ENERGY MANAGEMENT IN STEELWORKS BY USING ISO14404
AND COOPERATION WITH THE ASEAN STEEL INDUSTRY

BY

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SYNOPSIS:

As attentions towards the climate change increase, the global steel industry needs to cooperate in order to reduce energy consumption and CO₂ emissions. Since 2013, the Japanese steel industry has been working with the ASEAN steel industry on energy saving and environmental protection. One area of cooperation is activities for expanding the application of ISO14404. ISO14404 is an international standard to calculate energy intensity and CO₂ emission intensity from iron and steel plant, published in March 2013 with the leadership of the Japanese steel industry. There are standards for blast furnaces (ISO14404-1) and electric arc furnaces (ISO14404-2).

ISO14404 is a simple and easy calculation method only requires usual operational data, such as crude steel production, purchased raw materials and by-products energy purchase/sale. With this method, energy efficiency of the steel plant can be estimated to recognize the low energy efficiency performance facility/process, then the best technology to improve the energy efficiency can be applied from the Technology Customized List.

This paper presents the progress of ASEAN - Japan Steel Initiative. It contains an overview of ISO14404 and discussion of energy conservation diagnosis in steel plants in ASEAN to provide how ISO14404 is used.

Keywords: ISO14404, Energy Management, Energy Conservation, CO₂ reduction, energy conservation diagnosis, ASEAN-Japan Steel Initiative, Technology Customized List, JISF’s Commitment to a Low Carbon Society

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1. Introduction

As attentions towards the climate change increase, pressure on the steel industry, which is one of the energy-intensive industries, to take actions for conserving energy and lowering CO₂ emissions are becoming high. The Japan Iron and Steel Federation (JISF) is promoting three “Eco Process”, “Eco Solution” and “Eco Product”, under the commitment to a low carbon society(1).

The aim of “Eco Solution” is to contribute energy saving and CO₂ reduction worldwide by transferring the world’s most advanced energy-saving technologies to other countries, especially to developing countries. As the activity of “Eco Solution”, JISF has carried out steel plant diagnosis in India and ASEAN countries and transferring Japanese technologies under ASEAN - Japan Steel Initiative.

As a first action for energy saving and CO₂ reduction, performance evaluation of the energy consumption and CO₂ emission is very crucial. ISO14404(2) was established to enable global steel industry to assess the performance of energy consumption and CO₂ emission correctly. One of the features of ISO14404 is that energy consumption and CO₂ emissions are evaluated as a whole steelwork basis, which will lead to the comprehensive evaluation compared to separate evaluation on facility basis.

This paper explains the overview of ISO14404 and the steel plant diagnosis in ASEAN area and suggests how ASEAN steel industry can use ISO14404 as a tool of energy management.

2 Overview of ISO14404

2.1 Technical features of ISO14404

The World Steel Association (worldsteel) member companies and non-member companies submit CO₂ emission data to worldsteel to compare the performance with others from 2007. This initiative has made a major contribution to lowering CO₂ emissions in the global steel industry. CO₂ emission and energy consumption performance of steelwork is able to be evaluated by ISO14404 established in 2013 by ISO/TC 17 (Steel). It is based on the worldsteel’s calculation methodology.

ISO14404 is the world’s first ISO which establishes a method for calculating total CO₂ emission and intensity for a specific industrial sector. With the leadership of Japan, calculation standards for a blast furnace-basic oxygen furnace (BF-BOF) steelwork (ISO14404-1) and for an electric arc furnace (EAF) steelworks (ISO14404-2) have been established. Currently, ISO14404-3 for a DRI-EAF steelwork is under establishment.

As shown in Fig.1, ISO14404 defines energy consumption in a steelwork as the purchased energy (input) minus sold energy to external users (output). Example of major purchased energy includes oil, coal, electricity etc. and major sold energies are electricity and steam. Dividing consumed energy by crude steel production yields the energy intensity.
ISO14404 offers CO₂ conversion factors for major energy sources as shown in Table 1\(^{(3)}\). These conversion factors indicate carbon content per unit energy. Total CO₂ emission is obtained by multiplying the amount of energy used by these conversion factors. Then dividing CO₂ emissions by the crude steel production volume yields the CO₂ emission intensity.

Table 1 Inventories and CO₂ conversion factors defined in ISO14404
ISO14404 has three kinds of CO₂ emission category, namely “direct”, “upstream” and “credit”. Direct emission refers to CO₂ emission based on carbon content of energy sources. Upstream emission includes CO₂ emission derived from energy consumption to produce coke, burnt lime and other intermediate products. Credit emission is prepared to deduct CO₂ emission related to the sold energy, such as electricity and other by-products. Energy conversion factors are also available at worldsteel’s website in addition to the CO₂ conversion factors shown in Table1.

ISO14404 has four significant features as follows.

1. Calculation method used in ISO14404 is very simple. ISO14404 requires nothing more than data used for normal business operations, such as crude steel production volume, purchased and sold volume for the energy sources listed in Table1.

2. ISO14404 counts indirect CO₂ emission by applying “Upstream” concept. Direct CO₂ emissions of a steelwork decrease in relation to the degree of externally produced intermediate materials/gases, which is not related to the energy saving effort. In order to evaluate CO₂ performance regardless of outsourcing ratio, CO₂ emissions associated with off-site production of intermediate materials and gases are calculated as "upstream emission", as if these materials were produced in the steelwork.

Fig. 2 shows an example of the upstream concept. Oxygen is provided from the oxygen plant on-site the steelwork (1), on the other hand oxygen is outsourced in steelwork (2). For fair evaluation of energy consumption and CO₂ emission, those of in both cases shall be the same value. So, energy consumption and CO₂ emission on outsourced oxygen is considered in ISO14404 (A=B+C).

3. ISO14404 evaluates CO₂ emission as a whole steelwork basis. There are two methods for evaluating CO₂ emission performance as shown in Table2. One is to evaluate an entire steelwork and the other is to separately evaluate individual facilities, such as electric arc furnace, reheating furnace, oxygen plant etc.

As shown in Fig.2, the overall evaluation method has the advantages of simplicity and the ability to reflect progress made with conserving energy. Monitoring specific
facilities and optimizing energy consumption separately in each facility does not necessarily lead to energy saving as a whole steelwork, considering that facilities are providing and receiving energy to/from other facilities within the steelwork. Overall evaluation method, namely ISO14404, is better from the standpoint of evaluating and improving energy efficiency for an entire steelwork.

Table 2 Method for evaluating CO2 emission performance in the steel industry

<table>
<thead>
<tr>
<th>Entire Steelwork</th>
<th>Individual Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>This method determines the overall efficiency of a steelwork by reflecting energy conservation activities at the mill.</td>
<td>This method is suitable for precise inventory calculations, such as for emission volume transactions, but is not good for overall comparisons of efficiency.</td>
</tr>
<tr>
<td>✓ Require only data needed for steelwork operations (crude steel output, energy purchased, etc.) and do not require any monitoring or other special equipment</td>
<td>✓ Complicated and expensive because monitoring equipment is needed to determine CO2 emission volume</td>
</tr>
<tr>
<td>✓ Cover CO2 emissions for all energy used for iron and steel production</td>
<td>✓ Do not cover entire CO2 emission from the steelwork</td>
</tr>
<tr>
<td>✓ Incorporate benefits of byproduct gas and exhaust heat use and other energy conservation activities (recovery and reuse of energy)</td>
<td>✓ Do not incorporate energy conservation effects that cover more than one facility</td>
</tr>
</tbody>
</table>

4. ISO14404 offers CO2 conversion factors and anyone can start using ISO14404 immediately. CO2 conversion factors used in ISO14404 are cited from the value defined by worldsteel, IEA, IPCC and other institutions. One distinguishing characteristic of ISO14404 is the use of a global average CO2 conversion factor for calculating CO2 emissions associated with electricity, in order to eliminate the differences in CO2 emission depending on the types of electric sources.

2.3 Tools to utilize ISO14404

The user’s guide for ISO14404 and calculation sheets have been prepared to encourage steel companies to use ISO14404. The “ISO14404 User Guide” contains the overview of ISO14404 stated at the beginning of this paper and explanations about two types of calculation sheets, namely “ISO14404 Calculation Tool” and “ISO14404 Technology Introduction Simulator”. All of this information can also be viewed on the JISF’s website(4).

ISO14404 Calculation Tool allows using ISO14404 for monitoring fluctuations in a steelwork’s CO2 emissions from year to year.

Calculation sheet is already set to calculate energy and CO2 emission amount and intensity. Energy and CO2 data spanning a number of years can be used for identifying the reasons for changes in energy use and CO2 emissions as well as for selecting actions to take for improvements.

ISO14404 Technology Introduction Simulator is used to show the reduction in energy use and CO2 emissions resulting from the use of technologies in the Technologies Customized List (TCL) (Fig.3)(5). TCL was developed at ASEAN-Japan Steel Initiative
led by Ministry of Economy, Trade and Industry and JISF. It is a list of energy conservation and environmental protection technologies that are best suited for a specific country or region. Lists have been prepared for India and the ASEAN region. TCL for ASEAN first version was released in 2014 with 30 technologies, and second version was released in 2016 with 33 technologies.

TCL contain technologies customized list and technologies one-by-one sheet, with the reduction potential of energy consumption (kWh/ton-product or GJ/ton-product) for each technology. Entering the current crude steel output and energy use data in the ISO14404 Technology Introduction Simulator allows calculating the percentages of energy and CO₂ reductions that can be achieved by using a particular technology.

The initial cost, payback time and cost of maintenance are not included in the Technologies Customized List or ISO14404 User Guide because these items are different at each steelwork. The list does include contact information for companies that supply technologies. ASEAN steel companies are encouraged to contact a supplier directly in order to gain such information.

3. Steel plant diagnosis with ISO14404 in ASEAN countries

3.1 Energy consumption management in Japanese steel industry

Japanese steel industry has been tackling with energy saving and environmental protection since 1970s triggered by two oil crisis. In addition to complying with Japan’s Energy Conservation Act, Japanese steel industry is working for voluntary energy saving and CO₂ emission reduction under “JISF’s Commitment to a Low Carbon Society”. The target is to reduce 5 million tons of CO₂ emissions by fiscal 2020 compared to business as usual (BAU) level.
It employs a PDCA cycle as follows shown in Fig.4. Due to the effective functioning of this PDCA energy management process, JISF received ISO50001 certification (energy management) in 2014.

Japanese steel industry employs an original CO\textsubscript{2} calculation methodology similar to ISO14404 based on PDCA cycle, which leads to precise and transparent evaluation of energy saving and CO\textsubscript{2} reduction actions. It suggests that other countries may also develop their unique methodology to measure energy consumption and CO\textsubscript{2} emission based on ISO14404 and PDCA cycle.

3.2 Overview of the energy conservation diagnosis in ASEAN region

Energy conservation diagnosis have been performed at 12 steelworks in 6 ASEAN countries, namely Thailand, Malaysia, Singapore, Vietnam, Philippines and Indonesia, from 2013 to 2016. Steelworks for diagnosis was selected from the manufacturers with EAF, under the recommendation of authorities and/or steel manufactures’ association in each country.

The diagnosis aimed to investigate operational condition and energy consumption data and offer advices for operational improvement and technology introduction. In order to evaluate the performance of energy consumption and CO\textsubscript{2} emission, ISO14404 was utilized in the diagnosis.

Procedure of the diagnosis was as follows;
(1) Main targets for energy saving study are electricity consumption of EAF and fuel consumption of reheating furnace for rolling mill (RHF). Those are because EAF consumes approximately 50 \% of total plant energy and RHF consumes 25 \%, and those processes have the room of improvement.
(2) Questionnaire and ISO14404 data sheets were sent to the steelwork beforehand. Japanese experts analyzed operational data using ISO14404.
(3) Japanese experts visited the steelwork. They observed mainly EAF and RHF operation on the first and second day to confirm the supplied data and items to be improved and discussed with the operators and managers.
(4) Japanese experts reported the results of diagnosis to the top management on the last day and discussed about the way of improvements.

By using ISO14404, the Japanese experts examined changes in energy use during the previous five years operation. Next, causes of these changes were identified while taking into account the status of facility operations in steelworks and other factors. After a diagnosis, each steelwork received the results of ISO14404 analysis of five years of energy consumption data, advices to improve operations and recommendations for technology introduction to realize large-scale energy saving.

Some steelworks use a different data analysis method or did not perform comprehensive energy data analysis. Nevertheless, after explaining the overview of ISO14404 and discussing the necessary data for the calculation, all steelworks prepared data for ISO14404 calculation. Calculation results of ISO14404 revealed that ASEAN EAF steelworks still have room to reduce energy consumption and CO\textsubscript{2} emission compared to the level in Japanese EAF steelworks.
The results of ISO14404 suggest that energy performance will be greatly improved by introducing energy saving technologies. As some steelworks in ASEAN region were using outdated equipment, it is highly recommended to introduce the energy saving technology or more efficient technology when updating old technologies.

3.3 Results of energy conservation diagnosis of steelworks

In the case of steelwork A, fuel consumption of the reheating furnace was very high. Japanese experts has measured the oxygen content in the furnace and the wall temperature. They found oxygen content as 8.5%, estimated air ratio is 1.75 as shown in Fig.5. If air ratio can be controlled around 1.1 by TCL D-1 “Process control for reheating furnace”, energy consumption reduction was estimated 29130GJ/y, 782000Nm³-LNG eq./y. And by increasing preheated air temperature from 150 degree C to 500 degree C, and by decreasing wall temperature from 180 degree C to 90 degree C, total energy saving was estimated as 28.8%.

![Fig.5 Relationship between air ratio and oxygen content](image)

In the case of steelwork B, energy consumption of EAF was around 400 kWh/t, which is much higher than Japanese same capacity EAF plant’s average value. Japanese experts observed EAF operation and performed measurement, they advised several points. Firstly slag forming was in good condition only near the slag door, but it was insufficient in other area. That was because carbon was not injected into the slag, and the burner in the back did not contribute slag forming. Secondly too long period until tapping. Thirdly cold air took in because the slag door was open during all operation period. It also causes deterioration of operational circumstances.

According to the results of the diagnosis, Japanese experts recommended TCL A-7 “Optimized power control for EAF”, which comprises data logging and visualization of melting process, automatic judgment on meltdown and additional scrap charge and automatic phase power independent control for well-balanced melting, TCL A-6 “Optimizing slag foaming in EAF”, which comprises proper chemical ingredients of slag, high efficient burner and/or lance, etc., TCL A-3 “High efficiency oxy-fuel burner/lancing for EAF”, such as supersonic or coherent burner (Fig.6).
Fig.7 shows the summary of energy consumption of diagnosed steelworks calculated using ISO14404. In general, most energy consumption is among 8~10 GJ/ton-steel. The reason of high energy consumption of steelwork B and I are usage of hot metal from the blast furnace in the site, and low consumption of steelwork A is because half billet are sold to external customer.

![Graph showing energy consumption of diagnosed steelworks]

Energy intensity of benchmark are summarized in Table 3. Japan benchmark value is the target value in energy conservation low, 5 of 50 have achieved. The best performance of ASEAN steelwork are the same level as Japan average value. ASEAN model plant value will be described in detail later.

<table>
<thead>
<tr>
<th>Steelwork</th>
<th>Energy intensity (GJ/ton)</th>
</tr>
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<tbody>
<tr>
<td>ASEAN best</td>
<td>6.76</td>
</tr>
<tr>
<td>ASEAN model plant</td>
<td>9.23</td>
</tr>
<tr>
<td>Japan average</td>
<td>6.79</td>
</tr>
<tr>
<td>Japan benchmark</td>
<td>5.39</td>
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</table>
Electricity consumption of EAF are compared in Fig.8. As described above, steelwork B and I utilize hot metal from the blast furnace, EAF consume less electricity than other steelworks. And EAF electricity consumption of steelwork C is low because of a scarp pre-heater facility.

Fig.9 shows comparison of fuel consumption of RHF. Generally fuel consumption is among 1000~1200 MJ/ton-steel. Fuel consumption of steelworks C, F and H are very low, those are because of high hot charging rate. On the other hand, fuel consumption of steelwork B is very high because of poor burner performance.

3.4 “Model Steel Plant” for ASEAN region

Although the need is great for energy conservation diagnosis in steelworks at ASEAN region, performing a diagnosis at all the steelworks would be very difficult.

This is why simulations have been performed using a Model Steel Plant (MSP) for the benefit of all the stakeholders of ASEAN steel industry. MSP was established as a typical ASEAN electric arc furnace steelwork by using data obtained from diagnosis to seven steelworks in 6 ASEAN countries that had taken place up to the end of 2014.

ISO14404 was used to calculate energy consumption and CO₂ emissions for MSP, and to estimate benefits of technology introduction by using Technologies Customized List.

Table 4 shows the assumptions used for MSP. The plant has an electric arc furnace and reheating furnace and can produce 500,000 tons of crude steel in one year. By using the data in Table 4, energy and CO₂ emission intensities were calculated in accordance with ISO14404. The result is 9.23GJ/ton-steel as energy intensity and 0.56 ton-CO₂/ton-steel as CO₂ emission intensity. It should be noted that sizes, product mixes and energy sources are different between Model Steel Plant and actual steelworks. Nevertheless, the Model Steel Plant energy and CO₂ emission intensity figures can serve as useful reference data for the ASEAN steel industry.
MSP revealed that two technologies which are not widely used in the ASEAN steel industry can dramatically improve energy efficiency. One is TCL A-1 “High temperature continuous scrap preheating EAF” (Fig.10) and the other is TCL D-2 “Low NOx regenerative burner total system for reheating furnace” (Fig.11). By installing both of these technologies, steelworks can cut energy use by 18% and lower energy intensity to 7.57 GJ/ton-steel.

As shown in Table 5, by installing A-1, necessary electricity is evaluated to decrease from 330,000 MWh/y to 255,000 MWh/y (-22.7%), and By installing D-2, necessary natural gas is evaluated to decrease from 23,000 km³/y to 20,368 MWh/y (-11.4%).

As a result, steelworks can cut energy use by 18% and lower energy intensity to 7.57 GJ/ton-steel by installing both of these technologies.
### Table 5 Evaluated effect of installing TCL A-1 and D-2 technologies by MSP

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<tbody>
<tr>
<td>Electricity (MWh/y)</td>
<td>330,000</td>
<td>255,000</td>
<td>255,000</td>
</tr>
<tr>
<td>Natural Gas (km$^3$/y)</td>
<td>23,000</td>
<td>23,000</td>
<td>20,368</td>
</tr>
<tr>
<td>Energy Intensity (GJ/t)</td>
<td>9.23</td>
<td>7.76</td>
<td>7.57</td>
</tr>
</tbody>
</table>

### 4. Conclusions – The Outlook for ISO14404 in the ASEAN Region

As an action for energy saving and CO$_2$ reduction, JISF has carried out steel plant diagnosis in ASEAN countries with ISO14404 and TCL to transfer Japanese technologies under ASEAN - Japan Steel Initiative.

ISO14404 defines a calculation method to evaluate performances of energy consumption and CO$_2$ emission in steelwork. ISO14404 is a very simple calculation method to encourage the optimization of energy consumption in the entire steelwork.

Since the establishment of ISO14404 in 2013, there have been activities in ASEAN region for the widespread use of this new standard. In closing, this paper proposes three ways on how the ASEAN steel industry can use ISO14404.

Establishment and progress management of voluntary target for energy conservation and CO$_2$ emission reduction by ASEAN steelmakers;

- Model Steel Plant based on results of energy conservation diagnosis in ASEAN steelworks will be useful when determining these targets.
- “JISF’s Commitment to a Low Carbon Society” would be a good example when preparing the methodology and framework for determining these targets.

Energy conservation diagnosis by Japanese experts in other steelworks

- When ASEAN steel companies are considering the introduction of energy saving technologies, energy conservation diagnosis will be beneficial as steelworks may get valuable feedbacks to improve energy performance by the experts. Japanese experts analyze energy use and CO$_2$ emissions in prior years based on ISO14404 and provide advices for operational improvement and technology introduction.

Introduction of energy saving technologies

- Before introducing energy saving technologies, steel companies may simulate the energy saving by using ISO14404 and the Technologies Customized List for the ASEAN Region. In addition, the combination of ISO14404 and Technologies Customized List will also help ASEAN steelworks to establish their own PDCA cycle (Fig.4).

- Japan has Joint Crediting Mechanism (JCM)$^{(5)}$ agreements with Indonesia, Thailand and Vietnam and discussions about this mechanism are under way with the Philippines. ASEAN steel companies are recommended to explore ways to utilize this scheme with their own government and Japanese technology supplier in order to realize technology introduction.
Acknowledgements

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