot strip mill are mainly
1) Reheating furnaces heating capability
2) Slow roughing mill pacing for avoiding the material collision
3) Slow rolling speed of F-mill train
4) Down coiler handling loss time
5) Coil conveyor transfer speed
Each equipment capability should be decided according to the product mix of every plant.
For example, if its major strip is thin and narrow, finisher main motor speed may be faster, and rolling torque may lower. In this case, finisher mill rolling speed is usually still bottleneck and reheating furnace capability may be comparatively small. On the other hand, if its major strip is thick and wide, such as for piping material, finisher speed may be slower, and reheating furnaces facility is wide and reheating capacity is rich.
In every case, the bottleneck process will be changed to conveyor in case rolling short slab and small coil production.
In recent years, at rougher mills, high speed reverse mill with AC VVVF drives have been installed for saving the equipment cost. Because of its reversing operation, rolling material interference at front and backside is likely to happen. As a result, this interference also causes a bottleneck.
It seems that this bottleneck in rougher zone doesn't occur at old full-continuous type hot strip mill. But Rougher Mill modernization with new device, such as Slab Sizing Press, causes new bottleneck process. Even if recent improvement of pressing speed has been advanced, slab sizing press is obviously slow compared with edger mill rolling speed.
As I mentioned above, each process has their own bottleneck reason. In addition, it is very difficult to optimise bottleneck process to all production pattern. From the facility design stand point, bottleneck process is ether reheating furnace or F-mill train motor power, because these construction cost are the major.

Conventional rolling efficiency improvement plan is implemented as follows, i) Analyse the bottleneck process, ii) Establish the hardware capacity enhancement plan iii) Estimate the benefit after hardware enhancement.

For example in case the reheating furnaces is the bottleneck process, solution by adding hardware, such as additional burners, reheating furnaces extension, and construction for the HCR ratio and temperature enhancement.

On the other hand, if F-mill train is the bottleneck process, there are small scale modifications like raise the acceleration ratio and threading speed. Sometimes, more intensive revamping is done by reinforcing finishing mill main motor power, or developing and constructing endless F-mill rolling system like we did first in the world at JFE Steel East Japan Chiba Works.

Comparison with the reheating furnace and F-mill train, rougher mills, coiler and coil conveyor improvement are very effective by its small sequence modification. Naturally, rolling speed up at reverse roughing mill is also important.

Thus the conventional productivity improvement activity has been focused on the enhancement of hardware equipments capability.

3. IN 21TH CENTULY IMPROVEMENT METHOD IN PRODUCTIVETY

3.1 Present data analysis.

In advance of this project, we investigated the bottlenecks process at Fukuyama No1 Hot Strip Mill, that started operation in 1967, has 5 stands full-continuous 5 stand rougher and was modernized by slab sizing press in 1998. At this mill, rougher mills are no longer bottleneck process.

On the other hand, because of limited 6000kW main motors capability for 6 feet width mills, finisher rolling speed is not so fast.

Analysis data shows, bottle neck process is Reheating furnace when we roll over 4 feet width material and the finisher is the bottleneck process under 4 feet width material.

Furthermore, coil conveyor is the bottleneck in the narrower range, because of the small coils production. Conventional bottleneck ratios in each process are shown on Figure.1.

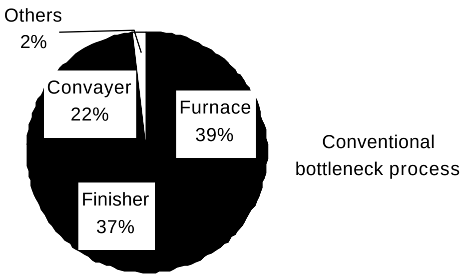

Fig. 1. Conventional bottleneck ratio in each process.

3.2 Strategy: Improvement of Reheating Furnace Capability

The strategy, Heating capability enhancement, was set and considered as the most important improvement activity. First task was to re-define the mission of reheating furnace in hot strip mill.

Re-definition: Reheating furnace

We determine Reheating furnace as follows.

Reheating furnace is the facility for obtaining the aimed slab temperature at the exit end, that is determined by metallurgical additional element diffusion, soften the material hardness of roughing mill zone, and keeping the alpha rolling temperature at F-mill train.

We strongly recognized from the beginning the importance of target extracting temperature determination. We re-evaluated the adequacy of these manufacturing conditions, and we established the new procedure of definition of extracting temperature.

Problem institution: Extraction target temperature.

By the method currently generally performed conventionally, reheating furnace extraction target temperature is determined with a host computer in consideration of manufacture conditions described above; reheating furnace itself, rougher rolling and finisher rolling. In many case, reheating furnace extraction target temperature is classified per 10 degrees C and is related with the rolling cycle schedule. This has the problem.

What does classification per 10 degrees C mean? If reheating furnace extraction target temperature is given as a "sufficient condition" for fulfilling many temperature conditions at rolling, this reheating furnace extraction target temperature has the 5 degree C margin at the maximum and the 10 degree C margin on an average. This condition is occurred regardless of whether a reheating furnace becomes a bottleneck or not. Even if reheating furnace is not a bottleneck, aggravation of a fuel field unit is caused.

Of course, control of 1 degree C unit of heating furnace extraction temperature is not performed, but the same lot may be continued.

In order to make average temperature 1 degree C at an extraction end, it takes about 2 minutes. Permission with an extraction target temperature margin of an average of 5 degrees C means lengthen heating time for 10 minutes on an average.

How much is it if 10 minutes is converted into furnace length. How mach is its construction cost?

Taking a lesson from the past: Unitary management by consistent temperature tracking

The determination of extract target temperature based on the above-mentioned "re-definition" is easy. Build the consistent temperature tracking system from reheating furnace extraction to F-mill train, and calculate the extraction target temperature to an opposite direction from every defined strip temperature at position of every mill line.

Of course, consistent temperature tracking system is not easy. Because consistent temperature tracking system should be consider all set up information for rougher mills and F-mill train included rescaling set up, roll diameter, heat generation by rolling. Supplemental saying, half of temperature descent in rougher mills is cause of heat transfer by the contact on a roll, and roll diameter relation to contact arc length is an important element. Thus our new procedure of definition of extract temperature necessary to cooperate with rougher set up calculation and finisher set up calculation.

Our new procedure can be found out at the textbook of 20 years ago. According to pp 94 at "Hot Strip Production Technology in Japan (in Japanese)", extract target temperature is calculated from finisher delivery temperature and rougher delivery temperature using temperature descent model through mill line.

3.3 Rougher mill temperature tracking system

The structure of consistent temperature tracking system is simple. It solves heat transfer equation by air and water at surface and back and solves internal heat conduction equation related to the direction of a section. Difference equation calculation has a problem that cannot consider the difference of specific heat related to the difference of material temperature within calculation period; we solved this problem by the modified algorithm using conversion temperature.

3.4 extract target temperature

Extract target temperature is given as the sufficient condition for extraction. Namely, it is considered altogether that reheating furnace control is a success, when extraction temperature exceeds extract target temperature. Though according to the conventional management method of the extract target temperature, extract target temperature had upper margin and lower margin, according to the new management method of the extract target temperature, extract target temperature is minimum temperature for extraction and doesn't have upper margin and lower margin. And we calculate this minimum temperature from required temperature at every point of mill line using consistent temperature tracking system.

3.5 Reheating furnace temperature tracking

The pyrometer is not used for estimation of the slab temperature in reheating furnace. Slab temperature in reheating furnace calculates by reheating furnace temperature tracking system started from the entry table pyrometer.

Reheating furnace temperature tracking system consists of the heat transfer on the slab surface from furnace gas and internal heat conduction. Internal heat conduction considers first dimensional thermal equation at direction of a section.

Although heat transfer on the slab surface consists of the heat transfer by radiation and the heat transfer by convection, it is quite difficult to divide these two elements. So one way has been popular; assumption united heat transfer combined two and treat as one heat transfer phenomenon.

United heat transfer coefficient was identified by the experiment; putted thermocouples into slab surface, inserted to reheating furnace and were heated together with other slabs, and measured heating history.

These experiments have done two or three times for every reheating furnace.

There are 4 reheating furnaces and every two furnaces are different its type. Two of them have axial-flow burners installed in the nose ceiling, and others have re-generative burners installed side of them and without axial-flow burners .So heating history of the slabs inserted to reheating furnaces have axial-flow burners and those of the slabs inserted to reheating furnaces have re-generative burners are different. Figure 2 shows heating history of the slab inserted to reheating furnaces have axial-flow burners; Figure 3 shows heating history of the slab inserted to reheating furnaces have re-generative burners. Figure 1 curve has the "landings", and these are influence of nose ceiling. Under the nose ceiling, the thickness of gas is thin and radiant heat energy becomes weak, as a result, heating speed of the slab becomes slow.

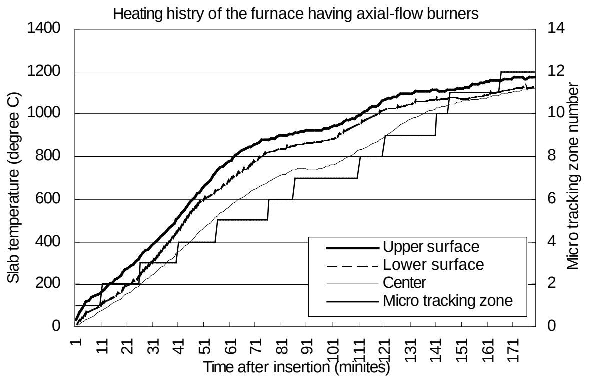

Fig. 2. Heating history of the furnace having axial-flow burners.

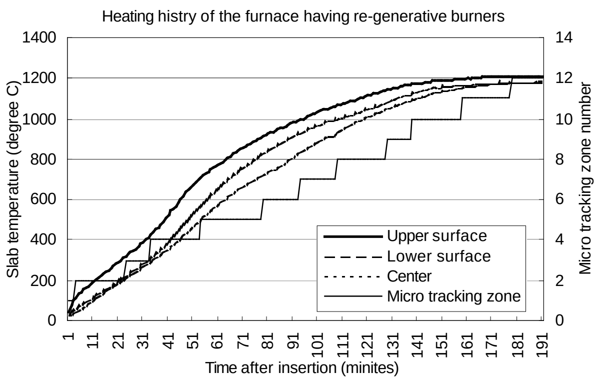

Fig. 3. Heating history of the furnace having re-generative burners.

3.6 Reheating furnace control

Reheating furnace control system sets furnace gas temperature to become slab temperature should be extract target temperature at a time predicted it should be extracted. Our furnace control system receives predicted extract time from mill pacing system and extract target temperature form the consistent temperature tracking system when slab inserted to the reheating furnaces.

Accuracy of extract temperature prediction by mill pacing system is quite important. If predicted extract time is earlier than actual extract time, reheating furnace control system sets furnace temperature higher temperature than that of adequate temperature, and as a result, excessive gas is used. And if predicted extract time is later than actual extract time, reheating furnace control system sets furnace temperature lower temperature than that of adequate temperature, and at actual extract time, slab temperature does not still become extract target temperature, and product delay will occur.

Our system modifies extract predicted time by mill pacing system and extract predicted temperature by reheating furnace control system for every slab in furnaces every control period. Our system can predict the delay would occur being compared with extract predicted temperature and extract target temperature, and can predict how long it should be wait.

Our reheating furnace consists of two types of reheating furnaces explained above, and it is also important to be equal the heating conditions when extracted from different type of furnaces. To be equal the heating conditions, not only extract temperature but also the history of heating also controlled. As a result cross-sectional temperature distribution becomes similar, and skid mark also becomes similar, rolling condition has no difference by reheating furnaces

3.7 Heating assistance by Bar Heater

In Fukuyama, the whole rougher bar heating device (we call "Bar Heater") was introduced prior to the world in 1998. Bar Heater can raise the bar temperature at the entry of F-mill train about a maximum of 30 degrees. When this is converted into extraction temperature, it is equivalent to about 50 degrees. Extraction target temperature differs every slab at a time by the method of calculating extraction target temperature on-line for every slab. Bar Heater lessens change of the extract target temperature of a heating furnace that followed in rolling schedule. Thereby, when the extract target temperature of one slab is especially high, the phenomenon in which the extract temperature of other slabs will go up unavoidably can be avoided, and average extraction temperature can be lowered. It is useful to fuel cost saving of a reheating furnace to be lower average extraction temperature, and when the heating furnace is a bottleneck, heating capability can be compensated with Bar Heater and it can contribute to the improvement in rolling efficiency.

4. RESULT

An actual control performance is described. The comparisons before applying and after applying about various operation indices are given.

4.1 Consistent temperature tracking accuracy

Figure.4. shows comparison with the estimated surface temperature and measured surface temperature at the delivery of rougher mills. The starting point of estimated surface temperature is the measured surface temperature on the reheating furnace entry table. With a reheating furnace entry temperature as the starting point, raise temperature tracking calculation in a reheating furnace is performed and it takes over to mill line descent temperature descent calculation at the time of extraction. Within a reheating furnace, the slab pyrometer is not used for adjusting slab temperature mentioned above. Furthermore, after extraction the compensation by the temperature measured by the pyrometer value at mill line is not carried out.

Still quite good temperature estimation is realized. This highly accurate consistent temperature tracking supports the ways that calculating every slab extract target temperature.

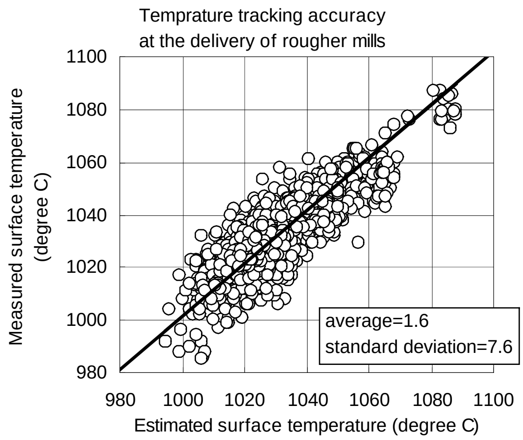

Fig. 4. Temperature tracking accuracy at the delivery of rougher mills.

4.2 Reheating furnace control performance

Figure.5 and Figure.6. show comparison between extract target temperature to estimated extract temperature. Our extract target temperature is lower limit temperature to be rolled, and all actual estimated temperatures exceed extract target temperatures. Figure.5. is for reheating furnaces having re-generative burners, and Figure.6. is for reheating furnaces having axial-flow burners. Figure.7. shows comparison between rougher delivery target temperatures to actual measured temperature. Almost actual measured temperatures exceed rougher delivery target temperatures. The rougher bar temperature being less target temperature is heated by sheet Bar Heater.

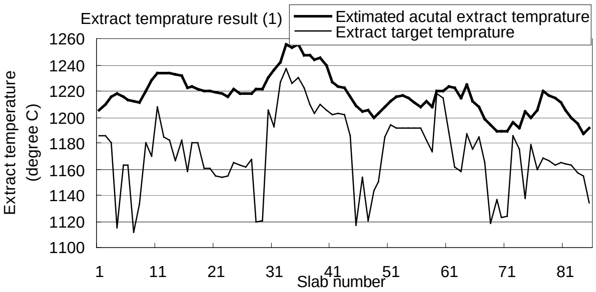

Fig. 5. Extract temperature result (1): furnaces having re-generative burners.

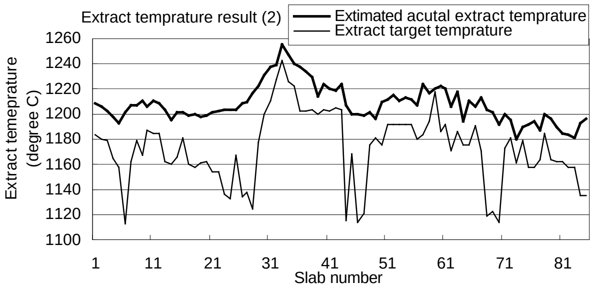

Fig. 6. Extract temperature result (2): furnaces having axial-flow burners.

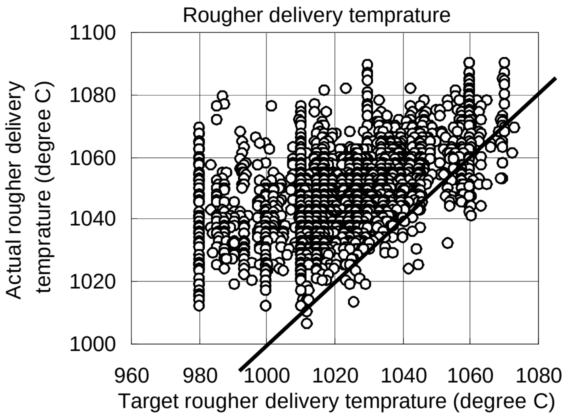

Fig. 7. Rougher delivery temperature.

Figure.8 shows deviation of extract temperature from target extract temperature. After installation of new technology, standard deviation became 23 degree C from 38 degree C and average became 28 degree C from 36 degree C. Especially conventional operation, it was the tendency that target extract temperature was high to compensate worse deviation.

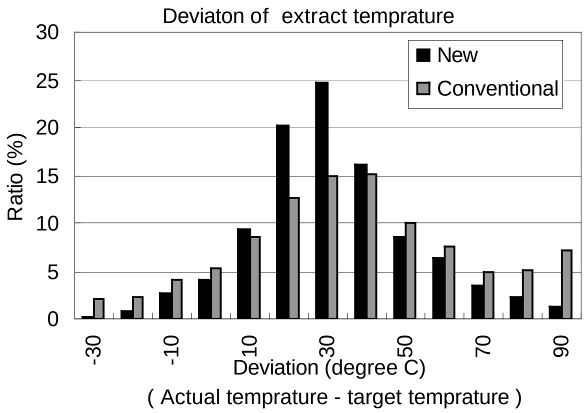

Fig. 8. Deviation comparison of extract temperature.

After installation of new technology, average target extract temperature also went down. As a result fuel field unit also improved.

4.3 Improvement of rolling efficiency

Figure.9. shows improvement of rolling efficiency. X-axis is strip width, Y-axis is rolling efficiency at every strip width. Reheating furnace is bottleneck in more than 4-feet width strip rolling, and adapting new technology, rolling efficiency is improved in these width strips rolling.

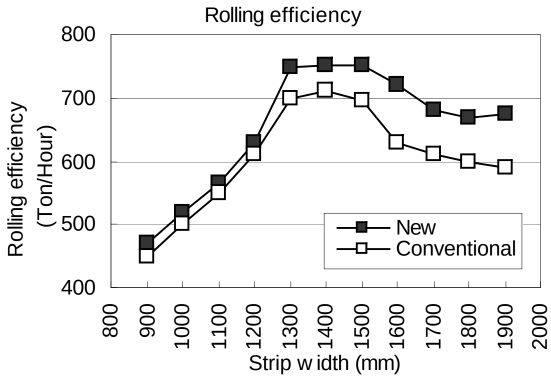

Fig. 9. Rolling efficiency improvement.

4.4 Improvement of fuel field unit

Figure.10. shows history of fuel field unit before and after installation of new technology.

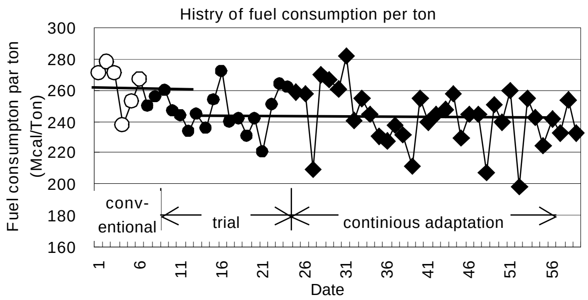

Fig. 10. Histry of fuel field unit.

4.5 Bottleneck ratios in each process

Figure.11 shows bottleneck ratios in each process after installation of new technology. Instead of decreasing of bottleneck ratio in reheating furnace, bottleneck ratio in conveyer increased.

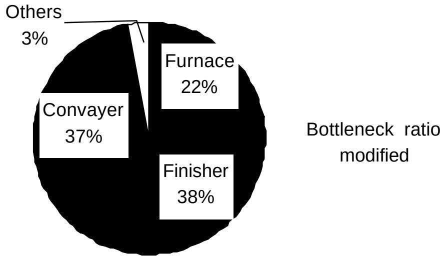

Fig. 11. Bottleneck ratios in each process.

Bottleneck process changes with strips. Reheating furnace was the bottleneck when more than 5-feet width strip rolling mentioned in chapter 3. After installed new technology, 17% of reheating furnace bottleneck was moved to finisher bottleneck. And 16% of finisher bottleneck was moved to conveyer.

4.6 Bar to bar time at entry of F-mill train

Figure.12 shows deviation of bar to bar time at entry of F-mill train. Sequence-limit of bar to bar control is 8 seconds. Considering the unknown transfer deviation time, the present bar to bat time is a mostly limit.

Bar to bar interval was shorten by modification of finisher rolling time estimation. This is because 16% of finisher bottleneck was moved to conveyer.

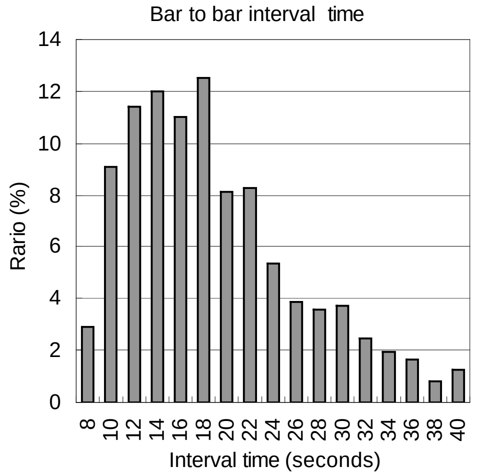

Fig. 12. Bar to bar time at entry of F-mill train

5 CONCLUSIONS

Productivity improvement technologies in JFE steel Fukuyama No.1 HSM was given. The Key technologies are 1) minimizing of extract target temperature of reheating furnace and highly accuracy prediction of extract time for minimizing requested heating capability. 2) Combination of reheating furnace control and mill pacing control. As a result, we succeed in coexistence of improvement of rolling efficiency and improvement of fuel field unit.

REFERENCES

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