United Nations Industrial Development Organization

Global Environment Facility

Bureau Of Energy Efficiency

Detailed Energy Audit Report

M/s Jaina Forging
Nagaur Handtools Cluster

Under GEF-UNIDO-BEE project

Promoting energy efficiency and renewable energy in selected MSME clusters in India

January 2016

pwc

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List of abbreviations

APFC	Automatic Power Factor Controller
AVVNL	Ajmer Vidyut Vitran Nigam Limited
BEE	Bureau of Energy Efficiency
DISCOM	Distribution Company
GEF	Global Environment Facility
HP	Horsepower
kCal	Kilo Calories
kVA	Kilo Volt Ampere
kVAr	Kilo Volt Ampere reactive
kW	Kilo Watt
kWh	Kilo Watt Hour
MSME	Micro, Small and Medium Enterprises
MT	Metric Tonne
PMU	Project Management Unit
UNIDO	United Nations Industrial Development Organization

Acknowledgement

We sincerely thank GEF- UNIDO-BEE for associating PricewaterhouseCoopers Private Limited (PwC) in its prestigious project "Promoting energy efficiency and renewable energy in selected MSME clusters in India" which involves developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India. Nagaur handtools cluster is one of them.

We express our sincere gratitude to all following officials of GEF-UNIDO-BEE PMU for their valuable support and guidance during the project:-

- Mr. Milind Deore, Energy Economist, BEE
- Mr. Abhishek Nath, National Project Manager, UNIDO
- Mr. Niranjan Rao Deevela, National Technology Coordinator, UNIDO
- Mr. Ashish Sharma, Project Engineer, BEE

PwC is thankful to Nagaur Handtool Manufacturer's Association for extending support for this assignment. We are also thankful to Mr. Sanat Kumar, Owner, Jaina Forging and his team for giving full support during the energy audit. We would like to thank Mr. Rajiv Singhal, Cluster Leader, GEF-UNIDO-BEE Project for providing on-field support during the energy audit.

Executive Summary

Jaina Forging is located in Basni Industrial Area of Nagaur and is involved in manufacturing of pliers. It uses EN 8 as raw material which is sheared into appropriate size through a shearing machine. Thereafter, blanks are fed to reheating furnace for heating up to a temperature of around 1150 – 1200 °C. After which the heated blank is rolled and pressed to give the shape of plier. During the process, excess material is cut and finally end cutting is done so that the final product is of correct size.

During the energy audit, following energy efficiency opportunities were identified:

S.No.	Energy Efficiency measure	Investment (INR)	Savings (INR)	Payback period (months)
1	Installation of electric billet heater	11,27,000	4,58,974	30
2	Installation of cogged belt on load side and poly-V belt on common shaft drive side	13,291	8,845	18
3	Preheating arrangement for raw material	20,000	56,033	4
Total		**11,60,291**	**5,23,852**	**27**

The details about the unit, load profiles, efficiency of furnace and description of energy conservation measures are discussed in appropriate sections of the report.

1. Project Background

1.1. Background of the project

GEF-UNIDO-BEE is developing and promoting market environment for introducing energy efficiencies in process applications in 12 selected energy-intensive MSME clusters in India which includes Nagaur handtools cluster also.

The overall motive of this assignment is to improve the productivity and competitiveness of units as well as to reduce overall carbon emissions and improve the local environment.

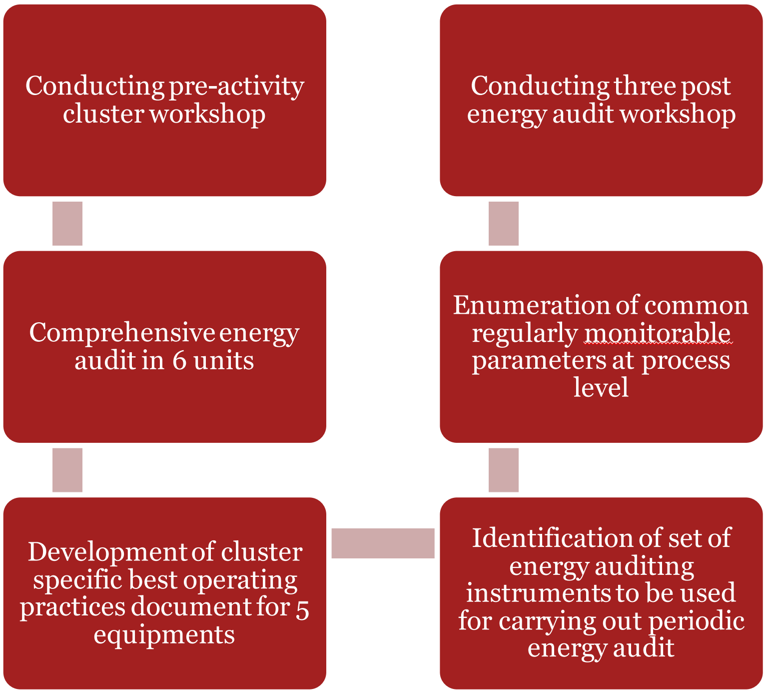
1.2. Introduction to assignment

Under GEF-UNIDO-BEE project 'Promoting energy efficiency and renewable energy in selected MSME clusters in India' India', PwC has been appointed for conducting activities of energy audit and dissemination in the Nagaur Handtools Cluster.

1.3. Scope of services

The activities being conducted by PwC under this assignment are shown at Figure 1.

Figure 1: Scope of services



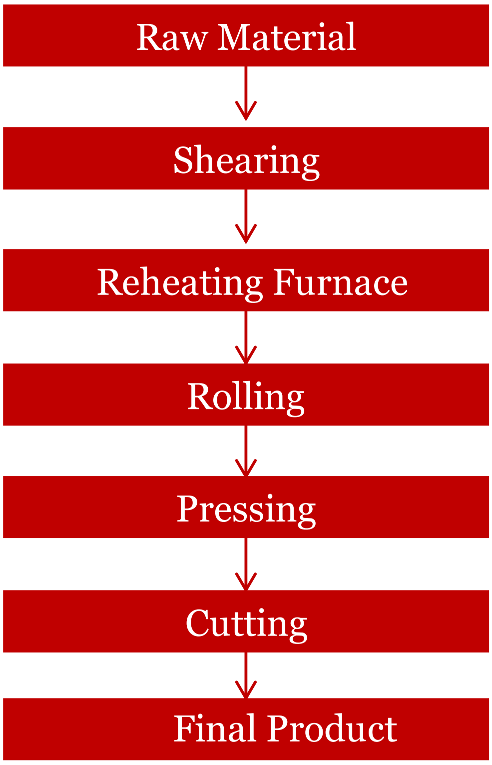
This current report has been prepared under the task 2 of above scope of services i.e. conducting comprehensive energy audits in 6 units in the cluster.

2. Energy Audit at Jaina Forging

2.1. Process flow

The process flow at Jaina Forging is shown at Figure 2 below. The raw material (EN 8) is sheared into appropriate size through a shearing machine. Thereafter, blanks is fed to reheating furnace for heating up to a temperature of around 1150 – 1200 °C. After which the heated blank is rolled and pressed to give the shape of plier. Then, the excess material is cut and finally end cutting is done so that the final product is of correct size. This is depicted in the following figure.

Figure 2: Process flow



The specialized instruments that were used during the energy audit included:

- Non-contact Infrared Thermometer (Testo-845 and Extech)
- Flue Gas Analyzer (KANE 900+)
- 3-phase Power Analyzer (Krykard, Circuitor)
- Digital Tachometer (Extech-461995)

Details about the make of energy audit instruments are provided at **Annexure A.**

This report presents the field measurements, design and operational data; and data analysis.

2.2. Baseline information of Jaina Forging

In order to assess the present energy consumption levels and possible energy efficiency measures at Jaina Forging, basic and general information was collected during the audit conducted on 9th and 10th June 2015.

The details of energy audit of unit are provided below.

2.2.1. About the Unit

This unit is located in Basni Industrial Area of Nagaur. The baseline profile of the unit is presented in Table 1.

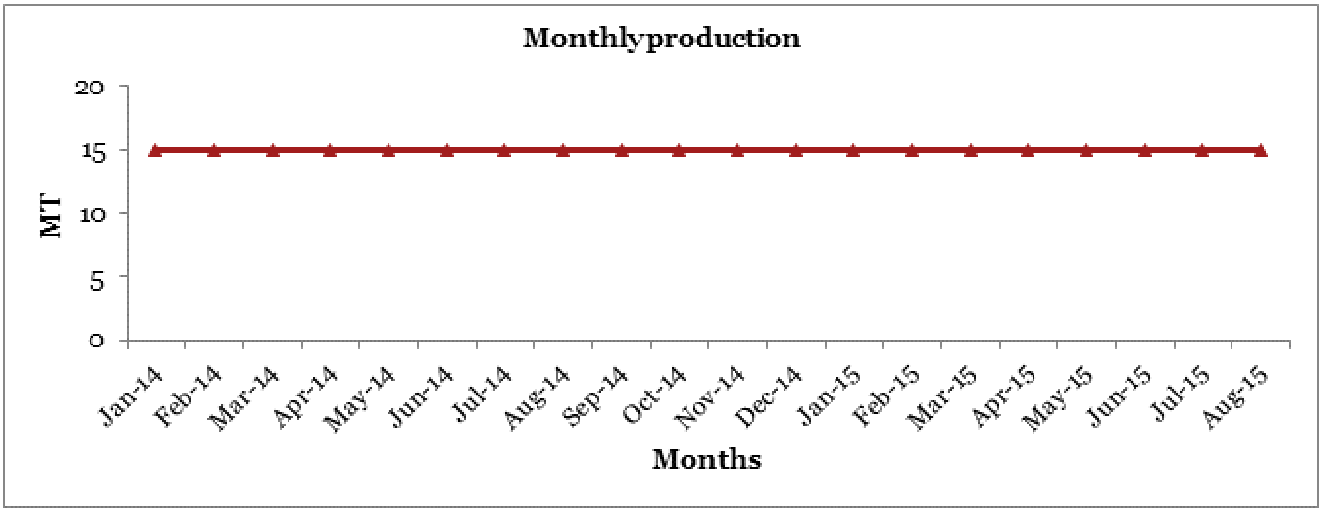
Table 1: Baseline profile

Parameters	Details
Name of the unit	Jaina Forging
Address of the unit	RIICO, Industrial Area, Basni Road, Nagaur
Name & contact number of contact person	Mr. Sanat Kumar, Partner Mobile - 9414216962
Date of Audit	9th and 10th June 2015
Raw material	EN-8
Final product	Plier 8”
Furnace	Box type
Dimension of furnace	34”4me21.5”1.524”4
Fuel used	Furnace oil
Press hammer weight	150 kg
Daily production	1700 pieces
Operating hours/day	7 hours
Sanction load	24 hp

2.3. Monthly trend of production

The audit team has collected monthly production data from the unit and the same has been depicted in the following figure. The monthly production is constant at 15 MT/month.

Figure 3: Monthly production data



2.4. Past electricity bill analysis

The electricity bills of unit are based on small industry tariff (LT-5) specified by AVVNL. The details of this tariff category are:

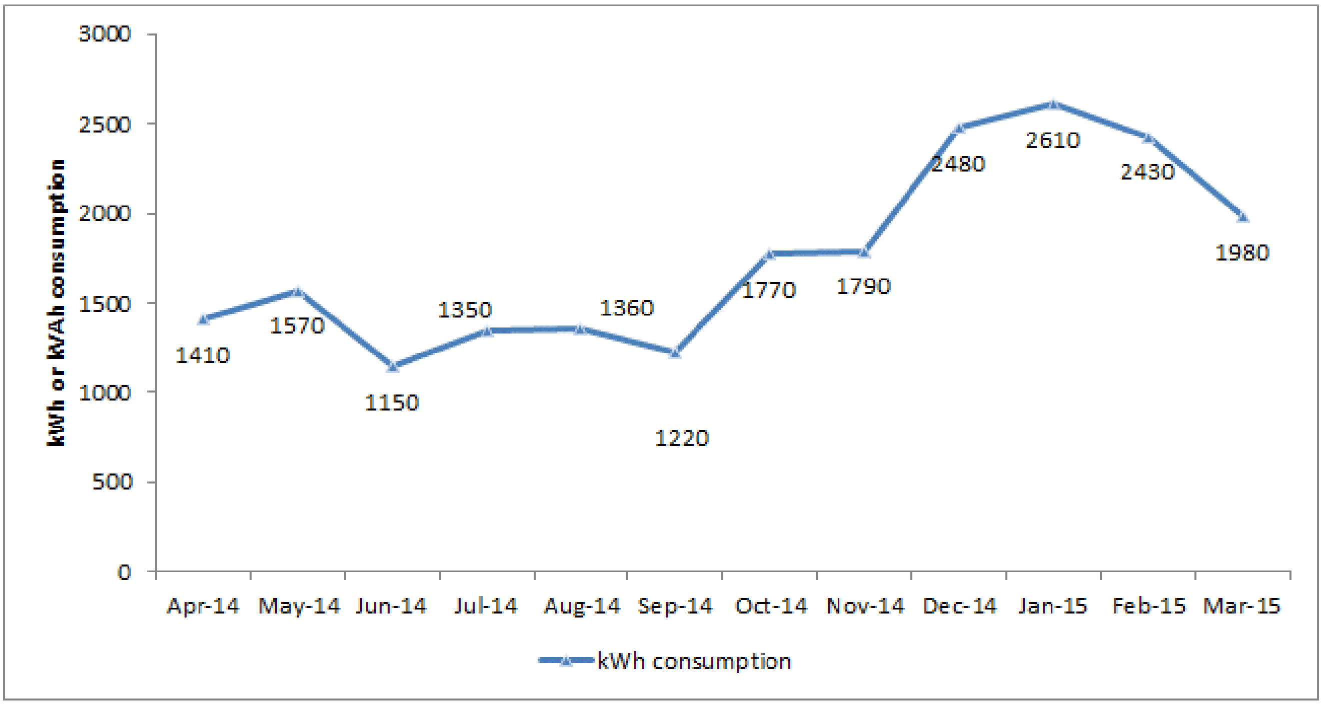
Table 2: Tariff description

Parameter	Specifications
Category description	Sanction load above 5 kW and not exceeding 25 hp
Fixed charges	INR 60/ kVA
Energy charges	INR 4.85/ kWh

* Electricity tariff has been revised to INR 5.85 from March 2015

Electricity bills were collected from April 2014 to March 2015 for the purpose of analysis.

Figure 4: Energy consumption pattern



It can be inferred from above figure that the energy consumption peaks during months of December, January and February prior to which the consumption was low in month of June, July, August and September. Further, the average energy consumption, for the said period, is 1646 kWh/month.

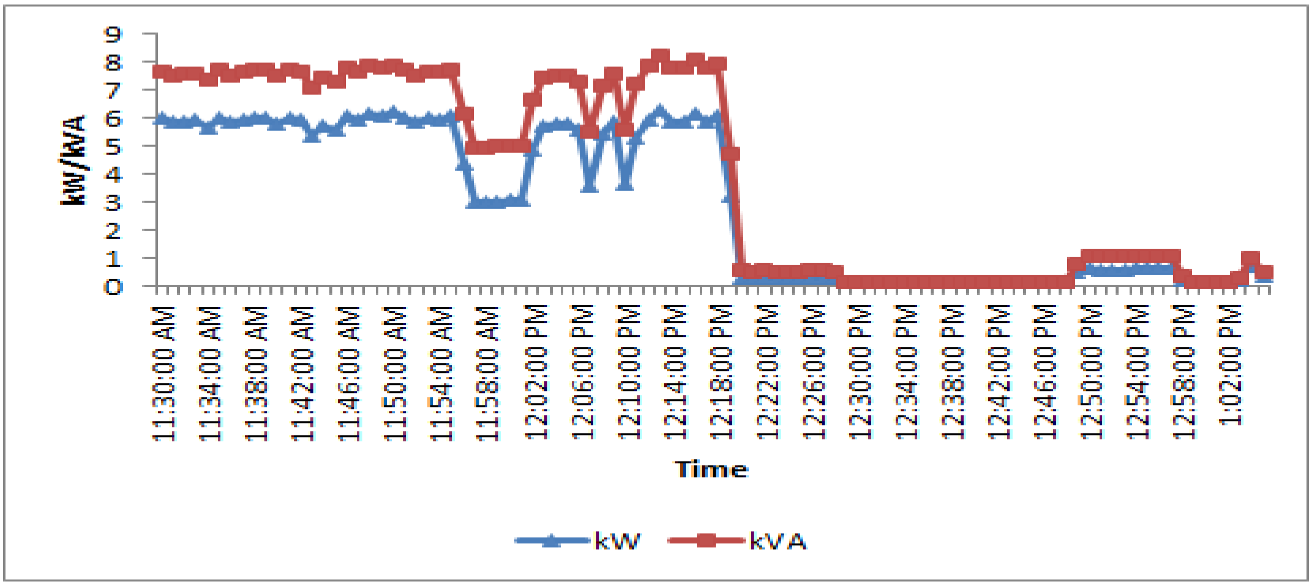
2.5. Load profile of Jaina Forgings

In order to derive the load profile of the unit, many electrical parameters were measured by using a sophisticated portable 3-phase power analyser (KRYKARD).

2.5.1. Load (kW) and apparent power (kVA) profile

Load profile and apparent power profile is a graph of the variation in the electrical load versus time. In any electrical system, the vector sum of the active power (kW) and reactive power (kVAr) make up the total (or apparent) power (kVA) used. This is the power generated by a generation station for the user to perform a given amount of work. Total Power is measured in kVA (Kilo Volts-Amperes) and the load or active power is measured in kW (kilowatts) and they become equal as and when the power factor approaches unity. Total electricity charges (units and demand) are based on the load or active power (kW) and apparent power (kVA).

Figure 5: Active power (Load) and apparent power profile during audit



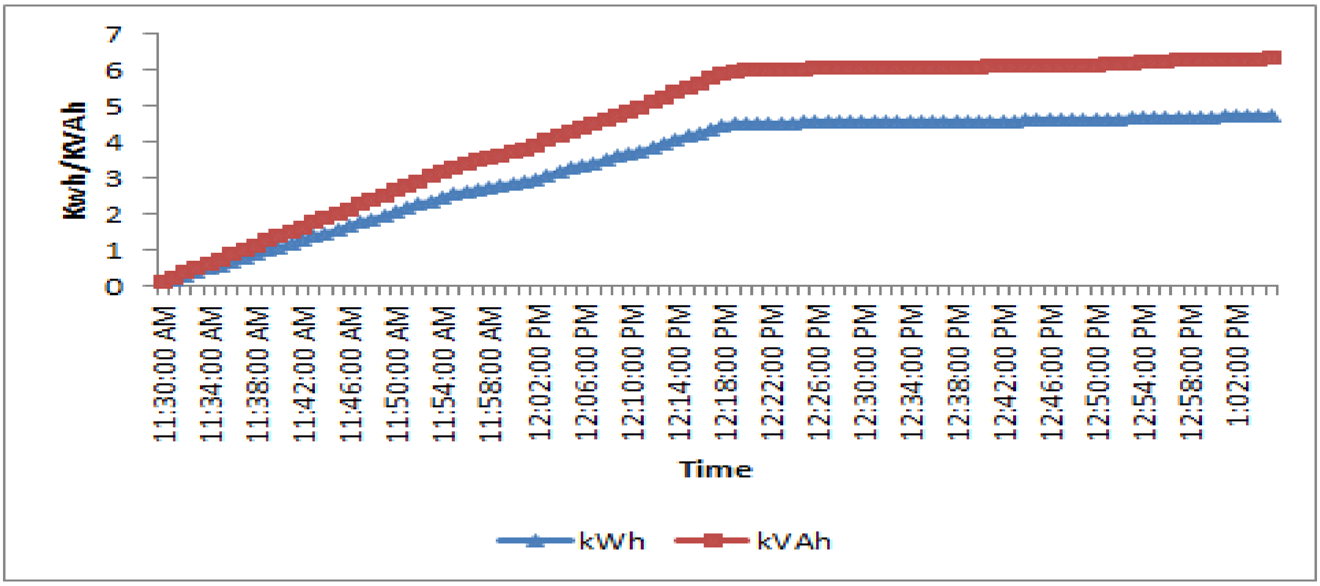
Observations made from the above graph:

- The maximum input power drawn by the unit is 6.3 kW. The graph shows that the unit stopped operation around 12:21 PM.
- Apparent power curve (kVA) line is significantly above the active power (kW) line indicating that power factor is on lower side.

2.5.2. Electricity consumption (kWh) profile

Electricity consumption profile is the pattern of the consumption of electricity in the unit during the energy audit. The following graph captures the electricity consumption (kWh) profile of the unit:

Figure 6: Electricity consumption (kWh) and (kVAh) profile during audit



Observations made from the above graph:

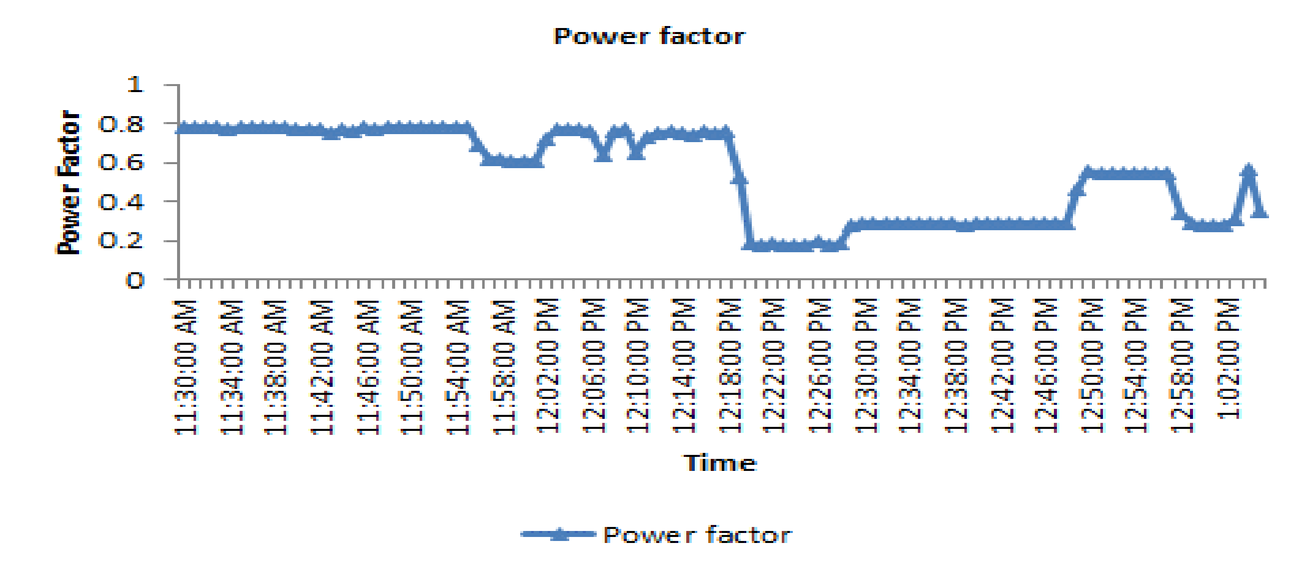
- The unit consumed nearly 4.73 kWh and around 6.32 kVAh during the recording period of almost 92 minutes.

2.5.3. Power factor profile of the unit

Power factor is an important parameter for the unit since its billing is based on kVAh wherein power factor plays a major role. Also, DISCOM's supplying power to the units impose power factor surcharge on the bills in case the power factor is below 0.90.

The following graph captures the power factor profile of the unit:

Figure 7: Power factor profile during audit



Observations made from the above graph:

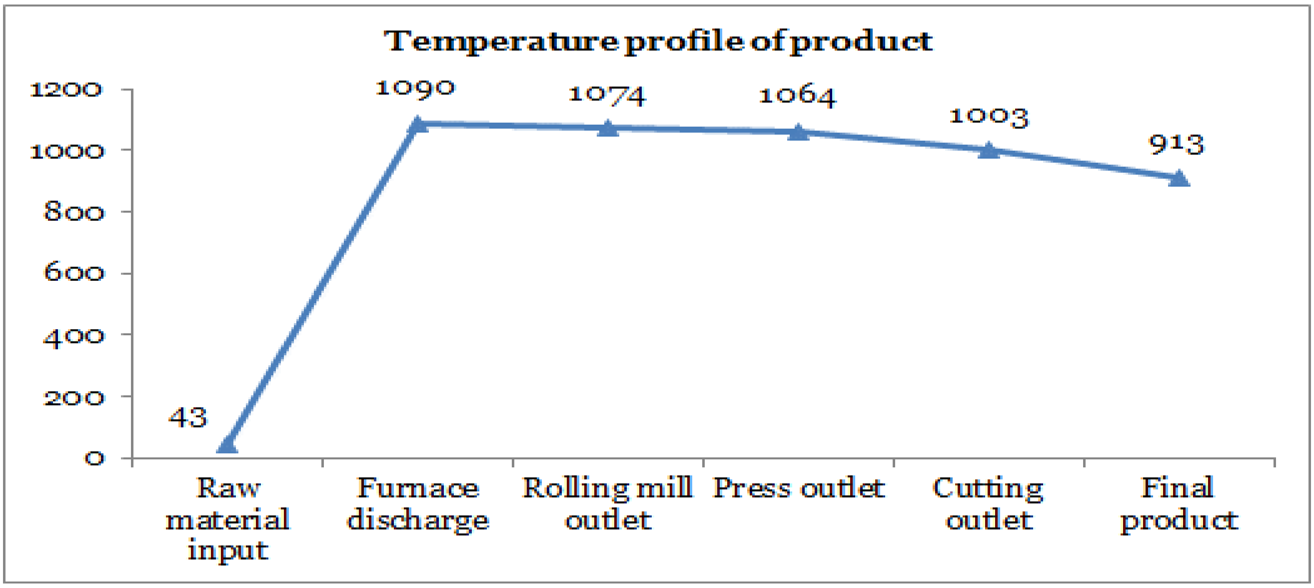
- The power factor of the unit is on lower side with maximum power factor being at 0.785
- If in future they go for capacity expansion, then increase in sanction load will include them in kVAh billing category. Hence, it is advisable that the unit may consider installing capacitor banks for improving the power factor so that they do not get charged with power factor surcharge.

2.6. Temperature profile of process and furnace

2.6.1.1. Temperature profile

During the baseline energy audit, temperature was measured at various stages of the process such as raw material temperature, furnace discharge, rolling mill outlet, press outlet, cutting outlet and final product. The temperature profile is presented at following figure.

Figure 8: Temperature profile from raw material to final product



There is total temperature drop of around 178°C from furnace outlet till final product.

2.6.1.2. Skin temperature

The skin temperature of furnace was captured using infrared thermometer. The temperature profile is mentioned below:

Figure 9: Skin temperature of furnace

Jaina Forging

Discharge side		
265	248.4	231.9
300.1	278.5	203.2
255		
Burner side		
358.1	271.5	266
307.9	267.5	207.7
280		

Back Side	
205.1	193.1
189.7	200.9
197	

It can be observed that the skin temperature is very high indicating that refractory lining is not proper inside the furnace and it also indicates that surface insulation is not present.

2.7. Thermal efficiency of furnace – direct method

Furnace thermal efficiency calculation by direct method involves comparison of useful heat content in the stock with the total thermal energy input to the furnace. Thermal efficiency for the reheating furnace is calculated by direct method in table below.

Table 3: Thermal efficiency of furnace – direct method

Parameter	Unit	Value
Production on audit day	kg/day	314.5
Furnace throughput	kg/hr	44.93

Parameter	**Unit**	**Value**
Fuel Consumption rate	kg/hr	6.88
Calorific Value of Fuel	kCal/kg	10,880.00
Specific heat of the material	kCal/kg °C	0.12
Material charging temperature	°C	43.00
Material discharge temperature	°C	1,090.40
Furnace efficiency by direct method	**%**	7.55

It can be seen from above table that furnace thermal efficiency is around 7.55% as calculated by direct method. However, using direct method, one cannot determine different heat losses associated with furnace operation. Hence, indirect method or heat loss method is employed to determine furnace thermal efficiency as well as heat losses due to various other factors. The same has been discussed in next.

2.8. Thermal efficiency of furnace – indirect method

Indirect Method helps to determine major heat loss from furnace which includes losses in flue gas and other heat loss parameters like surface radiation losses, CO formation loss, etc. All these losses are calculated in table below:

Table 4: Thermal efficiency of furnace – indirect method

Parameter	***Unit***	***Value***
Measured O_2 in flue gas	%	4
Measured CO in flue gas	ppm	250
Excess air used for combustion	%	23.53
Corresponding CO_2	%	14.12
Total air used for combustion	kg/kg of fuel	15.95
Sensible heat loss in flue gas	%	**59.93**
Heat loss due to moisture present in fuel	%	0.019
Heat loss due to evaporation of water formed due to hydrogen in fuel	%	**7.56**
Heat loss due to moisture present in air	%	1.60
Heat loss due to CO formation	%	0.08
Heat loss due to radiation and openings	%	**11.70**
Heat loss in scale generation	%	0.34
Heat content in the material	%	7.55
Unaccounted Heat Losses	%	11.20

The exit flue gas temperature of furnace is 1150 °C and it can be observed from above that heat loss due to flue gas is one of the major contributors to overall heat loss from the furnace followed by heat loss due to hydrogen in fuel and heat loss due to radiation & openings.

2.9. Material loss during production

As observed in the process flow, material loss happens in following forms:

- Burning loss
- Cuttings after pressing
- End cuttings after sizing of product

We have captured these parameters to assess the burning loss as well as other material loss during the production process.

The assessment is tabulated below:

Table 5: Material loss during production

Parameter	*Unit*	*Value*
Weight of raw material	kg/piece	0.185
Weight of final product	kg/piece	0.1601
Weight of cuttings	kg/piece	0.0127
Weight of end-cuttings	kg/piece	0.0039
Material loss in cuttings & end-cuttings	kg/piece	0.0167
Total material loss	kg/piece	0.0249
Burning loss	kg/piece	0.0082
Burning loss	%	**4.45**
Total material loss	%	13.47

2.10. Specific energy consumption

Specific Energy Consumption for the product is calculated by aggregating individual specific energy consumption of fuel and electricity, as shown in table next.

Table 6: Specific energy consumption

Parameter	Unit	Value
Production	kg/day	314.5
Furnace oil consumption	L/day	52.32
Electricity consumption	kWh/day	38.77
Specific fuel consumption	L/Tonne	**166.35**
Specific electricity consumption	kWh/Tonne	**123.27**

3. Energy Conservation Measures

During the energy audit, we have identified following energy conservation measures:

- Installation of electric billet heater
- Installation of cogged belt on load side and poly-V belt on common shaft drive side
- Preheating arrangement for raw material

We have analysed each of above mentioned measures next.

3.1. Measure 1: Installation of electric billet heater

Recommendation

The efficiency of reheating furnace used in the unit is pretty low and it generates lot of smoke making the environment not suitable for the workers. So, we recommend installation of electric billet heater in place of existing furnace oil fired reheating furnace. This will result in higher efficiency of billet heater and also better working environment for the workers.

Energy and financial savings

The following parameters and assumptions have been considered to estimate the energy savings and financial viability of this option:

Table 7: Installation of electric billet heater - Assumptions and parameters considered for estimation of energy and financial savings

Assumptions and Input parameters		
Present Scenario		
Particulars	Unit	Value
Existing burning loss	%	4.45
Specific fuel consumption	L/T	166.35
Hourly production	kg/h	44.93
Present Scenario		
Size of billet heater	kW	40
Proposed burning loss	%	0.35
Specific electricity consumption	kWh/T	436
Cost components		
Cost of electric billet heater	INR	8,00,000
Cost of new transformer	INR	1,50,000
Miscellaneous expenses	INR	50,000
Impact of increased sanction demand	INR	1,27,000
Total cost	INR	11,27,000
Electricity consumption	kWh/annum	41,138
Electricity charges (in kWh/annum X INR 5.85/kWh)	INR	2,40,657
Benefits		
Material savings	T/annum	3.86
Fuel savings	L/annum	15,695

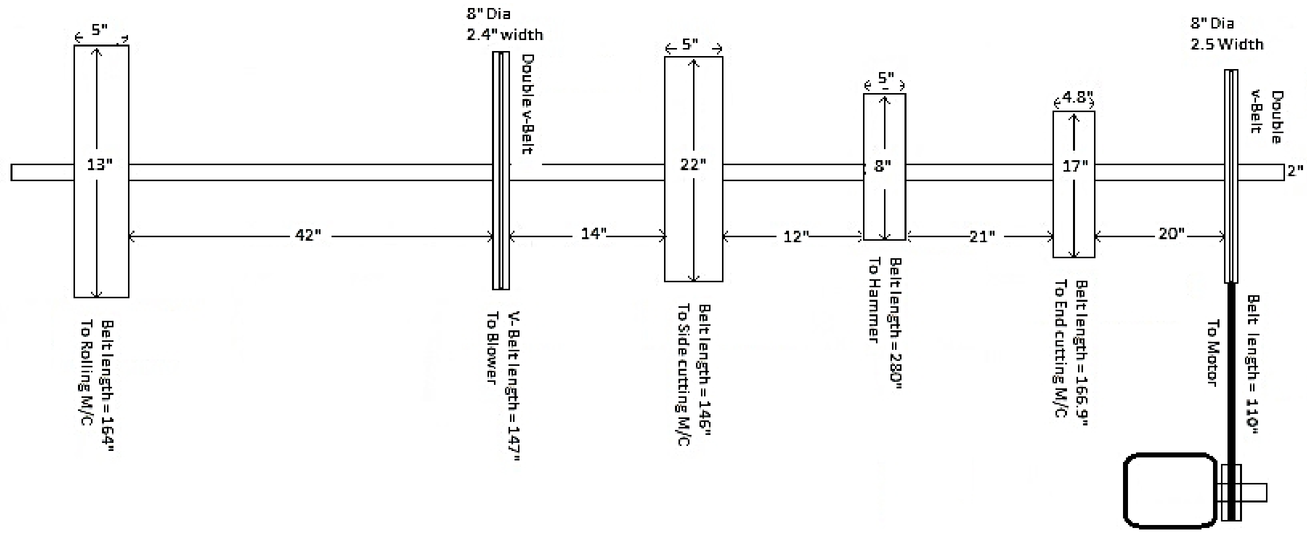
Material savings (in T/annum X INR 43000/T)	INR	1,65,980
Fuel savings (in L/annum X INR 34/L)	INR	5,33,651
Total benefits (Material savings + Fuel savings - Electricity charges)	INR	4,58,974
Simple payback period	Months	30

The implementation of this recommendation will help Jaina Forgings to save around INR 4,58,974 per year by installing electric billet heater of around 40 kW capacity. This will result in change in existing tariff category and the new tariff category will be LT-6 having INR 60/kVA as demand charges and INR 5.85/kWh as energy charges. The simple payback period of this investment is around 30 months.

3.2. Measure 2: Installation of cogged belt on load side and poly-V belt on common shaft drive side

Recommendation

Since the drive system in the unit is based on common shaft and different belts give input to other loads in the unit. Presently, the unit is using V-belt in common shaft drive side and flat belts on load side. However, if we replace existing belts with V-belt on load side and poly-V belt on common shaft drive side then it will give significant savings in electricity consumption of common drive motor as well as lower slippage losses. The line diagram of common shaft and belt lengths are provided in following figure.



Energy and financial savings

The following parameters and assumptions have been considered to estimate the energy savings and financial viability of this option:

Table 8: Installation of cogged belt on load side and poly-V belt on common shaft drive side - Assumptions and parameters considered for estimation of energy and financial savings

Assumptions and Input parameters		
Assumptions		
Particulars	Unit	Value
Efficiency of V-belt	%	0.85
Efficiency of normal belt	%	0.8
Efficiency of poly V-belt	%	0.92

Efficiency of cogged belt	%	0.85
Hours of operation per day	Hours	7
Annual operation days	Days	300
Tariff	INR/kWh	5.25
Present Scenario		
kW consumed	kW	5.50
kW at drive shaft	kW	4.68
kW at load	kW	3.74
Proposed scenario		
kW consumed	kW	4.78
kW at drive shaft	kW	4.40
kW at load	kW	3.74
Cost elements		
Cost of 14 feet cogged belt type "C"	INR	1622.65
Cost of 23 feet cogged belt type "C"	INR	2737
Cost of 12 feet cogged belt type "C"	INR	1427.15
Cost of 12.5 feet cogged belt type "C"	INR	1436.93
Cost of 13.6 feet cogged belt type "C"	INR	1603.10
Cost of 9 feet poly-V belt	INR	3264.25
Installation of pulleys of appropriate size	INR	1200
Total cost	INR	13291.08
Benefits		
Power savings	kW	0.72
Annual electricity savings	kWh/annum	1512
Monetary electricity savings	INR	8845.20
Simple payback period	Months	18

The implementation of this recommendation will help Jaina Forging to save around INR 8845 per year by installing cogged and poly-V belts with an investment of around INR 13291. The simple payback period of this investment is around 18 months.

3.3. Measure 3: Preheating arrangement for raw material

Recommendation

It was observed during the energy audit that exit flue gas temperature from furnace is as high as 1150 °C which is not being utilized. We have also observed that it takes approximately 90 minutes for processing a batch of 300 pieces. So, we propose installation of a preheating arrangement at exit of furnace wherein next batch of 300 pieces are kept. Thus during that time next batch of 300 pieces can be preheated and then transferred into furnace for processing. This will result in significant savings in fuel without any changes in furnace efficiency.

Energy and financial savings

The following parameters and assumptions have been considered to estimate the energy savings and financial viability of this option:

Table 9: Installation of preheating arrangement for raw material - Assumptions and parameters considered for estimation of energy and financial savings

Assumptions and Input parameters		
Assumptions		
Particulars	Unit	Value
Furnace efficiency	%	7.55
Material discharge temperature	°C	1090
Production	kg/h	44.93
Gross calorific value	kCal/kg	10880
Hours of operation per day	Hours	7
Annual operation days	Days	300
Fuel cost	INR/L	34
Present Scenario		
Material charging temperature	°C	40
Fuel consumption	L/day	52.44
Proposed scenario		
Material charging temperature	°C	150
Fuel consumption	L/day	46.94
Cost elements		
Lump-sum cost for installation of preheating system	INR	20,000
Benefits		
Fuel savings	L/day	5.49
Annual fuel savings	L/annum	1,648.03
Monetary savings due to fuel savings	INR	56,033
Simple payback period	Months	4

The implementation of this recommendation will help Jaina Forging to save around INR 56,033 per year by installing preheating system for raw material with an investment of INR 20,000. The simple payback period of this investment is around 4 months.

Annexure A: List of Energy Audit Instruments

PwC has multiple energy audit instruments kits. All the instruments are of have high quality, precision and are periodically calibrated. The instruments are capable to cover all electrical and thermal measurements required in the plants. A list of instruments used by PwC during the audit are shown below:

S. No.	Name of the Instrument	Make	Quantity Used
Thermal Instruments			
1	Non-contact Infrared Thermometer (Testo-845 and Extech)	Testo (USA), Extech (USA)	2
2	Flue Gas Analyzer (KANE 900+)	Kane (UK)	1
Electrical Instruments			
3	3-phase Power Analyzer	Circutor and Extech	3
Others			
4	Digital Tachometer (Extech-461995)	Extech (USA)	1

Annexure B: Calculation sheet of furnace efficiency by indirect method

		Data Sheet
General Details		
Name of unit	Jain Forgings	
No. of Energy Audit	1	
Product type	Plier	
Product size	200mm	
Raw material under process	EN8	
Production Capacity	0.3145	TPD
Standard Temperature for operation	1110	°C
Average scale loss	4.56	%
Average plant operation	7	hrs./day
Annual plant operation	300	days/annum
Fuel Details		
Type of fuel	Furnace Oil	
Total carbon	88.9	% by mass
Hydrogen content	8	% by mass
Sulfur content	0.5	% by mass
Oxygen content	1.4	% by mass
Nitrogen content	0.5	% by mass
Moisture content	0.35	% by mass
Ash content	0.35	% by mass
Gross calorific value	10880	kcal/kg.
Bulk Density	920	kg/m^3
Fuel consumption per hour	6.875982558	kg/hr
Fuel consumption per day	48.1318779	kg/day
Fuel consumption per annum	14.43956337	TPA
Cost of fuel	31	Rs./kg
Measured Data		
Ambient air temperature : (DBT)	40	°C
Ambient air temperature : (WBT)	38	°C
Material Temperature at feeding	43	°C
Temp. of supply air for combustion	43	°C
Average Oxygen level	4	%
Average CO level	250	ppm
Exit flue gas temperature	1150	°C
Average surface temperature -main body	267.5	°C
Average surface temperature -front & back	197	°C
Average surface temperature - Top	200	°C
Temperature at Discharge opening	1090	°C
Temperature at Charge opening	350	°C
Surface area - main body	0.94322392	m^2
Surface area - front & back	0.66580512	m^2
Surface Area - Top	0.47161196	m^2
Area - Discharge opening	0.02516124	m^2
Area - Charge opening	0.02516124	m^2
Material temperature at furnace exit	1090	°C
Material Feeding Rate	44.92857143	kg/hr
Material Feeding Rate	314.5	kg/day
Standard Data		
Specific heat of water	1	kcal/kg °C
Specific Heat of steel	0.12	kcal/kg °C
Specific Heat of coal	0.25	kcal/kg °C
Specific heat of air	0.24	kcal/kg °C
specific heat of water vapour at flue gas tempe	0.52	kcal/kg °C
Enthalpy of steam at flue gas temperature	639.9	kcal/kg
Enthalpy of water at supply air temperature	43	kcal/kg
Specific Heat of flue gas	0.3407	kcal/kg °C
Moisture content of supply air	0.019	kg/kg of air

		Results Sheet
Efficiency Calculation of Furnace		
Name of unit	Jain Forgings	
No. of Furnaces	1	
Type of furnace	Plier	
Application of furnace	200mm	
Raw material under process	EN8	
Production Capacity	0.3145	TPD
Material feeding rate	44.92857143	kg/hr
Fuel Consumption rate	6.88	kg/hr
Specific heat of the material	0.12	kcal/kg ^{o}C
Material temperature at furnace entry	43	^{o}C
Material temperature at furnace exit	1090	^{o}C
Furnace efficiency by direct method	**7.5**	**%**
Furnace efficiency by heat loss method		
Stoichiometric air required for combustion	12.913	kg/kg of fuel
Theoretical max. CO_2	17.44	%
Measured O_2 in flue gas	4	%
Measured CO in flue gas	250	ppm
Excess air used for combustion	23.53	%
Corresponding CO_2	14.12	%
Total air used for combustion	15.95	kg/kg of fuel
Heat loss due to dry flue gas	59.93	%
Heat loss due to moisture in fuel	0.019	%
Heat loss due to Hydrogen in fuel	7.56	%
Heat loss due to moisture in air	1.60	%
Heat loss due to CO formation	0.08	%
Heat loss due to radiation & openings	11.70	%
Heat loss in scale generation	0.34	%
Heat content in the material	7.55	%
Unaccounted loss	11.20	%

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