ENERGY EFFICIENCY IN GLASS INDUSTRY: PROBLEMS AND SOLUTIONS

(*EFISIENSI ENERGI DI INDUSTRI GELAS : MASALAH DAN PEMECAHANNYA*)

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ABSTRACT

Glass industry has a high level of energy consumption and is considered to be one of the intensive energy industries because of the high temperature required. The energy cost could be as much as 10-20% of the total cost. Therefore. glass industry faces many challenges related to becoming more efficient both from energy and productivity standpoint.

The energy efficiency depends on the technology applied. Higher efficiency could be achieved when oxygen is used instead of air in the furnace, the higher the amount of cullet and furnace capacity, the higher the inlet temperature of the batch and cullet, the higher the inlet temperature of secondary air and the lower the exhaust gas temperature, the lower the air ratio and the higher the amount of low melting temperature materials in the glass ingredient. Not all technique could be applied by the Indonesian glass industry because of the limited availability of oxygen and low melting temperature materials deposit has not been found in Indonesia, and the cost for additional investment for preheating. The relatively easy technique that could be applied in the Indonesian glass industry is the optimum amount of cullet used and air ratio adjustment.

Key words: energy efficiency, preheating, cullet, air ratio, glass ingredients

ABSTRAK

Industri gelas merupakan industri yang mengkonsumsi energi yang tinggi dan dipandang sebagai salah satu industri padat energi karena prosesnya memerlukan suhu yang tinggi. Biaya energi dapat mencapai 10-20% dari biaya total. Oleh karena itu industri gelas menghadapi berbagai tantangan agar lebih efisien baik dari segi energi maupun produktivitas.

Efisiensi energi tergantung kepada teknologi yang digunakan. Efisiensi makin tinggi bila oksigen dipakai sebagai pengganti udara pada tungku, makin tinggi jumlah beling dan kapasitas tungku, makin tinggi suhu pemanasan penda-huluan pada batch dan beling makin tinggi suhu pemanasan pendahuluan udara sekunder dan makin rendah suhu gas hasil pembakaran, makin rendah perbandingan udara dan makin tinggi jumlah bahan dengan titik lebur rendah pada komposisi gelas. Tidak semua teknik dapat diterapkan oleh industri gelas di Indonesia karena ketersediaan oksigen yang terbatas dan belum ditemukannya bahan yang mempunyai titik lebur rendah dan adanya tambahan permodalan yang cukup tinggi untuk penerapan pemanasan pendahuluan. Teknik yang relatif mudah dan mungkin diterapkan adalah pengaturan penggunaan beling yang optimum serta pengaturan perbandingan udara

Kata kunci: *effisiensi energi, pemanasan pendahuluan, beling, perbandingan udara, komposisi gelas*

I. INTRODUCTION

The need of energy in the world is huge. In Indonesia the need of energy is about 900 million barrel oil equivalent [1]. Indonesia is facing problems in energy supply indicated by the increase of oil import. The government program to switch the use of oil fuel to gas fuel for household need would reduce the dependency of this energy on import, however, Indonesia and the rest of the world still face the shortage of oil supply because of the exhausted of oil resources. The fossil oil such as coal, petroleum and natural gas as energy resources are limited resources which part of it must be left for people of next generations as much as possible. SO_x and NO_x are discharged into the atmosphere by the combustion of fuels which affecting the human health. This has raised serious problem because it causes global warming. To cope this situation, effort has to be made in all part of the world to reduce the amount of CO_2.

Another problems is the elasticity of energy used in Indonesia is still high (1.84) as compared with Thailand (1,16), USA (0,26) and Japan (0,10). The energy elasticity is an indicator of the relationship between economic development and the energy required. The higher the elasticity indicates that the economic development Indonesia's huge energy is used. [1]

Saving energy or energy conservation efforts in industrial activities including glass industry are directly connected to the effect of controlling the cost increase due to the reduction of unit energy consumption in industry. It is imperative for the industrialist to understand that energy conservation is one of the most important policies for industry.

Glass industry consumes much energy and belongs to the categories of "energy intensive industries" and that energy represents a huge part of glass manufacturing expenses which can be as much as 10 percent of all costs but in some glass products could be more than 20 percent [2]. Each steps of production shown in Fig. 1 needs energy.[3] Fuels are burnt to create high temperature inside the furnace, where the batch is reacted, vitrified, degassed, homogenized and taken out as products. The products are then put into the lehr for annealing, and the surfaces are printed for marking. Today, 80 percent to 90 percent of the energy used in glass industry is in the form of fossil energy while the rest as electricity [2]. According to International Energy Agency the primary source of energy will still be from fossil energy at least for 20 or 30 years to come [2].

A revolutionary change in the melting of glass must be made. This measure is expected to improve efficiency and reduce the production cost. Basically, the energy conservation in the glass factory is to reduce the unit energy consumptions. To reduce energy consumption it is necessary to reduce

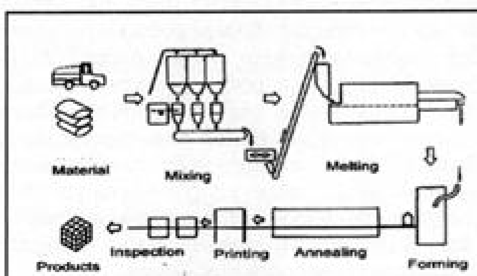

Fig. 1 Schematic diagram of glass production (bottles)

the amount of fuel used or to increase production without increasing the amount of fuels, to reduce the failure rate of productions, thereby ensuring production increase in the final stage.

In short, the energy efficiency in all industry including glass industry is really in needed due to the following [4,5]:

- Energy significant percentage of manufacturing cost
- Energy cost increasing
- Energy shortages
- Emission reduction – Green House Gas (CO2), NO_x, SO_x, Particulates (Environmental norms)
- Global competitiveness

This paper will review the latest technology/methods of energy reduction and efficiency improvement in glass industry

II. CHARACTERISTIC ENERGY CONSUMPTION IN THE GLASS INDUSTRY

Fig. 2 shows the share of total energy consumption in glass processing furnace for glass bottle manufacturing plant equipped with the tank furnace for large scale industry and the small scale industry provided with the pot furnace [3,4]. It can be seen that the melting process is the greatest energy consumer in both large and small scale industry. The melting process spends 75-85% of the total energy consumed in glass processing [3.4.6] However, from Fig.2 it can be seen that in the large scale industry the second highest energy consumption is in the forehearth, while in the small scale industry the second largest energy consumption is in the annealing furnace(lehr). Therefore, when energy conservation program is made, the top priority must be placed on

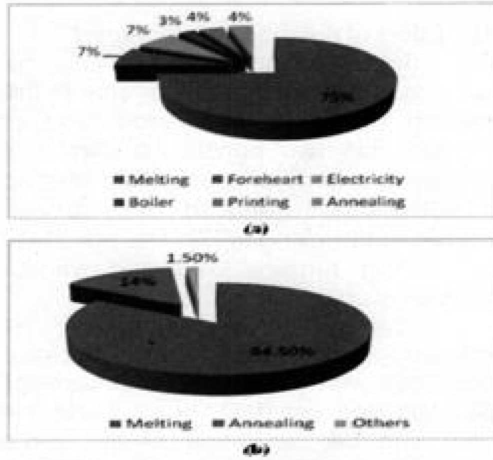

Fig. 2 Share of total energy con sumption in (a) large scale industry with tank furnace and (b) small scale industry with pot furnace.

melting plant in both of large and small scale industry followed by the forehearth in large scale industry and annealing lehr in small scale industry.

III. ENERGY CONSERVATION TECHNOLOGY IN GLASS PRODUCTION PROCESS

As has been mentioned before melting furnace is the largest energy consumer among the heat equipment user in the production of glass. Many efforts and tedhnology has been proposed to tackle the problem of efficiency in this important furnace. Several proposal on this matter will be discussed in the following

There are several measures proposed and practice in glass industry as follows:

1. Use of oxygen enrichment
2. Use of cullet
3. Exhaust heat recovery
4. Change of air ratio
5. Use of low melting materials

1) Effect of the oxygen enrichment

Introduction of oxygen into the furnace is a revolutionary change in the melting of glass. The introduction of oxygen has two benefit i.e., first, it improves energy efficiency and second it substantially reduced the nitrogen oxides in the exit gas [7]. The efficiency of melting furnace with and without oxygen is shown in Table 1.

Table 1 shows that the highest efficiency achieved in the furnace equipped with recuperator and capacity 350 tpd (ton per day). From Table 1 it also can be seen that at the same capacity of 250 tpd, energy efficiency could increase from 44% in the furnace using air to 56% in the furnace using oxygen.

Table 1 also shows that furnace capacity has some effect on the efficiency. Furnace with capacity of 61 m^2 has an efficiency of 53% which is higher than furnace with capacity of 73 m^3 which has efficiency of 50%, both furnace using oxygen-gas-electric as the sources of energy.

In Indonesia none of the glass industry has practiced the use of oxygen. The main cause is the limited availability of oxygen, while glass industry needs large amount of oxygen. Also the price of oxygen is an obstacle to the use of this technique. A careful cost calculation is needed when this technique is to be applied

Table 1. Energy efficiencies in melting glass

Furnace	Capacity	Efficiency, %
Electric	56 m2	57
Air-gas-electric	42 m2	47
Oxygen-gas-electric	61 m2	53
Oxygen-gas-electric	73 m2	50
Oxygen-gas-recuperator	350 tpd	64
Air-gas	250 tpd	44
Oxygen-gas	250 tpd	56

2) Effect of the use of cullet

The use of cullet in glass industry has been practiced for a long time. Cullet is broken glass to be remelted.

The effect of the amount of cullet in the glass batch on the heat required for glass melting at 1400°C is shown in Fig. 3. This figure was constructed from table in literature [3]. From Fig. 3 it can be seen that the more cullet added in the glass batch the less energy required to melt the glass. The reason behind this phenomena is that raw materials (silica sand, feldspar, oxides etc) require more energy for diffusion before reaction occurs, while cullet is chemically homogeneous, so no need any energy for diffusion.

Fig. 3 also shows that the energy required to melt sheet glass is higher than tableware glass and borosilicate glass. The differences in chemical composition of each glass causes the difference energy required to melt the mixture.

Sheet glass contains calcium oxide which form glass at higher temperature, while tableware glass and borosilicate glass contains boron oxide

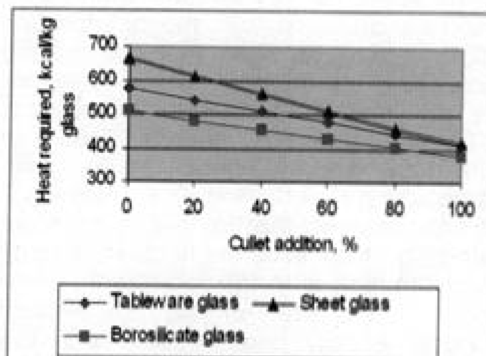

Fig.3. Effect of amount of cullet on the heat required for melting glass at 1400°C

which form glass at lower temperature. Fig. 3 also shows that at 100% cullet the differences in energy consumption among the three products is small.

Fig. 4 shows the pull effect or production capacity and the amount of cullet on the energy or fuel required [3]. From Fig.4 it can be seen that the higher the production capacity and the higher the cullet addition in the glass batch the lower the amount of fuel required to melt the glass. For example at capacity of 120 ton/day with 50% cullet the amount of fuel to melt 1 kg glass is about 187 kg gas. When the capacity increases to 220 ton/day the fuel required reduced to 160 kg gas.

The use of cullet reduce the amount fuel required to melt glass, however, there are some problems on using the cullet as follows:

- the cullet on the market are mixed with foreign substances, and it is expensive to separate them from the cullet to maintain the quality
- the quality of cullet produced in the plant is satisfactory, however the amount is limited. Higher cullet production means a high failure rate in production

The use of cullet has been a common practice in Indonesian glass industry. The cullet could be from factory itself but the amount is limited and needs additional cullet from the market. Because of the limited cullet available in the market some factories in Indonesia imports cullet from Australia, Singapore and Malaysia. In order to make melting furnace more efficient, the glass industry should find the optimum amount of cullet used by considering the technical and economical point of view.

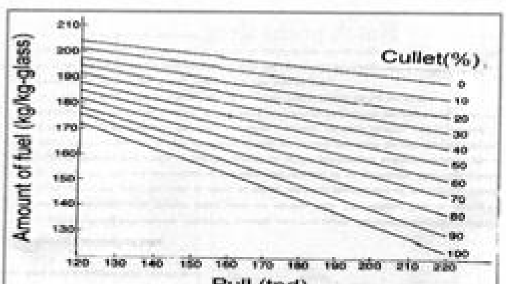

Fig. 4 . Effect of amount of cullet and capacity on the amount of fuel required,to melt glass in bottle production

3) Effect of exhaust heat recovery

The relationship between energy used and efficiency is shown in Fig. 5 which was constructed from data in literature [7].

Fig. 5 shows that the more energy used in glass melting the lower the efficiency. Therefore, it is imperative that the energy loss must be reduced and the energy must be recovered and reused

The melting of glass requires a temperature of 1450°C to 1550°C, so the exhaust gas contain a great amount of heat which can be used to preheat secondary air or preheat batch/ cullet.

This exhausted gas recovery can be done by using regenerator or recuperator. While regenerator used for large scale industry, the recuperator used for small to medium scale industries.

Fig. 6 shows the relationship between exhaust gas temperature, secondary air temperature and amount of fuel saved in percent, when LPG is used as fuel. It can be seen that when the temperature inlet at the regenerator is 1200°C, and the temperature of secondary air is 700°C the fuel saved is 40% and when the temperature of secondary air is 900°C the fuel saved becomes 50%.[3].

The relatively new technology in saving energy is batch/cullet preheat [4,8]. Previously the raw materials and cullet are mixed before introducing into the melting tank in cold condition. Some glass industry introduces raw materials and cullet in hot condition by preheating them before introducing into the melting furnace. The process of batch and cullet preheating is shown in Fig. 7[3]

By batch and cullet preheating the fuel consumption decreases, the flue gas volume decreases, lower temperature and lower volume flow. Fig. 8 shows the effect of batch and cullet reheating on energy consumption required for melting glass. It can be seen that the higher the batch charging temperature the lower the energy consumption for melting glass for both oxygen fired furnace and end-port furnace. However, the decrease of energy consumption depends on the type of the melting furnace. In oxygen fired furnace for example the energy consumption for glass melting without batch preheating (grey circle) is around 4 GJ/ton melt, and when the batch charging temperature is 400°C, the energy consumption reduced to about 3,35 GJ/ton melt (16,25% lower). In the end-port furnace, when the batch is cold (room temperature), the energy consumption is about 3,6 GJ/ton melt and when the temperature of batch is 200°C, the energy consumption reduced to about 3,1 GJ/ton melt or 13,89%

No glass industry in Indonesia applies this technology yet. In order to use this technology the industry need additional investment on the preheater which cost is relatively high. In general,

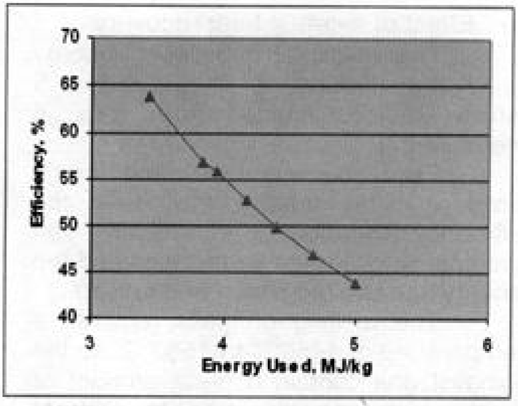

Fig. 5. The relationship between effi ciency and energy used in glass melting.

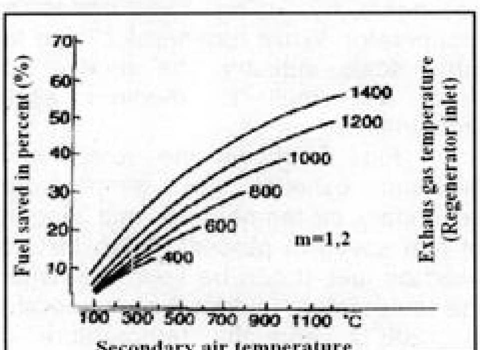

Fig. 6. Relationship between exhaust gas temperature, secondary air temperature and amount of fuel saving.

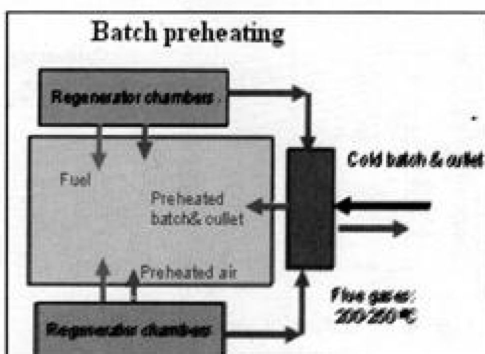

Fig. 7. The diagram of batch and cullet preheating process[8]

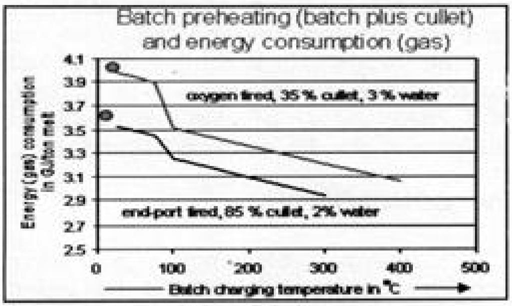

Fig. 8. Effect of batch charging tem perature on energy consump tion for melting glass

most glass industry are reluctant to add additional investment to the existing factory.

4) Effect of change of air ratio

The amount of air introduced into the furnace has some influence on the consumption on the fuel for glass melting. Fig. 9 shows that the higher the air ratio (m) the lower the percentage of fuel that can be saved. The higher m means that some cold air is has entered the recuperator or regenerator. At m=1, no cold air entering the recuperator/regenator and if m>1 means that some cold air has entered the heat recovery system and causes the temperature of preheated air entering the melting furnace is lower than it should be, therefore lowers the efficiency or fuel saved as shown in Fig 6. The air ratio could be detected by analyzing the content of oxygen at the inlet and at the outlet of the heat recovery system.

Fig. 9 also shows that the percentage of preheated air compared with total air affected the fuel saved. The higher the percentage of preheated air the higher the fuel can be saved.

Glass industry in Indonesia could apply this technique to reduce the amount of fuel by preventing cold air infiltration to the exhaust gas heat recovery system. This could be done relatively easy by controlling the draft pressure in the melting furnace , checking the leak all over the system, reducing the opening through which cold air entering the system and perform regular inspections.

5) Effect of the use of low melting temperature materials

Some studies have been made on the raw materials for reducing melting temperature without lowering the quality of glass which can be achieved through reformulation of existing glass batches. The method considered to be most effective is to add lithium in the form of lithium carbonate (Li_2CO_3) or spodumene [3,9].

Spodumene ($Li_2O.Al_2O_3.4SiO_2$) is one of the important minerals that can contribute to this improvement through reduction of specific energy; reduced melting temperature. The typical spodumene is composed of 5% of Li_2O, 18,7 % of Al_2O_3. 74,7% of SiO_2 and 0,1% Fe_2O_3 [3]

The addition of small amount of lithium and reducing the amount of high

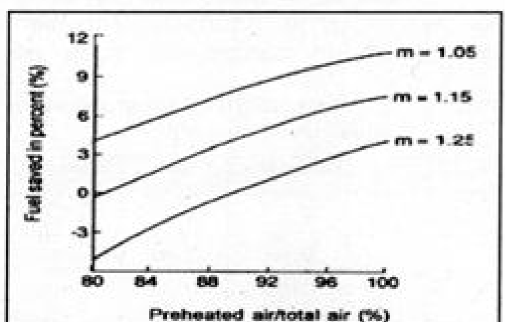

Fig. 9 Effect of air ratio and ratio of preheated air/total air on fuel save in melting glass.

melting temperature oxides such as MgO and SiO_2 reduces the viscosity of the glass at high temperature and therefore reduces the melting temperature of the batch

Table 2 shows the new compositions of glass by using Li_2O. In this composition the amount of MgO and SiO_2 was reduced and the amount of glass modifiers (K_2O and Na_2O) was increased. In the composition of Glass2, another low melting temperature substance B_2O_3 which is a glass former was added as much as 1%. It can be seen that the addition of Li_2O as much as 0,30% and 0,50% increasing the amount of K_2O and Na_2O, and reducing the amount of SiO_2 and MgO could reduce the melting point as much as 74°C and 115°C. At the same time the amount of NO_x release was reduced to 36 % and 43% due to the reduction of the amount of fuel to melt the glass.

The choice of technology, of course, should also consider the techno-economy of the system, the initial capital and the annual savings, and return on investment (pay back) of the new system. Whatever the choice is, it should not deteriorate the quality of the glass produced

There is no glass industry using this technology in Indonesia. The high cost of lithium compounds such as Li_2CO_3 and spodumene is an obstacle to apply this technology. Meanwhile, so far the deposit of this mineral has not been found in Indonesia. A search on the availability of this mineral in Indonesia could help the glass industry.

Table 2. Example of new composition of glass using lithia [9]

Oxide	Standard, %	Glass1, %	Glass2, %
SiO_2	72,00	69,50	68,90
Al_2O_3	1,40	1,50	1,40
Na_2O	13,40	14,50	14,50
K_2O	0,40	2,40	2,00
Li_2O	0,00	0,30	0,50
CaO	10,90	11,10	11,20
MgO	1,70	0,50	0,30
B_2O_3	0,00	0,00	1,00
T_m, °C	1458	1384	1343
T_m reduction, °C	0	74	115
Estimated NO_x reduction, %	0	36	43

IV. CONCLUSION

Energy efficiency in glass industry can be performed by using oxygen in the furnace, using cullet, preheating secondary air, preheating batch and cullet, changing air ratio and using low melting materials in the glass ingredients, as follows:

- Introducing air into the furnace could increase the efficiency up to 12%.
- the higher the amount of cullet and the furnace capacity the higher the efficiency
- the higher the furnace capacity and the inlet temperature of the batch and cullet and the higher the efficiency
- the higher the inlet temperature of secondary air and the lower the exhaust gas temperature the higher the efficiency.
- the lower the air ratio the higher the furnace efficiency
- the higher the amount of low melting temperature materials in the glass ingredient the higher the efficiency
- Not all the technique available mentioned above can be easily applied by the industry
- In order to make glass industry more efficient in energy it is recommended for them to do the following action:
- find the optimum cullet amount in the glass composition technically and economically
- maintain lower air ratio by regular inspection and maintenance of the exhaust gas recovery system.

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