

Utilization and Optimization Methods of Process Gases in Steel Making

Lloyd Birkin
School of Engineering
University of Wales Trinity Saint David
Swansea, Wales

Abstract— The steel industry is one of the largest energy consumers in the world and inadequate utilization and scheduling of process gases in the steel industry leads to actions such as flaring process gases which in turn results in higher imported fuel energy costs and has a negative impact on the environment due. Based on a review of the literature by steel industries employing tested methods to optimize the usage of process gases can increase energy cost savings by the reduction of fuel imports such as natural gas and oil and lowers the negative environmental impact of producing steel by reducing flaring and venting harmful gases to the atmosphere.

I. INTRODUCTION

This report will cover the different methods that have been researched and studied in the literature to optimize the usage of by-product gasses created from the steel making process. It will show different methods used within the studies to control the gas systems and the benefits of employing said methods.

The steel industry accounts for a large portion of the industrial sectors energy consumption worldwide [1] so it is in their best interest to implement methods of reducing imported energy costs and focus on using energy sources that are produced within the process such as the by-product gases. The way the steel companies manage their systems will also play a part in how much they can save on energy costs but also the utilization of these in-house sources will be a factor also [2].

The three gasses in question that are by-products of the steel making process are Blast Furnace Gas (BFG), Coke Oven Gas (COG), and Basic Oxygen Steelmaking Gas (BOSG). BFG is produced when the charge of iron-bearing materials e.g. Iron-ore and sinter, coke and flux fall through the shaft and reacts with rising gases to produce a liquid iron and slag which accumulate in the hearth of the furnace [3]. COG is produced when coal is heated to around 1000°C in large chambers that air is not present. Roughly 12% of the total weight of coal heated is converted into gas which then goes on to be treated to remove by products such as dust, tar and oil which are often used elsewhere in other processes [4]. BOSG is produced during the primary steel making process, this is done by using lances that inject pure oxygen into a refractory lined converter filled with liquid iron and scrap. The liquid elements then oxidise rapidly and release the gas [5].

The gases discussed are recovered from the process and tend to be stored temporarily in gasholders before they are distributed to the different areas of the plant to be used as

fuel. What often happens due to the limited size of these gasholders, there will be more gas produced than the holder can safely store, and it will instead be flared into the atmosphere. This is a waste of potential energy and it also poses an environmental issue which the steel industry is often scrutinized for [6].

II. METHODS

A. Time Series Analysis

A time series is sequence of data points that are collected over specific time intervals in a defined period. This data is then analysed using statistical methods to extract meaningful characteristics of the data [7]

A study was conducted by Young-Hwan Chu et al. [8] which detailed how to use time series analysis to better predict the gas holder levels through monitoring gas production and consumption levels.

For each of the gases they took the generation and consumption rate in kNm³/min over 60 minutes at 15 second intervals and applied this to an equation that would predict the holder level. From their initial findings it was noted that the logic used in the equation was not adequate enough in correctly predicting the holder levels live at the present time thus giving sub par results. They highlighted that one problem was due to having static parameters within the equation, this was substituted for an average model which updated regularly which included past values to increase accuracy and this logic has also been noted to provide accurate results in a study by Ismael Matino [9]

They also used process heuristics and liaised with operators who control the gas systems to provide a better insight in to the process times for collecting the gasses as they can vary depending on a multitude of factors. They noted that the operators were the only source of detecting any early issues within the primary steelmaking operations which would cause delays. They would also be able to give a timeframe for these delays based on previous experiences. These would have to be implemented to the equations as an when.

With the new logic, a series of simulations were run using the old prediction logic against the new average logic which compared the actual gas produced and consumed within a time vs what was predicted by the logic equations, positive results were seen with each gas. BFG seen an improvement of 64.3%, COG – 39.4%, BOSG – 92.6%. It showed that the new logic provided a fairly accurate prediction on gas holder levels.

By implementing this logic into an automated system such as SCADA to control the gas system there will be a greater control over the gas which would increase the usage of these process gasses as an energy source for consumers within the steel plant. This would then drive imported fuel costs down and reduce the negative environmental impact of the plant due to less excess gas being flared into the atmosphere.

B. Process Gas Mixing

It has been noted that BFG is produced in extremely large quantities, but for it to be used as a fuel in high temperature processes it must be mixed with other gases that yield a higher calorific value (CV) such as Natural gas (NG) due to its low calorific value of roughly 2.5-3.6 MJ/Nm³. It has also been noted that when the BFG was mixed with a richer gas higher thermal efficiency was achieved allowing the mixed gas to be used as a fuel for boilers [10].

Due to COG and BOSG having a higher CV value you tend to not have an issue with sending these gases directly to the consumers where they can use the gas in its raw state but with BFG it tends not to be the case. When you compare the CV of BFG to the CV of NG which sits roughly at 35.5 MJ/Nm³ or the other process gases, COG which is between 16-18 MJ/Nm³ and BOSG which is 8.5-10.5 MJ/Nm³, you can see how BFG is significantly lower [11].

For some steel plants this may cause an issue due to not having the adequate systems in place to mix process gases together therefore leading to not utilizing the gas to its full potential which in turn would lead to an increased flaring of the gases which could lead to the reprimand from the governing environmental agencies.

It is also worth noting that using this method would decrease imported energy costs by reducing the amount of natural gas and oil that would have to be used on fuelling consumers. By having this mixed gas available when needed over time the benefits will be seen.

III. PROJECTS

A. Superheater

Projects are a good way to create ideas to utilize process gasses more efficiently. At TATA steel a project was undertaken to create a superheater to increase steam pressure for the BOS plant. This system utilizes BFG to heat the steam. It works by reclaiming steam produced during steelmaking to supplement the 11 bar distribution supply. The aim of this operation was to recover the energy content and usefully employ it to generate electricity via an 11bar steam driven turbo alternator. Steel production is a batch, rather than continuous process, so a system had to be devised whereby the steam would be “captured” into a bank of accumulators partially filled with water. This would enable a steady stream flow to be exported into the 11 bar network. The steam produced during the blow is however at a higher pressure, and lower temperature than required for the system. This led to the development of a system “Superheater”, which performs the required physical changes to the captured steam. It raises the temperature from approx. 255°C to 320°C and lowers the pressure from approx. 25barg to 11barg.

The burner - used for raising the steam temperature - utilises BFG along with natural gas in a combined fuel unit. The burner can only use the BFG when the steam throughput rate exceeds 26tph, at which point, the volume of natural gas utilised is reduced. The maximum steam rate throughput of the system is 75tph. If at rates up to this point the BFG cannot provide enough energy to the burner to effectively raise the steam temperature, the volume of natural gas increases in the burner unit. The BFG ceases to be used when the steam rate drops below 24tph.

The burner unit can utilise BFG through the CV range of 2.7 to 3.7 GJ/Km³, with a maximum volume utilised approx. 9.5 Km³/hr.

B. BOS Gas Recovery

Another project that has been completed at TATA is the BOS gas recovery system. As we know during the primary steel making operation is when BOSG is produced. The waste gases are collected by the “Off Gas” (OG) system. The gas temperature at evolution is in the region of 1650 °C – 1850 °C, which is then cooled and cleaned by the individual elements of the BOSG collection system at the BOS plant. The main cleaning method is using Wet electrostatic precipitation, this works by passing the dirty gas through a series of electrodes that alternate between negative and positive charges of electricity causing the particles to attach to the electrodes where they can then be washed off by sprayers and collected in a sump [12].

These waste gases evolved from steelmaking process are now selectively separated into high and low CV gases, with the recovery point reached when CO levels reach 50%. The separation occurs via two linked valves, one opens as the other shuts sending low CV gas directly to the flare, and the higher CV gas is collected into the common duct main straight to the gasholder. So even though some gas is still being flared there is a reduction by utilizing the high CV BOSG which can be used in the mixing stations as previously discussed or as a standalone fuel for consumers such as the boilers.

IV. CONCLUSION

From the literature that has been studied and through knowledge obtained from working within a steel plant it is possible to better utilize the process gases which are sometimes classed as ‘waste gases’ from steel making operations. Some methods may be more efficient such as predicting the holder levels using the time series analysis, this gives you a greater control over any current systems in place and wouldn’t really require many alterations or the need for building new systems. It also makes good use of previous data by looking at historian graphs which would be easily available for steel making plant to get hold of and the more of this data that is available the better the predictions will be.

The mixing of the process gases also showed that it would increase the utilization by making richer gases that can be used in high temperature processes across the plant. One key area would be at the boilers of a power plant, this would increase energy generation and lowering energy costs. If the mixing stations were not available a lot of the gas would be flared into the atmosphere.

Projects that have been created specifically to utilize process gases have shown good results as they also help other processes and systems within the steel plant such as increasing steam pressure which is used within the BOS plant. Before the BOSG recovery project was built the gas created from the primary steel making process would have just been flared to the atmosphere which is complete waste of opportunity.

In the future I believe the utilization of these gases will become more efficient as technology and research develops and new projects are developed. In turn this will hopefully help the steel industry reduce its energy costs and its carbon footprint.

V. REFERENCES

- [1] The Editors of Encyclopædia Britannica, "Encyclopædia Britannica," Encyclopædia Britannica, inc. , 26 September 2016. [Online]. Available: <https://www.britannica.com/technology/blast-furnace>. [Accessed 20 November 2019].
- [2] J. Lacey, "Thermopedia," © Thermopedia, 8 February 2011. [Online]. Available: <http://www.thermopedia.com/content/641/>. [Accessed 20 November 2019].
- [3] U.S. Energy Information Administration, "Industrial sector energy consumption," International Energy Outlook , 2016.
- [4] H. B. J. H. Xiancong Zhao, "A review on the optimal scheduling of byproduct gases in steel making industry," *Energy Procedia*, vol. 142, no. 1876-6102, pp. 2852-2857, 2017.
- [5] J. N. Edward F. Wentz, "Primary Steelmaking," Encyclopædia Britannica, inc. , 10 April 2019. [Online]. Available: <https://www.britannica.com/technology/steel>. [Accessed 20 November 2019].
- [6] E. A. Emam, "GAS FLARING IN INDUSTRY: AN OVERVIEW," Department of Chemical Eng. and Pet. refinery, Egypt, 2015.
- [7] J. H. K. S. J. M. I. S. K. S. J. Q. C. H. Young-Hwan Chu, "CONTROL OF GASHOLDER LEVEL BY TREND PREDICTION BASED ON TIME-SERIES ANALYSIS AND PROCESS HEURISTICS," IFAC, Austin, Texas, USA, 2002.
- [8] Research Optimus, "What is time series analysis," Research Optimus, 2019. [Online]. Available: <https://www.researchoptimus.com/article/what-is-time-series-analysis.php>. [Accessed 20 November 2019].
- [9] D. C.-R. P.-D. N. V. B. M. F. A. D. R. M. A. A. R. C. W. J. N. T. E. C. R. W. A. Víctor Cuervo-Piñera, "Blast Furnace Gas Based Combustion Systems in Steel Reheating Furnaces," *Energy Procedia*, vol. I, no. 120, pp. 357-364, 2017.
- [10] Department for Business, Energy & Industrial Strategy, "Digest of UK Energy Statistics (DUKES): calorific values," 25 July 2019. [Online]. Available: <https://www.gov.uk/government/statistics/dukes-calorific-values>. [Accessed 20 November 2019].
- [11] C. Woodford, "Electrostatic Precipitators," US DOE National Renewable Energy Laboratory (NREL), 25 September 2019. [Online]. Available: <https://www.explainthatstuff.com/electrostaticsmokeprecipitators.html>. [Accessed 20 November 2019].
- [12] S. D. V. C. V. W. S. S. Ismael Matino, "Forecasting blast furnace gas production and demand through echo state neural network-based models: Pave the way to off-gas optimized management," *Applied Energy*, vol. 253, 2019.