A review on Energy Saving in Furnace through Energy Audit

Dhaval H.Patel[1], Prof. Shirish k.Patel[2]

[1]P.G. Student, M. E., Energy Engineering, Government Engineering College – Valsad, Gujarat, India
[2]Assistant Professor, Mechanical Engineering Department Government Engineering College - Valsad, Gujarat (India)

ABSTRACT

Furnace is one of the most Energy intensive Equipment. The major part of the energy consumed in Industries in Furnaces. Energy also contributes to the major cost input to the production of castings. Besides it, high energy consumption is upbringing the threat of climate change and global warming. Therefore it becomes very much necessary to look into various means by which energy consumption in Furnaces can be minimized considerably. Plenty of work is being done by Researches to reduce specific energy consumption in Furnaces. The present paper Review talks about some of the major steps or techniques taken in Furnaces to reduce energy consumption and improve furnace thermal efficiency.

Keyword: - *Furnace, Energy Audit, Energy Consumption.*

---

1. INTRODUCTION : -

The global economic boom and growing demand of energy lead to gradual depletion of fossil fuel sources and increasing global warming problems. Solving the current energy and global warming problems are closely intertwined with economic and industrial developments. Major industrial nations have developed various energy policies to target different industries for addressing these problems. Before new or alternative energy sources can be developed, major research efforts have been directed toward increasing the energy efficiencies, e.g. raising the thermal efficiency for burning petroleum fossil fuel , improving combustion efficiency, recovering waste energy (waste heat energy and gas), and developing new technology to achieve savings of energy consumption. Without making significant changes on existing equipment, the current operational procedures need to be examined to find out ways of reducing fuel consumption and improving green gas emissions.

Numerous furnaces and boilers are extensively used in industrial and commercial facilities to generate thermal energy so that small improvements of the furnace thermal efficiency will amount to tremendous reduction of energy consumption and green gas emission. Numbers of researchers have been done research on reduced Energy consumption or Energy Saving in Furnace and also some researches are needed to improve furnace performance and reduced fuel consumption. In this Paper, Describe How to different way to reduce fuels Consumption, Reduced CO_2 Emission and How to improve Furnace Thermal Efficiency. Following Research has been done by Researchers.

2. LITERATURE REVIEW : -

ROMAN WEBER *et al.* (2000) [1] Presented this paper deals with the new technology of burning fuels with high-temperature air and large quantities of flue gas. Furnace experiments at 0.58 MW fuel input and combustion air preheat of 1300 C were undertaken to examine the process. Comprehensive in-furnace measurements of velocities, temperature, gas composition (O_2, CO_2, CO, H_2, CH_4), and radiation were carried out. The furnace was operated under conditions resembling a well-stirred reactor, and almost all furnace volume was filled with combustion products containing 2%–3% oxygen. Both the natural gas streams and the combustion airstream entrained large quantities of hot combustion products before their mix. The whole furnace was “glowing,” and no visible flame was observed. The experiments were simulated using a computational fluid dynamics–based mathematical model. Three main conclusions were drawn: (1) the combustion process was much slower if compared with conventional burner technology, and hydrocarbons, hydrogen, and carbon monoxide were measured far downstream into the furnace, (2) high and uniform radiative heat fluxes were observed, and (3) novel simplified chemistry models applicable to this new combustion conditions are required.

U.P. Singh *et al*. (2003) [2] The Petroleum Conservation Research Association (PCRA) carried out energy audit studies in about 10 mills in the Jodhpur cluster during 1998-99 and identified large potentials for improvement in energy efficiency and reduction in GHG emissions through upgrading of technology in the re-heating and annealing furnaces of these mills.

Salient observations made during energy audit studies in these mills were as follows:

- Efficiencies of furnaces were in the range of 30-32% which can be improved to 55-60%.
- Large amount of heat is wasted in flue gases. Waste heat recovery should be done. Maximum waste heat can be recovered by preheating the metal.
- Preheating of air by installation of a Recuperators leads to better combustion.
- Preheating of combustion air/oil leads to higher flame temperature, this again leads to faster heat transfer. Due to this, increase in production can be expected.
- Motors are driven through V belt drive hence for better efficiency energy efficient flat belts can be used.

General Recommendations:-

1. Recycle Waste heat to the maximum extent possible.
2. Use fuel efficient equipment.
3. Use fuel efficient low excess air burners.
4. Clean burner nozzles and oil filters regularly.
5. Maintain pre-heat temperature of oil at the optimum level.
6. Reduce excess air (keep CO_2 above 13% or 0_2 below 3.5%).
7. Check thermal insulation.

By Following PCRA Recommendations the energy cost in these mills has reduced significantly from a level of 40-50% to 25-30% of the total cost of the mills. In addition, fuel savings of about 60% and CO2 emissions reduction of more than 50,000 MT/annum have been achieved.

David Yih-Liang Chan *et al*. (2009) [3] performed on-site energy audits of 118 firms in the Taiwanese iron and steel industry during 2000–2008. This study has established a national database presenting information and energy saving methods for energy users and has identified the potential areas for making energy savings to provide an energy conservation reference. It can assist the energy users in performing energy audits and increasing energy utilization efficiency. The following describes the energy saving methods and techniques used for arc furnace process:

- Pre-treatment of Scrap steel: Smaller sized scrap steel is treated first, enabling the treatment of a larger quantity per unit volume. Such pre-treatment also increases the heat efficiency and reduces the electricity consumption per unit of production.
- Reduction of scrap steel feeding times: This can reduce radiation heat loss from the furnace body and feeding process.
- Optimization of Electricity Control: During the initial stage of the charging process, electricity current must be controlled to protect the furnace cover and maintain electric arc stability. During the primary melting stage, large current is required to accelerate steel melting.
- Shortening of Reduction Period: Using quick lime and limestone with small particle size can accelerate the reduction.
- Reduction of Melting and Oxidation Period: Using an oil oxygen combustor can reduce electricity consumption, increase productivity and reduce electrode consumption.
- Using a large arc furnace can reduce production costs.
- Using water-cooled furnace cover and wall can maximize electricity output during smelting and significantly increase the life of the furnace cover and wall.
- Energy Saving in Carbon and Oxygen Blowing.

It was found that the total potential energy savings was estimated about 79,160.8 KL of crude oil equivalent (KLOE). It was identified to generate potential electricity savings of 170,322.8 MWH, fuel oil savings of 22,235.1 KL, steam coal savings of 4922 tons, and natural gas (NG) savings of 10,735 kilo cubic meters. It was represented a total reduction of 217,866.5 tons in carbon dioxide emissions, equivalent to the annual carbon dioxide absorption capacity of a 5836 ha plantation forest.

Chih-Ju G. Jou *et al .(*2010)[4] Presented In this research, the waste tail gas emitted from petrochemical processes, e.g. catalytic reforming unit, catalytic cracking unit and residue desulfurization unit, was recovered and reused as a replacement of natural gas (NG). The tail gas from many petrochemical processing units, e.g. residue desulfurization unit and residue cracking, may contain higher percentages of hydrogen (60–80%, % in volume) but is still worthy recovering. If properly applied and managed, the recovered fuel gas will enable savings of fuel consumption and reduction of carbon dioxide emission with potential economic benefits. A complete replacement of natural by the recovered fuel gas has been tested in this research using a full-scale heating furnace. The results show that a complete replacement of the NG by the recovered fuel gas will save 5.8 x106 m3 of natural gas consumption and reduce 3.5 x104 tons of CO_2 emission annually. If the residual O_2 concentration in flue gases decreases from 4% to 3%, additional 1.1 x106 m3 of natural gas consumption will be saved, and the additional annual reductions of NOx and CO_2 emissions will be 43.0% and 1.3x103 tons of CO_2.

Chih-Ju G. Jou *et al.(*2011)[5] Presented In the study, replacing natural gas and fuel oil by the tail gas recovered from the catalyst recombination or heavy oil cracking processes to replace natural gas and fuel oil for powering plant-scale boiler and furnace has been evaluated and lowering the residual O_2 concentration (%) in flue gases by lowering the input air to the furnace will reduce the transmission rate of the thermal flow into the convection zone causing a slower rise of the thermal from the radiation zone to the convection zone. Hence, the heat can be fully absorbed in the radiation zone to raise the thermal adsorption efficiency of the furnace. The field test results using a full-scale furnace show that reducing the residual O_2 concentration from 4% to 2.5% in the flue gas, 1.8 x 105 m3 of natural gas consumption and 3.9 x 105 tons of CO_2 emission can be reduced annually for the heating furnace operated at 70% of loading with 3.6 x107 kcal/h of combustion capacity.

Chih-Ju G. Jou *et al.* (2014)[6]Presented In this research, on-site studies using a full-scale furnace to investigate the impact of reusing the recovered tail gas on the overall furnace operation and efficiency is carried out. The results will be valuable for industrial nations to plan the recovery and reuse of wasted tail gas as an alternative fuel for industrial applications Using the recovered tail gas (FG) that consists of 60 mol% (50-70 mol%) of hydrogen gas to replace heavy fuel oil (FO) as furnace fuel was studied. With higher FG/FO ratios, the hydrogen content in the fuel increases so that the volume of flue gas reduces to reduce the furnace internal pressure that leads to slower uprising velocity of the thermal flow in the furnace and hence more efficient thermal transmission in the furnace. The results reveal that complete replacement of fuel oil with the recovered tail gas will reduce about 45.8% of the resulting flue gas, lower the furnace radiation zone temperature by 45 °C, and raise the furnace convection zone temperature by 18 °C. Additionally, the annual savings of heavy fuel oil can be 2.3 x 104 m^3 heavy fuel oil with the reduction of 53.4 tons SOx emission, 21.9 tons of NOx emission and 4.9 x 104 tons of CO_2 emission.

Therefore, reusing the recovered tail gas to completely replace heavy fuel oil (FO) as the furnace fuel along with operational adjustments of fresh air flow rate and flue baffle angles will alleviate the discharge of greenhouse gas.

Maria T. Johansson *et al.* (2011) [7] opportunities for both integrated and scrap-based steel plants are presented and this paper focuses on the iron and steel industry's energy flows and possibilities to reuse excess energy. The iron and steel industry's primary energy sources are coal, coke and electricity SSAB Strip produced around 2.2 million tonnes of steel slabs. Sandvik Company produced 258,000 tonnes of steel slabs and 87,000 tonnes of refined steel products In 2008, the CO_2 emissions from SSAB Strip Products and Sandvik AB total 1.3 million tonnes and 113,000 tonnes, respectively The opportunities for Swedish integrated steel plants and scrap-based steel plants which are presented in this paper are as follows.

- Electricity production by the use of:
  - Energy-rich process gases as fuel in a combined heat and power (CHP) plant (IS).
  - Low-grade heat in an organic Rankine cycle (ORC) or Kalina cycle (IS, SS).
  - Heat radiation converted by thermo photovoltaic (TPV) technology (IS, SS).
  - Heat and pressure from the blast furnace off-gases in a top pressure recovery turbine (TRT) (IS).
- Coke dry quenching (CDQ) with heat recovery (IS).
- Hot water from cooling beds (IS, SS).
- Industrial symbiosis (IS, SS).

SSAB Strip Products is to generate electricity and in addition to burning process gases in a CHP plant for heat and power production, there are several technologies that can be used; ORC/Kalina cycle, TRT and TPV. Installation of TRT at SSAB Strip Products would generate approximately 90-130 GWh electricity/year. This corresponds to a reduction in global CO_2 emissions by approximately 80,000-120,000 tonnes/year. SSAB can substitute some of its fossil fuels with biomass. Then the emissions of reduced by approximately 760,000 tonnes/year. In 2008, Sandvik used 290 GWh of LPG; where of approximately 98% was used in heating and heat-treatment furnaces. A substitution of the LPG used in heating and heat-treatment furnaces requires about 26 millionNm^3 of SNG per year, corresponding to an annual biomass input to the gasifier of 473 GWh. This would reduce the CO_2 emissions from Sandvik by approximately 70,000 tonnes/year if the biomass

Wang Ping *et al.* (2011) [8] Presented in This paper according to the status of production technology of atmospheric and vacuum unit vacuum furnace and optimizes the design by simulation to get to the purpose of plant expansion and saving with less investment. With the continuous development of energy conservation, demand lower and lower exhaust gas temperature furnace. But often in the steel pipe waste heat recovery equipment, heat exchangers and other heat transfer surface will produce strong low-temperature dew point corrosion. It is to improve the thermal efficiency of vacuum furnace and achieve the requirements of energy saving by using new technologies. The prerequisite of improving furnace thermal efficiency and energy conservation should ensure the safe operation of heating and normal life. If you ignore this, it often results in greater waste.So In this Paper, Authors focus on is the furnace flue gas waste heat recovery technological applications, and discuss how to prevent low-temperature dew point corrosion, as well as the effect of waste heat recovery.

Following Measures to prevent the corrosion of flue gas dew point

- **Exhaust gas temperature control**

  According to the dew point temperature of flue gas reasonably determine the exhaust gas temperature, the exhaust gas temperature should be higher 20 ~ 30 °C than the dew point temperature. In addition, because summer and winter temperature difference too much, should control the different exhaust gas temperature, exhaust gas temperature should be raised in winter.

- **Addition pre-heater**

  Addition pre-heater can increase the temperature of the air entering the preheater, so as to effectively prevent the dew point corrosion.

- **Method using hot air reflow**

  Warm air with flue gas is the primary method to recover waste heat and improve thermal efficiency; it is also the most commonly used method. To avoid the cold end of low-temperature dew point corrosion of air preheater, the use of hot air reflow method, send a part of the warm-hot air to the entrance of the air blower to improve the inlet temperature of the air side. It is worth noting that, with the air temperature increasing, the NO x of the combustion products increase, if no appropriate measures to reduce NOx, then for environmental protection is bad. In addition, if the air temperature is too high, it may cause the fuel nozzle coking or deformation of the excessive burner or other issues, unless you change the burner structure and materials, the general air preheating temperature should not exceed 300 °C .point corrosion is removed. So it is Conducive to cleaning, at the same time fouling on the surface of heat exchange tube can also be removed in time. Through the above measures the heat exchange tube can in good sate for a long time .It can also reduce exhaust gas temperature, full recovery of waste heat, improve the thermal efficiency of furnace and to achieve the purpose of energy saving

- **Structure of the Heat Pipe Air Preheater**

  Heat pipe air preheater is also composed by iron and glass, and if it good for low temperature corrosion resistance. To make entire exchange has good insulation properties, both sides of the top, bottom and around of the exchange are filled with insulation layer.

- **Using Low Sulphur Heavy Oil**

  From a technology view, using low sulphur heavy oil can avoid corrosion due to smoke of the dew Point or adding some additives which can occur combination reaction with sulfur trioxide and produce No Corrosion materials into heavy oil can also reduce the concentration of sulfur trioxide to a large extent. At the same time, reduce corrosion. In the process of design and operation, the exhaust gas temperature should do not drop too low in order to save energy blindly. Reducing dust in the flue gas and treating dirt on the equipment surface in time during downtime etc.

Shirley Thompson et al. (2014) [9] Presented Analysis of energy efficiency opportunities at a steel mill were under taken by Carried out Energy Audit. A number of energy efficiency opportunities were found to be feasible in this analysis at Gerdau, North America Long Steel-Manitoba Mill. The waste heat recovery opportunities included: (1) preheating combustion air in the ladle preheater, with an estimated energy savings of 22,000GJ/yr and a payback period of 10 months and, (2) Preheating billets to 315 °C decreases energy consumption by 60,323 GJ/yr. The annual Natural gas saving is estimated to be Rs.30 million/yr. when the rate is Rs.514/GJ. The estimate of GHG reduction is 2999 ton CO_2/yr. The simple payback for the project is estimated to be 3 years based on an initial cost of Rs.82.5 million, 5% inflation rate and an annual maintenance cost of 3.6 million. The project life span chosen was twenty years. (3) Replacing natural gas heaters with direct fired heaters. The fuel savings are estimated to be 2 GJ/h with annual energy Savings of Rs.2.9 million/yr. The simple payback period forRs.13.2 million in costs wascalculatedtobe4.5years.The CO_2 emission reductions is estimated to be 282 ton/yr.

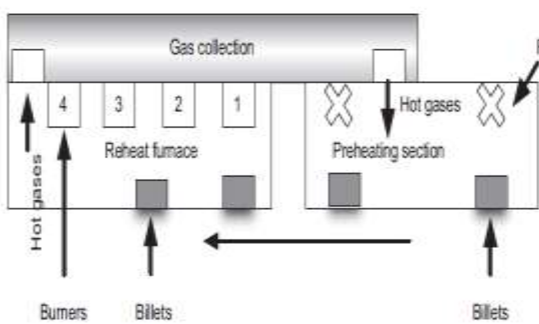

Fig.1 Preheating billets process

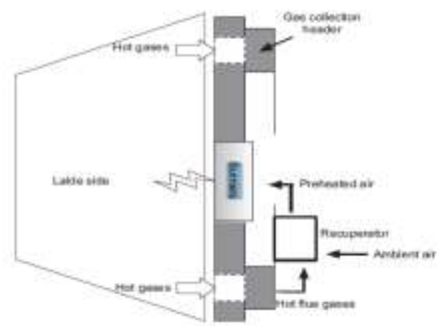

Fig.2 Pre heating combustion air in The ladle preheater

This Paper demonstrates that energy efficiency projects have many benefits. These positive impacts include: (1) reducing emissions and environmental impacts, (2) decreasing fuel use, (3) providing savings annually after a short payback period and (4) increasing Productivity.

M.S.Prashanth *et al*. (2014) [10] Investigates into the possibilities of finding a solution towards reducing the energy wastage in foundries. An energy audit was conducted towards this purpose by identifying key areas which were compressed air, raw materials and furnace. The audit started by studying the compressed air system. Using Compressor Modulation, control varies the compressor output to meet the flow requirement by adjusting inlet valve. Power consumption can be reduced to 35%. Every 4 °C rise in inlet air temperature results in a higher energy consumption. Temperature in the foundry was found to be around 32 °C amounting to 4 % loss in power. By bringing down the temperature to 26 °C, 1.5 % power can be saved. The audit then focused on the raw materials where the inventory and raw material usage was studied. It has been found that around 105 kg of sand is wasted every day during the strike off operations. To overcome this issue, a sand recovery system was designed (Modified Design of Model Box) to save close to 100 kg of sand which amounts to almost 3 tonnes of sand every month. The thermal aspect of the audit was then conducted by observing the energy consumption of the furnaces. The options for energy savings in melting are preheating of the raw materials, selection and maintenance of furnaces, insulation and maintenance of furnaces, continuous monitoring and control of melting and heat treating devices, avoidance of lid-off periods of furnaces, maintenance of furnace cover and seal cover gaps, investments for heat recovery systems of furnaces and furnace accessories. This various factors were improved, showing better energy usage. These simple initiatives taken in a small scale foundry could give rise to cost savings of around 10 lakhs rupees per year and energy saving of 58 MWh. Such initiatives prove that scopes for energy conservation in foundries are immense and simple steps are sufficient.

T. T. CHANDRATILLEKE *et al*. [11] Represent, an audit of energy use at a National Iron and Steel Mills (NISM) in Singapore which produces wire rods and bars from scrap iron using the arc furnace process. The Paper shows that the specific energy consumption is 1095 KWh/tonne of rolled steel. The energy audit shows that electricity and fuel oil account for over 90% of the total annual energy consumption of 59784 KWh. The arc and reheat furnaces are the major energy consumers of electricity and fuel oil, respectively, and they account for 46 % and 31%, respectively, of the specific energy use. The overall efficiency of the electric arc furnace is about 50%, which is below average for similar types of reheat furnaces. Several areas for sub process energy and productivity improvements have been identified. Substantial savings are possible through preheating of the third charge of the arc furnace, optimizing the production rates of the reheat furnaces and recovery of waste heat for preheating fuel oil.

Fabio Dal Magro et al. (2015) [12] Presented In this Paper, An efficient energy recovery from off-gas in the steel industry. The aim of this study is to enhance energy recovery from the Electric Arc Furnace(EAF) process due to the introduction of a smoothing system based on phase change materials (PCMs) acting on the off-gas temperature profile. Energy recovery performance is increased by introducing a heat transfer fluid through PCM containers, which enables the adoption of smaller pipe diameters while overcoming overheating issues. A conjoint direct–indirect recovery of off-gas thermal energy is proposed in order to maximize energy efficiency in EAF with continuous charge. After preheating the scrap charge as in direct recovery, off-gas enters a PCM (aluminum) smoothing device which reduces its temperature variability, providing a more regular feeding of the downstream indirect recovery system by steam generation and power production. The resulting low cost device allows increasing energy efficiency of the whole recovery system. Maximum off-gas temperature is lowered. This has a direct impact on the downstream energy recovery system based on consolidated Rankine cycle technologies and use smaller sizes of both the boiler and the steam turbine. The installation of the proposed PCM smoothing device allows also overcoming some of the environmental issues that have hindered energy recovery in the steel industry. Since recovery of energy from EAF steelmaking processes has been identified as opportunity for reducing energy use.

.

3. CONCLUSIONS : -

In this Review Paper, Development on Energy Savings techniques in Furnace has been carried out. Following Conclusion are describe from this paper:

- Recover waste heat recovery from flue Gases by using Recuperators, ladle preheater.
- Recover waste heat from flue Gases by Preheating billets process.
- Reduced Excess air by maintain inlet air.
- Reduced Fuel Consumption by reusing the recovered tail gas
- Electricity production from flue gases by using combined heat and power plant and Heat radiation converted by thermo photovoltaic (TPV) technology.

4. REFERENCES:-

[1] Roman Weber, Stefano Orsino, Nicolas Lallemant And Ad Verlaan "Combustion Of Natural Gas With High-Temperature Air And Large Quantities Of Flue Gas" Proceedings of the Combustion Institute, Volume 28, 2000/pp. 1315–1321.

[2] U.P. Singh "Improvement In Energy Efficiency Of Re-Rolling Furnaces For Stainless Steel Industry At Jodhpur, Rajasthan, India", Elsevier Science Ltd Volume 2 (2003).

[3] David Yih-Liang Chan , Kuang-Han Yang , Jenq-Daw Lee , Gui-Bing Hong "The case study of furnace use and energy conservation in iron and steel industry "Energy 35 (2009) 1665–1670.

[4] Chien-Li Lee, Chih-Ju G. Jou "Reduction of energy cost and CO_2 emission for the furnace using energy recovered from waste tail-gas ",Energy 35 (2010) 1232 - 1236.

[5] Chien-Li Lee, Chih-Ju G. Jou "Improving Furnace and Boiler Cost-Effectiveness and CO2 Emission by Adjusting Excess Air",Environmental Progress & Sustainable Energy (Vol.31, No.1) DOI 10.1002 / ep (2011).

[6] Ching-Kuei Hsu, Chien-Li Lee , Chen-Hua Wang, Chih-Ju G. Jou "Reduction of energy consumption and pollution emissions for industrial furnace using hydrogen rich tail gas" International journal of hydrogen energy (2011) 1-6.

[7] Maria T. Johansson, Mats Söderström "Options for the Swedish steel industry - Energy efficiency measures and fuel Conversion", Energy 36 (2011) 191-198.

[8] Wang Ping, Xie Changfang, Xu Shiming, Ge Yulin "Application of Energy-saving Technology on Furnaces of Oil Refining Units" Procedia Environmental Sciences 12 (2012) 387 – 393

[9] Shirley Thompson, Minxing Si “Strategic analysis of energy efficiency projects: Case study of a steel mill in Manitoba”, Renewable and Sustainable Energy 40 (2014) 814–819.

[10] M.S.Prashanth, R.Eshwar, Vikram K. Patel, J Selvaraj, Rohit R., Rahul R., Gopi Krishna Menon “A Multi-Faceted Approach To Energy Conservation In Foundries”, Procedia Engineering 97 (2014) 1815 – 1824.

[11] J. C. Ho,S. K. Chou, And T. T. Chandratilleke “Energy Audit Of A Steel Mill”, Printed In Great Britai, Energy Vol. 16, No. 7, Pp. 1021-1029 (1991).

[12] Fabio Dal Magro, Antonella Meneghetti, Gioacchino Nardin, Stefano Savino “Enhancing energy recovery in the steel industry: Matching continuous charge with off-gas variability smoothing”, Energy Conversion and Management 104 (2015) 78–89.