EVALUATION OF ENVIRONMENTAL IMPACTS IN IRON-MAKING BASED ON LIFE CYCLE ASSESSMENT

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Abstract

In this paper assessment results of environmental impacts in conventional blast furnace iron-making system based on LCA (Life Cycle Assessment) will be presented. LCA is an important tool in implementing the Environmental Management System (EMS). LCA is a technique for assessing the environmental aspects and potential impacts associated with the product or technology. LCA is an environmental assessment tool for evaluation of impacts that a technology or product has on the environment over the entire period of its life i.e. from the extraction of the raw material through the manufacturing, packaging and marketing processes, the use, re-use and maintenance of the product, to its eventual recycling or disposal as waste at the end of its useful life. LCA analysis will be carried out in accordance with standard EN ISO 14040:2006, by four phase: goal and scope definition of LCA, inventory analysis LCI (Life Cycle Inventory), impact assessment LCIA (Life Cycle Impact Assessment) and interpretation. The input and output data needed to perform the LCA will be collected and presented. Evaluating iron-making processes to assess their environmental impacts is often difficult due to the many inputs and outputs involved. Tests will be performed at the Central Mining Institute. In order to perform LCA analysis for ferrous metallurgy will be used SimaPro 7 software and will be applied two of the life cycle impact assessment methods - Ecoindicator 99 and IPCC GWP 100a.

Keywords: LCA (Life Cycle Assessment), blast furnace iron-making system, environmental assessment, ULCOS project (Ultra-Low Carbon dioxide Steelmaking)

1. SIGNIFICANCE OF LIFE CYCLE ASSESSMET IN IRON AND STEEL INDUSTRY

1.1 Environmental Life Cycle Assessment

Life Cycle Assessment is one of the eco-efficiency analysis tool. Linked LCA with economic tools can be used to measure and compare eco-efficiency of selected technologies, products or processes. Eco-efficiency is a new concept in environmental management which integrates environmental considerations with economic analysis to improve products and technologies. Eco-efficiency is a strategic tool and it is one of the key factors of it sustainable development. Eco-efficiency analysis allows to find the most effective solution taking into account economic aspects and environmental compatibility of products or technologies. The purpose of eco-efficiency is to maximise value creation while having minimised the use of resources and emissions of pollutants [1].

In this article methodology of LCA is shown in case study of conventional blast furnace iron-making system. This research focused on identifying and quantifying the environmental impact by using Life Cycle Assessment (LCA). The scope of the study included blast furnace ironmaking process which associates with all emission (air, water and soil), energy and materials acquisition. The results were then compared in order to identify the major environmental impacts based on gate-to-gate0 approach. In this research, environmental impact categories were quantified using SimaPro 7.1 software with Eco-indicator 99 and IPCC methods.
LCA is a technique of the evaluation of environmental aspects and potential impacts associated with all stages of the life of products and technology. LCA takes into account the environmental impacts of the manufacturing processes of a product, the extraction of the raw materials used by these processes, the use and maintenance of the product by the consumer, its end of life (recycling, reuse or disposal) as well as the various methods of transport occurring between every link of the chain. LCA can be assist tool for the decision and apply to design of the new products and the technology, and their development. The LCA method consists of four phases (according to EN ISO 14040:2006) [2,3]:

1. Goal and scope definition,
2. Inventory analysis LCI (Life Cycle Inventory),
3. Impact assessment LCIA (Life Cycle Impact Assessment),
4. Interpretation.

LCI (Life Cycle Inventory) is phase of Life Cycle Assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. LCI studies comprise three phases: the goal and scope definition, inventory analysis and interpretation. LCIA (Life Cycle Impact Assessment) is phase of Life Cycle Assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impact for a product system throughout the life cycle [2,4].

1.2 Life cycle of steel

The European Steel Industry has created a consortium of industries and of research organizations that has taken up the mission of developing the breakthrough technologies for the ULCOS (Ultra-Low CO\textsubscript{2} Steelmaking). The consortium develops a breakthrough steelmaking process that has the potential of meeting the target of reducing GHG (Greenhouse Gas) emissions. The ULCOS project is today the largest endeavour within the steel industry worldwide, proactively looking for solutions to the threat of global warming [5]. LCA analyses are performed in the frame of ULCOS project in the purpose of assessing of the influence of metallurgical processes on the environment and choice of new technologies. According to ULCOS interconnection between LCA and Aspen Plus is a powerful tool in the selection of new technologies for environmental friendly steel production [6,7,8].

LCA in analysis of metallurgical processes is acting as part of International World Steel Association (Worldsteel). In 1996 International Iron and Steel Institute (IISI) carried out a "cradle to gate" Life Cycle Inventory (LCI) study [10]. The World Steel Association has released its 2010 global steel Life Cycle Inventory (LCI). The American Iron and Steel Institute (AISI) initiated a LCA program in 1994. The program centers on training and education, conducting studies of steel products, participating in LCA projects which include steel, and promoting the development of LCA [11].

2. METHODS

For environmental impact evaluation of blast furnace iron-making system were used two of the life cycle impact assessment methods — IPCC GWP 100a method (Intergovernmental Panel on Climate Change, Global Warming Potential, 100 years) to evaluate the greenhouse gas emissions of iron-making and Ecoindicator 99 to environmental impact assessment. IPCC method allows a quantitative assessment of impacts of greenhouse gases (GHG - greenhouse gases) on the greenhouse effect, related to the CO\textsubscript{2} in the assumed time horizon of 100 years. Ecoindicator 99 method allows to present result in three categories: Human Health, Resources and Ecosystem Quality and presents the results in eleven specific categories contained within those of the three categories. In accordance with ISO 14040:2006, set the objective, scope, system boundaries and limitations of LCA and the analysis of inputs and outputs of LCI (Life Cycle Inventory). Carry out a full analysis of the life cycle of technology is a complex process, therefore study has limitations. In the first stage of the research conducted environmental impact analysis techniques LCA for
steel (in integrated steel plant). The study included blast furnace iron-making process. In order to obtain environmental data, data collection sheet was developed for the unit processes including the input data (consumption of raw materials and energy) and outputs (products, emissions of dust and gas, wastewater and waste). For comparative purposes, all data were determined in relation to the same functional unit, a ton of liquid steel.

3. RESULTS AND DISCUSSION

LCA analysis for iron and steel plant and for conventional blast furnace iron-making system was conducted using the SimaPro 7.1.8. in the Central Mining Institute. This analysis was performed by the IPCC method to assess the effect of iron making technology on greenhouse gas emissions. In the domestic steel industry approximately 60% of supplied energy consuming technologies, ferrous metallurgy (coke ovens, sinter plants and blast furnaces), with over half of this consumption in blast furnaces, which are the largest source of CO\textsubscript{2} emissions in the steel plant. Figure 1 presents five main elements of the input technology of iron and steel, which have the largest impact on greenhouse gas emissions (in accordance with the IPCC method). The main factors are 58.84% of all materials used for steel producing. It was found that the largest impact is coke, which is primarily used in the production of pig iron in a blast furnace.

![Fig. 1. Influence of main input factors in steel mill on greenhouse gas emissions (own calculations in the SimaPro)](image)

Next step of research was conducted evaluation of the impact of conventional blast furnace iron-making system on greenhouse gas emissions. Figure 2 shows the five elements of blast furnace process, which, in accordance with the results obtained LCA analysis made by the IPCC method have the greatest impact on greenhouse gas emissions. It was found that the greatest impact of them is coke, which is the main fuel in the process. Then described the size of the impact of various raw materials used in the blast furnace process of global warming (Table 1).
Fig. 2. Global warming influence tree of the blast furnaces technology (own calculations in the SimaPro)

Table 1. Influence of different raw materials of blast furnace on global warming, per one ton of liquid steel (own calculations in the SimaPro)

<table>
<thead>
<tr>
<th>Input to the blast furnace process</th>
<th>Coke</th>
<th>Sinter</th>
<th>Blast furnace gas</th>
<th>Coke oven gas</th>
<th>Anthracite</th>
<th>Electricity</th>
<th>Pellets</th>
<th>Slag</th>
<th>Natural gas</th>
<th>Iron ore</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg CO₂-Eq</td>
<td>2294.46</td>
<td>502.68</td>
<td>424.00</td>
<td>89.62</td>
<td>49.32</td>
<td>28.67</td>
<td>20.60</td>
<td>4.95</td>
<td>0.83</td>
<td>0.62</td>
</tr>
</tbody>
</table>

On the basis of conducted analysis found that the largest source of greenhouse gas emissions in the iron blast furnace process is due to the high coke consumption (an average 430 kg per one ton of liquid steel). Based on previous work in this field was set two emission lines: the replacement of coke by substitute fuels and the use of alternative technologies to the blast furnace process [12].

The second analysis was performed using Ecoindicator 99 assessment method. The evaluation of environmental impacts caused by the BF ironmaking effects of three categories: "Human Health", "Ecosystem Quality" and "Resources" in Pt per one ton of liquid steel is shown in Figure 3 (using Ecoindicator 99 method). In Table 2 was shown eleven impact categories using Ecoindicator 99 assessment method for blast furnace iron-making production, in Pt per one ton of liquid steel.
LCA analysis by using Ecoindicator 99 method shows that the average Ecoindicator value for conventional blast furnace iron-making system in national conditions is 155 Pt per one ton of liquid steel. It was found that the highest impact on the environment occurs in the category of "Human Health" amounts 128 Pt. The category "Human Health" is 83% of risks posed by this process.

4. CONCLUSION
Among the methods available to evaluate the environmental, economic and social performance of materials, technologies and products, Life Cycle Assessment (LCA) provides a holistic approach that considers the potential environmental impacts from all stages of manufacture, product use and end-of-life.

It is important to integrated environmental assessment and results of LCA with other economic methods into product design at an early stage to improve the environmental and economic performance of the product or technology and to eco-efficiency analysis.
Environmental Life Cycle Assessment study in iron and steel industry is widely developing in the world. This method can be used for selecting new optimal technologies or products. LCA is important methods using for environmental impacts assessment of current, alternative and future technologies in iron-making.

Fossil fuel is the main source of greenhouse gas emissions for steel plant, especially for iron-making. Energy saving is an important strategy for CO₂ emission reduction.

Depending on the coke consumption and blast furnace process conditions a greenhouse gas emissions and environmental impact assessment are widely divergent. It depends, inter alia, on whether the substitute fuel is used.

LITERATURE