Journal of Thermal Engineering and Application
ISSN: 2349-8994(online)
Volume 3, Issue 1
www.stmjournals.com

Improvement in Energy and Exergy Efficiency by Applying Thermal Insulation as per ASTM C680: A Review

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Abstract
Small and medium enterprises (SMEs) consume a lot of energy due to inefficient usage of energy which otherwise can be conserved by the usage of effective thermal insulations. In the present study, an Indian SME was identified on the basis of replication potential for implementing thermal insulation practice and energy conservation. This paper includes literature about energy, exergy and importance of thermal insulation to improve efficiency. Thermal insulation thickness, heat loss and exergy loss calculations are included as per ASTM C680 to compare efficiency before and after applying thermal insulation.

Keywords: *SME, ASTM C680, energy, exergy, Reynold number, Nusselt number, Prandtl number*

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INTRODUCTION
Background
We all are using energy every day for house hold applications, transportation, manufacturing, etc. We are using energy to make our lives comfortable, quantitative, and enjoyable. To maintain our life's quality, we have to make use of our energy resources effectively. The alternates of how we are using energy machines or when we are not using them or selecting to buy energy saving equipments which impact our environment and our lives. There are many solutions from which we can minimize the use of energy and use it more effectively. So, this is energy efficiency and conservation.

Utilization of energy is energy efficiency in the most of the cases by effectively doing manufacturing process or by providing a service, where energy wastage and all over energy consumption can be reduced. Many factors contribute to achieving energy efficiency. The following aspects should be considered to achieve this for industrial process: 1) environment; 2) resource; 3) economics; 4) time; and 5) technology. Improvement in system of energy seems to be higher efficiency which usually reduces damage of environment damage and increases the advantages. All the resources are limited; if the utilization will be done more effectively, then resources availed could last for long.

Energy efficiency of India is fifth lowest in the world, but there is option for substantial energy savings. For generating 1 KWh electricity, 7 KWh equivalent energy of fuel is consumed. By energy efficiency, saving 1 KWh electricity is greater than 2 KWh electricity generated and equivalent saving to 1.6 Kg of CO_2 emission. Biggest issue in many industries is energy; manufacturing survey of pilot plant acturers must have to adopt effective energy efficiency technology and measures of energy conservation. The research and development of new technology benefits increased energy efficiency as they are demanding more energy efficient equipments.

There are so many technologies involved to increase energy efficiency like; minimization of generated waste heat and recover it up to maximum economic level; improvement in maintenance system; utilization of manufactured equipments for maximum efficiency as per the best modern standards;

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cogeneration; optimum system of control over key operating key parameters. The best technology is minimizing waste heat generation, which is achieved by applying insulation over any surface of the equipment which is responsible for energy waste.

Use of Energy

World's energy usage has increased at 2% of an average annual rate for the next two decades. The total use of energy over worldwide was nearby 1.32×10^5 Twh in 2008 [1, 2].

Figure 1 shows that natural gas is the quickest growing source of energy which is highlighted. Maximum expectation is from natural gas contribution to increase the usage of energy over the major fuels because of its environmental and economical benefits compared to the other fossil fuels [3]. Still oil is having power and influence over other energy fuels. In 2007 it shared about 39% of total world's energy. For electricity generation in the world about 55% of the coal is consumed, and in the future fuel, for power generation is expected to be first and then as a source of energy in few important industrial sectors like steelmaking. In the forecast of 2007–2035 horizon, renewable energy will maintain 8% of their share of total energy consumption [3].

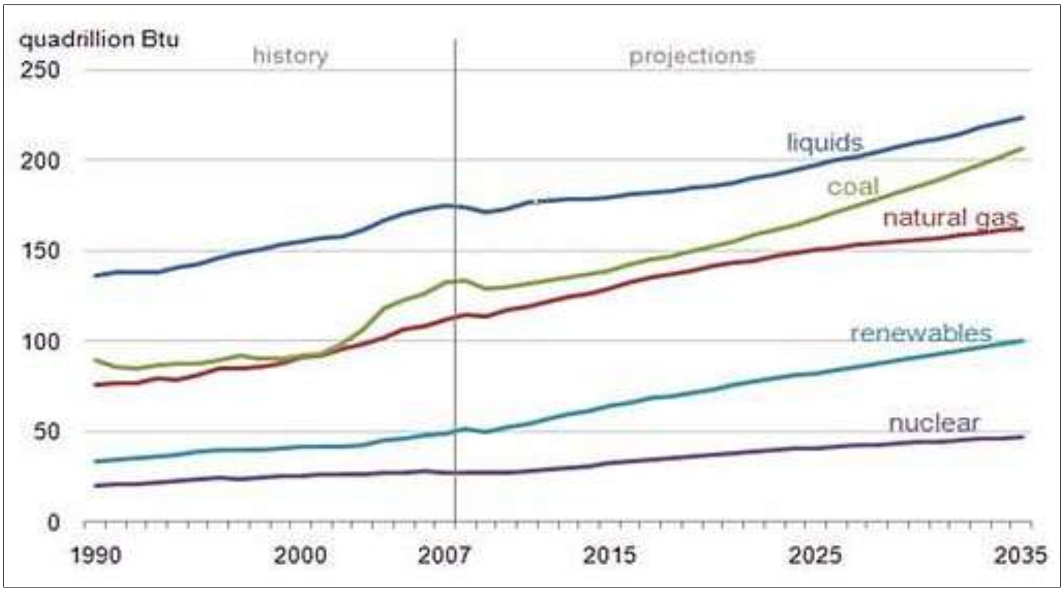

Fig. 1: *World Energy Use by Energy Sources, 1990–2035.*

For improvement in energy efficiency by reducing usage of energy can increase supply security, protect the environmental condition, and more establishment in system energy.

LITERATURE REVIEW

Need of Energy Efficiency and Condition of Indian SME

The survey of SMEs conducted through MSME, presented in annual report 2009–2010 of Government of India that khadi and village/rural enterprises including micro, small and medium enterprises (MSMEs) progressed with highest rate of employment growth generation. They are playing important role in the development of economics by their effective participation in, flexible, innovative and efficient way. Contribution of SMEs in India is 95% for establishment of all industries, 40% for output of industry and domestic exports and 45% for manufacturing field. Employment is about 59 million employers in 26 million units of all over the country by SMEs. This sector further has continuously been considered as high growth rate than remaining industrial sectors. SMEs in India are manufacturing 1000 products from conventional to advanced items. By implementing energy efficiency EE measures, SMEs could reduce their costs and thus improve their competitiveness [4].

SME's should have ability to produce customized and labour intensive products, both traditional (brass, utensils, tea) and developing markets (castings). SME's have some weaknesses like they follow old/inefficient technologies, low energy productivity, lack of awareness to access of an EE or new products/technology, low technical expertise.

Environmental competition made improvement in productivity by considering reduction in energy cost. Energy conservation and energy saving potential for various sectors like industrial, residential, commercial, etc. are given in this paper [5, 6].

Exergy Analysis and Efficiency Evolution-Concepts and Applications

The exergy method is a tool for measuring the efficiency of processes or system, especially energy intensive systems. Exergy is an important tool for society of sustainable energy and nowadays exergy analysis is widely used in simulation, performance evaluation and design of thermal systems. Meanwhile the exergy theory is used to study topics of environment impact. Any technologies that increase efficiency will use lesser resource to drive the processes for the same products or services.

This leads to less extraction of energy resources from the environment. When a more efficient process uses lesser resources, a direct result is normally to emit lesser wastes to the environment. Due to character of irreversibility, exergy destruction often disorders the whole system, or destroys the order in an organized system, such as environment system, so irreversibility of exergy destroys or impacts the environment.

Definition of Exergy

Paper industry in India is the 15th largest industry in the world. Nearly 1.5 million people employment and contribution of Rs.25 billion is provided by paper industry and it is one of the 35th highly contributing industries. There were 17 paper mills in 1951, and now days 515 units are engaged in the field of manufacturing of paper, paperboards and news printing in India. In India, paper and pulp industries are categorized by large and small scale industry. Large scale paper industries are those having above 24000 t per annum capacity.

Exergy Method: A Brief Review

In 2004, Gong presented the brief review of exergy. The exergy concept is of most importance in engineering in the design of energy systems to meet environmental constraints. Valuable insights into the concepts of efficiency achieved by thorough understanding of exergy, sustainability of energy systems and global effect are needed for any technical and qualified person working in the field of energy systems and the surroundings. Modern development of analysis of exergy is initiated by this scientist or engineer; also he calculated the relation against irreversibility. Since then, individual industrial processes have been presented by great many exergy analyses, as well as of entire countries [1].

The detection and evaluation of thermodynamic imperfection reasons in energy process, is the main goal of exergy analysis. The information about the potential of improvement is offered by exergy analysis. If these are reasonable to realize then it will shown by economic analysis. By using energy resource in effective and efficient way, exergy analysis can be improved in those industries where energy is the key contributor in operating cost.

Exergy methods are powerful tools for analyzing which are referred by many of researchers and engineers for designing, optimizing, assessing and improvement of process. So, the usage of exergy analysis is being increased in industries.

Interest in exergy analysis has grown steadily in early 70s and the usage of exergy analysis is explored more widely in industries. Now a day, there is keen focus on second law concept of thermodynamic system of process for minimization of heat losses.

For more efficient utilization of energy resources, exergy method is the most important and valuable tool, from which the types, locations and correct magnitudes losses and wastes need to be determined. The exergy utilization strategy is concerned with wide area. Exergy is explained by the maximum available work when system attains stable condition. Exergy is tool for physical measures of quality or effectiveness. As far as exergy concern, maximum efficiency attained for process energy conserved. Measure of potential for growth efficiencies are calculated by using exergy ratios. Possibility of exergy efficiency is always maximum.

Increased efficiency seems to reduction in environment impact and reduction in losses. Same way, resources reduced per unit output also indicates reduction in environmental damage. Also reduction in overall environmental impact is possible from production process by minor improvement in life cycle.

Difference between Exergy and Energy

In 2003, Lee presented the difference between exergy and energy efficiency. First law of thermodynamics represents energy efficiency and exergy is based on combination of first law and second law of thermodynamics both represent the exergy. Unlike energy, exergy is not conserved and the initial exergy is destroyed at least in part by the irreversibility in any process [7].

The first law of thermodynamics represents energy conservation law. The second law of thermodynamics represents the energy quality and asserts that destruction of exergy occurs during irreversible process.

For example, the energy associated with 11 L of water at 80°C is approximately 1 KJ, at room temperature, 25°C. Compared to 1 KJ of electricity, electricity is more useful than the 11 L of water since electricity can be used for a wider range of services, e.g. heating at low or high temperature, or providing shaft work, etc.

The difference of usefulness can be evaluated by exergy value. The exergy value of 11 L of water at 80°C in an environment of 25°C is approximately 0.16 KJ, less than the 1 KJ of electricity.

The exergy of a system or a flow is the sum of two contributions: the thermo mechanical exergy and the chemical exergy, when other forms of contributions, such as kinetic exergy or potential exergy, etc., are neglected.

- ***Thermo Mechanical Exergy and Chemical Exergy From the Point of View of Exergy***

When one analyzes a system or process with defined incoming flows to system and outgoing flows from the system, the exergy flow balance can be expressed as: Ainput=Aoutput+ICV, i.e., A input is not equal to A output. It shows exergy is not conserved in a real system.

- ***Energy Efficiency and Exergy Efficiency***

There are many types of efficiencies; the following energy and exergy efficiencies are used in this study. Energy efficiency is expressed as the ratio of product energy output to total energy input in a system or process. Exergy efficiency takes into account the losses caused by irreversibility which destroy exergy in the process. This expression both gauge how effectively the energy/exergy input is converted to the product.

Energy Efficiency

$\eta = Eproduct/Einput$

$\eta = 1 - Eloss/Einput$

On another hand,

$\text{exergy efficiency} = Aproduct/Ainput$

$= 1 - (Aloss + ICV)/Ainput$

Contrary to energy efficiency, exergy efficiency relates to maximum amount of work (or work equivalent; exergy efficiency also applies for non-work situation). Although this maximum can never be reached, exergy efficiency provides an indicator to identify those areas with large improvement potentials.

Detail Study of Thermal Insulation: Design, Material and Application

A thermal insulation is a poor conductor of heat and has a low thermal conductivity. Thermal insulation delivers the following benefits:

- Reduces overall energy consumption,
- Offers better process control by maintaining process temperature, and
- Provides re-protection to equipment and absorbs vibration.

Design of insulation thickness is calculated as per Indian standard IS as well as American standard [8]. There are various types of insulation material depending on temperature and applications listed in bureau of energy

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efficiency (BEE) chapter note under heading of Insulation and Refractories. Guideline on application of insulation is reviewed from BHEL (Bharat Heavy electrical limited) and BEE and bee-india website [5, 9].

Heat Loss and Energy Calculation Thermal and Financial

Thermal insulation thickness depends mainly on the surface temperature of the object. Surface temperature of any hot/cold object can be found out accurately by thermal imaging camera, by just facing the camera in front of any suspected object whose surface temperature have to be calculated. Some research papers explained typical barriers to implementation of emission reduction technologies in transportation manufacturing sector, such as the relatively long payback period, are disadvantage. The formulas used to calculate heat loss are taken from BEE website and IS standard [10, 8].

Theoretical Calculation of Insulation Thickness

Insulation thickness can be calculated by different reference like Indian standard, American standard, heat transfer book and bureau of energy efficiency website.

Insulation thickness was calculated using American standard (ASTM C 680). This standard is titled; standard practice for estimation of heat loss or gain and surface temperature of flat, pipe and spherical surfaces.

Considering suitable insulation thickness, the following is the procedure for finding out the heat loss:

Reynold number $Re_l=\frac{v \times L}{\mu}$

V=velocity of air (m/sec).

L=length of object (m).

μ=Kinematic viscosity of air at 30° surface temperature=1.60E-05.

Nusselt number for at surface $N_{ul}=\frac{0.6774 \times \sqrt{Rel} \times \sqrt[3]{Pr}}{\sqrt[4]{1+\sqrt[\frac{3}{2}]{\frac{0.0468}{Pr}}}}$

Pr=Prandtl number.

Convection Heat Transfer Coefficient

$H_{cv}=N_{ul} \times K_f/L$ (W/m^{2}K)

K_f=conductivity of air at 30° temperature =0.0264 W/mK

Radiation Heat Transfer Coefficient

$H_{rad}=\varepsilon \times \sigma \times (T_s^4 - T_a^4)/(T_s - T_a)$

ε=Emissivity of cladding material,

T_s=surface temperature,

T_a=Ambient temperature.

Total heat transfer coefficient $H=H_{rad}+H_{cv}$

Surface resistance $R_s=1/H$ (m^{2}K/W)

Thermal resistance $R_t=(X_2-X_1/K)+R_s$(m^{2}K)

X_2=Thickness of dryer after applying insulation,

X_1=Thickness of dryer before applying insulation,

K=Thermal conductivity of insulation material (W/mK).

Heat loss $Q=(T_o-T_s)/R_t$(W/m^{2}K)

T_o=Process Temperature (°C)

Surface temperature after insulation $T_s=T_a+(Q/H)$

Sample Heat Loss and Exergy Loss Calculations

Surface heat loss (in J)

Qloss={[10+(Ts−Ta)]/20}×(Ts−Ta)

Exergy loss=Qloss x (1–T_o/Tloss) (in J)

CONCLUSION

Besides saving energy, thermal insulations minimize pollution by minimising energy usage and also saving precious petroleum resources. The followings conclusions are made:

- By implementation or choosing effective thermal insulations in a SME, the total energy and exergy loss can be minimized.
- Fuel saved and cost of fuel can be minimized by implementation or choosing effective of thermal insulations.
- As India's economy depends heavily on SMEs, if their energy efficiency is increased specially by usage of effective thermal insulations, it will definitely increase the fuel security for nation.

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Cite this Article

Sagarkumar Indravadan Shah. Improvement in Energy and Exergy Efficiency by Applying Thermal Insulation as per ASTM C680: A Review. *Journal of Thermal Engineering and Application*. 2016; 3(1): 43–48p.