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Forging Plant Processes Energy Conservation by Energy Audit Approach-A Case Study

Atul Modi¹, Bhagwat Dayal Verma²

Assistant Professor, Dept. of Industrial Production Engineering, S.G.S.I.T.S. College, Indore, M.P., India¹

P.G. Student, Dept. of Industrial Production Engineering, S.G.S.I.T.S. College, Indore, M.P., India²

ABSTRACT: The modern forging plant, due to heavy energy consuming equipment and critical working conditions requires minimum energy losses and sustainable development during conversion process. The Forging process energy conservation is a tool in recent time to improve environment, economy and productivity and at the same time, the costly natural resource / cost saving [8]. The increased manufacturing and energy costs and volatile steel markets have created the demand in the forging plants to improve manufacturing process in a manner so that the energy cost of present and further processing may be reduced or avoided for finished product and improved grain structure is obtained [20]. An energy optimization / conservation model for forging plant improved process can be obtained by help of **Energy Audit approach** to improve the **combustion process** in the **reheating furnace**.

I. INTRODUCTION

The forging process goes back from to 8000 B.C. and evolved from the manual art of simple black smithy. All metals and alloys are forgeable, but each will have a forge ability rating from high to low or poor [6]. The factors involved to control forge-ability are the material's composition, crystal structure and mechanical properties, all within a particular temperature range [17]. In India generally conventional forging plants are preferred, in comparison to modern automatic plant because of low investment cost, interrupted batch production and large product ranges [8]. Modern Forging uses machine driven impact hammers or presses which deform the work piece by controlled pressure. Forging process is superior to casting in that the parts formed have denser microstructures, more defined grain patterns, and less porosity by making such parts much stronger than a casting. Industrial sector is the largest user of energy in India and many parts of the world. More than half of the total energy is used in industries to operate various energy using machineries [14]. The energy cost is vital to reduce total manufacturing cost of the final product [7]. Energy savings are possible by redistributing production sequences among the basic production systems functions optimally [5].

Industrial sector is the largest user of energy in India and many parts of the world [6]. The energy cost constitutes a significant portion of the product cost [1]. Any waste in energy result in to increased manufacturing cost [4]. The complete forging processes are performed in different sequences of operations in different department or work centres. In recent time forging plants need a technology for their survival and sustainable economical development. The energy efficiency of forging furnace is around 40-50%, which indicates the energy loss or wastage [14]. Energy conservation is a cost-effective approach in any energy optimization program that can be implemented in industrial activities [3]. In this work data was collected and critically analysed to eliminate unnecessary process energy wastage by using energy audit approach. Energy conservation strategies are cost effective and essential for economical manufacturing in forging plants in different sequences [10]. The Forging manufacturing industry of deferent parts of world's faced new challenges of global competition and challenges can be transformed into opportunities by proper care [20].

II. FORGING PROCESS

Forging is the controlled deformation of metal into a specific shape by compressive forces. In forging is the metal convert into a useful shape by hammering and pressing. A series of compressive hammer blows performs the shaping or forging of the part [6]. In figure 1 general forging flow process sequences are shown. In forging process optimization of radial forces is essential to obtain the require quality during forging processes [8].

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Most forging is done in heated conditions of work pieces. “Cold forging” can occur at room temperatures. The Most forgeable materials are aluminium, copper, and magnesium. Lower ratings Are applied to the various steels, nickel, and titanium alloys. In the forging the requirements are for smooth surface finish, considerable material weight saving preferred fiber structure, minimum notch effect and increase material strength and minimum defects [11]. Every manufacturing activity now needed cost saving [7].

In forging plant energy different forms as electrical, pneumatic, hydraulic, and mechanical are used. The electrical energy is used to run motors, saws and blasting machine, hoists, electrical electronics drives, water pumps, cooling

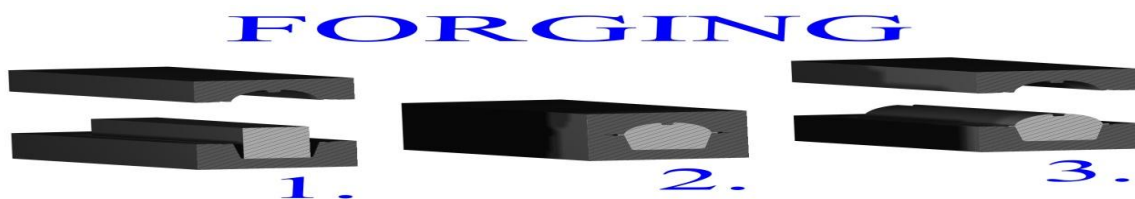


Fig: 1 General forging process flow process sequences diagram [17]

Tower, air compressor, blower and heaters etc. The Thermal energy is used to heat the blanks in the furnace by burning furnace oil. for perfect movement of hammer control system are used and material movement is done but help of forklift ,The electrical &electronic system are also used for gear cutting &other machine operation[6] .The hot forging has advantages over cold working as shown in table-1.

TABLE-1-COMPARISON OF HOT FORGING WITH COLD FORGING

S.N.	Hot Working	Cold Working
1.	Hot working is carried out above the re-crystallization temperature and below the melting point.	Cold working is carried out below the re-crystallization temperature.
2.	No internal or residual stresses are set-up in the metal.	Internal/ residual stresses are set-up in metal.
3.	It helps in irradiating irregularities in metal composition, breaking up the non metallic impurities in to tiny fragments and dispersing them throughout the metal.	It results in loss of uniformity of metal composition and thus affects the metal properties.
4.	Close tolerance cannot be maintained.	Better tolerance can be easily maintained.
5.	Surface finish of this process is comparatively not good	Surface finish of this process is better.
6.	It results in improvements of properties like impact strength and elongation	It results in reduction of the properties like impact strength and elongation.
7.	Due to re-crystallization, negligible hardening of metal.	The metal gets work hardened.
8.	The stress required for deformation is much less.	The stress required for deformation is higher.
9.	Hot working refines metal grains resulting in improved mechanical properties.	Most of the cold working processes lead to distortion of grains.
10.	Cracks / blow boles are finished through hot working.	Existing cracks propagate/ new cracks obtain.
11.	If properly performed, it does not affect UTS, hardness, corrosion resistance yield strength and fatigue strength .	It improves UTS, hardness, yield strength but reduces the corrosion resistance of strength.

III. COMMON APPLICATIONS OF FORGING

Forged products has wide applications in automotive passenger cars, trucks, buses, trailers, motorcycles and transmission equipments, internal combustion engines, oil field machinery and equipments, fixtures, valves and fittings, pumps and compressors, railroad equipments and metalworking and special industry machinery, bicycles, bearings, ball and roller, industrial and commercial machinery and equipment are other examples of forging [13].

Forging Hammer The hammer is the least expensive and most versatile type of equipment for generating load by different energy sources to carry out forging process. This technology is characterized by multiple impact blows

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between contoured dies. Hammers are primarily used for hot forging. Figure-2 and 3 shows mechanical boards hammer and steam hammer principle[17].

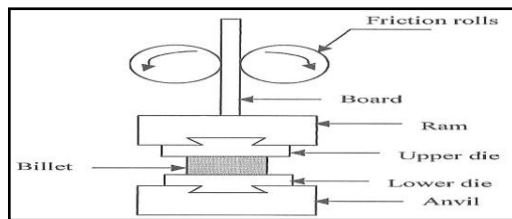


Fig: 2 Mechanical boards hammer

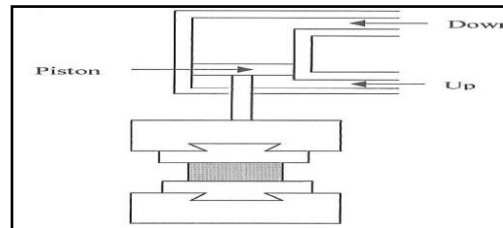


Fig: 3 Stream hammer

IV. GRAIN STRUCTURE IN FORGING PROCESS

In drop/press forging process pressure is applied length wise to a hot bar held between grooved dies to enlarge some section usually the end. In this method the metal is displaced from interior & made to flow outside. This result in controlled grain structured with dense fibre in full length, generally a through hole is made in length for feeding of bar stock. The die is made in two half, one is fixed & other moving so met .can admit, these die or jaws also clamp work piece. Figure-4 represents a comparison of forging grain flow with machining operation[17].



Fig: 4 Grain structure in forging

The process is performed in different stages or sequences. It is difficult to optimize the complete sequence with some objective as different sequence has different goal or target and associated parameter of each sequence to response quickly for ever-changing demands of customer for different products of similar families ,The object is to reduce cycle time , defects minimization ,waste reduction for energy cost optimization[1].

V. IMPORTANCE OF ENERGY AUDIT APPROACH

The energy audit approach is a key approach for systematic decision making in energy management. It quantifies the energy uses according to its various functions. It attempts to balance the total energy inputs with the output or the uses. The role of energy audit changes from preliminary audit to detailed audit [16]. The detailed audit goes beyond quantitative estimates to the energy cost and saving and includes engineering applications and recommendations. The preliminary audit can be used as control tool to take feed-back of the implemented projects and form basis of next project of improvements [8]. The energy conservation and maximization strategies are cost effective, which conserve the environment automatically [10]. Continues monitor and optimally control of energy use with allowance for changes in production conditions are needed [5].

Energy conservation is a cost-effective approach in any energy optimization program that can be implemented in industrial activities [2]. Energy-intensive industries in developing economies offer significant energy-saving potential owing to the technology gap as well as lower operating efficiency. Energy conservation implies reducing the physical consumption of energy resources per unit output [11]. A detailed energy flow analysis was conducted in a paper carton manufacturing unit in India to quantify the energy-saving potential [7]. The study revealed that the compressed

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air leakage is responsible for energy losses. In forging the furnaces heating is very importance because in furnace causes many forging defects also.

VI. METHODOLOGY

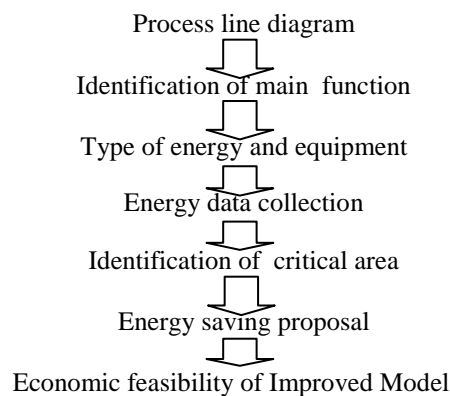
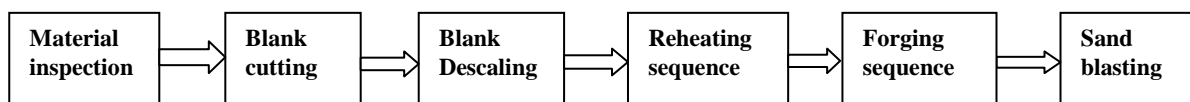


Fig. 5 Methodology

Fig.5 represents the proposed methodology for forging unit. There is no tailor made methodology, as the energy audit role change with the organization type. The first step of methodology is the identification of main work center of function of the forging unit. The different types of energy used and equipment are listed for detail energy audit. The energy audit is conducted on selected function's selected equipment only. The main options for energy conservation are more efficient energy use in production processes and reduction in the losses during energy distribution [7]. The data of energy consumption and energy related data are collected. The cause and effect diagram are used to analyze the critical area and finally improvement is made in forging different sequences by reducing rejection / rework as proposal by energy audit method.

VII. CASE STUDY OF A MODERN FORGING UNIT PLANT

In this work, conventional forging plant which manufacturing forging unit of different sizes is considered, Forging process start from material inspection as shown in flow process diagram in figure-6, the material visually inspect than blank of M S billets are cut in accurate size by saw machine .then after it blanks are de-scaling[6]. The blanks are reheated in furnace in different sequences, at high temperature as desired and after heating the pieces are ready for forging sequences. In forging sequences vertical hammer are used then finally the forged pieces are sand blasted



Fig; 6 Flow diagram of forging unit

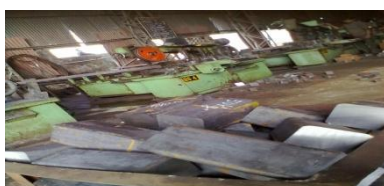


Fig: 7 Blank cutting, saw m/c and Finished gears after forging sequences in forging plant

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Fig- 7 indicates the forging unit raw material cutting and finished gears after forging sequences and saw machine used to cut the blank pieces. Among various equipment, air compressors, electric motors, furnace and A.C. studied. The forging unit is suitable for wide range of gears, and other special quality gears as shown in figure as above.

VIII. MANUFACTURING CAPABILITY

The forging unit has a manufacturing capacity of 6,100 MT yearly, of forging and different diameter of gears, crank shaft, pistons and defense or railways gears under different standard. The plant is capable to run on more than 100% capacity also. The plant product mix of different types of gears as Buses for trucks and cars also

IX. PREPARATION FOR ENERGY AUDIT

Before conducting a detailed energy audit in the in steel forging plant facility, the preparations have been made for developing a positive atmosphere for the auditors. A meeting was held with the plant operating peoples familiar with the physical conditions and day-to-day operation of the manufacturing facility of the plant. The purpose of the meeting was to identify areas and equipment, where auditors' attention should be focused during the detailed audit study and limitation and scope of the work. The energy audit role in the plant is also discussed to remove any misconception about the work. After the meeting, the audit team visit to the manufacturing plant, for visual observation of the various facilities of measuring points.

X. ELECTRICITY AND OTHER DATA COLLECTION

The power supply for the plant is from MPSEB, Co.Ltd with the help of 33kv feeders. There are 2 no of transformers with different rating capacity; with contact demand of 2000KVA.The different data and specification is collected along with energy consumption data for 4 year. The production energy and fuel consumption data are collected as below in figure-8 & 9. The yearly production and energy/ fuel consumption indicates that plant performance is in improvement direction.

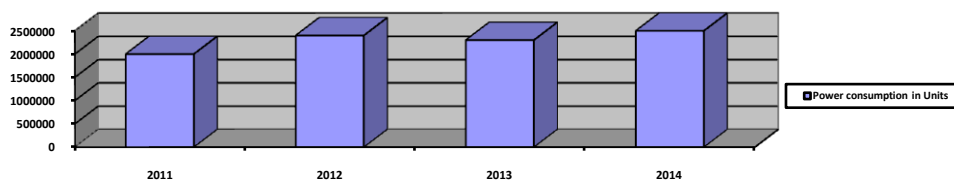


Fig: 8 Forging process power consumption

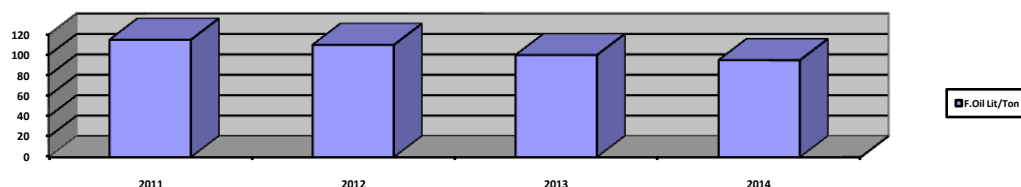


FIG: 9 FORGING PROCESS FURNACE OIL CONSUMPTION

XI. DATA ANALYSIS

The various data collected are analysed for delays and responsible sources. Figure-10 represents the plant processes analysis according to responsible for cumulative delays. In order to improve the plant final performance results the management also purchased an automatic machine shop for gear blank rough and final machining and final heat-treatment. The new plant is useful for R & D activity as well as to feed back the forging product quality. The data are analysed with a view to compare with the standard system to minimize the plant losses.

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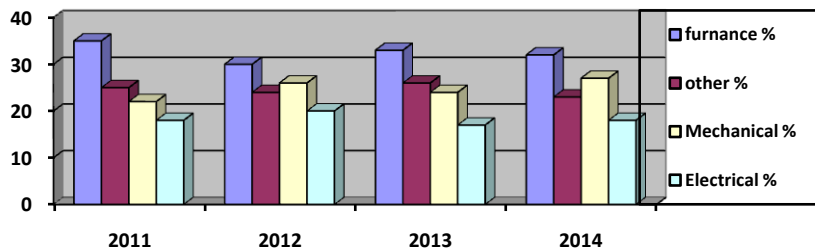
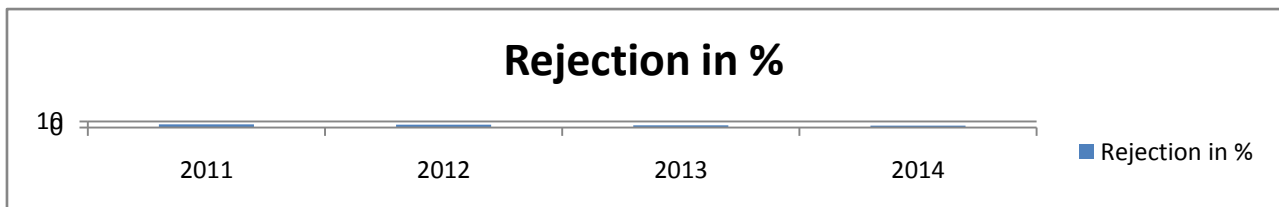
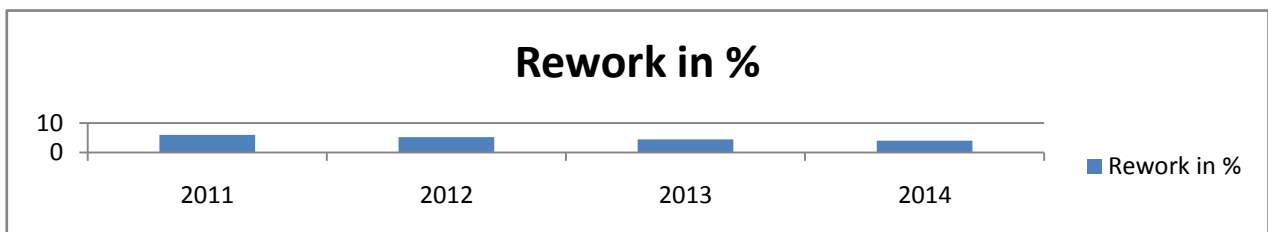


Fig: 10 Forging functions analysis in forging plant

The plant rejection and rework percentage is a serious problem, which result into losses. Main reason of rejection is furnace which also developed some defects due to non-efficient working and practices. In the forging plant the rejection & Rework are calculated for 4 years as in figure-11 & 12. Both rework and rejection are reduces, indicates that the production quality is improved, so the rejection or rework automatically improve. The forging plant different functional department analysis indicates that reheating furnace is the department which influences the complete process and also affects delays, rework and rejection.



Fig; 11 Forging Rejection %



XII. IDENTIFICATION OF CRITICAL AREA

In forging processes the reheating furnace plays a critical and important role as determined by data analysis. The furnace heating is done in different sequences and furnace energy efficiency is around 40/45%. The different sequence of reheating furnace are important for proper and defect-free heating and reheating process has mainly influenced by combustion process, different equipments like blower, burner, etc. The other factors like man power as operator and material like raw material, insulation material, refractory bricks etc. also affect the process. The cause and effect diagram along with Perato diagram act as critical examine tool for complete reheating sequences failure. Figure-13 indicates the various causes of furnace problems. The different causes are due to man, equipment, material and process.

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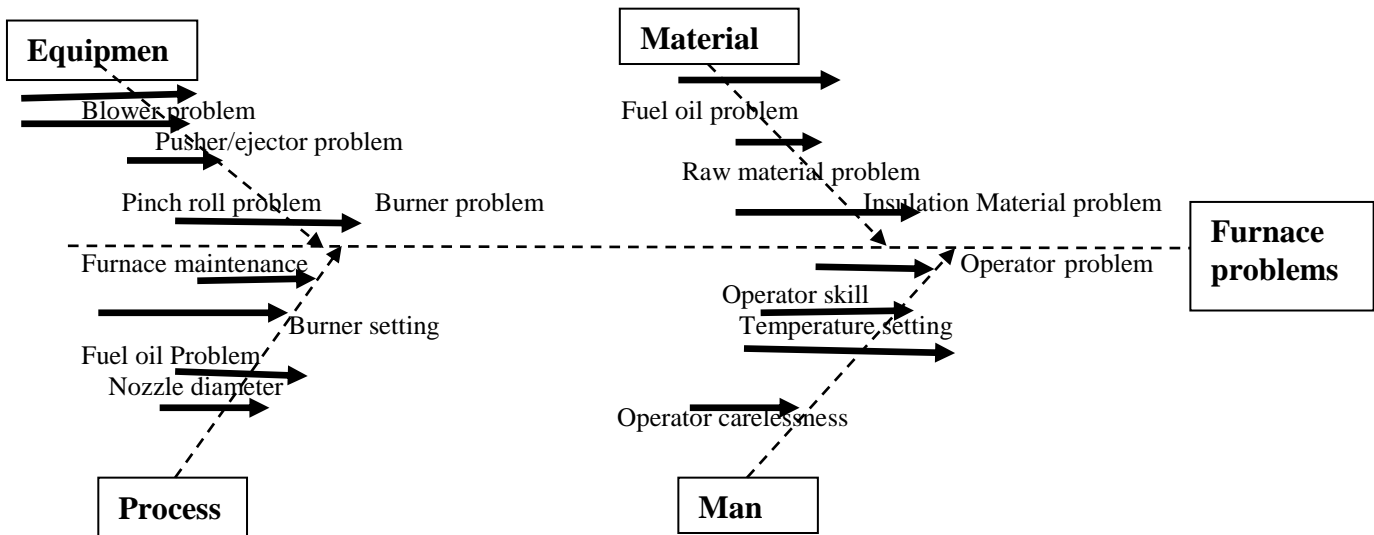


Fig.13 Fish Bone Diagram of Steel Rolling Plant Furnace problems

The rework and rejection percentage due to furnace are also summarized in figure-14 and 15 and the final conclusion drawn indicates that reheating sequences are influence maximum by the fuel reheating or combustion process. The combustion process in reheating process which is performed in different sequences is depending on variables like flame setting, excess air percentage, blower performance, operator performance etc.

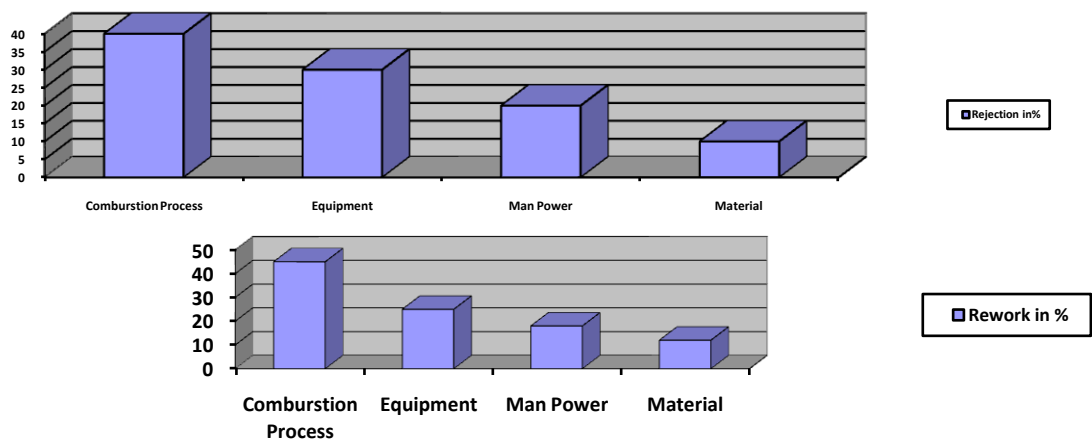


Fig: 15 Critical Analysis of Rework in Furnace Area

The furnace problem & limitation are determined by different factors analysis by cause and effect diagram along with Pareto diagram of rejection and rework and summarized in table-3 for possible improvement in different causes of man, machine and material.

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Table-3

S.N	Particular	Possible Improvement and limitations
1	Combustion Process	The process heating delays is to be minimized the, process need proper O2 level control
2	Burner	The burner used is of high pressure type & to be replaced by LAP burners.
3	Operator	Automatic control system needed so to reduce operator mistakes.
4	Material	Correct fuel, insulating material, refractory brick & insulating blanket are needed.

XII. IMPROVE MODEL

The improve model of forging process can be obtained by different development and R & D work in the furnace. Depend on furnace delays, rejection and rework a proposal is made to conclude the energy audit work to improve the furnace reheating sequence; the proposal is useful to overcome the furnace problem due to man, machine, and material and process itself. The plant has already installed the automatic control system to control heating process in the furnace but operator prefers manual control system.

Table-4- Energy saving proposal

S.N.	Particular	Description	Possible Investment	Payback
1	Automatic system	The furnace has all equipments for automatic control system but plant is not using it.	NIL	NIL
2	LAP Burner	To replace existing burner with LAP Burner need 2- week shut down for furnace, but plant has 2 furnaces so one by one new burner can replaced.	2,00,000	Maximum one years
3	Combustion Process	The proper combustion flame need proper furnace atmosphere & excess O2 level control	25,000	One month
4	Furnace leakage	1. Proper blanket are needed at furnace doors 2. Proper insulation of furnace	5,000 10,000	7 days 15 days
5	Oil heating unit	Before combustion for proper mixing of fuel with air a temperature of 95-105oC is require for LDO	Installed but not properly set	-

XIII. RESULT & DISCUSSION

The expected saving by changing the existing burners by LAP burners is around 20% of total fuel consumption. The manufacturer claims for 22% and cost of new burners are Rs.2, 000, 00/- total including the other accessories like valves, ratiotrol valve etc. The plant total annual fuel consumption is 6954 K.L. The expected results are summarized in table-5.

Table-5 Reheating Furnace Energy and Fuel Saving

S.N.	New change	Result	% Change
1	By New Burner	1390K.L.	20.0%
2	By Excess Air Control	695.4 K.L.	10.0 %
3	By Automatic Control System	329.7 K.L.	5.0%
Final	Total Saving	2415.1 K.L.	35%

Fuel saving due use of LAP burners-20% = $0.20 \times 6954 \text{ K.L.} = 1390.8 \text{ K.L.}$ For furnace or LDO the air required is 22.56 kg for each kg of fuel used. The chimney exhausts temperature indicates high air excess percentage but in absence of proper exhaust temperature monitoring equipment which cost about Rs.25, 000/- the assumed saving is 10%. = $0.10 \times 6954 \text{ K.L.} = 695.4 \text{ K.L.}$ The Automatic control system used to overcome operator mistakes as single settings for all burners for the set final temperature of finished blanks. About 5-10 % saving is expected by use of this system.

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The expected change in furnace fuel consumption indicates the importance of the study and act as motivational factor both for the individuals and the organization. Figure-16 indicates the expected change in fuel consumption due to all these improvement in the combustion process.

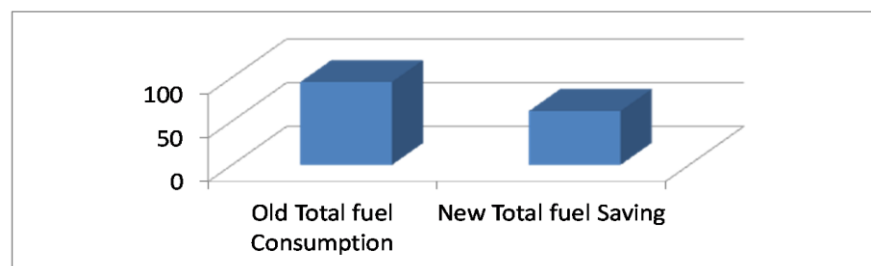


Fig: 16 Final outcome of the improved model

The forging operation and process are mainly influenced by reheating furnace to reduce the final rejection and rework. The furnace sequence has critical role not for proper heating but any variation in the combustion process results into product rejection. The proposed improvement proposal included the different weak area of reheating furnace determined by detailed energy audit. The possible investment is determined by different proposals available in the forging plants. To improve forging process and to reduce the rework or rejection all work as mentioned in proposal are necessary. A proper feedback system is also needed for continuous improvement in different areas.

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