REPLACEMENT OF OIL FIRED HEATER WITH INDUCTION HEATER

(***For Punjab Forging and Foundry Cluster***)

Cluster Brief:

The Indian Forging Industry has emerged as a major contributor to the manufacturing sector of the Indian Economy. The composition of the Indian forging and foundry industry can be categorised into four sectors – large, medium, small and micro. The industry is predominantly labour intensive but now with increasing globalization it is becoming more capital intensive. The current investment in the plant and machinery by Indian forging companies is worth of INR 27,833 crore.

The Indian forging industry is well recognized globally for its technical capabilities. With an installed capacity of around 38.5 lacs MT with capability to forge variety of raw materials like Carbon steel, super alloy, titanium, aluminium and so forth as per the requirements of user industry. [1] The increasing trend in exports and domestic sales are the triggers for capacity utilization of 60-80% observed in past few years. The small scale units too are increasing their capital investment to keep pace with the increasing demand especially in the global markets as also to broaden the areas of demand for forgings. Many of them are now suppliers to Original Equipment Manufacturers (OEMs) in the sectors like automobile, construction and mining equipment, railways, etc. which speaks volumes about efforts at technology and quality upgradation.

These industry needs energy in each and every process of value addition. Just like any other industry in India, the forging industry is also facing stiff competition from international market due to efficient technologies and their cost competitiveness. The major forging clusters in India are Pune, Rajkot, Mumbai, Vadodara, Chennai, Bangalore, Coimbatore, Hyderabad, Kolkata, Jamshedpur, Ludhiana, Faridabad, Ghaziabad, Gurgaon, etc.

In North India, the region of Batala, Jalandhar and Ludhiana represented in adjoining map is known for its forging and foundry industry. The major products that the forging industry in the region manufactures are bearings, hand tools, gears, valves, automotive products and agricultural machinery. The foundry industry is concentrated in the Batala region which is mostly involved in job work based casting production. The foundry industry mostly produces castings for agricultural equipment, engines, gears etc.

Table 1: MSME forging and foundry industry details in Punjab region

S. No.	Region	Type	Number of units	Article manufactured
1.	Batala	Foundry	100	Agricultural equipment, motor casing, gearboxes

[1] The data adopted from Association of Indian Forging Industry (AIFI) website

S. No.	Region	Type	Number of units	Article manufactured
2.	Jalandhar	Forging	200	Hand tools
3.	Ludhiana	Forging	1500	Hand tools, Automotive parts, Railway parts

The production processes followed in hand tool and automotive parts is shared below. The areas where we propose the intervention are highlighted in red.

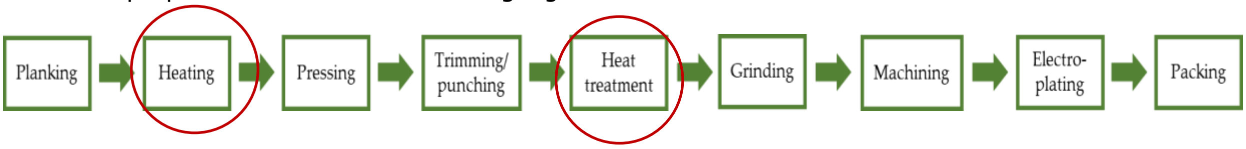

Figure 2: Process in automotive parts manufacturing

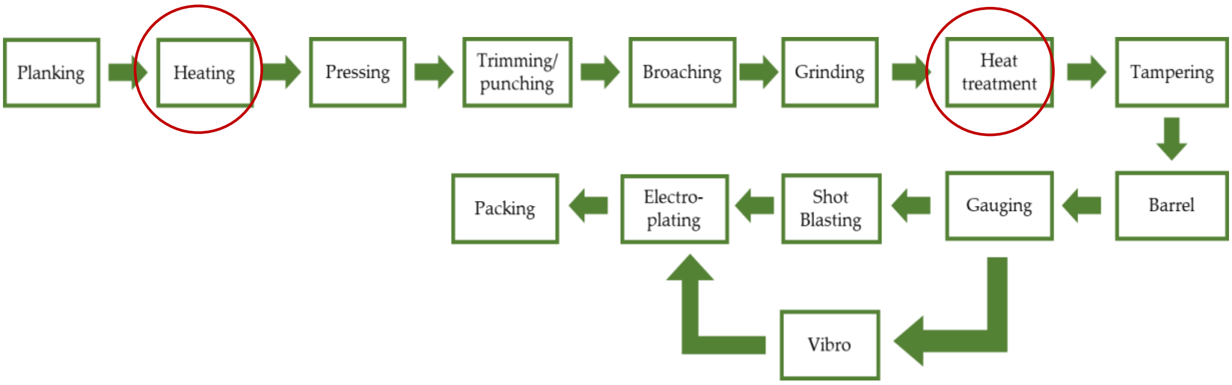

Figure 1: Process in hand tool manufacturing

Existing practice:

Forging process operate on work pieces with compressive forces applied by hammers or presses through the use of dies and tools to transform into desired dimensions. There different types of forging processes mostly categorized into cold, warm and hot forgings.

In a hot forging process, a part is heated over the material recrystallization temperature prior to forging. This process enables a part to be moulded with minimum pressure and produces finished parts that have a reduced residual stress, thus making it easy for machining or heat treatment. In warm forging proceeds, a part is forged below the recrystallization temperature, usually below 700°C.

Most of the units in forging industry in Ludhiana and Punjab region are using oil/ gas fired heating furnaces. Few factories do have induction heaters installed but these heaters are mostly more than a decade old. The billets in these furnaces are usually heated up to the temperature of 1200 °C. The efficiency of the gas/ oil fired furnaces is low due to multiple reasons

1. The combustion chamber of the exiting furnace is not optimally designed so flue gas measurement was not measured correctly
2. door opening loss is high as flame is coming out directly from the door
3. Local fabrication: Since most of the furnaces are fabricated locally, they are not designed to operate optimally
4. Multiple air ingress points in the furnace leading to higher fuel consumption
5. The surface temperature of the furnace is about 120^0 C
6. Inherent characteristic of furnace to heat the refractory lining first and then heat is transferred effectively to charged material

7. Lack of waste heat recovery systems like recuperator as exhaust temperature is in the range of 240 ^{0}C -250 ^{0}C

Figure 3: Oil fired furnace in operation

Due to all these reasons, the consumption of fuel for a 250 ton/ month production varies in the following range:

a. Oil: 3,250 liter/ month to 4,500 liter/ month
b. Gas (LPG): 15,000 kg/ month to 16,000 kg/ month

Currently, almost all the units are using oil/ gas fired furnace and very few induction heating furnaces for heating the raw material. During the audits, the efficiency of oil fired furnace was measured and calculated to vary in range of 7% to 10%.

It is identified that the installation of new IGBT based induction heaters may substantially reduce energy consumption and associated costs

Proposed technology:

Based on the initial surveys, energy audits of forging units and discussions with few unit owners, we understand that there exists a good interest among the unit owners to shift from oil fired re-heating furnace to induction based reheating furnace. Billets with higher mass and can also be heated to the desired temperature in a very short time span. Since, the heating of billet in induction billet heater happens by means of electromagnetic field, the heating phenomenon can be concentrated and billet can be reheated evenly. Apart from production, the capacity of proposed system will also depend on operating hours, type of raw materials used and size of raw material to be reheated.

Induction Billet Heating System

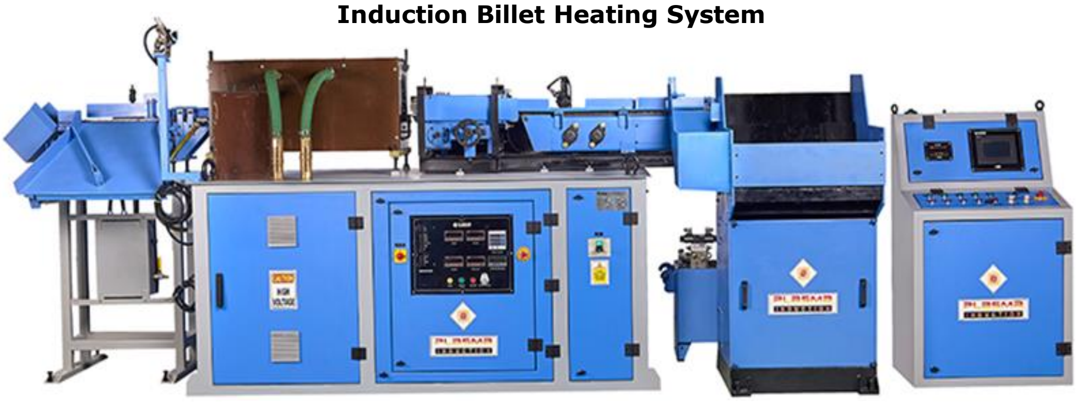

Figure 4: Representative image of induction billet heater

Image courtesy: Plasma Induction

Basic building block of Induction billet heating furnace:

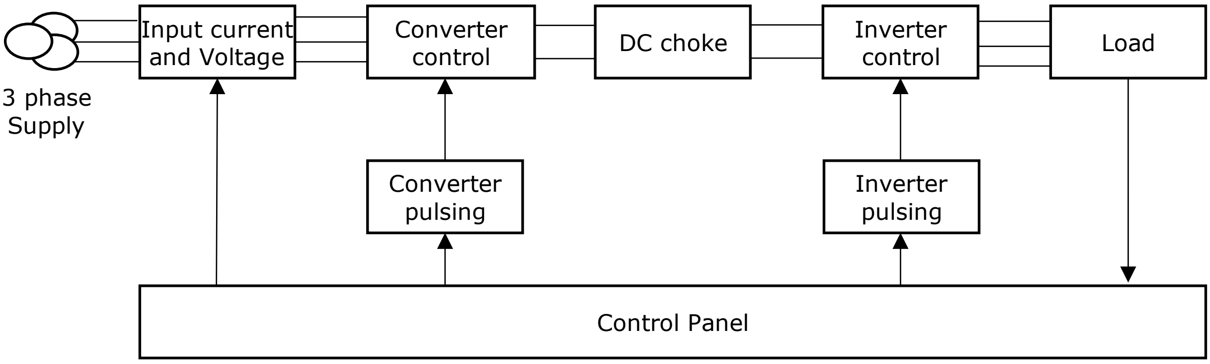

Figure 5: Simplified block diagram of induction billet heater

The block view of technology is provided here for highlighting the simplistic operation and control mechanisms involved in the heating process. The electronic circuitry brings the timely precision operation and repeatability of the desired outcome.

The effect of each of these factors on choice of technology is provided below:

Production and hours of operation

The scale of operation determines suitability of technology to a large extent as monetary savings achieved are in direct proportion to the production. For example, if monetary savings of a technology is marginal to current practice, however, scale of operation is large then overall monetary savings become so much that even an expensive technology has an attractive payback period. The overall increase in productivity is always encourage and welcomed by business owners for incrementing scale of operations with less time and capital invested.

Figure 6: Induction heater in operation

Raw Material

Type of raw material

Induction heater works directly, only with conductive materials, normally metals. Plastics and other non-conductive materials can often be heated indirectly by first heating a conductive metal susceptor which transfers heat to the non-conductive material. Use of non-conductive material may permanently damage the coil and should be strictly avoided. With conductive materials, about 85% of the heating effect occurs on the surface or "skin" of the part; the heating intensity diminishes as the distance from the surface increases.

Size of raw material

So small or thin parts generally heat more quickly than large thick parts, especially if the larger parts need to be heated all the way through. Research has shown a relationship between the frequency of the alternating current and the heating depth of penetration: the higher the frequency, the shallower the heating in the part. Frequencies of 100 to 400 kHz produce relatively high-energy heat, ideal for quickly heating small parts or the surface/skin of larger parts. For deep, penetrating heat, longer heating cycles at lower frequencies of 5 to 30 kHz have been shown to be most effective

Justification of technology selection:

Thermal energy profoundly used in forging production processes. The thermal energy is needed to either equipment heating or process heat treatment requirements. Process heat treatment includes tampering, hardening, specific heating requirements. Currently, sector industries are dependent on consumption of furnace oil contributing to nearly about 80% of total energy needs. The studies shows the energy requirement in heating furnaces form a major chunk of energy (including thermal and electrical) needed in the forging unit. A representative chart below depicts the same.

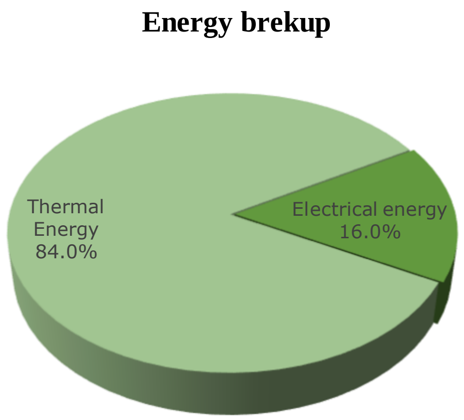

Figure 7: Representative energy breakup of a unit

The industries use mix of raw materials (e.g. Iron and SS) for the products. Steel type includes mild steel, cobalt steel, stainless steel, aluminum steel, and round steel bars, etc. being used. Also, iron types like cast iron, pig iron, scrap iron along with aluminum, gun metal, zinc, brass metals, EN8, EL45 are being used. Most of these raw materials are available locally or obtained from other domestic markets and are manufactured in India. The most of the units utilizes raw material sizes from 8 to 250 mm for forging applications.

Considering the criteria of raw material and productivity in extent to induction billet for different applications, following advantages can be highlighted over oil fired furnace:

Productivity

Induction heating claim to be faster, accounting more billets heated in shorter period. Since very high temperatures can be reached in very less time the throughput time for each billet is reduced. The approximate temperature requirement for the cluster is between 1050°C to 1200 °C depending on type of material such as chrome vanadium steel. This further can be complimented by automatic billet feeding system.

Higher heating efficiencies

The oil fired furnace needs to be heated and then raw material is poured for heating. The heating losses due to conduction, convection and radiation are accounted during this process. While in induction billet heater the work piece can be inserted immediately and for shorter time. Comparing an overall maximum heat transfer efficiency of oil fired furnace is around 15%, on the other hand induction furnace, this can go up to 70%. The heating extent can be controlled by simple change in frequency according to type, size and thickness, area to heat of the raw material.

Uniform heating

Induction heater helps in uniform heating across the billet. This helps in reducing the material wastage, better product quality and improved overall workflow. For any critical OEM component manufacturers the quality constraints are imperative. The complementary accept or reject system can take a notch up by sorting the non-uniformly heated billets to be sorted automatically.

Easy control

Due to electro-mechanical amalgamation of technology the heating control in induction furnaces is quick and with minimum response time. The visual indications, feedback systems helps in reducing wastage of raw material due to overheating.

Operating Cost

The overall operating costs of the induction furnace are lower. This is due to the fact that, manpower requirement is lower, no insulation problems lower losses due to reduced rejection

Scale losses

The scale losses in the raw material heated in induction furnace are lesser. This will also depend on type of raw material being heated and its magnetic properties, but, overall scale losses are lesser

Floor size

The floor size requirements are less as compared to oil fired furnace. So as to storing the large quantity of fuel is eliminated, leading to overall improvement in EHS conditions.

Environment friendly

By the extent of phenomenon of induced electromagnetic current, induction furnaces heat up the pieces. The technology is environmental friendly without producing any flue gases. As compared to most of the conventional fossil fuel based technologies, it is cleaner and eliminates the cost of installing pollution control equipment.

Ease of operation

The latest advancement in induction billet heater technology sets human machine interface interactive with the operator friendly intelligent digital displays, control of voltage, frequency, current and output power for monitoring process parameters, simple set-up and diagnostics information.

However, there are certain challenges involved with installation of electric billet heaters that needs to be thought through before making investment:

High cost

The cost of technology is high when compared to traditional oil/ gas fired furnaces. Also, associated costs such as higher sanction load or provision of additional transformer or cost of additional cabling are some of the costs that sometimes makes cost of technology even higher than previously thought.

Specific product size

In an electric billet heater, the heating is done with raw material is in between the coils so that even heating is achieved. However, the size and dimension of coil are very specific to the product that needs to be heated up thereby making same coil not suitable for use for a different product with different dimensions.

Trained manpower requirement

The operation of induction heater requires a skilled technician as current in heater has to be changed depending on thickness of material as well as there are other ancillary equipment that needs maintenance as well. However, oil/gas fired furnaces are old technologies and there are plenty operators available in market who can operate such furnaces.

Energy & monitoring saving:

An actual case has been considered for calculating the energy and monetary benefits where energy consumption for 3000 ton annual production is estimated. The rated capacity of heater used in calculation is 350kW. The saving calculations are as below:

Table 2: Energy saving calculations

Parameters	Unit	Values	Unit	Values
	Oil fired furnace		Induction heater	
Time	sec	300	sec	35
Pieces produced in measured time	No	2	No.	1
production time 1 piece	sec	150	sec	35
Weight of 1 piece of billet	kg	2.32	kg	9.90
Operating time	Hours	8.	Hours	8
Operating time	sec	28,800	sec	28,800
Billets heated in 8 hours	No.	192	No.	822.86
Weight of total billets	kg/day	445.44	kg/day	8,146.29
Fuel used in heating furnace	l/hr	10	kWh/ hr	364.60
Fuel used in a day	l/day	80	kWh/ day	2,916.80
Temperature of billet before entering the furnace	°C	30	°C	30
Temperature of billet leaving the furnace	°C	1,200	°C	1,200
Specific heat capacity of Cast Iron	kJ/kg	0.46	kJ/kg	0.46
Calorific Value of fuel	MJ/kg	37.70	MJ/kWh	3.60
Input Heat Value in a day	MJ	3,016	MJ	10,500.5
Output heat value in a day	MJ	239.74	MJ	4,384.33
Efficiency of Furnace	%	7.95%	%	41.75%
Fuel needed for heating 1 kg billet	l/kg	0.18	kWh/kg	0.36
GHG emission in heating 1 kg billet	kg	0.53	kg	0.33
GHG emission in heating 3000 ton billet	kg	15,83,675	kg	9,77,484
Cost of 1 unit of fuel	₹/l	40	₹/kWh	7.50

Parameters	Unit	Values	Unit	Values
Cost of fuel for heating 1 kg billet	₹/kg	7.18	₹/kg	2.69
Cost of heating 3000 ton billet annually	₹	2,15,51,724	₹	80,56,187

It can be inferred from above that there is significant savings in cost of production through induction billet heater. A simple payback period estimation of installation of such 350 kW induction billet heater is provided below:

Table 3: Simple payback analysis

Parameters	Unit	Values
Total cost savings in 3000 ton annual production	₹	1,34,95,537
Cost of 350 kW induction billet heater	₹	80,00,000
Simple payback	months	7.11

The benefits can be summarized as:

- ✓ Reduction in specific energy consumption of forging furnace
- ✓ Reduced environmental pollution
- ✓ Better productivity

Replication Potential:

Based on the discussion with associations, units, sample survey and energy audits, it is estimated that the technology has an initial replication potential in 20 units of the cluster with an annual average production of 1,000 tons. This replication potential is based on the survey of units conducted so far.

Table 4: Replication potential calculations in cluster

Parameters	Units	Values
Reduction in cost of heating 1 kg billet	₹/kg	4.50
Number of units with replication potential	No.	20
Average annual production of each unit	tons	1,000
Total annual production in 20 units	tons	20,000
Total cost saving estimated in 20 units	₹	8,99,70,248.46
Cost of replicating technology in 20 units	₹	16,00,00,000.00
GHG emission reduced in heating 1 kg billet	kg	0.20
Total GHG emission estimated to reduce in 20 units	kg/year	40,41,270.41

Total TOE reduction	TOE	3,013.13

Availability of the technology

There are good many technology providers available in India and many of them have their base in Ludhiana, Jalandhar, Amritsar or Chandigarh. The following are the technology providers available in the cluster.

1. **Inductotherm (India) Private Limited**

   Address: 203, Vileram Tower 6, Rajendra Place, New Delhi, Delhi 110008

2. **EMT Megatherm Pvt. Ltd.**

   Address: 1, Taratala Road, Kolkata- 700088

3. **EFD Induction Private Limited**

   Address: 201, 2nd Floor, ILD Trade Centre, Sector 47, Sohna Road, Gurugram, Haryana 122018

4. **Plasma Induction Private Limited**

   Address: 330/1, Hajipur, Near JK Laxmi Cement, Ta. Kalol, Dist. Gandhinagar, Gujarat-382721

5. **Interpower induction India**

   Address: Opp SP Stadium, Navrangpura, Ahmedabad, Gujarat

Effect on the process

Due to improved and more even distribution of heat, this technology can increase the heating process throughput, reduce wastage due to reduction, provides faster heating and reduces impact on air pollution.