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European Journal of Advances in Engineering and Technology, 2016, 3(11): 42-45

Research Article ISSN: 2394 - 658X

Saving Energy Consumption in Glass Printing Lehr

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ABSTRACT

Sri Lanka glass industry is mainly engaged in glass container production from the year of Second World War. On average, energy cost in the glass industry account for around 14% of total glass production cost. Energy efficiency improvement is an important way to reduce these costs and to increase predictable earnings, especially in times of high energy price volatility. The Glass Company selected for this study is the leader in container glass manufacturing in Sri Lanka, mainly facing at high energy cost as other countries in the world. This research is focused on finding a method of saving energy consumption of annealing lehr in the glass printing section. Annealing is a process specific to glass manufacturing. In glass decoration, special annealing process is carried out to adhere the print permanently to the glass. Therefore, the study is focused to finding the reasons to high-energy consumption of decorating lehr in Company. Using theoretical calculation, it was found that, cooling rate can be changed slightly for different types of bottles. Temperature profile adjustments for existing cooling rate in decorating lehr was done for different types of bottles based on theoretical calculations. According to the trial run results it was shown that production rate of printed bottles can be increased by adjusting temperature profile. Thereby, some energy can be saved (LP gas) per kg of glass.

Key words: Annealing, Annealing Lehr, Energy consumption, Glass industry, Temperature profile

INTRODUCTION

Glass is a super cooled liquid, which becomes rigid without crystallization. The canonical definition of glass by Mopey is ‘Glass is an inorganic substance in a condition which is continuous with an analogous to the liquid state of that substance as a result of reversible change in viscosity during cooling, has attained a high degree of viscosity to be useful for all practical purposes’ [1]. After a glass container has been formed at a high temperature, it must be cooled to room temperature in such a way that it will be free from internal stresses to avoid the weakening of bottles and spontaneous breakages. Annealing is done in order to minimize the stresses in glass, by slow cooling through the annealing region. For the annealing purpose, the company uses three LP gas fired annealing lehrs. After cool down through the annealing lehr, some types of bottles are send to the printing department to print the bottle as per the customer requirement.

RATIONALE FOR STUDY

Few problems were identified in bottle printing section of Glass Company, as follows. Mainly, Gas consumption of bottle printing annealing lehr is not deviate according to the bottle sizes. This problem clearly describes by the gas consumption data given below [5].As an example, quantity of LP gas consumption for 175 ml coca-cola bottle and 300 ml coca-cola bottle is same. Also, for very small bottles like perfume bottles, the temperature settings of the lehr is no done. But, the gas consumption needs to be different with the bottle sizes. Also, due to the heat loss from the lehr walls, it could be consumed more energy for the process. But, it could not be overcome without doing a major reconstruction of the Lehr. Even this annealing lehr is used with advanced techniques for controlling the flame and air flow with the given temperature profile; the temperature profiles were not changed with the bottle type or bottle size at every job change. Due to these problems which were mentioned above, high variation of LP gas consumption is recorded in decorating lehr. By considering the Coca-cola bottle as an example theoretical and actual cooling rate were found for slow cooling region.

Table-1-Existing Gas Consumption Data

Bottle	Capacity(ml)	Drawn tonnage/day	Gas consumption(m3/day)
Coca cola	300	35	**250**
Coca cola	175	15	**248**
Sprite	175	18	**250**
DCSL Square	750	60	**250**
Vat 69	1000	52	**214**
Bacadi	1000	50	**224**
MD jam	300	28	**210**
V& A	750	50	**214**
DCSL Old	375	46	**214**
Old keg	375	45	**214**

METHODOLOGY

Theoretical temperature profile was designed using the following equation [1]. The relation for cooling rate h from above the annealing point to below the strain point and generated permanent thermal stress is given by the following equation,

$$\sigma = \frac{E.\alpha_{ex}}{1-\mu} - \frac{\rho.C_p.h.d^2.b[Pa]}{\lambda} \qquad (1)$$

h – Cooling rate [K/s] | **ρ**– density [kg/m^3] | **C$_p$** – specific heat [j/(kg.K)]
d - Characteristic dimension[m] | **α$_{ex}$** –Thermal expansion coefficient (K^{-1}) | **b** - shape factor
λ –thermal conductivity [W/(m.K)] | **E** – Young's modulus [Pa] | **µ** - Poisson's ratio

As shown in Fig. (1), Regions -1- Rapid reheating to T >T $_{annealing}$
-2- Dwell – equalization of the temperature throughout the Zone
-3- Slow cooling
-4- More rapid cooling

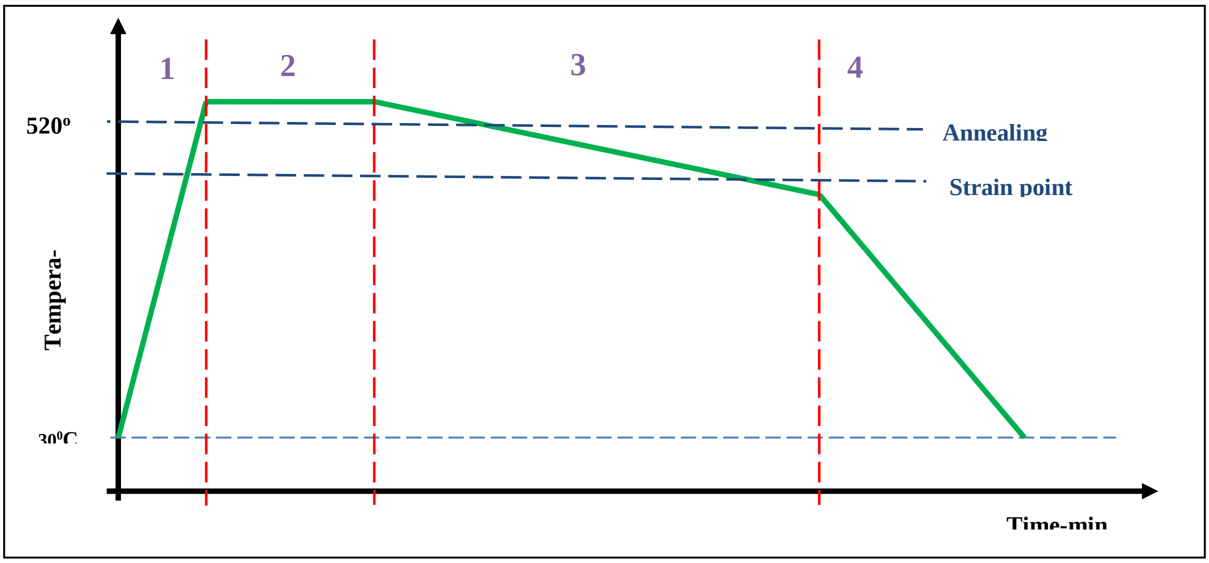

Fig. 1 Theoretical annealing curve for glass bottles [1]

Using Equation 1, let's take $M = \frac{E.\alpha ex}{1-\mu}\frac{\rho.Cp}{\lambda}$ $\sigma = \mathrm{Mhd^2b}$ (2)

For **soda-lime-silica glass**, the factor M is equal to 1.2x10^6 MPa.s.K^{-1}.m^{-2} which gives:-
σ = 1.2 x 10^6 h.d^2.b [MPa] with **d** in m and **σ** in MPa.[1]

$$h = \frac{\sigma}{Md^2\,b}$$

d = L for pots and bottles with thick bottoms [3] (L = bottom thickness)

Ex: - 300 ml Coca-cola beverage

L=5.7mm [4]

Therefore: - $d = 5.7 \times 10^{-3}$mb = Shape factor = 0.3 (for hollow products)

When a maximal permanent stress of 1 MPa is permitted after cooling,

$$h = \frac{1}{1.2\times10^{6}\times(5.7\times10^{-3})^{2}\times 0.3} K/s$$

$$h = 5.13 \ K/min$$

So, Theoretical cooling rate, h= 5.13 K/min

Calculation of theoretical mat speed of lehr

$$5.13 = \frac{923 - 773}{Time}$$

$$Time = 29.3 \ min$$

$$Speed = \frac{225 \times 2 + 200}{29.3 \ min}$$

$$Speed = 22 \frac{cm}{min}$$

Zone wise existing temperature profile is given in Table-2.

Experimental trial was carried out adjusting theoretical cooling rate and the mat speed according to calculated values as follows.

Theoretical cooling rate = 5.13 K/min

Theoretical Mat speed = 22 cm/min

Theoretical Temperature profile is given in Table -3. This procedure was repeated for 5 types of bottles and energy saving was calculated as given in Table -4.

Table -2

		Zone No. 1	Zone No. 2	Zone No. 3	Zone No. 4	Zone No. 5	Zone No. 6	Zone No. 7	Zone No. 8	Zone No. 9	Zone No. 10
Zone Length	Entry	2m	2m	2m	2.25m	2.25m	2m	2m	2.25m	2.25m	2.25m
Time(min)	0	12.5	25	37.5	51.56	65.62	78.12	90.62	104.68	118.74	132.8
Temperature(^{0}C)	30	240	420	650	650	580	500	400	300	200	130
Temperature(K)	303	513	693	923	923	853	773	673	573	473	403

Table -3

	Entry	Zone1	Zone2	Zone3	Zone4	Zone5	Zone6	Zone7	Zone8	Zone9	Zone10
Time(min)	0	9.09	18.18	27.27	37.49	47.71	56.8	65.89	76.11	86.33	96.55
Temperature(K)	306	513	693	923	923	853	773	673	573	473	403

Table -4

	Specific gas consumption with existing profile(m3/kg of glass)	Specific gas consumption with new Temperature profile(m3/kg of glass)	Energy saving (m3/kg of glass
300ml Coca cola	0.0116	0.0081	0.0035
200ml Winchester	0.0113	0.007	0.0043
175ml Coca Cola	0.0094	0.0054	0.0008
1L Sprite	0.0094	0.0081	0.0013
300ml Lion soda	0.0069	0.0043	0.0026

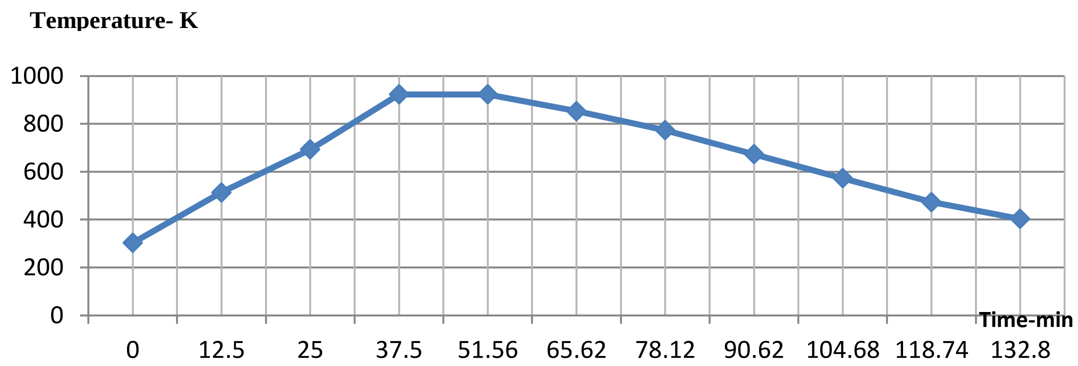

Fig. 2-Existing temperature profile curve

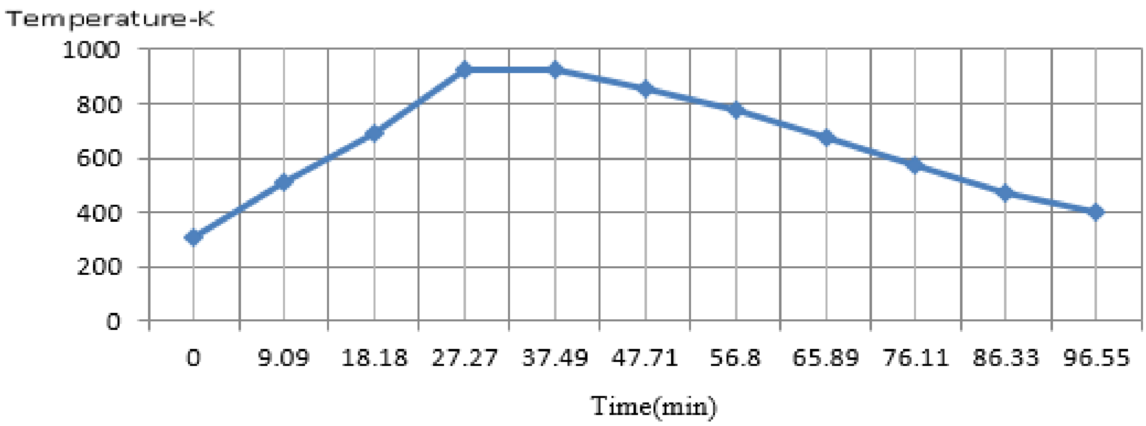

Fig. 3-Theoretical temperature profile curve

DISCUSSION AND CONCLUSION

Under the rationale for study, it was observed that, there is no considerable deviation of gas consumption with different bottle type. But using theoretical calculation, it was found that, cooling rate can be changed slightly for different types of bottles. Existing cooling rate in slow cooling region (region 3 in Fig. (1)) in the decorating lehr can be increased for different types of bottles based on theoretical calculations. According to the existing temperature profile adjustments, time taken to complete the annealing process was 132.8 minutes whereas according to the theoretical temperature adjustments it was only 96.55minutes. Quality of the bottles was observed using polarize cope. It was observed that the quality is good. According to the trial run results it was shown that production rate of printed bottles can be increased by adjusting cooling rate and mat speed based on theoretical temperature profile. Thereby, considerable amount of energy can be saved (LP gas) per kg of glass as shown in Table 4.

Acknowledgement
Authors are thankful to Department of Mechanical Engineering, The Open University of Sri Lanka, and the Glass Company for supporting to this work.

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