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Developing Of Expandable Polystyrene Industry Using Cleaner Production Technology

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Abstract: ***In terms of the importance of cleaner production technology in industry for saving environment and cost, also with the importance of expandable polystyrene industry for the current development in Egypt in multi fields such as modern agriculture, construction and Building, home appliances and electrical instruments industries, the study deals with application the cleaner production technology on the expandable polystyrene factory. The study applied in EL Araby foam factory for backing and thermal insulation to reduce the energy csonsumptions and save both cost and environment. In year 2016 data was accumulated analyzed and points of weakness presentsed. Several scenarios and modifications were proposed and the most effective were chosen and designed, due to cleaner production technology study according to UNIDO rules a modification was selected as the most beneficiary option and was made by separate machines air pressure feeding to two groups one with high pressure from 6-8 bar and second with low pressure from 3-5 bar since January 2017 and the significant parameters for energy consumptions and wastes were measured again during year 2017 and the results were analyzed, evaluated and the difference between the before and after cleaner production technology application was illustrated. The totsal saving from this modification is 1,008,393 Kw that is equal 35% from compressors electricity and 29.45 % from total factory electrical consumptions. Also this environmentally achieved increasing the lifetime of compressors oil and change oil periods increased by 20%. The low air pressure used in EPS machines are not need drying and the dryer was removed its circuit, that reduces using of CFCs gases for dryers. Also it reduces the noise inside the factory from de-molding process by 10%. The total cost to implement this modification was 300,000 L.E for new air pipe line added to the machines circuits and two air tanks and man power cost. This achieved the reduce of the low pressure compressors maintenance annual expenses by 20%. And reducing the electrical consumption cost specially with annual increasing of electrical price by 20 % yearly until 2020. For new factories it saves in the low pressure circuit the air dryers and the pumps capacities and pressure that saves about 35% of the system cost in addition to 25% of its maintenance needs.***

Key Words: Expandable polystyrene industry, cleaner production technology, application on industry.

I. INTRODUCTION & LITERATURE REVIEW

With the spreading of expandable polystyrene molding industry which called -in Egypt- Foam manufacturing to meet the market requirements for several applications.

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It used in building and construction sectors, as isolation and decoration material. Also, it used in agricultural sector for help in improving the incubating the seeds. And it applied mainly in packing of food, agricultural and fish for their safe transportation. And also the electrical home appliances packing to protect the breakable products in handling and transportation. The paper deals with applying the cleaner production technology on El Araby foam factory in Quwesna to improve the foam industry by reduce the energy consumptions, save cost and reduce the environmental impacts from this industry.

II. EXPANDABLE POLYSTYRENE INDUSTRY (EPS)

The styrene polymers story began in 1839. To start the industrial production of styrene it took almost 100 years when its production was started at BASF in Ludwigshafen in 1931 in Germany **[1]**.EPS is obtained by polymerizing styrene and introducing small amounts of blowing agent pentane **[2]**. In 2009 the global production of EPS reached more than 5 million tons/year and currently it is close to 100 thousand metric tons /year **[1]**.EPS with its properties and qualities are expanded into a variety of useful products combined with customized molding capabilities, insulation properties and ease of processing make it a high performance packaging material. EPS is serving an important role in our everyday lives for it is relied upon to provide superior performance in various foam product applications, as a closed-cell, rigid foam plastic, a blowing agent to allow individual beads to be expanded from 2 to 50 times their original size. Whether used as protective packaging for fragile items and insulation in building applications or even as a bicycle helmet. **[3]**.EPS widely used in many applications due to many advantages such as low density, thermal and acoustic insulation and consistent performance. EPS produced with various density ranges, used on boats as floatation devices; in packaging, as an energy and shock absorber; in buildings as insulation; and in other applications as a moisture barrier **[1]**.A schematic of the production process of the conventional EPS beads and the bead foams is shown in Figure (1) **[4]**.

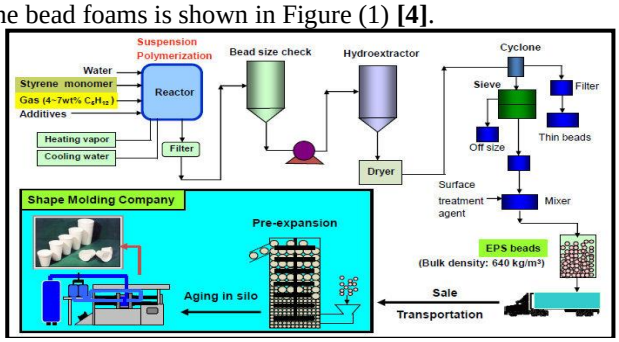

Figure (1) Conventional Manufacturing Process Of EPS Beads [4]

The EPS is manufactured by a suspension polymerization process using styrene monomers. Pentane is added as part of the polymerization process so that PS and the blowing agent made homogeneous phase at the end of the polymerization reaction. To decrease the EPS density, steam used in a pre-expander, stabilized in silo under atmospheric conditions several hours up to one day to achieve the maturing phase and steam molded into EPS foam products using a steam chest molding machine alike shape or/and block molding machine. After the mold cavity of steam chest molding machine is filled with pre expanded EPS beads, steam whose temperature is about 110ºC should be injected into the mold. At this moment, the remnant n pentane in the beads evaporates and further expands so that the EPS beads can form strong bonding among beads by forming inter-penetrating networks **[4]**.

III. CLEANER PRODUCTION CONCEPT

EPA had introduced the cleaner production concept **[5]** in 1988. From 1990 Bass **[6]** is define cleaner production as the production conceptual and procedural approach to that demands of the life-cycle of a product or process should be addressed with the objective of prevention or the minimization of short and long term risks to humans and the environment. Huisingh **[7]** defines cleaner production approach as a process involving technical as well as attitudinal, motivational and other non technical factors that are essential for corporations to benefit from the preventative approach.The cleaner production strategy by UNEP **[8]** is the continuous application of an integrated preventive strategy to process products and services and/or to make efficient use of raw materials, including energy and water, to reduce emissions and wastes and to reduce risks for humans and the environment.Cleaner Production is the efforts of industry to improve the environmental performance of its production cycles **[9]**.UNEP In 1994, made a study to the Toxic Use Reduction Institute in Lowell, Massachusetts classifies in it cleaner production to four different types based on their general characteristics **[10, 11]**. This classification has several weak points that make its application difficult for no systematic approach but mainly classifies the kinds of technologies on a quantitative basis into four rather general categories. However, UNEP prepared more than 500 concise reports contained in the International Cleaner Production Information Clearing house (ICPIC) database **[12, 13]**.Cleaner Production summarized in several properties as follows **[14]**:

1. Add value to the EMS (Environmental management system).
2. Place emphasis on pollution prevention rather than control with clear improvement in environmental performance.
3. Does not deny or impede growth but insists that growth can be ecologically sustainable.
4. Not limited only to manufacturing industries of a certain type or size it can be applied towards the provision of services also.
5. Includes safety and protection of health.
6. Emphasizes risk reduction.
7. Improves immediate efficiency as well as long-term efficacy.
8. Win-Win-Win factor for the environment, communities and businesses.

Cleaner Production improves products and services with lowers risks (liability), improves company image, improves worker's health and safety conditions, reduces waste treatment and disposal costs, integrated with the business EMS, saves costs on raw material, energy and water and makes companies more profitable and competitive **[14].**

IV. STUDY PROCEDURE

The main procedures to apply Cleaner Production Technology (CPT) in Expandable polystyrene (EPS) industry through the study case mentioned. And UNIDO documents **[15]** are guiding the factories and organizations to apply Cleaner Production Technology (CPT) by easy and clear procedures which considered standards applied anywhere and anytime by everyone needs to apply cleaner production technology.

The main procedures are arranged as following:-

1. Initial assessment
2. Policy statement
3. Test team
4. Identifying total costs of non-product outputs and priority flows
5. Setting up focuses areas
6. Revealing sources and causes of inefficient material and energy use
7. Option generation
8. Feasibility analysis
9. Action plan
10. Information system
11. Implementation of the action plan
12. Monitoring and evaluation
13. Act and sustain
14. Follow up and continuous improvement

Abbreviation definitions, Concepts and details will be explained in this chapter and applying method of the mentioned steps upward in EPS industry and makes reader can apply the same steps for any industry to apply cleaner production technology.

V. MODIFICATION BY SEPARATE MACHINES TO TWO AIR PRESSURES

After applying CPT procedure on El Araby Foam manufacturing factory, the optimum solution was the separate machines to two air pressures. The idea is separate all machine steps which need high air pressure from 6 – 8 bars and collecting them in one feeding pipe and supply this feeding pipe only by high air pressure which from 6 to 8 bars. In the same time separate all steps which can work correctly and safely on the low pressure air from 3 – 5 bars and collecting them in one feeding pipe and supply this feeding pipe only by low air pressure which from 3 to 5 bars. After study the EPS machines and come back to the machines makers the researcher found some makers allow operating the pneumatic control only with high pressure and some other allow to operating the pneumatic control and the filling process with high pressure. And the all remaining steps such as purging mold, filling tank pressure and de-molding pressure can be operated with low air pressure (3-5) bar.

That is means 50% at least from consumed air can be used with lower pressure which is from 3 to 5 bars and the remaining 50% with high pressure which is from 6 – to 8 bars can be operated on the lower limit which is 6 bars.

By measuring the electrical consumptions in air compressors station before and after separating low air pressure and high pressure are found the following final results. The total electrical power consumed to run compressed air station and all compressors working on high pressure only shown in table (2)

Table (2) KW consumed in running compressors before application

Months	Jan.	Feb.	Mar.	Apr.	Ma.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Compressors KW.	224,272	219,168	219,163	224,447	247,255	179,536	255,960	275,569	252,846	281,170	233,384	236,695	2,849,465

After improvement and separating the air pressure circuits to low pressure line and high pressure line and working two air compressors on low pressure(3-5) bar and two compressors on high pressure (6-8) the total electrical power consumed is shown in the following table (3).

Table (3) KW consumed in running compressors after application

MANTHS	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Compressors Kw.	124,304	137,752	170,057	116,582	139,602	146,657	186,479	197,133	126,670	168,466	169,586	157,783	1,841,072

To explain the improvement and compare the results between before and after applied the idea. The date put in table (4) and figure (4) as following.

Table (4) The Results Between Before (2016) And After (2017) Modification

MANTHS	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Compressors KW.- 2016	224,272	219,168	219,163	224,447	247,255	179,536	255,960	275,569	252,846	281,170	233,384	236,695	2,849,465
Compressors Kw.- 2017	124,304	137,752	170,057	116,582	139,602	146,657	186,479	197,133	126,670	168,466	169,586	157,783	1,841,072

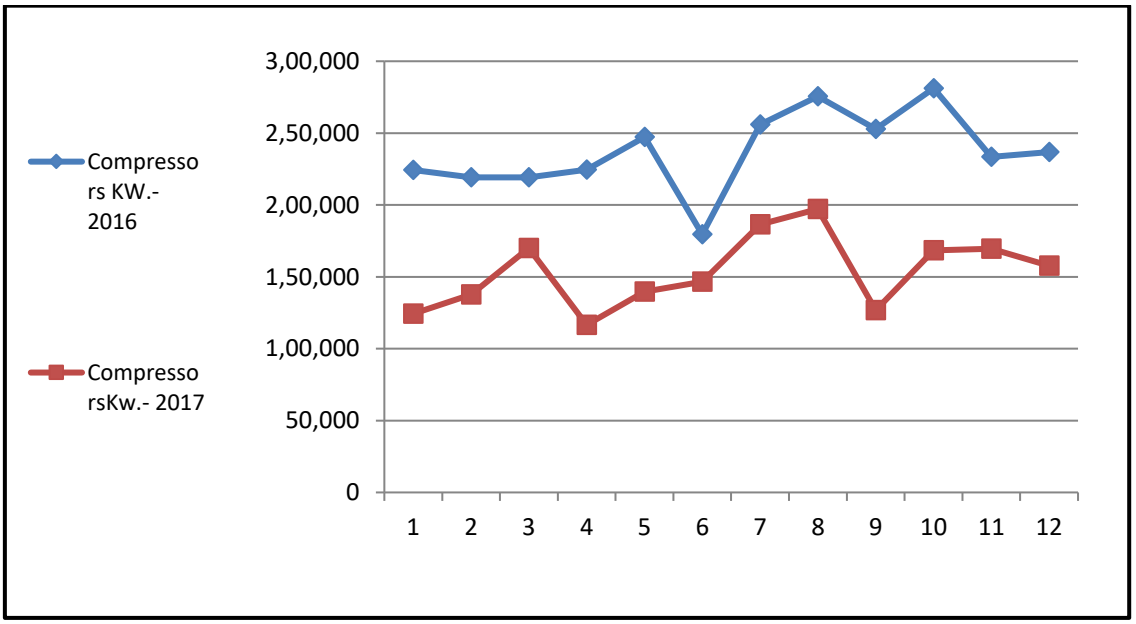

Figure (4) Difference in Compressors Kw Consumption before and after Modification

The total saving power is 1,008,393 Kw per year which is verifying some of cost and environmental objectives from theses. And the figure (4/7) explains more the improvement achieved in electrical power consumption due to run two air compressors with low pressure

Running machines with two air pressure lines one line with high pressure 6-8 bar for pneumatic control and operating injectors and the second line with low air pressure 3-5 bar for pressure filling, dosage cooling and de-molding, saved electrical power needed to run compressors. This modification is compatible with reduce concept of CPT. the saved power has technical, environmental and financial side.

VI. TECHNICAL DISCUSSION

For the first modification which is separating machines to two air pressures which is compatible with the reduction concept of CPT and operating machines actually with two air pressures saving in one year 1,008,393 Kw in one year which is 2017. The total saving from this modification is equal 35% from compressors electricity and 29.45 % from total electrical consumptions. Table (4) and figure (5) are show the comparing of electrical consumptions difference in air compressors before and after modification.

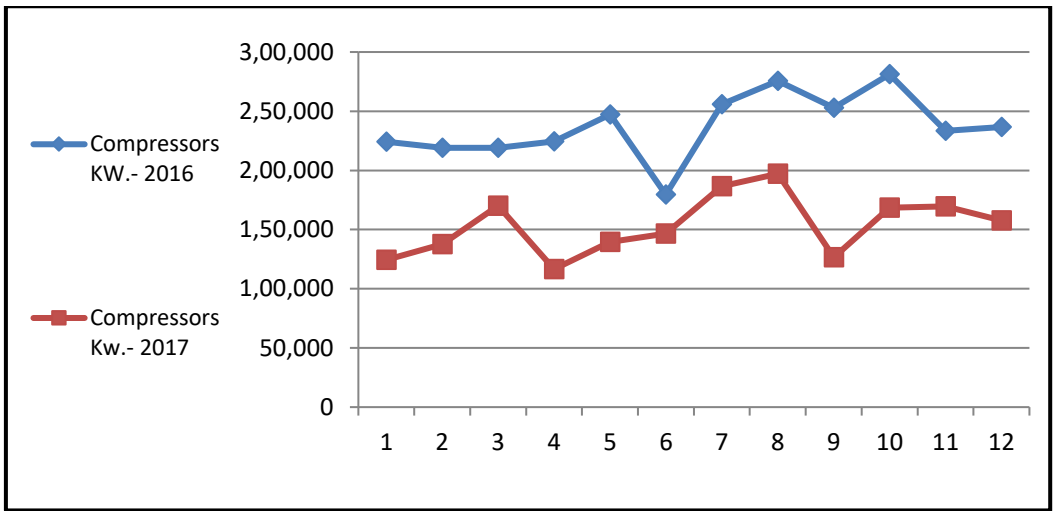

Figure (5) the Compressors KW Consumption before and after modification

From figure (5) the consumption has a variance from month to month and this is acceptable because consumption depends on the production plans which change from month to month and operating conditions. Also the consumptions increased in summer more than in winter and this normal due to air temperature and air density.

Also the figure (5) shows decreasing in consumption in June month even before or after and June month is in summer too. To analyze this it is noted that the study and measuring was in 2016 and 2017 and Ramadan month in this two years came in June month and working hours reduced and air compressors stopped due to machines stopped 3 hours per day and all factory stopped from 3 to 4 days after the end of Ramadan for feast vacation.

VII. ENVIRONMENTALL DISCUSSION

Environmental discussion here is concerning with external and internal environment to measure the effect of modification on both. For external environment the reduction of using electrical power leads to reduce amount of emissions during electricity generation and save amount of electricity to supply another areas by electricity without over generations. Also electrical power utilization is an efficient use of resources and is global request as a proactive policy to protect the environment and save world from the environmental degradation. For internal environment as lower electrical power consumptions as lower internal environmental impacts and running two compressors on low air pressure 3-5 bar leads to environmental benefits as following

1- Running compressors on low pressures is increasing the lifetime of compressors oil and change oil periods increased by 20% (before modification the oil was changed every 2000 running hours and after modification the oil is changing every 2400 running hours) and the rate of producing liquid oil waste had been improved by 20%

2- The low air pressure used in EPS machines are not need drying and the dryer was removed from the low air pressure circuit. The dryer is working with classical refrigeration circuit and has CFC gases and removing the dryer reduces using of CFCs.

3- Using low air pressure in de-molding process reduces the noise inside the factory because in this step the pressurized air escaping to the atmosphere directly through the mold and with high pressure difference a high sound produced and lower pressure difference leads to lower noisy. Before modification the average sound inside the factory during de-molding process which has time from 2 – 4 seconds per every cycle equal to 102 decibel and after modification became 92 decibel and employees must use ear sound damper to prevent the noise effect on their hearing.

VIII. FINANCIAL DISCUSSION

Generally any engineering work has relation and dependents on financial parameters such as the initial cost and running cost. The total cost to implement this modification was 300,000 L.

E for new air pipe line added to the machines circuits and two air tanks and man power cost. After install the low air pressure line to machines and connected to the compressors reset the compressors to run with maximum operating pressure with 5 bars instead of 7.5 bars. This cost if compared with the directly saving cost in the first year which was 1,038,650 L.E the return back time of this modification is only four months. Before modification the factory produced 1,190,329 Kg EPS products and consumed 2,849,465 Kw. With cost equal 2,934,949 L.E according to price equal 1.03 L.E/Kw. And after modification the factory produced 1,422,271 Kg EPS products but consumed 1,841,067 Kw with cost equal 1,896,299 L.E according to price equal 1.03 L.E/Kw. From financial view the compressed air cost per Kg of product equal to 2.488 L.E / Kg before and equal to 1.35 L.E / Kg after modification. The improvement ratio equal to 46 % and this is logic due to running 66% from compressors on low pressure conditions.

Also the modification has another indirect benefits and illuminated in the followings

1- Reduce the low pressure compressors maintenance annual expenses due to running with low pressure and increasing the oil and spare parts working time by 20%.

2- Reducing the electrical consumption cost specially with annual increasing of electrical price by 20 % yearly until 2020 due to governmental plan.

3- For new EPS factories if the design of air circuits takes into consideration this modification the compressors for low pressure have volume lower than the high pressure compressors and no need for air dryers and the compressed air station will be smaller.

4- Reducing the amounts of air which must be dried allow to increase the efficiency of the air dryer used for high pressure and the life time of pneumatic control valves increased due to increasing in pressurized air quality. That is reducing the machines maintenance annual expenses.

5- The modification reduces the factory maximum electricity demand which reduce the overall cost of electricity

IX. CONCLUSIONS

The total saving from this modification is 1,008,393 Kw that is equal 35% from compressors electricity and 29.45 % from total factory electrical consumptions. Also this environmentally achieved increasing the lifetime of compressors oil and change oil periods increased by 20%. The low air pressure used in EPS machines are not need drying and the dryer was removed its circuit, that reduces using of CFCs gases for dryers. Also it reduces the noise inside the factory from de-molding process by 10%. The total cost to implement this modification was 300,000 L.E for new air pipe line added to the machines circuits and two air tanks and man power cost. This achieved the reduce of the low pressure compressors maintenance annual expenses by 20%. And reducing the electrical consumption cost specially with annual increasing of electrical price by 20 % yearly until 2020. For new factories it saves in the low pressure circuit the air dryers and the pumps capacities and pressure that saves about 35% of the system cost in addition to 25% of its maintenance needs.

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