BEE's National Program
on
Energy Efficiency and Technology Up-gradation in SMEs

Ludhiana Forging Cluster

Best Operating Practices for Energy Intensive Technologies




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ENERGY IS LIFE
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CHAPTER 1:

Introduction

1.1 Brief about the project

Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India, in association with Ministry of Micro, Small & Medium Enterprises (MSME), Government of India is implementing a national level program to support energy efficiency and technology up-gradation in five different MSME clusters, across the country. The Ludhiana Forging cluster is one such MSME clusters, wherein the project aims to bring down the energy demand of forging industries located at Ludhiana by supporting them to implement Energy Efficient Technologies. There are more than 1500 MSME forging units operating in the various industrial pockets of the district, located in areas of Ludhiana, Jalandhar, Phagwara and Moga. BEE's National Program for SMEs for Ludhiana Forging Cluster is also being supported by Auto Parts Manufacturers Association, located at Ludhiana, Punjab.

InsPIRE Network for Environment, New Delhi has been appointed as the executing agency to carry out the project activities in the cluster. The program started with the conduction of Walk through Energy Audits and organizing a pre-activity workshop for the forging unit owners located in Ludhiana cluster. Major industrial bodies working for the development of industries in the cluster are MSME-DI Ludhiana, Auto Parts Manufacturing Association, Ludhiana; Central Tool Room, MSME, Ludhiana.

Activities conducted / envisaged under the proposed energy efficiency study in the Ludhiana forging cluster include the following:

- Walk-through Energy Audits (WTAs) in 5 Forging units
- Pre-activity Workshop
- Identification of 2 Energy Efficient Technologies viz. Induction Heater & Special Purpose Machine.
- Identification of Energy Efficient technology suppliers
- Signing of Memorandum of Understanding (MoU) with 20 Forging units
- Baseline energy audit in 20 Forging units
- Post implementation energy audits in 8 numbers of implemented units.
- Development of technology specific AV- clips & case studies
- Preparation of Best Operating Practices (BOP) document for 5 energy-intensive technologies
- Preparation of document on common monitoring parameters and measuring instruments
- Supporting BEE in conducting Technology Workshops

1.2 Brief about the cluster and production process

Ludhiana is one among the biggest forging cluster in India consisting of over 1500 units. Most of the forging units in Ludhiana are making hand tools and parts suitable for automotive, agricultural and industrial sectors. Majority of the units are using free hammer to forge the heated steel. The temperature required for forging is around 1150 - 1200 ^{0}C. The raw material used for hand tool & cycle parts is Mild Steel, whereas for automotive, agricultural and industrial machine parts, largely Alloy Steel is used.

The typical process flow in a forging unit has been diagrammatically depicted below:

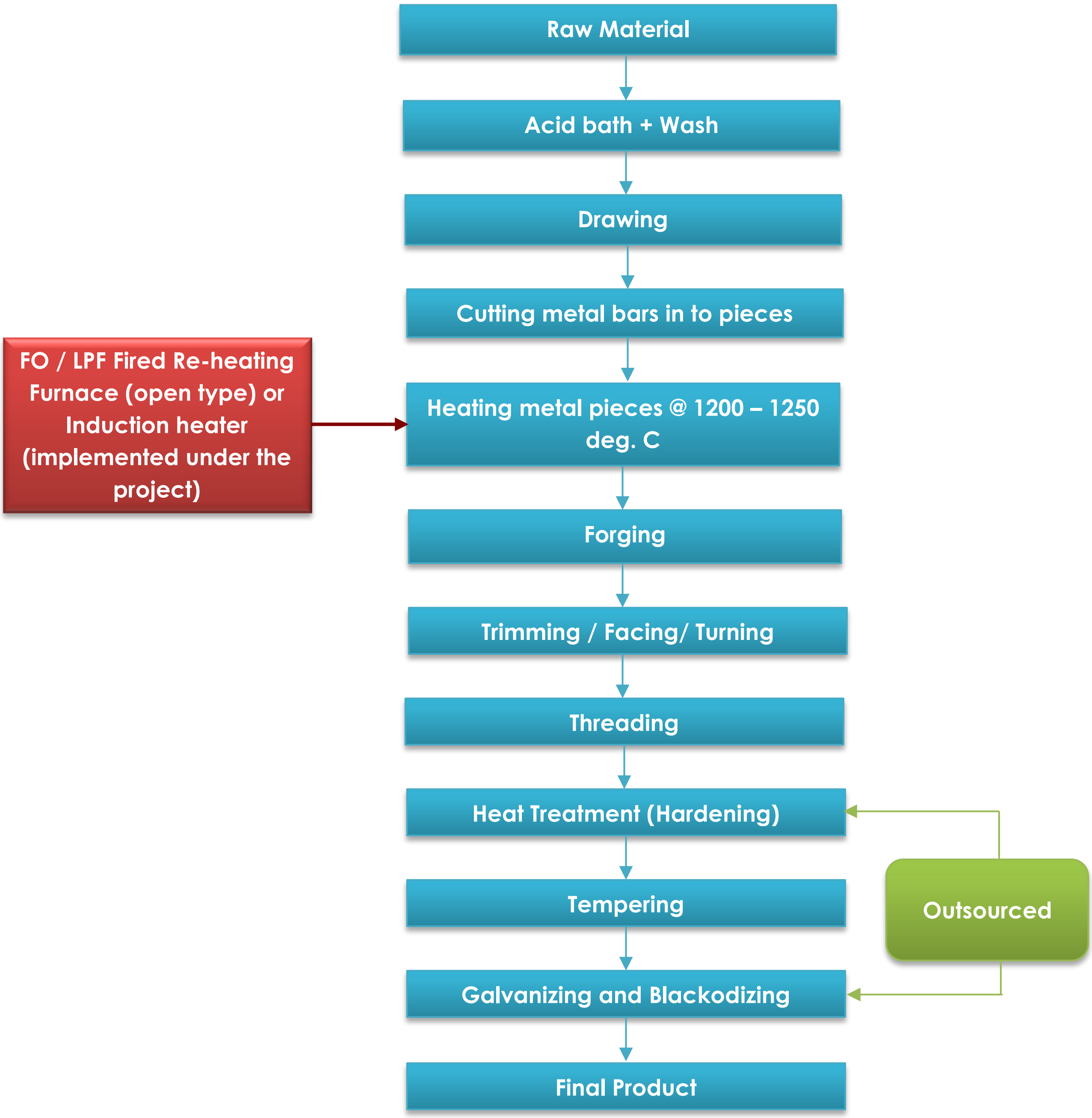

Figure 1.1: *Process flow diagram for forging unit*

In the process, the raw material i.e. Mild Steel or Alloy Steel is usually treated with acid bath & wash to remove surface impurities. This is followed by hot drawing operations, where cross-sectional area of the material is reduced to the required size. The metal bars are cut to pieces as per requirement and are ready for forging operations. The forging process usually involves feeding the metal bar into a batch type furnace (FO or LPG Fired) on an Electric Induction heater (implemented under current project), to raise its temperature to the forging temperature which in case of mild steel is 1150 – 1200^{0} C. This is followed by processing the heated bar in between the forging die, using a free hammer. The hammer impact causes the metal bar to attain required size of the die. Once cooled, the material is machine processed through turning, facing and trimming operations. Subsequently, threading and drilling is carried out, as per the need. A number of heat treatment process is carried out before the material is ready for dispatch.

1.3 Best operating practices of 5 key technologies

Major energy sources being used in manufacturing of forging products in forging cluster is the heating process which accounts for 50-70% of the total energy consumption. The heating operation in a typical forging unit is carried out either in re-heating furnace or an induction heater. Thermal energy in the form of Furnace Oil or LPG is also used in the heat treatment furnace. Other critical equipment in the forging process includes lathes, drilling machines and other machines, which typically uses motor as the driving force.

The heating of raw material to forging temperature of 1150-1200^{0}C is either done using electricity in an induction heater or using furnace oil or LPG in a re-heating furnace. However, all heat treatment furnaces are either furnace oil or LPG fired.

Like all manufacturing process, efficiency of a unit depends on the performance and efficiency of key technologies installed. The assignment envisages development of cluster specific 'Best Operating Practices (BOPs)' for the top 5 energy using equipment/process in the industry cluster on the basis of:

- process/technology used in the cluster
- energy audits conducted in 20 forging units in the cluster

Based on the outcome of the energy audits in 20 units under Ludhiana forging cluster, following 5 technologies has been identified as key energy intensive technologies and best operating practices corresponding to these technologies has been listed under subsequent chapters:

- Induction Heater
- Special Purpose Machines (SPM) – For Facing, Grinding, Drilling, Chamfering, Threading operations etc.
- Motors
- Electrical Transformers
- Heat Treatment / Annealing Furnace

The list of equipment suppliers discussed with, under the assignment, is placed at ***Annexure 1***.

CHAPTER 2:

Best Operating Practices: Induction Heater

2.1 Introduction

Induction heating is the process of heating an electrically conducting object by electromagnetic induction, where eddy currents are generated within the metal and resistance leads to Joule heating of the metal. So it is possible to heat a metal without direct contact and without open flames or other heat sources (like IR). An induction heater consists of an electromagnet (coil), through w hich a high-frequency alternating current (AC) is passed. The frequency of AC used depends on the object size, material type, coupling (between the work coil and the object to be heated) and the penetration depth. An induction heating system is composed by an inductor (to generate the magnetic field) and a converter (to supply the inductor with a time-varying electrical current).

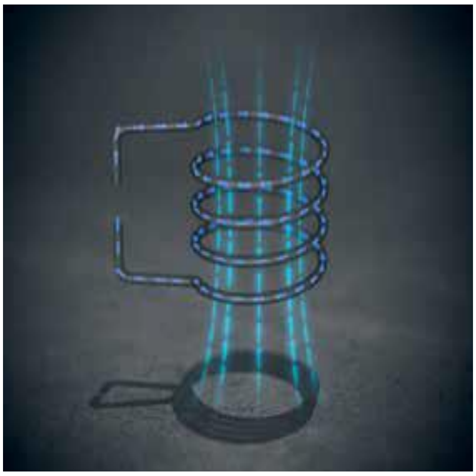

Figure 2.1: ***Induction heating coil***

2.2 Operating principle

Alternating current flowing through an electro-magnetic coil generates a magnetic field. The strength of the field varies in relation to the strength of the current passing through the coil. The field is concentrated in the area enclosed by the coil;

Eddy currents are induced in any electrically conductive object—a metal bar, for example—placed inside the coil. The phenomenon of resistance generates heat in the area where the eddy currents are flowing. Increasing the strength of the magnetic field increases the heating effect. However, the total heating effect is also influenced by the magnetic properties of the object and the distance between it and the coil. In case of the forging process, the induction heating system is used to heat the metal bar to the forging temperature which is typically 1150-1200^{0}C depending on the material.

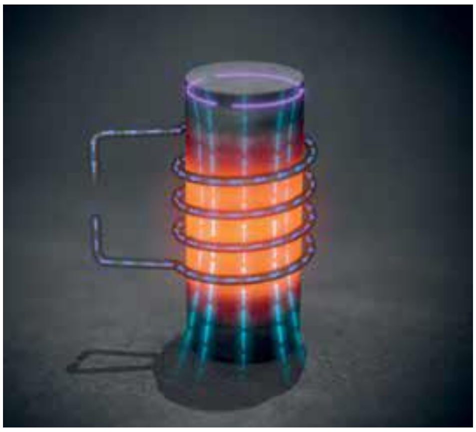

Figure 2.2: ***Induction heating coil***

2.3 Use of induction heating in forging units

Forging is a process where metal is formed into shape using pressure applied by an impact hammer or press. It is one of the oldest known metal working processes. Metals can be forged cold, warm or hot. Cold forging is used for forming softer materials and smaller steel parts, but this process hardens the material making it brittle and difficult to process after forging.

Hot forging is a process where the part is heated above the material recrystallization temperature before forging, typically 1100°C (2012°F) for steel. Hot forging allows a part to be formed with less pressure, creating finished parts with reduced residual stress that are easier to machine or heat treat. Warm forging is forging a part below the recrystallization temperature, typically below 700°C (1292°F).

As a superior alternative to furnace heating, induction heating provides faster, more efficient heat in forging applications. The process relies on electrical currents to produce heat within the part that remains confined to precisely targeted areas. High power density means extremely rapid heating, with exacting control over the heated area.

Recent advances in solid-state technology have made induction heating a remarkably simple and cost-effective heating method. Benefits of using Induction heating for forging are:

- Rapid heating for improved productivity and higher volumes
- Precise, even heating of all or only a portion of the part
- A clean, non-contact method of heating
- Safe and reliable – instant on, instant off heating
- Cost-effective, reduces energy consumption compared to other heating methods
- Easy to integrate into production cells
- Reduced scaling

2.4 Best operating practices for Induction heating

Induction heating is commonly used for heating bar ends and metal billets prior to forging operation. There are several critical considerations (best operating practices) when using induction heating for forging.

➲ BOP-1: Setting current frequency based on the size of the heated part

In addition to the amount of energy required to heat the part to the forging temperature, the size of the part also dictates the required operating frequency of the induction system to optimize operating efficiency. While designing the electro-magnetic coil for heating operation, the size of the part should be given due consideration, which will also determine the current frequency at which the system should operate. Working on extra frequency than required, may damage the machine or the coil.

➲ BOP-2: Time for Thorough-Heating

The induction process produces heat within the part, but the heat is generated near the outside surface and will take time to conduct to the center of the part. Typically, bar ends up to 20 mm in diameter through-heat in less than 10 seconds, whereas a 75 mm diameter bar will take 150 seconds to heat to the center.

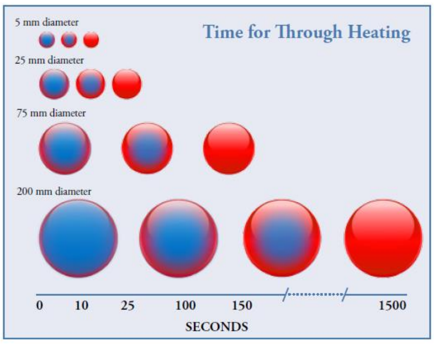

Figure 2.3: *Time required for Thorough Heating*

The time required for uniform heating of the bar, based on its physical properties to transform heat from the outer surface to the inner core must be calculated prior to the heating process. Under heating or over heating may cause damage to the forging die in addition to the damaged piece.

➲ BOP-3: Avoiding Radiation Loss

Energy loss due to radiation from the hot part becomes significant with forging temperatures in the 1000°C (1832°F) to 1200°C (2192°F) range and can be controlled by using thermal insulation during the manufacturing of the induction coil.

➲ BOP-4: Avoid charging on non-conductive material

Induction heating 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.

➲ BOP-5: Avoid charging of non-magnetic material

It is easier to heat magnetic materials. In addition to the heat induced by eddy currents, magnetic materials also produce heat through the hysteresis effect. This effect ceases to occur at temperatures above the "Curie" point - the temperature at which a magnetic material loses its magnetic properties. The relative resistance of magnetic materials is rated on a “permeability” scale of 100 to 500; while non-magnetics have a permeability of 1; magnetic materials can have permeability as high as 500. Thus, charging of non-magnetic material may make the heating process negligible and permanently damage the machine.

➲ BOP-5: Setting frequency based on thickness of part

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. 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.

➲ BOP-6: Setting heating time based on resistivity of material

If you use the exact same induction process to heat two same size pieces of steel and copper, the results will be quite different. Why? Steel – along with carbon, tin and tungsten – has high electrical resistivity. Because these metals strongly resist the current flow, heat builds up quickly. Low resistivity metals such as copper, brass and aluminum take longer to heat. Resistivity increases with temperature, so a very hot piece of steel will be more receptive to induction heating than a cold piece.

➲ BOP-7: Degree of temperature change required

The efficiency of induction heating for specific application depends on the amount of temperature change required. A wide range of temperature changes can be accommodated; as a rule of thumb, more induction heating power is generally utilized to increase the degree of temperature change. Based on the material of the part, its relative size and the forging process requirement, the degree of temperature change is fixed.

➲ BOP-8: Provision of automatic system cut off

In certain time, the charged material may block the passage of heating coil, due to some obstruction. In such case, the machine will have a tendency to increasing heat on a concentrated location, which may damage the coil permanently. Required sensors may be affixed in the system for automatic power cut, during such conditions.

➲ BOP-9: Ensuring safe operations

The heating process using induction heating, relatively heats the part quite quickly. It is important to remove the heated part instantly while giving passage to a new part. The entire process involves handling of material at an elevated temperature, which in most cases is done manually, due to the relative size of the part. Required amount of safety parameters should be followed while handling the induction heater.

➲ BOP-10: Ensuring proper coil cooling using cooling water circuit

The induction furnace coil is subjected to continuous high temperature heating, which may lead to internal thermal stress and failure of the coils. A cooling water circuit is usually inbuilt with an induction heater. It is important to ensure the continuous use of the cooling water circuit for longer life of the electro-magnetic coil.

CHAPTER 3:

Best Operating Practices: Special Purposes Machines (SPM)

3.1 Introduction

Special purpose machine is a kind of multi-tasking machine used for machining purpose. A special purpose machine is used as a replacement to conventional machines like lathe, drilling or trimming machine. A special purpose machine is designed based on the customized requirement of a unit and may be used for one or multiple task as per the design. For example, a conventional lathe machine takes 3 mins (say) to machine (turn) a metal piece. Thereafter it is transferred to another machine for facing and trimming operations. In some cases, a third machine is used for threading operations. A special purpose machine specifically designed can replace all the three machines with a single machine. The replaced special purpose machine can perform all the four activities i.e. turning, facing, trimming, and threading on sequential manner. The sequence of operation is pre-set using timers and sensors. The entire operation is maintained using pneumatic and mechanical control. For ease of operation, each special purpose machine is equipped with an automatic feeder. Replacement of conventional machines with special purpose machines usually increases machine productivity by 5 times, easing the life of the operators by avoiding manual intervention during each operation.

3.2 Operating Principle

A special purpose machine (SPM) is usually customized based on the specific requirement of a unit. A SPM is used for multi-task operation, which are typically performed in more than one conventional machine. The sequence of operation in a SPM is pre-set using timers and sensors. Usually, a SPM is equipped with two or more machine tools fitted in different axis. The operations are carried out in sequential manner. The axial motion of the machine tool is usually powered by a pneumatic controls, whereas positioning of the tool is done using sensors. A particular operation e.g. turning operation in a metal piece of 400 mm is pre-set using timers. Once the operation is over, the sensor directs the next sequence of operations, which are also pre-fed programs in the machine. Thus, manual intervention in each operation can be prevented. Also, two or more operational can be performed simultaneously in a SPM.

Figure 3.1: ***Special Purpose Machine- Turning***

Similar is the case for SPM-drilling machine, where the time taken in conventional drilling machine which performs one drilling operation at a time, can be significant reduced by simultaneously performing two or more drilling operations at a time.

3.3 Best operating practices for Special Purpose Machine

Some practices that are to be followed while operation of SPM is listed below:

BOP 1: Machine tool wear & tear to be regularly checked

Due to continuous working of a machine tool and the nature of work performed on it, wear and tear is observed in the sliding parts of machine tools. Since, operation in a SPM is completely sensor based without manual intervention, the wear & tear in the machine tool may affect the accuracy of the product. In order to avoid this, regular monitoring of the machine tool should be carried out manually before starting of an operation. If need be, the affected machine tool should be replaced.

BOP 2: Ensure proper lubrication

Rotating and sliding parts, which make contact with other parts, are subjected to wear due to friction. Viscous oil called lubricant is applied to these parts to avoid direct contact between them. The process of reducing friction is called lubrication. Friction occurs as the shafts are rotating and the sliding parts moving on each other.

It generates heat and the parts get damaged. In order to keep the machine tools accurate and durable, it is necessary to apply lubricants between mating parts. It will reduce friction and wear is minimized. Lubrication is the nerve centre of machine tool. As it is blood circulation for the human body, lubrication is for the machine tools. Be sure to keep the oil to the full level as indicated on the oil gage, and drain and replace the oil when it becomes dirty or gummy.

Methods of lubrication

The different methods of lubrication are:

- Ring lubrication
- Wick lubrication
- Splash lubrication
- Grease lubrication

Ring lubrication

The method of ring lubrication involves a ring hanging from down the rotating shaft. The bottom portion of the ring is immersed in the oil container. When the shaft starts rotating, the ring also rotates. While the ring rotates, it carries a small amount of oil and the oil is spread into the bearing and the shaft.

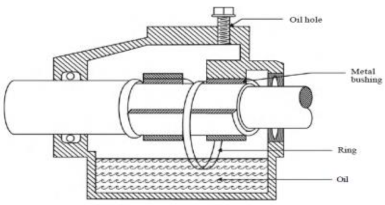

Figure 3.2: *Ring lubrication*

Wick lubrication

Wick lubrication is a method in which the wick along with a flexible thin piece of metal is used. A container having oil is placed above the bearing. The wick connects the container and the part to be lubricated. This lubrication enables the oil to flow from the container to the required place.

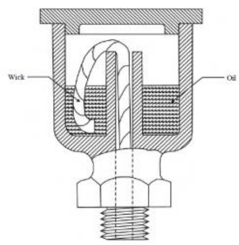

Figure 3.3: *Wick lubrication*

▸ Splash lubrication

The rotating part of the machine itself is made to be immersed in the oil container. When the part starts rotating, the oil is splashed and the moving parts are lubricated. Bearings are generally lubricated by this method. Little spoons are attached to the rotating parts to get more quantity of oil to the part to be lubricated.

▸ Grease lubrication

Grease lubrication is done with the help of grease guns. Another way of doing it simply is to fill a container with grease and the container is connected to the parts to be lubricated by means of a small tube. When a screw is screwed into the container, a good amount of grease is taken to the required place. Lubricating oil and grease are manufactured under several trade names by the Indian oil companies. Suitable lubricants are used for specific purposes.

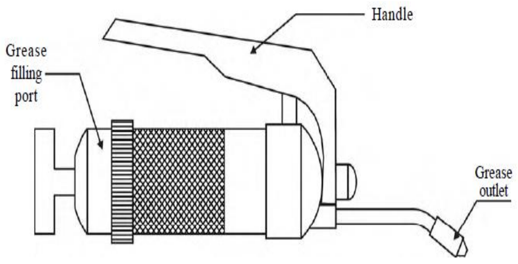

Figure 3.4.: ***Grease lubrication***

BOP 3: Trained man power

Special purpose machine are automatic programmed machines and are very sensitive in operation. The operators are needed to be well trained while operating these machines.

BOP 4: Ensure regular cleaning of V-ways

Like all lathe machines, a SPM also consist of a bed and V-ways. The headstock holding the job to be machined is fixed, whereas the carraige holding the machine tool travels through the V-ways. Since the operation of a SPM is automatic, any resistance caused in the V-ways may affect the performance of the machine. It is important to regularly check and clean the V-ways. Another area which needs to be regularly checked and corrected is the operating line of the machine tool and its alignment with respect to the job.

BOP 5: Ensure proper flow of coolant in the machine tool tip

Due to high resistive working, the machine tool tip is usually gets heated up. To constantly maintain the temperature of operation below critical temperature, a coolant is used during the machining operations. It should be ensured that the coolant is continuously in use during any machining operation.

BOP 6: Maintenance of machinery

Scheduled preventive maintenance is the best way to ensure longer life and better durability of the machine. There are different types of maintenance and some of them are:

- Routine maintenance
  - Daily maintenance
  - Weekly maintenance

- Preventive maintenance
- Breakdown maintenance
- Capital repairs or Corrective maintenance

Routine maintenance

Routine maintenance is done to avoid unnecessary breakdown of machine tools. It involves regular works like cleaning and lubricating, making minor adjustments and doing small repair works. It is important to chart out what are all to be done daily, weekly and monthly.

Daily maintenance

- Cleaning all the parts of the machine tool
- Lubricating the movable parts with grease and oil as per requirements
- To correct the machine tool to make it operate accurately
- To look at whether the coolant supply and auto lubricating equipment's are working properly
- To remove the burrs cleanly

Weekly maintenance

- The measuring instruments, gauges and hand tools are checked and corrected if necessary.
- The spare parts and integral parts of the machine tools should be cleaned.
- The entire workshop premises should be maintained cleanly.
- Grinding wheels of bench grinders and tool and cutter grinders should be dressed.
- The work rests of these machines should be adjusted properly.
- The protective devices in the machine tool are checked whether they are properly fixed. And they are corrected if necessary.
- The cables and electrical connections should be checked.
- The position and working of belt, chain etc., are checked and adjusted.
- Parts like gears, clutches and bearings are checked for their proper functioning.
- The accuracy of precision measuring instruments are checked and corrected. They are also checked for zero error.

BOP 7: Ensure proper cleaning

Like conventional machining operation, a SPM also generated lots of metal chips, and dust. It is important to thoroughly clean the machine parts, as a single chip may damage the entire machining process. A chip of metal can damage the metal surface thus affecting the surface finishing of the job. So, a SPM machine should be regularly cleaner, with chips and dust transferred to a common dumping area, so that every new day, the place of work is absolutely clean for starting production. Each set of machines should have a set of maintenance kit, which should be located conveniently near the place of use.

CHAPTER 4:
Best Operating Practices: Motors

4.1 Introduction

Electrical motors are the principal source of motive power in any forging unit. Machine tools, auxiliary equipment and other utilities come equipped with one or more electric motors. A machine tool can have several electric motors other than the main spindle motor. These are used for allied operations. Motors are generally efficient, but their efficiency and performance depends on the motor load. Figure 5.1 shows the variation in efficiency and power factor vis-à-vis the total load, for a typical motor.

Since there are many different types of motors in a forging unit, it is very important to maintain them and adopt proper operating practices. As they run for years, motors can become less efficient because of wear, breakdown of lubricants, and misalignment. Good motor-maintenance practice helps avoid or postpone these problems. A lack of maintenance can reduce a motor's energy efficiency and increase unplanned downtime. Scheduled maintenance is the best way to keep the motors operating efficiently and reliably.

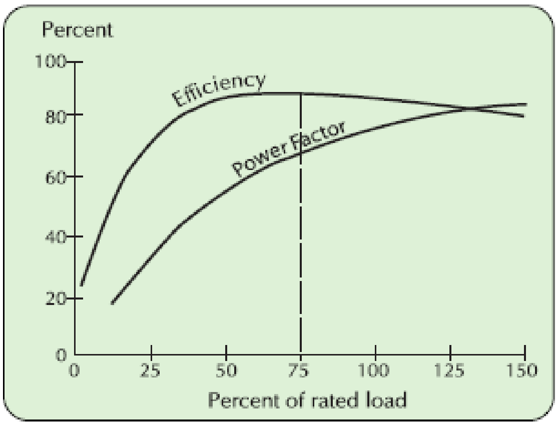

Figure 4.1: ***Motor efficiency / power factor vs load curve***

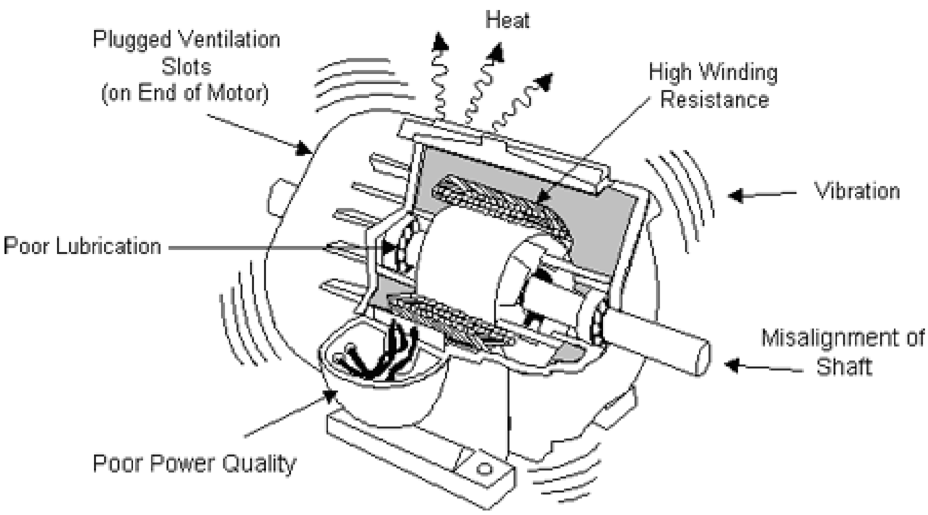

Figure 4.2: ***Operational problems of a motor***

4.2 Types of motors

➲ Induction motors

Induction motors are the most commonly used prime mover for various equipment in industrial applications. In induction motors, the induced magnetic field of the stator winding induces a current in the rotor. This induced rotor current produces a second magnetic field, which tries to oppose the stator magnetic field, and this causes the rotor to rotate. The 3-phase squirrel cage motor is the workhorse of industry; it is rugged and reliable, and is by far the most common motor type used in industry. These motors drive pumps, blowers and fans, compressors, conveyers and production lines. The 3-phase induction motor has three windings each connected to a separate phase of the power supply.

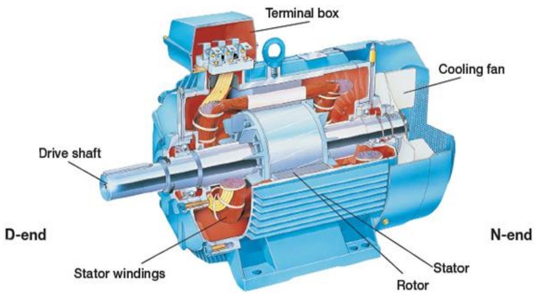

Figure 4.3: *Sectional view: induction motor*

➲ Direct-Current motors

Direct-Current (DC) motors, as the name implies, use direct-unidirectional, current. Direct current motors are used in special applications- where high torque starting or where smooth acceleration over a broad speed range is required.

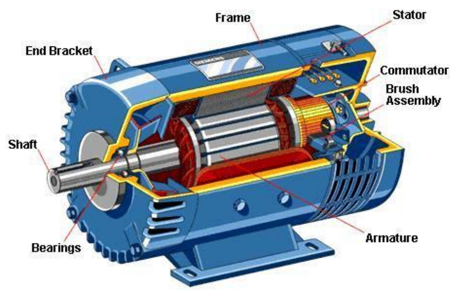

Figure 4.4: *Sectional view: DC motor*

➲ Synchronous motors

Synchronous Motor is called so because the speed of the rotor of this motor is same as the rotating magnetic field. It is basically a fixed speed motor because it has only one speed, which is synchronous speed and therefore no intermediate speed is there or in other words it's in synchronism with the supply frequency Alternating Current (AC) power is fed to the stator of the synchronous motor. The rotor is fed by DC from a separate source. AC power is fed to the stator of the synchronous motor. The rotor is fed by Direct Current (DC) from a separate source. The rotor magnetic field locks onto the stator rotating magnetic field and rotates at the same speed. The speed of the rotor is a function of the supply frequency and the number of magnetic poles in the stator. While induction motors rotate with a slip, i.e., rpm is less than the synchronous speed, the synchronous motor rotate with no slip, i.e., the Revolutions Per Minute (RPM) is same as the synchronous speed governed by supply frequency and number of poles. The slip energy is provided by the D.C. excitation power.

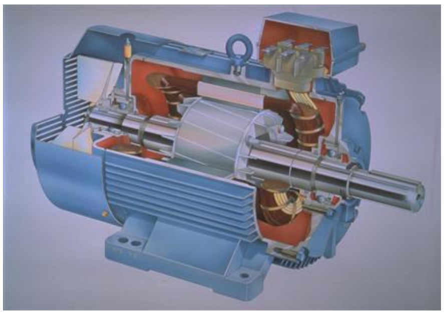

Figure 4.5: *Synchronous Motors*

4.3 Best operating practices for motors

BOP 1: Replace, rather than rewind, motors when appropriate

Motors are generally repaired more than once, with a typical loss of nearly 2 % in efficiency at each rewind. These motors are generally less efficient than their nominal ratings, and must be replaced appropriately. It is more common to rewind larger motors due to their high capital cost. But these motors usually operate at very high duty, and even a modest efficiency improvement may make it worthwhile to replace them with new, premium-efficiency motors rather than repair them.

BOP 2: Use appropriately sized motors for replacement

- Many motors are oversized for their applications, resulting in poor motor efficiency and excessive energy use. Always use motors sized according to the requirement of the load. It is good practice to operate motors between 75 -100 % of their full load rating because motors run most efficiently near their designed power rating.
- When replacing motors, always buy energy efficient motors instead of conventional motors. The cost of energy consumed by a conventional motor during its life is far greater than the incremental cost of the energy efficient motor.

BOP 3: Ensure voltage balance across motor terminals

A properly balanced voltage supply is essential for a motor to reach its rated performance. An unbalanced three-phase voltage affects a motor's current, speed, torque, and temperature rise. Equal loads on all three phases of electric service help in assuring a voltage balance while minimizing voltage losses. The options that can be exercised to minimize voltage unbalance include:

- Balancing any single phase loads equally among all the three phases
- Segregating any single phase loads which disturb the load balance and feed them from a separate line / transformer

BOP 4: Reducing under-loading

Probably the most common practice contributing to sub-optimal motor efficiency is that of under-loading. Under-loading results in lower efficiency and power factor, and higher-than-necessary first cost for the motor and related control equipment.

- Carefully evaluate the load that would determine the capacity of the motor to be selected.
- For motors, which consistently operate at loads below 40 % of rated capacity, an inexpensive and effective measure might be to operate in star mode. A change from the standard delta operation to star operation involves re-configuring the wiring of the three phases of power input at the terminal box
- Motor operation in the star mode is possible only for applications where the torque-to-speed requirement is lower at reduced load.

- For applications with high initial torque and low running torque needs, Del-Star starters are also available in market, which help in load following derating of electric motors after initial start-up.

BOP 5: Regular up-keep

Properly selected and installed motors can operate for many years with minimal maintenance. Nonetheless, regular care will extend their life and maximize their energy efficiency. A list of such practices and measures is presented below.

- Clean motor surfaces and ventilation openings periodically. Heavy accumulations of dust and lint will result in overheating and premature motor failure.
- Properly lubricate moving parts to avoid unnecessary wear. Be sure to apply appropriate types and quantities of lubricant. Applying too little or too much can harm motor components.
- Keep motor couplings properly aligned. Correct shaft alignment ensures smooth, efficient transmission of power from the motor to the load. Incorrect alignment puts strain on bearings and shafts, shortening their lives and reducing system efficiency.
- Check motor for over-heating and abnormal noises/sounds, sparking and ensure proper bedding of brushes.
- Tighten belts and pulleys to eliminate transmission losses.

BOP 4: Install variable frequency drives

Motors frequently drive variable loads such as pumps, hydraulic systems and fans. In these applications, the motors' efficiency is often poor because they are operated at low loads. It is appropriate to use a Variable Frequency Drive (VFD) with the motor.

Figure 4.6: ***VFD in motors***

BOP5: Install capacitor banks

Induction motors are characterized by power factors less than unity, leading to lower overall efficiency (and higher overall operating cost) associated with a plant's electrical system.

- Install capacitors banks across motors with a high rating to reduce the distribution losses.
- Capacitors connected in parallel (shunted) with the motor are typically used to improve the power factor.
- The size of capacitor required for a particular motor depends upon the no-load reactive kVA (kVAR) drawn by the motor, which can be determined only from no-load testing of the motor. In general, the capacitor is selected to not exceed 90 % of the no-load kVAR of the motor. (Higher capacitors could result in over-voltages and motor burnouts)

CHAPTER 5:

Best Operating Practices: Transformers

5.1 Introduction

Distribution transformers are very efficient, with losses of less than 0.5% in large units. Smaller units have efficiencies of 97% or above. It is estimated that transformer losses in power distribution networks can exceed 3% of the total electrical power generated. In India, for an annual electricity consumption of about 500 billion kWh, this would come to around 15 billion kWh.

Reducing losses can increase transformer efficiency. There are two components that make up transformer losses. The first is "core" loss (also called no-load loss), which is the result of the magnetizing and de-magnetizing of the core during normal operation. Core loss occurs whenever the transformer is energized; core loss does not vary with load. The second component of loss is called coil or load loss, because the efficiency losses occur in the primary and secondary coils of the transformer. Coil loss is a function of the resistance of the winding materials and varies with the load on the transformer.

In selecting equipment, one often conveniently avoids the concept of life cycle costing. But the truth is that even the most efficient energy transfer equipment like a transformer, concept of life cycle cost is very much relevant. The total cost of owning and operating a transformer must be evaluated, since the unit will be in service for decades. The only proper method to evaluate alternatives is to request the manufacturer or bidder to supply the load and no-load losses, in watts. Then, simple calculations can reveal anticipated losses at planned loading levels. Frequently, a small increase in purchase price will secure a unit with lower operating costs.

The load profile of electronic equipment—from the computer in the office to the variable speed drive in the factory—drives both additional losses and unwanted distortion. Since transformer manufacturers test only under ideal (linear) conditions, a substantial gap exists between published loss data and actual losses incurred after installation.

5.2 Operating principle

A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit. The voltage can be raised or lowered in a circuit, but with a proportional increase or decrease in the current ratings.

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure below.

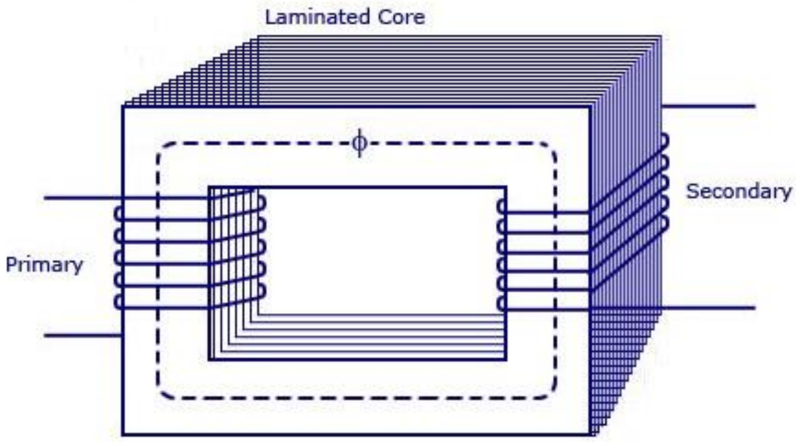

Figure 5.1: ***Transformer Working***

As shown above the transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricated'. Both the coils have high mutual inductance. A mutual electro-motive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction as

$e=M*dI/dt$

If the second coil circuit is closed, a current flow in it and thus electrical energy is transferred magnetically from the first to the second coil. The alternating current supply is given to the first coil and hence it can be called as the primary winding. The energy is drawn out from the second coil and thus can be called as the secondary winding.

In short, a transformer carries the operations shown below:

- Transfer of electric power from one circuit to another.
- Transfer of electric power without any change in frequency.
- Transfer with the principle of electromagnetic induction.
- The two electrical circuits are linked by mutual induction.

5.3 Best operating practices for Transformers

BOP-1: Standard test for Transformer

To ensure efficient performance of a transformer, a standard transformer test should be performed, which includes the following:

- Ratio, for voltage relationship;
- Polarity for single- and 3-phase units (because single-phase transformers are sometimes connected in parallel and sometimes in a 3-phase bank);

- Phase relationship for 3-phase units (important when two or more transformers are operated in parallel)
- Excitation current, which relates to efficiency and verifies that core design is correct
- No-load core loss, which also relates to efficiency and correct core design;
- Resistance, for calculating winding temperature
- Impedance (via short circuit testing), which provides information needed for breaker and/or fuse sizing and interrupting rating and for coordinating relaying schemes;
- Load loss, which again directly relates to the transformer's efficiency;
- Regulation, which determines voltage drop when load is applied; and
- Applied and induced potentials, which verify dielectric strength.
- There are additional tests that may be applicable, depending upon how and where the transformer will be used. The additional tests that can be conducted include the following:
- Impulse (where lightning and switching surges are prevalent);
- Sound (important for applications in residential and office areas and that can be used as comparison with future sound tests to reveal any core problems);
- Temperature rise of the coils, which helps ensure that design limits will not be exceeded;
- Corona for medium voltage (MV) and high-voltage (HV) units, which helps determine if the insulation system is functioning properly;
- Insulation resistance (meg-ohmmeter testing), which determines dryness of insulation and is often done after delivery to serve as a benchmark for comparison against future readings; and
- Insulation power factor, which is done at initial installation and every few years thereafter to help determine the aging process of the insulation.

BOP-2: Making connections that work

The connections shall be made, between the transformer's terminals and the incoming and outgoing conductors, carefully following the instructions given on the nameplate or on the connection diagram. Check all of the tap jumpers for proper location and for tightness. Re-tighten all cable retaining bolts after the first 30 days of service. Before working on the connections make sure all safety precautions have been taken. Arrangements shall be made to adequately support the incoming/outgoing connecting cables, so that there is no mechanical stress imposed on transformer bushings and connections. Such stress could cause a bushing to crack or a connection to fail.

BOP-3: Make sure the transformer is grounded

Grounding is necessary to remove static charges that may accumulate and also is needed as a protection should the transformer windings accidentally come in contact with the core or enclosure (or tank for wet types).

Note that for MV transformers, the secondary neutral is sometimes grounded through impedance. Ensure that all grounding or bonding systems meet NEC and local codes.

BOP-4: Applying the load

Before energizing a 3-phase transformer, arrangement for monitoring the voltages and currents on the low-voltage side shall be done. Then, without connecting the load, energize the transformer. The magnitude of the voltages shown (line-to-ground and line-to-line) should be very similar. If this is not the case, de-energize the transformer and contact the manufacturer before proceeding further.

Next, connect the load and energize the transformer. While monitoring the voltages and currents, gradually increase the load in a stepped or gradual application until full load is reached. Both the voltages and currents should change in a similar fashion. If this does not happen, de-energize the transformer and contact the manufacturer.

The maximum continuous load a transformer can handle is indicated on its nameplate.

BOP-5: Adjustment for correct tap setting

After installation, check the output voltage of the transformer. This should be done at some safe access point near or at the load. Never attempt to check the output voltage at the transformer. Dangerous high voltage will be present within the transformer enclosure.

When changing taps, the same changes must be made for all phases. Consult the transformer diagrammatic nameplate for information on what tap must be used to correct for extra high or extra low incoming line voltage. The same adjustment should be made to compensate for voltage drop in the output due to long cable runs. When the load-side voltage is low, tap connections below 100% of line voltage must be used to raise the load voltage. If the load-side voltage is high, tap connections above 100% of line voltage must be used to lower the load voltage.

BOP-6: Analysis of Electrical Power Systems

An analysis of an electrical power system may uncover energy waste, fire hazards, and equipment failure. Operator / in charge increasingly find that reliability-centered maintenance can save money, energy, and downtime (see Table Below).

Table 5.1: ***Trouble shooting of electrical power systems***

System Problem	Common Causes	Possible Effects	Solutions
Voltage imbalances among the three phases	Improper transformer tap settings, singe-phase loads not balanced among phases ,poor connections, bad conductors, transformer grounds or faults	Motor vibration premature motor failure A 5% imbalance causes a 40% increase in motor losses.	Balance loads among phases.

System Problem	Common Causes	Possible Effects	Solutions
Voltage deviations from rated voltages (too low & high)	Improper transformer settings incorrect selection of motors	Over voltage in motors reduce efficiency, power factor and equipment life increased temperature	Correct transformer settings, motor rating and motor input voltage
Poor connections in distribution or at connected loads	Loose bus bar connections loose cable connections, corroded connections, poor crimps, loose and warm contactors	Produces heat causes failure at connection site, leads to the voltage drop and imbalances	Use Infrared camera to locate hot spots and correct.
Under sized conductors	Facilities expanding beyond original designs, poor power factors	Voltage drop and energy waste	Reduce the load by conservation load scheduling
Insulation leakage	Degradation over time due to extreme temperatures abrasion, moisture, chemicals	May leak to ground or to another phase, variable energy waste	Replace conductor, insulators
Low power Factor	Inductive loads such as motors , transformers and lighting ballasts, Nonlinear loads, such as most electronic loads	Reduces current carrying capacity of wiring, voltage regulation effectiveness and equipment life	Add capacitors to counteract reactive loads

CHAPTER 6:

Best Operating Practices: Annealing Furnace

6.1 Introduction

The Annealing furnace is a type of industrial furnace used for heat-treatment process. Usually a forged material undergoes heat-treatment after completion of all machine work. The heat-treatment or annealing is carried out to obtain the required level of surface hardness in the finished product. A typical Annealing furnace uses liquid- or gaseous fuel to provide the required amount of thermal energy for the purpose of annealing. The annealing temperature usually depends on the material type and properties. Annealing furnace varies in size from few kilograms to a five tones per hour (TPH) capacity.

Figure 6.1: *Annealing furnace*

6.2 Operating principle

An Annealing furnace typically consists of a furnace chamber made of refractories and insulation. For heat-treatment or annealing, a metal piece is subjected to slow heating to a required temperature after which it is cooled under controlled atmosphere or in open based on the quality of surface hardness required. Heat is transferred to the steel stock during its traverse through the furnace mainly by means of convection and radiation from the burner gases and the furnace walls. The target exit temperature of the steel stock is governed by the requirement of surface hardening. Steel quality aspects put constraints on temperature gradient and surface temperature. Fuel used in these furnaces can be liquid or gaseous fuel.

6.3 Best operating practices in annealing furnace

- **BOP 1: Efficient fuel preparation**

  Furnace efficiency depends significantly on the type of fuel being used, its chemistry and quality. Different types of fuels have different preparation criteria, which affects the overall efficiency of the furnace:

  - For oil fired furnace, pre-heat the fuel feed to attain the required viscosity level. Viscosity is the most important characteristic in the storage and use of fuel oil. Viscosity influences the degree of pre-heat required for handling, storage and satisfactory atomization. If the oil is too viscous, it may become difficult to pump to light the burner as well as tough to operate which causes poor atomization. Therefore pre-heating is necessary for proper atomization as it may result in the formation of carbon deposits on the burner walls.
  - For gas fired furnaces, maintain correct discharge pressure of gas at burner tip to avoid carbon deposits in furnace.

➲ BOP 2: Maintaining correct air-fuel ratios

In an annealing furnace if air fuel ratio is not properly maintained furnace efficiency decreases by 3-5%. High level of excess air in the flue gas results in excessive heat loss through flue gases, as well as cooling of the combustion chamber due to excess air. In a few cases it was observed that sometimes excess air present in annealing furnace is less than excess air required for complete combustion. Both the cases lead to improper fuel combustion, which automatically leads to poor furnace efficiency. Excess air in the furnace chamber at times also affects the annealing process. For optimum air-fuel ratio, following needs to be adopted:

Determine the quantity of fuel required based on operational condition.

- Calculate corresponding amount of air required for stoichiometric combustion.
- Add percentage of excess air required for complete combustion.
- Determine optimum blower ratings based on manufacturers recommendation.
- Air-fuel ratio to be monitored and controlled on a regular basis.
- Install automatic air-fuel ratio controller for better control.
- Periodically monitor oxygen percentage in flue gas. Optimum oxygen percentage needs to be maintained based on fuel type and composition.

➲ BOP 3: Selection and sizing of blower system

A proper capacity blower is necessary for combustion air to be delivered at correct pressure and in appropriate volume. Generally blowers are either locally fabricated without any proper design parameters or are under/over- sized without any consideration for correct air pressure.

- Select correct rating of blower as per manufacturers' recommendation
- Do not use locally fabricated blowers without any proper design parameters.
- Place blower near to the furnace to avoid transmission loss.
- Regular maintenance of blower impeller.

➲ BOP 4: Using optimum insulation and refractory for re-heating furnace

Around 5-8% of the total furnace losses accounts for wall and roof losses due to improper use of insulation and refractory. Furnace lining in a typical re-heating furnace are done with the locally available firebricks. The firebricks with low alumina content tend to get worn out in a short duration. Also, the insulation required for plugging heat loss through the furnace are usually done with locally available red bricks, which do not serve the purpose of insulation.

- Select optimum refractories and insulation based on manufacturers' recommendation.
- Maintain furnace skin temperature to < 60 ^{0}C.
- Minimise losses from openings such as pusher end, discharge door and inspection door.
- Use of ceramic fibre to be ensured for optimum thermal insulation.
- Furnace emissivity coating can be adopted for better thermal insulation.
- Refractory bricks of higher alumina backed by hot face & cold face insulation bricks and hysil blocks/ceramic fibre to be used in furnace side walls.

- High alumina bricks backed by hot face insulation and ceramic fibre blanket to be used in furnace roof.
- Minimum heat losses to be ensured after furnace shut-down.

BOP 5: Installation of temperature gauge in re-heating furnace

It is important to maintain the correct furnace temperature regime for optimum furnace efficiency. In a typical furnace, the zonal chamber is usually 50 ^{0}C higher than the stock temperature. Over-heating of stock can lead to increased scale loss and melting of stock, whereas under-heating can lead to improper rolling condition.

- Maintain furnace zonal temperature regime to desired level.

Figure 6.2: *Thermocouples used in re-heating furnace*

- Install thermocouples in different zones of furnace (soaking, heating and pre-heating zone) with proper digital display.
- Furnace discharge temperature to be maintained at optimum level.
- Recommended annealing temperatures of different type of material in annealing furnace are presented in table below:

Table 6.1: *Recommended annealing temperatures different materials*

SN	Type of material	Temperature (^{0} C)
1	Free cutting brass	700/750
2	Forging brass	700/750
3	Modify forging brass	600/650
4	High tensile brass	700/750
5	Lead free brass	800/850
6	IS319-II	800/850
7	DTP	800/850
8	SVF	800/850
9	CuZn40Pb2	800/850
10	C-3602	800/850
11	C-345	800/850

- Thermocouples to be selected based on temperature range to be monitored.
- It is recommended to install temperature gauges or thermocouples in annealing furnaces for proper temperature control. This will lead to proper monitoring of the furnace temperature thereby leading to optimum furnace temperature control.

BOP 6: Maintaining optimum heating regimes

The importance of temperature control in the furnace for fuel economy and reduction of burning losses are well established. Heating regimes is the temperatures at which the furnaces are required to be controlled. The fundamental principle that governs heating of steel rods in a annealing furnace is that the metal should reach the desired level of temperature and within the permissible temperature gradient from top to bottom when it reaches the discharge point.

- Maintain correct temperature regimes in furnace as per manufacturers' recommendation
- Automatic furnace temperature control system to be installed for proper monitoring and control of furnace temperature.

List of Suppliers - Ludhiana Foundry Cluster

Name of LSP	Address	Contact details	Empanelled for
Weldwel Systems	B-XXI 10459/1, Street No. 5 Janta Nagar, Bhagwan Chowk Ludhiana	Contact No.: 0161-2532653, 2531466 E-Mail ID: sunrisemek@gmail.com	Special Purpose machine
Akal Induction Pvt. Ltd.	G.T. Road Phagwara-144401	Contact No.: 01824-261533, +91-9815221313 E-Mail ID: akalinduction@gmail.com	Induction Reheating Furnace
GRD Induction	Opp. Hotel Country Inn, G.T. Road Jalandhar, 144001	Contact No.: 0181-5016159 E-Mail ID: bhajanpreetsinghkalsi@gmail.com	Induction Reheating Furnace
Sohal Electric Works	13243, Link Road, Dholewal Ludhiana-141003	Contact No.: 0161-2532255, 0161-2531116 E-Mail ID: mail@sohal.org	Induction Reheating Furnace
Electrotherm India Ltd.	72- Palodia Via Thaltej-Ahemdabad-382115, Gujarat	Contact No.: 01765-242463, 250182 E-Mail ID: lakshdeep.gupta@electrotherm.com	Induction Reheating Furnace
Micro Engineers	3668, Street No. 5, Chet Singh Nagar, Opp. ATI, Gill Road, Ludhiana	Contact No.: 9814127526 E-Mail ID: Microengg_3668@rediffmail.com	Special Purpose machine
Harkaram Enterprises	10529/1, St. No. 10, Partap Nagar, Bhagwan Chowk Ludhiana	Contact No.: 0161-3209676 9815143513 E-Mail ID: indervir.84@gmail.com	Special Purpose machine
Harjit Turners	J.B. Industrial Estate, Near Sunny Kharay Dharam Kanda, Jaspal Bangar Road, Ludhiana	Contact No.: 097797-31313, 093179-91313 E-Mail ID: infor@harjitturner.com	Special Purpose machine
Bhambar Engineers	1208, GT Road, Dhandari Khurd, Ludhiana		Special Purpose machine
Harisons International	#2, Pannu Vihar, Leather Complex Road, Jalandhar-144003		Special Purpose machine