Journal of Engineering and Applied Sciences 12 (8): 2181-2184, 2017
ISSN: 1816-949X

Review and Analysis of Coal Substitution with Refuse Derived Fuel (RDF) in Cement Plant Using System Dynamic

K.K. Ummatin and Q.A.M.O Arifianti
Department of Engineering Management, Universitas Internasional Semen Indonesia,
61122 Gresik, Indonesia

Abstract: Regarding to the depletion of fossil fuel issue, one of the biggest cement industry in Indonesia, PT. XYZ has a program by substituting 30% of the total coal with RDF. This policy is related to the company's commitment to support Corporate Social Responsibility (CSR) program to reduce the amount of Municipal Solid Waste (MSW) in Gresik City. However, in the implementation, several problems were found, for example, a high percentage moisture content and also impurity (sand, gravel) in RDF. To solve those problems, in the present study, the RDF usage in PT. XYZ is evaluated by building a system dynamic model. A Vensim software is used to simulate the problem. The general result shows that the quantity and quality of RDF determine how much of coal substitution. Some policy scenarios have been created by modifying the RDF's machine production, for example, adding rotary screen and drying equipment. Those actions can improve quantity and quality of RDF.

Key words: MSW in Gresik City, RDF, substitution, system dynamic (CSR), Indonesia

INTRODUCTION

Cement industry is a fast growing company along with the development of a country. A large amount of heat are required to support this company. Mostly, cement industry uses coal as fuel to meet up the daily energy needs. A higher tendency of coal usage causes the cement company sensitive to the rise of fossil fuel price. Whereas, the energy cost component (include the electricity cost) reached 51% to a total of production cost.

In Indonesia, the total amount of estimated coal reserves is only 7.6 billion tons. As the coal reserves continue to decrease, the coal prices tend to be higher and further it will influence the industry that use coal as fuels.

On the other hand, along with the rapid economic growth, the amount of Municipal Solid Waste (MSW) generated is higher. According to some experiments, the waste can be used to produce energy (Chyang *et al*., 2010; Singh *et al*., 2012; Miskolczi *et al*., 2011; Cheng and Hu, 2010; Moulod *et al*., 2016). Therefore, the utilization of the waste might be a solution to the problems of limited fossil fuel in cement industry.

The product of the waste utilization is called Refused Derived Fuel (RDF). There are various investigation about RDF (Dalai *et al*., 2009) found that the major components in RDF were carbon and hydrogen based on the proximate and ultimate analysis (Chyang *et al*., 2010) investigated the pollutant emissions from co-firing of RDF and coal (Singh *et al*., 2012) performed pyrolysis of RDF using two Thermo Gravimetric Analyzer (TGA). The characteristic of RDF utilization in different kind of reactor were also studied, for example, in a down draft gasifier (He *et al*., 2010), a fluidized bed reactor (Wagland *et al*., 2011), a continuously stirred batch reactor (Miskolczi *et al*., 2011), so forth.

RDF could be used as an alternative fuel in cement manufacturing since RDF provides a high calorific value for the cement kiln. The caloric value of RDF is around 5178 kcal/kg. These value is higher than that of coal which is only 4800 kcal/kg. Based on this fact, substituting coal with RDF in cement plant can be possibly executed.

One of the biggest cement plants in Indonesia, PT. XYZ has substituted 30% coal with RDF. This policy is related to the company's commitment to support Corporate Social Responsibility (CSR) program to reduce the amount of MSW in Gresik City. Unfortunately as PT. XYZ continues to operate, the RDF could not be produced constantly. It is occurred because of some factors related to the RDF machine. Accordingly, in the present study, the coal substitution with Refused Derived Fuel (RDF) in PT. XYZ were reviewed and analyzed to define the parameter which influence the RDF production. Moreover, by using those parameter, the solution to optimize the RDF production would be provided. In many

Corresponding Author: K.K. Ummatin, Department of Engineering Management, Universitas Internasional Semen Indonesia, 61122 Gresik, Indonesia

complex system, system dynamic can be used to represent the information related the problem, thus the solution (some scenarios) can be generated systematically. Many researchers had applied system dynamics. For example, Li *et al.* (2012) built a system dynamic model to simulate CO_2 emission trends in traditional industrial region with large CO_2 emission (Suryani *et al.*, 2010) developed system dynamic model to forecast air passenger demand (Dace *et al.*, 2014) adopted a system dynamic model to analyze the various policy instruments on packaging waste management system. Sukholthaman and Sharp (2016) evaluated the impact of source separation on waste collection and transportation using a system dynamics model. Therefore, in the present study, to describe the problem in RDF production and also obtain a better understanding about its relationship to another issue, a model was created by using system dynamics in Vensim simulation.

MATERIALS AND METHODS

To obtain the coal substitution model, the variables related to cement production were identified. The input variables. The data used in the present simulation comprises primary and secondary data. The primary data was based on the result of Focus Group Discussion (FGD) conducted with department of energy and material of PT XYZ. While, the secondary data obtained from literature study and annual work summary of PT XYZ.

Input variables related to cement production:

- Kiln production capacity
- Coal demand
- RDF production capacity
- RDF calorie
- Coal price
- RDF price

The following step was operating the Vensim software to build the model. Vensim is an industrial strength simulation software to improve the performance of real systems. After the model was created, the next procedure was running the simulation based on the defined time period. The simulation result showed the significant level of coal substitution with respect to financial and environment aspect in PT XYZ. Subsequently this output were validated and analyzed.

RESULTS AND DISCUSSION

Actual condition RDF production model: The coal substitution program have been applied since May 2016. The raw material of RDF is Municipal Solid Waste (MSW). RDF is produced in final disposal of waste site in Gresik city (about 84 km from PT. XYZ). The final disposal site has been established since 1998 and the area is about 6 ha. Approximately 217 ton of garbage ended up in the landfill per day. The composition of the garbage contains around 51% organic garbage and 49% inorganic garbage. The detail composition can be shown in Table 1.

Table 1: The garbage composition in final

Material	Percentage
Plastic	17
Textile	2
Paper	28
Wood	2
Organic garbage	51
Total	100

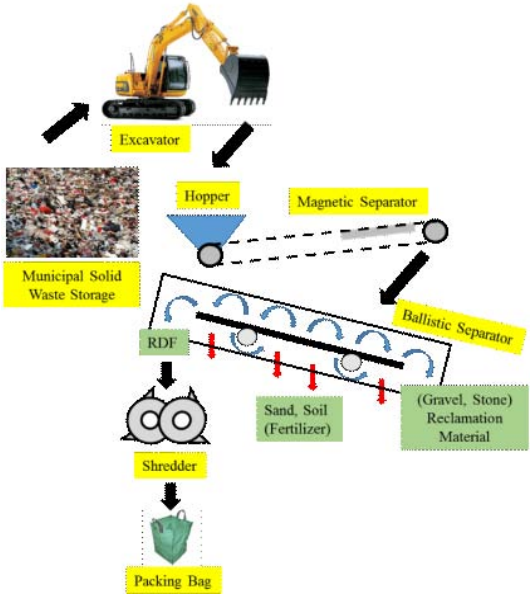

Fig. 1: RDF production process

Figure 1 RDF production process shows the RDF process production. The first step, MSW is moved from landfill using excavator to hopper. Then, the MSW is transported to ballistic separator using belt conveyor. In belt conveyor, there is a magnetic separator this component is used to extract any magnetic material from the MSW. The separation process will be continued in ballistic separator. In the ballistic separator, the MSW is classified into three kinds of composition. This equipment separates the waste using the movement of inclined screen. The RDF is then shredded into the smaller part. The final composition from those process comprises around 35% reclamation material, 37% fertilizer and 28% RDF. To process the waste, municipal solid waste treatment plant were installed in final disposal site.

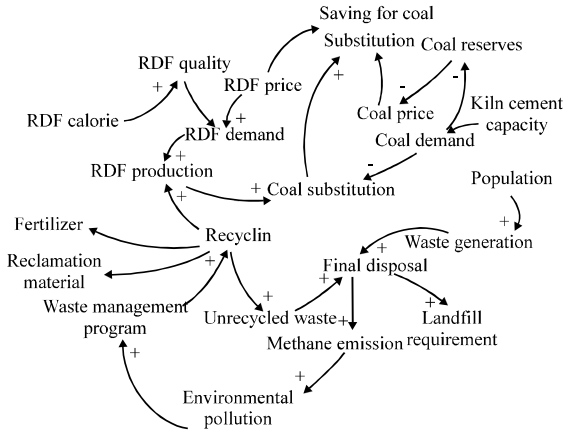

Fig. 2: Influence diagram for coal substitution

However, this plant operated out of the specification since only 3 ton of RDF could be produced each day (35 operating hours a week). The machine was expected to generate 3.3 ton of RDF per hour. On the other hand, the amount of coal substitution in PT. XYZ was around 270 ton/day. Thus, to fulfill the 30% coal substitution, the company also mix RDF with rice husk and coconut shell. An imbalance between supply and demand of RDF was occurred not only due to the low RDF capacity but also the quality of RDF itself. The quality of RDF was poor since the RDF did not meet the minimum criteria for moisture. The company stated that the moisture content could not exceed 10%. According to the data collected, the moisture level of RDF reached almost 30%.

Influence diagram for coal substitution describes influence diagram for coal substitution. The kiln cement capacity influences coal demand. The rise of kiln cement capacity leads to the increase of coal demand. The coal demand affects coal reserves. Increasingly scarce supply of coal, coal prices will increase. Coal price and RDF price influence saving for coal substitution. The greater substitution of coal, the greater the saving. However, to achieve production targets, quality RDF must be met by keeping moisture content to achieve calorie criteria (Fig. 2).

Based on the model of RDF production systems that have been developed, it is known that MSW management system can answer the problem about the need to build more landfills which is related to the growth of the waste in Gresik City. Figure 3 shows that final disposal in landfill will increase as the population increase. If the amount of waste that is processed is not proportional to the increase of municipal waste in Gresik that is a problem. The model shows that RDF production capacity is determined by its quality. Several factors that affect the quality of RDF are

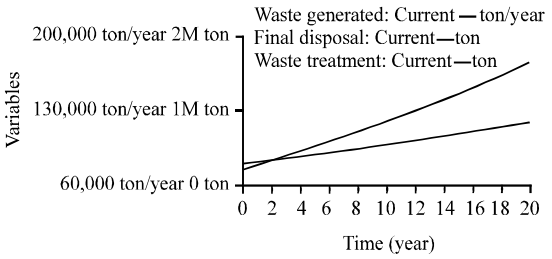

Fig. 3: Projection of final disposal and waste treatment

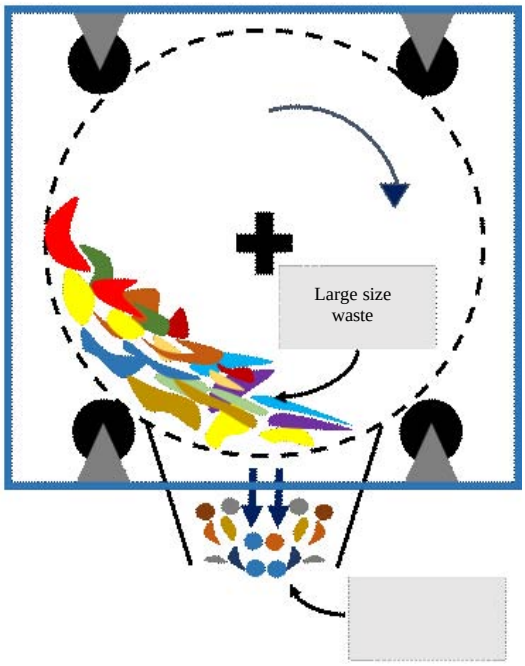

Fig. 4: Rotary screen mechanism

the percentage of moisture content and also impurity (sand, gravel) in RDF. Those two factors also affect the quantity of RDF production due to the production time. Some problem was detected because of a high level of waste moisture. It could cause the waste jammed in shredder unit. Thus, the machine should be switched off and further the waste is removed. Moreover, the existence of the moisture content in RDF should be diminished, since the moisture level can lower the calories of RDF.

Modified scenario RDF production model: An improvement is required to optimize the RDF production. It could be completed by doing some procedures.

Adding the rotary screen: In previous RDF production, sand and soil were still included in RDF (Fig. 4). PT. XYZ as a consumer tested the quality of RDF and found that

the mixture decreased the heating value of RDF. To overcome this problem, a rotary screen would be added in the RDF production system. The principle of the rotary screen is to separate the RDF raw material with undesirable material (e.g., sand and soil) by their size. Later, each fraction is collected separately. The concept of rotary screen is presented in Fig. 4 rotary screen mechanism.

Adding the drying equipment: The drying system is used to decrease the moisture content. It plays a role to increase the combustion efficiency in the kiln. Although, the RDF raw material tends to have a low moisture content but during the rainy season, the rain water drop falling to the material. Thus, the drying system must be installed.

CONCLUSION

In the present study, based on the system dynamic analysis, variables that influence coal substitution are RDF capacity production and RDF's quality. The improvements could be executed by adding rotary screen and drying mechanism. The result showed that those additional system could significantly increase the quality and quantity of RDF production.

ACKNOWLEDGEMENTS

This research was supported by Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) Universitas Internasional Semen Indonesia in 2016. The title of the research is Pemanfaatan Refuse Derived Fuels (RDF) Sebagai Substitusi Batubara Pada Industri Semen: Studi Kasus PT. Semen Indonesia. This grant number is 01/KP.01/10-01/02.16.

REFERENCES

Cheng, H. and Y. Hu, 2010. Municipal solid waste (MSW) as a renewable source of energy: Current and future practices in China. Bioresour. Technol., 101: 3816-3824.

Chyang, C.S., Y.L. Han, L.W. Wu, H.P. Wan and H.T. Lee *et al*., 2010. An investigation on pollutant emissions from co-firing of RDF and coal. Waste Manage., 30: 1334-1340.

Dace, E., G. Bazbauers, A. Berzina and P.I. Davidsen, 2014. System dynamics model for analyzing effects of eco-design policy on packaging waste management system. Resour. Conserv. Recycl., 87: 175-190.

Dalai, A.K., N. Batta, I. Eswaramoorthi and G.J. Schoenau, 2009. Gasification of refuse derived fuel in a fixed bed reactor for syngas production. Waste Manage., 29: 252-258.

He, M., B. Xiao, S. Liu, Z. Hu, X. Guo, S. Luo and F. Yang, 2010. Syngas production from pyrolysis of municipal solid waste (MSW) with dolomite as downstream catalysts. J. Anal. Applied Pyrolysis, 87: 181-187.

Li, F., S. Dong, Z. Li, Y. Li, S. Li and Y. Wan, 2012. The improvement of CO2 emission reduction policies based on system dynamics method in traditional industrial region with large CO2 emission. Energy Policy, 51: 683-695.

Miskolczi, N., N. Borsodi, F. Buyong, A. Angyal and P.T. Williams, 2011. Production of pyrolytic oils by catalytic pyrolysis of Malaysian refuse-derived fuels in continuously stirred batch reactor. Fuel Process. Technol., 92: 925-932.

Moulod, M., A. Jalali and R. Asmatulu, 2016. Biogas derived from municipal solid waste to generate electrical power through solid oxide fuel cells. Int. J. Energy Res., 40: 2091-2104.

Singh, S., C. Wu and P.T. Williams, 2012. Pyrolysis of waste materials using TGA-MS and TGA-FTIR as complementary characterisation techniques. J. Anal. Appl. Pyrolysis, 94: 99-107.

Sukholthaman, P. and A. Sharp, 2016. A system dynamics model to evaluate effects of source separation of municipal solid waste management: A case of Bangkok, Thailand. Waste Manage., 52: 50-61.

Suryani, E., S.Y. Chou and C.H. Chen, 2010. Air passenger demand forecasting and passenger terminal capacity expansion: A system dynamics framework. Expert Syst. Appl., 37: 2324-2339.

Wagland, S.T., P. Kilgallon, R. Coveney, A. Garg and R. Smith *et al*., 2011. Comparison of coal/solid recovered fuel (SRF) with Coal/Refuse Derived Fuel (RDF) in a fluidised bed reactor. Waste Manage., 31: 1176-1183.