STUDY ON POWER OPTIMIZATION IN HEAT TREATMENT PROCESS (A CASE STUDY)

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Abstract : A real time analysis of heat treatment process has been done with an Objective to optimize power in heat treatment process for this a heat recovery system consisting of Exhaust gas chamber, gas compressor, and gas turbine have been introduced in between system to run the product handling device used in heat treatment process .which result 20% power saving. And approximate 20% power saving has been calculated.

Index Terms - **HT, centrifugal compressor, wind turbine, dynamo and rechargeable battery.**

Introduction :

In recent years there has been a considerable growth in heat treated work piece and trend is set to continue for the forcible future. Today heat treated objects find useful in aircraft, marine, automobile, production, thermal station etc, which undergoes a wide variety of changes in above field. Even its application in domestic appliance kitchen wares and crockeries is found considerably.. Improvement in heat treatment process is depended on proper heating; redaction in scale formation, heating then thoroughly and covering all points on the work piece .Heat treatments is the control process uses to alter the micro structural of metal such as alloys to impart properties which benefit the working life of a component. For example increased surface hardness, temperature resistance, ductility and strength etc.

There are various types of heat treatment process, majors are hardening, normalizing, tempering and annealing. Annealing is basically a stress relieving process in which material is heated at a temperature above is critical temperature and is cooled in furnace itself. Normalizing is a grain refining process in which material is heated just like annealing but is cooled in a still air. . Hardening is the process of heating the material well above the critical temperature and then quenching it in a medium like oil and water. Tempering comprises of reheating of previously harden material to increase is toughness by heating below the lower critical temperature and then cooling it in air.

Exhaust Flue Gas :

Exhaust flue gas from oil fired furnace the exhaust gas is emitted as a result of the combustion of fuels such as gasoline, petrol, biodiesel blend ,diesel fuel, fuel oil or coal The composition of this gas is nitrogen(N_2),water vapor (H_2O) (except with pure=carbon fuels),and Carbon dioxide(CO_2): this are non toxic or noxious (although carbon dioxide is a greenhouse gas that contributes to global warming).A relatively small part of combustion gas is undesirable, noxious, or toxic substances, such as carbon monoxide (CO) from incomplete combustion, hydrocarbons(properly indicated as C_xH_y from un burnt fuel, nitrogen oxides (NO_x) from excessive combustion temperatures.

Wind Turbine :

A wind turbine or a wind energy converter ,is a device that converts the winds kinetic energy into electrical energy. Wind turbines are manufactured in wide range of vertical and horizontal axis The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs Larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid. Wind power density is a quantitative measure of wind energy available at any location .It is the mean annual power available per square meter of swept area of a turbine and is calculated for different heights above the ground. Calculation of wind power density includes the effect of wind velocity and air density .Conservation of mass requires that the amount of air entering and exiting a turbine must be equal. Accordindly ,Betzs law gives the maximal achievable extraction of wind power by a wind turbine as (59.3%) of the total kinetic energy of the air passing through the effective disk area of the machine. If the effective area of the disk is A, and the wind velocity ,then maximum theoretical power output P is given by

$$\mathbf{P}=\frac{16}{27}\times\frac{1}{2}\times \mathrm{p}\times \boldsymbol{v}^3\times \mathbf{A}$$

where p is the density of the air.
Wind turbines can rotate about either a horizontal axis or vertical axis

Dynamo :

Dynamo is an electrical generator. This dynamo produces direct current with the use of a commutator. Dynamo were the first generator capable of the power industries. The dynamo uses rotating coils of wire and magnetic fields to convert mechanical rotation into a pulsing direct electric current. A dynamo machine consists of a stationary structure, called the stator, which provides a constant magnetic fields and a set of rotating windings called the armature which turn within that fields. On small machines the constant magnetic field may be provided by one or more permanent magnets; larger machines have the constant magnetic field provided by one or more electromagnets, which are usually called field coils. The commutator was needed to produce direct current. When a loop of wire rotates in a magnetic field, the potential induced in it reverses with each half turn, generating an alternating currents. However, in the early days of electric experiments, alternating current generally had no known use. The few uses for electricity, such as electroplating, used direct current provided by messy liquid batteries. Dynamos were invented as a replacement for batteries. The commutator is a set of contacts mounted on the machine's shaft, which reverses the connection of the winding to the external circuit when the potential reverses, so instead of alternating current, a pulsing direct current is produced.

Pyrometer :

In its simplest sense, pyrometer is the measurement of temperatures. Practically speaking, in the business of heat treatment, the term also refers to the equipment, standards and specifications that make it possible to measure high temperatures accurately. In heat treatment, the need for accuracy even more critical. If the temperature reading for your furnace are inaccurate, those aircraft parts your heat treating could literally put lives at risk. AMS 2750**.**To address these complications, industry leaders have developed a number of systems and guidelines that help lead to consistency and quality. One of the most important such programs is the National Aerospace and Defense Contractors Accreditation Program .Programs is the National Aerospace and Defense Contractors Accreditation Program (NADCAP). NADCAP certification is essential to any business that wants to do heat treating work for the aerospace industry.

AMS 2570 covers all aspects of pyrometer in heat treatment, including –

- Controllers [calibrations, specifications and readability requirements]
- Thermocouples [calibrations, usage, types]
- Recording instruments [calibrations, accuracy] Calibration requirements for thermocouples and equipment.
- Accuracy requirements and tolerance for acceptance. Calibration procedures.

(a) Principle of pyrometer :

Temperature measurement is based on the measurement of radiation either directly by a sensor or by comparing with the radiation of a body of known temperature. The radiation pyrometer is a non contact type of temperature measurement. The wavelength region having high intensity is between 0.1 to about 10 μm. In this region, 01 to 0.4μm is the ultraviolet region, 0.4 to 0.7 is the visible region and 0.7 onwards is the infrared region. With the increase in temperature, radiation intensity is stronger toward shorter wavelengths. The temperature measurement by radiation pyrometer is limited within 05 to 8 μm wavelength region.

(b) Total radiation pyrometer :

A radiation pyrometer consists of optical component to collect the radiation energy emitted by the object, a radiation detector that converts radiant energy into an electrical signal, and an indicator to read the measurements. The optical pyrometer is designed to respond narrow band of wavelengths that fall within the visible range of the electro-magnetic spectrum. Thermal detectors are used as sensors. Their hot junction is the radiation sensing surface. Thermopiles can detect of all wavelength. It is important that gases like CO_2, H_2O and dust should not obstruct the path of radiation. The dust particles scatter the radiation, whereas CO_2 and water vapor selectivity absorbs radiation. Any instrument built to sense the radiation has to be in an enclosure to avoid dirt, dust and gases present in industrial environment. Normally a window is provided with some optical materials to see the radiating body. The materials should have good transmissivity. All optical materials allow only particular wavelength to pass through it with sufficient intensity. For other wavelength they are opaque.

Rechargeable battery :

Rechargeable battery is a type of electrical battery which can be charged discharged into a load and recharged many times as opposed to a disposable or primary battery, which is supplied fully charged and discarded after use .It is composed of one or more electrochemical cells The term accumulator is used as it accumulates and stores energy through a reversible electrochemical reaction Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network .Several different combinations of electrode materials and electrolytes are used, including lead-acid, nickel-cadmium, nickel-metal hydride ,lithium-ion polymer. Devices which use rechargeable batteries include automobile starters, portable consumer devices, light vehicles ,tools ,uninterruptible power supplies, and battery storage power stations.

Literature survey :

E.kardas at al (2012) He have determined the operating efficiency of the blast furnace by indentifying several factors influencing its performance. This is done by checking continuity of production, periodic maintenance of the machines and renovation of blast furnace'[1]Lawler (2012) He investigated thermal fluid heating system in electronics and nanotechnology industry as energy required for heat treatment process is very large. Asif Ahmad Bhat at.al (2012) have analysed on thermal aspect of induction furnace with complex geometry ,rising the maximum temperature in the furnace of about 1500^0celcius,current of 400A and frequency of 8KHz and finally concluded that only high melting point of the metal like copper can easily be hardened.[2]Viral Kumar Solanki at al (2013) has determined simulation of induction furnace by designing inverter snubber and rectifier and he found that at full load the furnace will give high power factor and total harmonic distortion will be low.[3] Bhuj bal Nitin B at al.(2013) investigated about the optimum thickness of the refractory to prevent heat loss and thus he concluded that it can be done by using 24 pulse convertor instead of 12 pulse convertor. There should not be any barrier for current and voltage waveform.[4]Vipul Gondaliya at. al; (2013) He used finite element analysis to optimize the thickness of refractory material which must range from (3-10) mm to prevent heat loss.[5]Nihar P Bara at al (2013) .He investigated Finite element analysis to evaluate the heat transfer characteristics of the composite wall thickness to achieve efficiencies in the furnace.[6]Ramesh Babu P et al (2013) have studied a model of hybrid active power filter to compensate the supply current frequency by the use of MATLAB simulation[7]. Nihar Bara at al (2013) have developed new generation Induction furnace with the help of numerical analysis by optimizing with several mechanical parameters of the furnace[8].Sri P.K Thakur at al (2014) He optimized the efficiencies of the furnace by best utilization of measurement and automatic control and best use of waste heat recovery from flue gases and reduction in specific fuel consumption. scale loss ,surface oxidation .controlling temperature to achieve the good quality of product[9]. Dr R.K. Jain at al (2014) has experimented the effect of reducing the excess air in the furnace and reuse of preheated air of 2000^0C which drastically compensate fuel consumption and melting rate also increases. [10] Dr Ali K M Alshaikhliai al (2014) had designed the coreless induction furnace to melt the metal with variable parameter and finally it is constructed.[11]Sneha P Gadpayle at al (2014) have experimented the burning loss on the material by varying the material composition without altering the grade. After several experimentation only 4.28% burning loss was reduced [12].Prof Uma Kulkarni at al (2014) have investigated the production of silicon wafers for PV Cells by induction melting and did the necessary steps to design the induction furnace. [13]She developed natural resonant frequency to get zero voltage or zero current switching of the convertor and there is a reduction in power losses. [14] Prof L.P. Bhamare at al (2015) have concentrated the research on furnace monitoring and billet cutting system. [15]Ufuomareter Anaidhuno at al (2015) have focused deeply on design of electric induction furnace for ferrous and non ferrous alloys and considered temperature measurement, holding capacity of metals depth/surface area to be heat treated ,safety in operation. space utilization. cost minimization and ease of transport and maintenance schedule.[16] Isam M. Abdulbaqi at al (2015)developed finite element method to perform electromagnetic thermal analysis of billet to a certain temperature in pre determined time.[17]Rakesh S, Ambade at al (2015) have stressed his research on energy conservation, which yield high quality steel with minimum time. Thus efficiency is directly depend on coil, height, charge mix, furnace utilization etc.[18] Blynn Ferguson et al (2017) determine the hardenability keeping in view of stress induced in side the axle rotating shaft .He did the hardening by scan heating method by which internal stresses and tendency to crack gets reduced [19]. Mrunal A. Kukade at al (2018) have investigated non uniform flame distribution, metal oxidation, scale formation and emission of pollutants and also suggested several ill practices which is to be improved from existing system in an oil fired or coal fired furnace. [20] Shimaa EI- Hadad at al (2018) have investigated the effect of heat treatment and titanium addition on the microstructure and mechanical properties of cast $Fe_{31}Mn_{28}Ni_{15}Al_{24.5}Ti_x$ High entropy alloys.[21]

Research objectives :

1 Waste recovery of exhaust gas exiting from furnace
2 Utilising this waste with a mechanical device to regenerate useful source favouring the entire plant
3 Develop concentration of waste exhaust gas to achieve the goal

Problem indentification of the project :

It is observed that a huge amount of power is consumed estimated at the end of the year in the heat treatment plant which is unable to save by any means .We have indentified a way by which small percentage of power can be saved and will bring quality, quantity and cost minimization from the output.

Research Methodology :

To analyze the desired target there are some procedures to be followed -

(a) Select iron specimen of square shaped and volume of the square equals volume say $125cm^3$.we took about 5kg material grade of steel selected C40. Hardness checked to be 150 BHN.
(b) We are preparing prototype model which is fabricated to test the power saving in the entire HT plant whose figure is shown below.
(c) Steps for conducting the investigation.

1. The specimen selected is undergone grinding ,cleaning, sulphating and allowed to remain still for some time.
2. The furnace is preheated to 300ºC.which is controlled by thermostat.
3. The shutter is opened automatically for entry of specimens and there is a trolley to load them on the rotating bed. Thereby the entry shutter is closed and packed tightly.
4. The rotary bed is inside the HT chamber of the furnace .It starts rotating as soon as hardening command is given and pyrometer is fitted to sense the mechanical properties of the specimen and displays on the screen.
5. The time duration is maintained as per planned that is for 5kg we can allow to harden for 5 hours
6. As soon as hardening completes, the shutter of exit door opens and is quickly dropped into quenching tank, mounted adjacent to HT chamber and the tank is filled with oil.
7. During hardening a huge amount of flue gases are evolved which is blown from chimney to outside. we will attach a exhaust ejector and feed to the separate chamber .
8. There will be a feed centrifugal pump to increase energy and this energy is transferred to wind turbine

9. The wind turbine will start rotating mounted inside the casing and thus there will be a development of rotational energy.
10. This rotational energy obtained from the shaft of turbine is captured and send through dynamo which generate electricity and stores electrical energy in the rechargeable battery.
11. Finally the rechargeable battery is full. As soon as it becomes full now there is a cutoff power from main supply which connects- automatic handling devices and there units, rotary bed ,heating coils surmounted over HT chamber and other minor units.

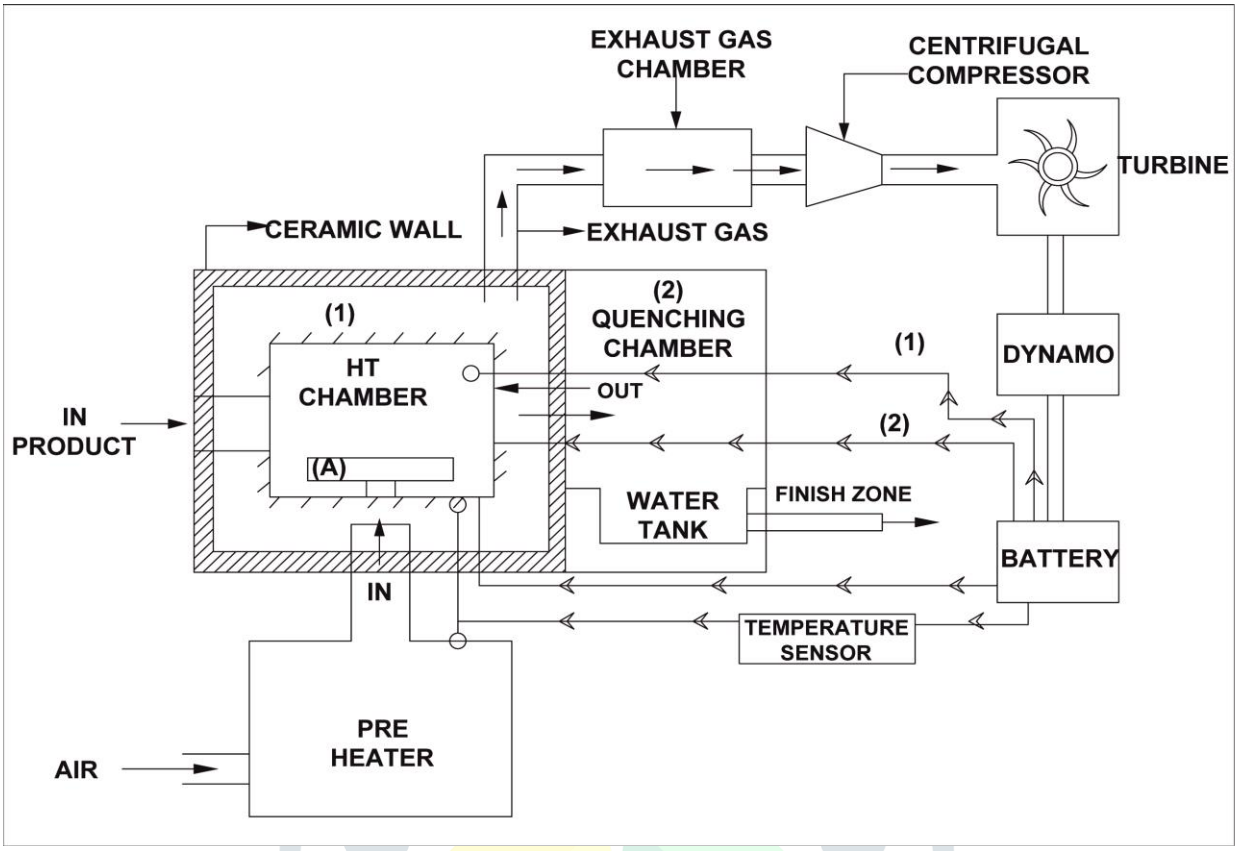


Figure No1 .Prototype Model of proposed furnace shown above.

Table No.1 Data collected for Conventional and proposed prototype model

S.NO.	Particulars	Conventional Furnace	Prototype Model
1	Diameter of exhaust gas duct	1 meters	0.05 meters
2	Velocity of exhaust gas	V_e=18.68m/s	V_e=18.66m/s
3	Selection of Batch size	5 ton/batch	5kg
4	Duration of Hardening	18hrs/batch	5 hrs/lot
5	Temperature of Hardening	1000^0C	300^0C
6	No.of hours of hardening /yr	8400	7800
7	No. of Batches per year	467	1560
8	Final Hardness attained in BHN	300	350
9	Height of chimney	50 meters	5 meters
10	power Cosumption/yr	1300000kwh	421kwh

Calculations :

Formula used

- Q = $C.A.\sqrt{2g.H.(\frac{T1-T2}{T1})}$

- Q = $A_d \times V_e$
- A_S = $\frac{3.14}{4} \times (D_T)^2$
- V_T = $3.14 \times D_T \times N_T$
- P = $0.5 \times p \times A_S \times (V_T)^3$

Where the symbols are having the meanings as follows:

Q = Discharge of exhaust gas from exit in m^3/s
C = Discharge coefficient (0,65 -0,70)
A = Area of cross section of chimney in m^2
g = gravitational acceleration in m/s^2
H = Height of chimney in m
T1 = Absolute average temperature of flue gas inside the stack in degree kelvin
T2 = Absolute outside temperature in degree kelvin
A_d = area of duct of exhaust chimney in m^2
V_e = velocity of exhaust flow in m/s
D_T = Diameter of the turbine in m
N_T = Revolution of turbine blades in rpm
ꝑ = density of the air in kg/m^3
A_S = Swept volume in m^2
V_T = Velocity of turbine in m/s

Values after calculating with the help of above formulas

Sr. No	Particulars	Conventional	Prototype model	Remarks
1	Discharge	14.76 cm3/s	0.11 cm3/s	Neglecting minor
2	Swept area	0-785 m2	0.00785 m2	Losses ,machining,
3	Velocity of turbine	52.33 m/s	3.14 m/s	Parameters and
4	Power consumption after modification	27078 kwh	54.27 kwh	Man power.

Results and discussion :

Sr. No	Particulars	Conventional	Prototype	Remarks
1	Power yearly consumption	Minimum 130000 kwh	Minimum 421 kwh	Taken from a plant SSI
2	Power saved by the project yearly	27078 kwh	84 kwh	Nearly 20% saved
3	Saved Power distribution	About 16% used and remaining for maintenance	About 14% used and remaining for maintenance	Reserved for special expenditure

Graph plotted against datas

Table No. 2
Power consumption (kwh) vs months of a year

Month	Power with Modification	Power without modification
1	108333	86666.4
2	216666	173332.8
3	324999	259999.2
4	433332	346665.6
5	541665	433332
6	649998	519998.4
7	758331	600004.8
8	866664	693331.2
9	947997	779997.6
10	1083330	866664
11	1191663	953330.4
12	1299996	103999.6

Graph No. 1
Power consumption conventional furnace without, with modification vs months of a year

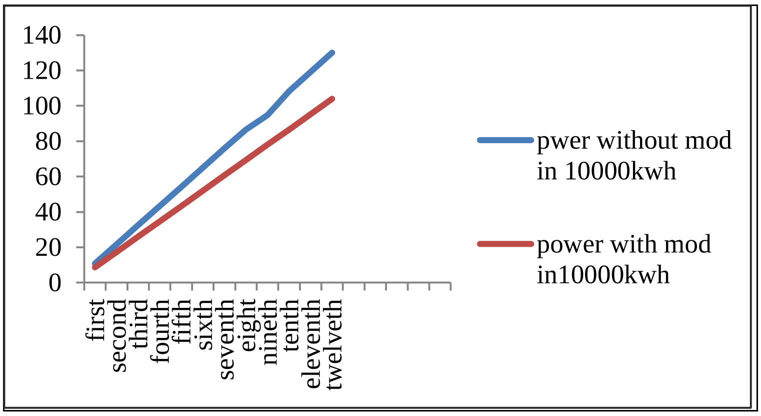
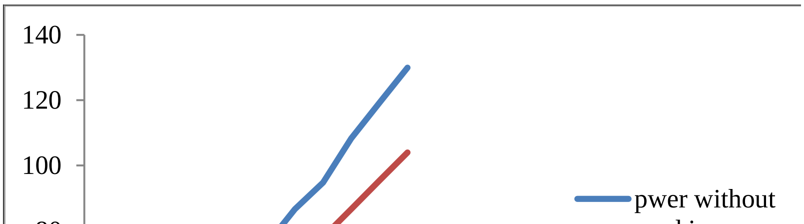


Table No. 2
Relation between power consumption after two days with and without modification

Days Gap	Without modification	With modification

Graph No. 2
Power consumption conventional furnace without, with modification vs two days of the month



2	7222	5777.6
4	14444	11555.2
6	21666	17332.8
8	28888	23110.4
10	36110	18888.8
12	43332	34665.6
14	50554	40443.2
16	57776	46220.8
18	64998	51998.4
20	72220	57776
22	79442	63553.6
24	86664	69331.2
26	93886	751088
28	101108	80886.4
30	105330	86664

Conclusion :

We thus can modify the economy of plant and quality is checked simultaneously. We have saved about 20% power from waste and is reliable for the plant running on long term else it will be failed. It is assumed that there must be continuous production also.

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