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Department of Electrical and Electronics Engineering/ Mechanical Engineering

Bridge Course On ELECTRICAL AND MECHANICAL TECHNOLOGY (15A01301)

Voltage : Voltage is defined as the work done per unit charge.

$$V=\frac{\text{workdone}}{\text{chrage}} \text{ (volts)}$$

Current : Current is defined as the rate of change of charge with respect to the time.

Mathematically the current is given by $I = \frac{dq}{dt}$ (Amps)

Energy : Capacity for doing work. Its S.I units are Joules.

Power : Power is defined as rate of change of energy with respect to the time.

Mathematically the power is given by $P = \frac{dw}{dt}$ (Watts)

Passive Components:

Definition : The passive component is a device, which is basically static in operation. It is not capable of amplification or oscillation. It does not require power for its operation.

Examples of passive components are resistors, capacitors, inductors and fuses.

Resistors:

The resistor is an electrical device whose primary function is to introduce resistance to flow of electric current. The magnitude of opposition to flow of current is the resistance of resistor. The resistance is measured in ohms. The various uses of resistor includes setting biases, controlling gains, fixing constants, matching and loading circuits, voltage division, and heat generation.

There are two classes of resistors. They are fixed resistors and variable resistors.

Fixed reistor

Variable resistor

Fixed Resistors:

A fixed resistor is one in which the value of its resistance cannot change.

Variable Resistors:

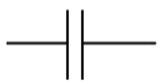
A variable resistor is one in which the value of its resistance can change in different ranges.
The different types of variable resistors are:
1.Rheostat
2.Potentiometer

3.Preset

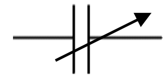
Capacitor:

Capacitance of a capacitor is the ability of a dielectric to store electric charge. Its unit is Farad. It is named after Michael Faraday. A capacitor is made up of an insulator between two conductors. The capacitors are characterized by two effects namely, charging and discharging.

The symbol of the capacitor is as shown below:



Fixed Capacitor



Variable Capacitor (Trimmer)

Characteristics of Capacitor:

- The capacitor is represented by the capacitance value and the voltage.
- Its Capacitance, $C = \frac{Q}{V}$
- Its energy stored $W = \frac{1}{2}CV^2$
- If N capacitors are in series the resultant capacitance is $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ... + \frac{1}{C_N}$
- If N capacitors are in parallel the resultant capacitance $C = C_1 + C_2 + C_3 + ... + C_N$
- The common problem in capacitors are open or short or leaky.
- They are tested with ohmmeter.
- They can be measured by the capacitance meter.
- Its reactance $X_C = \frac{1}{\omega C}$
- They are classified on the basis of shape of conducting plates and type of dielectrics.
- Its power factor is $\frac{R}{X_C}$.
- Its quality factor is $\frac{X_C}{R}$.
- Capacitance does not depends on Q or V.
- Capacitance depends on dielectric constant, area of the plates and distance between the plates.
- Current in a capacitor leads voltage by 90°.

Inductors:

Inductance is used for the storage of magnetic energy. Magnetic energy is stored as long as current keeps flowing through the inductor. Components which are definite value of Inductance are called fixed inductors. A long wire has more Inductance than short wire since conductor length cuts by magnetic flux produces more induced voltage. Similarly a coil has more inductance than equivalent length of straight wire because coil concentrates more fluxes.

The symbol of inductor is shown in figure below:

Characteristics of Inductors:

- The inductor is represented by L, Henrys.
- Its L is given by $\frac{V_i}{\left(\frac{di}{dt}\right)}$.
- Its energy stored $W = \frac{1}{2}LI^2$
- Series inductance of two coils is $L = L_1 + L_2$
- Parallel inductance of two coils is $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$
- The common problem in inductors is open windings.
- They are tested with ohmmeter.
- All inductors have internal resistance.
- Its reactance $X_L = \omega L$.
- Its quality factor is $\frac{X_L}{R}$.
- Current in a inductor lags the voltage by 90°.

Ohm's Law:

The law stating that the direct current flowing in a conductor is directly proportional to the potential difference betweenits ends. It is usually formulated as *V* = IR, where *V* is the potential difference, or volt age, *I* is the current, and *R* isthe resistance of the conductor.

$$I = \frac{V}{R} \qquad R = \frac{V}{I} \qquad V = I\,R$$

KIRCHOFF'S LAW:

Kirchoff's Voltage Law

Kirchoff's Voltage law states that the algebraic sum of voltages in a closed loop is equal to zero.

Kirchoff's Current Law

Kirchoff’s Current law states that the algebraic sum of currents at node or junction is equal to zero. It can also be stated as the sum of currents entering a node is equal to sum of currents coming out of that node .

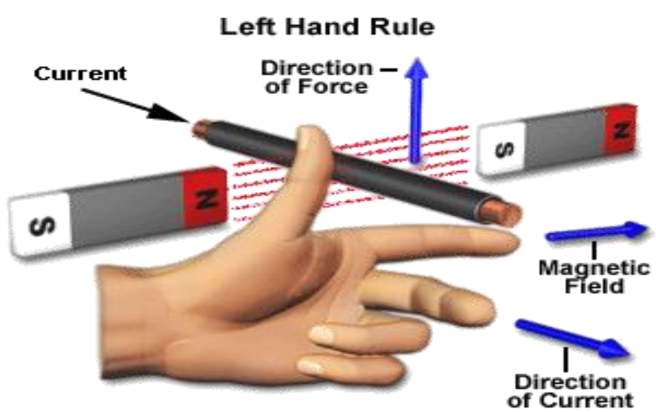
Series Circuit :
In a Series Circuit the current is same and voltage is different.

Parallel Circuit :
In a Parallel circuit the voltage is same and current is different.

Fleming Left Hand rule and Fleming Right Hand rule:

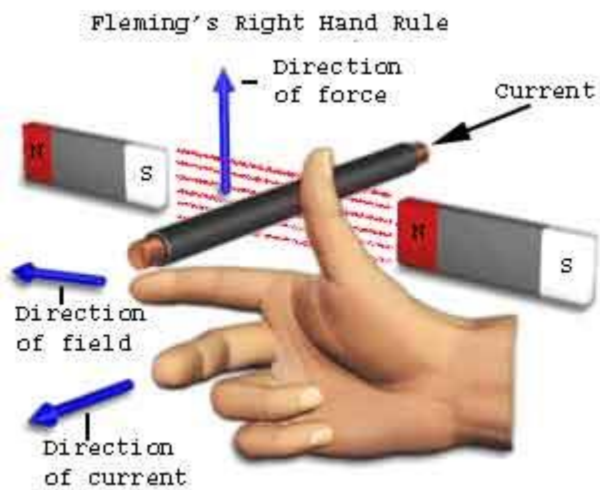
Whenever, a current carrying conductor comes under a magnetic field, there will be force acting on the conductor and on the other hand, if a conductor is forcefully brought under a magnetic field, there will be an induced current in that conductor. In both of the phenomenons, there is a relation between magnetic field, current and force. This relation is directionally determined by **Fleming Left Hand rule** and **Fleming Right Hand rule** respectively. Directionally means these rules do not show the magnitude but show the direction of any of the three parameters (magnetic field, current, force) if the direction of other two are known. **Fleming Left Hand rule** is mainly applicable for electric motor and **Fleming Right Hand rule** is mainly applicable for electric generator. In late 19^{th} century, John Ambrose Fleming introduced both these rules and as per his name, the rules are well known as **Fleming left and right hand rule**.

Fleming Left Hand rule:



It is found that whenever an current carrying conductor is placed inside a magnetic field, a force acts on the conductor, in a direction perpendicular to both the directions of the current and the magnetic field. In the figure it is shown that, a portion of a conductor of length L placed vertically in a uniform horizontal magnetic field strength H, produced by two magnetic poles N and S. If i is the current flowing through this conductor, the magnitude of the force acts on the conductor is,
F = BiL

Fleming Right Hand Rule:



As per Faraday's law of electromagnetic induction, whenever a conductor moves inside a magnetic field, there will be an induced current in it. If this conductor gets forcefully moved inside the magnetic field, there will be a relation between the direction of applied force, magnetic field and the current. This relation among these three directions is determined by this rule states "Hold out the right hand with the first finger, second finger and thumb at right angle to each other. If forefinger represents the direction of the line of force, the thumb points in the direction of motion or applied force, then second finger points in the direction of the induced current.

Lenz Law of Electromagnetic Induction:

Lenz's law is named after the German scientist H. F. E. Lenz in 1834. Lenz's law obeys Newton's third law of motion (i.e., to every action there is always an equal and opposite reaction) and the conservation of energy (i.e., energy may neither be created nor destroyed and therefore the sum of all the energies in the system is a constant).

Lenz law is based on Faraday's law of induction, so before understanding Lenz's law; one should know what is Faraday's law of induction? When a changing magnetic field is linked with a coil, an emf is induced in it. This change in magnetic field may be caused by changing the magnetic field strength by moving a magnet towards or away from the coil, or moving the coil into or out of the magnetic field as desired. Or in simple words, we can say that the magnitude of the emf induced in the circuit is proportional to the rate of change of flux. Lenz's law states that when an emf is generated by a change in magnetic flux according to Faraday's Law, the polarity of the induced emf is such, that it produces an current that's magnetic field opposes the change which produces it.

The negative sign used in Faraday's law of electromagnetic induction, indicates that the induced emf (ε) and the change in magnetic flux ($\delta\Phi_B$) have opposite signs.

$$\mathcal{E} = -N\frac{\partial\Phi_B}{\partial t},$$

Where,
ε = Induced emf
$\delta\Phi_B$ = change in magnetic flux
N = No of turns in coil

Faraday Law of Electromagnetic Induction:

In 1831, Michael Faraday, an English physicist gave one of the most basic laws of electromagnetism called **Faraday's law of electromagnetic induction**. This law explains the working principle of most of the electrical motors, generators, electrical transformers and inductors. This law shows the relationship between electric circuit and magnetic field. Faraday performs an experiment with a magnet and coil. During this experiment, he found how emf is induced in the coil when flux linked with it changes. He has also done experiments in electro-chemistry and electrolysis.

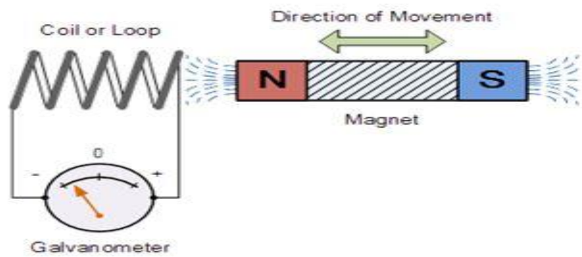
Faraday's Laws:

Faraday's First Law
Any change in the magnetic field of a coil of wire will cause an emf to be induced in the coil. This emf induced is called induced emf and if the conductor circuit is closed, the current will also circulate through the circuit and this current is called induced current.
Method to change magnetic field:

1. By moving a magnet towards or away from the coil
2. By moving the coil into or out of the magnetic field.
3. By changing the area of a coil placed in the magnetic field
4. By rotating the coil relative to the magnet.

Faraday's Second Law
It states that the magnitude of emf induced in the coil is equal to the rate of change of flux that linkages with the coil. The flux linkage of the coil is the product of number of turns in the coil and flux associated with the coil.

Faraday Law Formula



Consider a magnet approaching towards a coil. Here we consider two instants at time T_1 and time T_2.

Flux linkage with the coil at time, $T_1 = N\Phi_1$ Wb

Flux linkage with the coil at time, $T_2 = N\Phi_2$ wb

Change in flux linkage = $N(\Phi_2 - \Phi_1)$

Let this change in flux linkage be, $\Phi = \Phi_2 - \Phi_1$

So, the Change in flux linkage = $N\Phi$

Now the rate of change of flux linkage = $N\Phi / t$

Take derivative on right hand side we will get the rate of change of flux linkage = $Nd\Phi/dt$

But according to Faraday's law of electromagnetic induction, the rate of change of flux linkage is equal to induced emf.

$$E = N\frac{d\phi}{dt}$$

Applications of Faraday Law:

Faraday law is one of the most basic and important laws of electromagnetism. This law finds its application in most of the electrical machines, industries and medical field etc.

- Electrical Transformers
- It is a static ac device which is used to either step up or step down voltage or current. It is used in generating station, transmission and distribution system. The transformer works on Faraday's law.
- Electrical Generators
- The basic working principle of electrical generator is Faraday's law of mutual induction. Electric generator is used to convert mechanical energy into electrical energy.
- Induction Cookers
- The Induction cooker, is a most fastest way of cooking. It also works on principle of mutual induction. When current flows through the coil of copper wire placed below a cooking container, it produces a changing magnetic field. This alternating or changing magnetic field induces an emf and hence the current in the conductive container, and we know that flow of current always produces heat in it.
- Electromagnetic Flow Meters

- It is used to measure velocity of blood and certain fluids. When a magnetic field is applied to electrically insulated pipe in which conducting fluids are flowing, then according to Faraday's law, an electromotive force is induced in it. This induced emf is proportional to velocity of fluid flowing.
- Form the bases of Electromagnetic Theory
- Faraday's idea of lines of force is used in well known Maxwell's equations. According to Faraday's law, change in magnetic field gives rise to change in electric field and the converse of this is used in Maxwell's equations.
- Musical Instruments
- It is also used in musical instruments like electric guitar, electric violin etc.

Principle of DC Generator:

There are two types of generators, one is ac generator and other is DC generator. Whatever may be the types of generators, it always converts mechanical power to electrical power. An AC generator produces alternating power. A DC generator produces direct power. Both of these generators produce electrical power, based on same fundamental principle of Faraday's law of electromagnetic induction. According to this law, when a conductor moves in a magnetic field it cuts magnetic lines of force, due to which an emf is induced in the conductor. The magnitude of this induced emf depends upon the rate of change of flux (magnetic line force) linkage with the conductor. This emf will cause a current to flow if the conductor circuit is closed.

Working or Operating Principle of DC Motor:

A DC motor in simple words is a device that converts electrical energy (direct current system) into mechanical energy. It is of vital importance for the industry today, and is equally important for engineers to look into the **working principle of DC motor** in details that has been discussed in this article. In order to understand the **operating principle of DC motor** we need to first look into its constructional feature.

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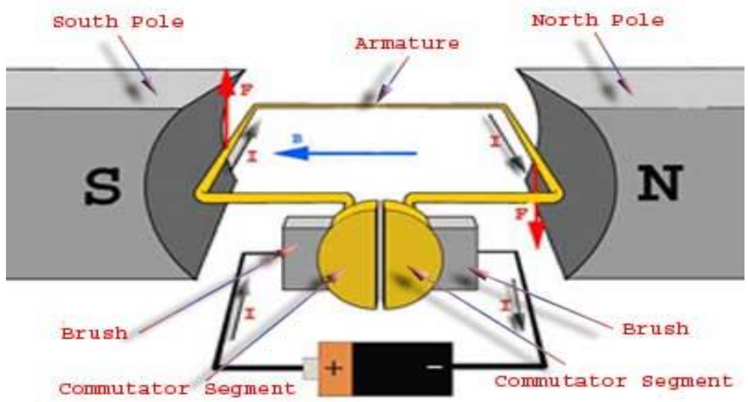


Transformer

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. A varying current in one coil of the transformer produces a varying magnetic field, which in turn induces a voltage in a second coil. Power can be transferred between the two coils through the magnetic field, without a metallic connection between the two circuits. Faraday's law of induction discovered in 1831 described this effect. Transformers are used to increase or decrease the alternating voltages in electric power applications.

Transformers are capable of either increasing or decreasing the voltage and current levels of their supply, without modifying its frequency, or the amount of electrical power being transferred from one winding to another via the magnetic circuit.

A single phase voltage transformer basically consists of two electrical coils of wire, one called the “Primary Winding” and another called the “Secondary Winding”. For this tutorial we will define the “primary” side of the transformer as the side that usually takes power, and the “secondary” as the side that usually delivers power. In a single-phase voltage transformer the primary is usually the side with the higher voltage.

These two coils are not in electrical contact with each other but are instead wrapped together around a common closed magnetic iron circuit called the “core”. This soft iron core is not solid but made up of individual laminations connected together to help reduce the core’s losses.

The two coil windings are electrically isolated from each other but are magnetically linked through the common core allowing electrical power to be transferred from one coil to the other. When an electric current passed through the primary winding, a magnetic field is developed which induces a voltage into the secondary winding as shown.

Single Phase Voltage Transformer

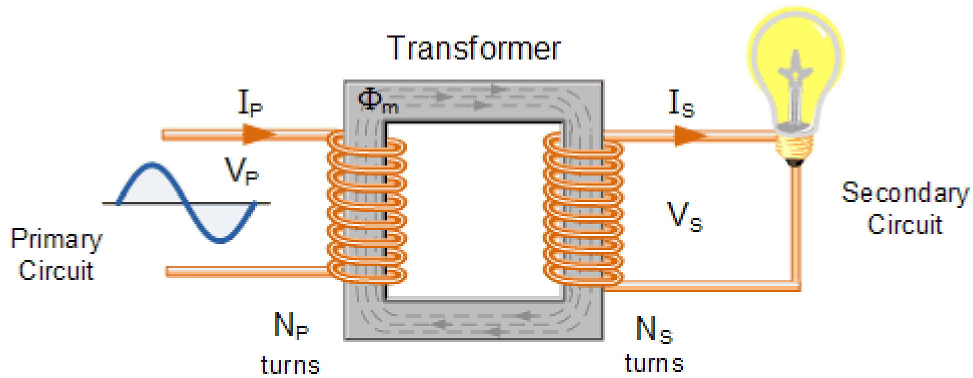
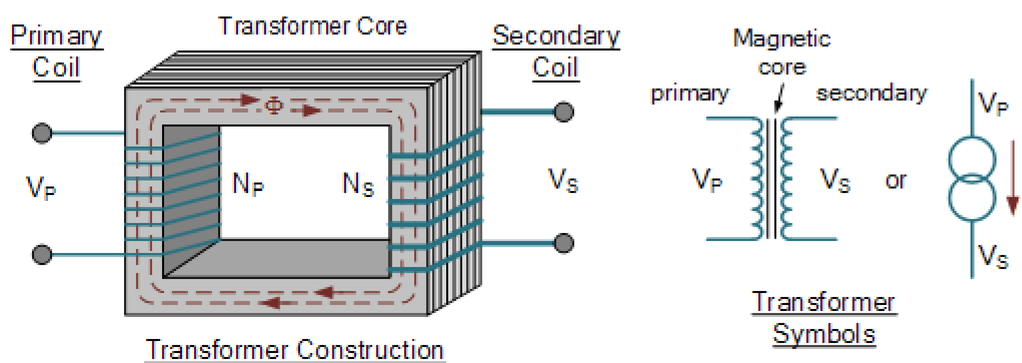


Fig : Principle of Operation of a Single Phase Transformer

In other words, for a transformer there is no direct electrical connection between the two coil windings, thereby giving it the name also of an Isolation Transformer. Generally, the primary winding of a transformer is connected to the input voltage supply and converts or transforms the electrical power into a magnetic field. While the job of the secondary winding is to convert this alternating magnetic field into electrical power producing the required output voltage as shown.



Where:

VP - is the Primary Voltage

VS - is the Secondary Voltage

NP - is the Number of Primary Windings

NS - is the Number of Secondary Windings

Φ (phi) - is the Flux Linkage

Notice that the two coil windings are not electrically connected but are only linked magnetically. A single-phase transformer can operate to either increase or decrease the voltage applied to the primary winding. When a transformer is used to “increase” the voltage on its secondary winding with respect to the primary, it is called a Step-up transformer. When it is used to “decrease” the voltage on the secondary winding with respect to the primary it is called a Step-down transformer.

The difference in voltage between the primary and the secondary windings is achieved by changing the number of coil turns in the primary winding (NP) compared to the number of coil turns on the secondary winding (NS).

As the transformer is basically a linear device, a ratio now exists between the number of turns of the primary coil divided by the number of turns of the secondary coil. This ratio, called the ratio of transformation, more commonly known as a transformers “turns ratio”, (TR). This turns ratio value dictates the operation of the transformer and the corresponding voltage available on the secondary winding.

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Department of Mechanical Engineering

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WELDING

Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing fusion, which is distinct from lower temperature metal-joining techniques such as brazing and soldering, which do not melt the base metal. In addition to melting the base metal, a filler material is typically added to the joint to form a pool of molten material (the weld pool) that cools to form a joint that is usually stronger than the base material. Pressure may also be used in conjunction with heat, or by itself, to produce a weld. Although less common, there are also solid state welding processes such as friction welding or shielded active gas welding in which metal does not melt.

Some of the best known welding methods include:

- Oxy-fuel welding – also known as oxyacetylene welding or oxy welding uses fuel gases and oxygen to weld and cut metals.
- Shielded metal arc welding (SMAW) – also known as "stick welding or electric welding", uses an electrode that has flux around it to protect the weld puddle. The electrode holder holds the electrode as it slowly melts away. Slag protects the weld puddle from atmospheric contamination.
- Gas tungsten arc welding (GTAW) – also known as TIG (tungsten, inert gas), uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas such as argon or helium.
- Gas metal arc welding (GMAW) – commonly termed MIG (metal, inert gas), uses a wire feeding gun that feeds wire at an adjustable speed and flows an argon-based shielding gas or a mix of argon and carbon dioxide (CO_2) over the weld puddle to protect it from atmospheric contamination.
- Flux-cored arc welding (FCAW) – almost identical to MIG welding except it uses a special tubular wire filled with flux; it can be used with or without shielding gas, depending on the filler.
- Submerged arc welding (SAW) – uses an automatically fed consumable electrode and a blanket of granular fusible flux. The molten weld and the arc zone are protected from atmospheric contamination by being "submerged" under the flux blanket.
- Electroslag welding (ESW) – a highly productive, single pass welding process for thicker materials between 1 inch (25 mm) and 12 inches (300 mm) in a vertical or close to vertical position.
- Electric resistance welding (ERW) – a welding process that produces coalescence of laying surfaces where heat to form the weld is generated by the electrical resistance of the material. In general, an efficient method, but limited to relatively thin material.

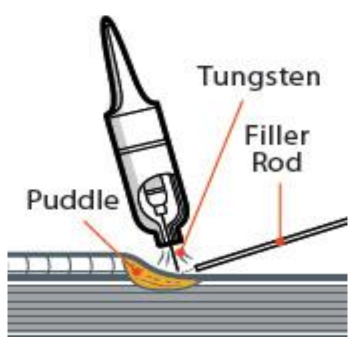
Many different energy sources can be used for welding, including a gas flame, an electric arc, a laser, an electron beam, friction, and ultrasound. While often an industrial process, welding may be performed in many different environments, including in open air, under water, and in outer space. Welding is a hazardous undertaking and precautions are required to avoid burns, electric shock, vision damage, inhalation of poisonous gases and fumes, and exposure to intense ultraviolet radiation.

Until the end of the 19th century, the only welding process was forge welding, which blacksmiths had used for centuries to join iron and steel by heating and hammering. Arc welding and oxyfuel welding were among the first processes to develop late in the century, and electric resistance welding followed soon after. Welding technology advanced quickly during the early 20th century as the world wars drove the demand for reliable and inexpensive joining methods. Following the wars, several modern welding techniques were developed, including manual methods like SMAW, now one of the most popular welding methods, as well as semi-automatic and automatic processes such as GMAW, SAW, FCAW and ESW. Developments continued with the invention of laser beam welding, electron beam welding, magnetic pulse welding (MPW), and friction stir welding in the latter half of the century. Today, the science continues to advance. Robot welding is commonplace in industrial settings, and researchers continue to develop new welding methods and gain greater understanding of weld quality.

Other Types of Welding

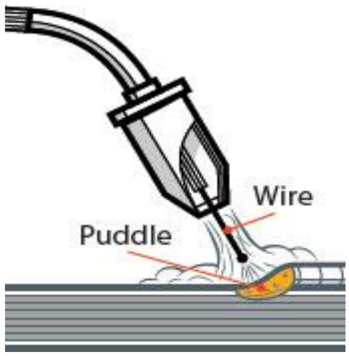
TIG Welding

Instead of a consumable electrode, which conducts current and melts into the metal, a TIG (Tungsten Inert Gas) machine has a non consumable tungsten electrode to strike the arc and establish the puddle of molten metal. A separate filler rod, held in the welder's other hand, is added to fill the puddle.



MIG Welding

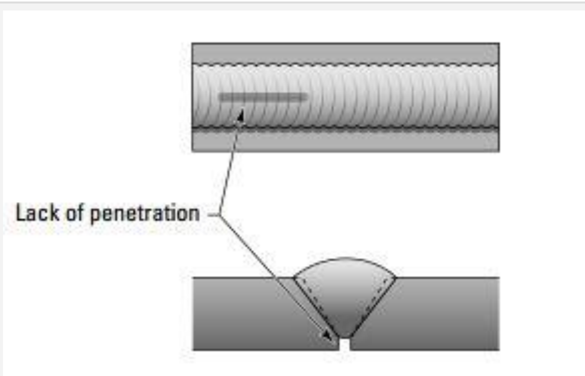
Use a solid-core filler wire, surround it with an inert gas like argon or CO_2, and your wire-feed welder becomes a MIG machine (Metal Inert Gas). It leaves a cleaner, slag-free weld and can be used on stainless steel or aluminum.



Most Common Types of Welding Defects

Incomplete Penetration

Incomplete penetration happens when your filler metal and base metal aren't joined properly, and the result is a gap or a crack of some sort. Check out the Figure below for an example of incomplete penetration.



a common case of incomplete penetration

Welds that suffer from incomplete penetration are weak at best, and they'll likely fail if you apply much force to them. (Put simply, welds with incomplete penetration are basically useless.) Here's a list of the

Most common causes of incomplete penetration welding defect.

The groove you're welding is too narrow, and the filler metal doesn't reach the bottom of the joint.

✓You've left too much space between the pieces you're welding, so they don't melt together on the first pass.

✓You're welding a joint with a V-shaped groove and the angle of the groove is too small (less than 60 to 70 degrees), such that you can't manipulate your electrode at the bottom of the joint to complete the weld.

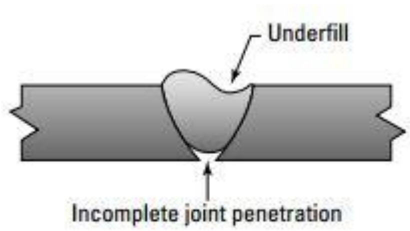
✓Your electrode is too large for the metals you're welding.

✓ Your speed of travel (how quickly you move the bead) is too fast, so not enough metal is deposited in the joint.

✓Your welding amperage is too low. If you don't have enough electricity going to the electrode, the current won't be strong enough to melt the metal properly

Incomplete Fusion

Incomplete fusion occurs when individual weld beads don't fuse together, or when the weld beads don't fuse properly to the base metal you're welding, such as in below.



a textbook example of incomplete fusion

The most common type of incomplete fusion is called overlap and usually occurs at the toe(on the very top or very bottom of the side) of a weld. One of the top causes is an incorrect weld angle, which means you're probably holding the electrode and/or your filler rods at the wrong angle while you're making a weld; if you think that's the case, tweak the angle a little at a time until your overlap problem disappears.

Here are a few more usual suspects when it comes to incomplete fusioncauses.

✓Your electrode is too small for the thickness of the metal you're welding.

✓You're using the wrong electrode for the material that you're welding.

✓Your speed of travel is too fast.

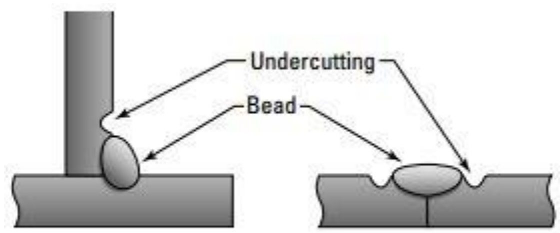
✓Your arc length is too short.

✓Your welding amperage is set too low. If you think your incomplete fusion may be because of low welding amperage, crank up the machine! But be careful: You really need only enough amperage to melt the base metal and ensure a good weld. Anything more is unnecessary and can be dangerous.

✓ Contaminants or impurities on the surface of the parent metal(the metal you're welding) prevent the molten metal (from the filler rod or elsewhere on the parent metal) from fusing.

Undercutting

Undercutting is an extremely common welding defect. It happens when your base metal is burned away at one of the toes of a weld. To see what I mean, look at Figure.



When you weld more than one pass on a joint, undercutting can occur between the passes because the molten weld is already hot and takes less heat to fill, yet you're using the same heat as if it were cold. It's actually a very serious defect that can ruin the quality of a weld, especially when more than 1⁄32 inch is burned away. If you do a pass and notice some undercutting, you must remove it before you make your next pass or you risk trapping slag (waste material — see the following section) into the welded joint (which is bad news). The only good thing about undercutting is that it's extremely easy to spot after you know what you're looking for.

Here are a few **common causes of undercutting:**

✓ Your electrode is too large for the base metal you're welding.

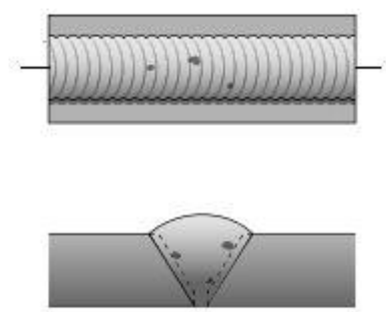
✓Your arc is too long.

✓You have your amperage set too high.

✓You're moving your electrode around too much while you're welding. Weaving your electrode back and forth is okay and even beneficial, but if you do it too much, you're buying a one-way ticket to Undercutting City (which is of course the county seat for Lousy Weld County).

Slag Inclusions

A little bit of slag goes a long way . . . toward ruining an otherwise quality weld. Slagis the waste material created when you're welding, and bits of this solid material can become incorporated (accidentally) into your weld, as in Figure . Bits of flux, rust, and even tungsten can be counted as slag and can cause contamination in your welds.



Common causes of slag inclusions include

✓ Flux from the stick welding electrode that comes off and ends up in the weld

✓ Failure to clean a welding pass before applying the next pass Be sure to clean your welds before you go back in and apply a second weld bead.

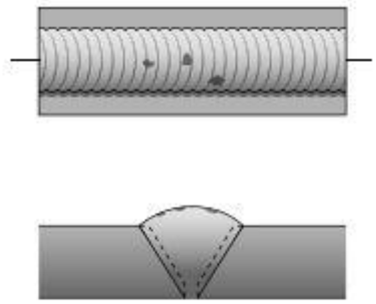
✓ Slag running ahead of your weld puddle when you're welding a V-shaped groove that's too tight

✓incorrect welding angle

✓ Welding amperage that's too low

Flux Inclusions

If you're soldering or brazing (also called braze welding), flux inclusions can be a real problem. If you use too much flux in an effort to "float out" impurities from your weld, you may very well end up with flux inclusions like those in Figure .(Head to Chapter 13 for more on brazing and soldering.)

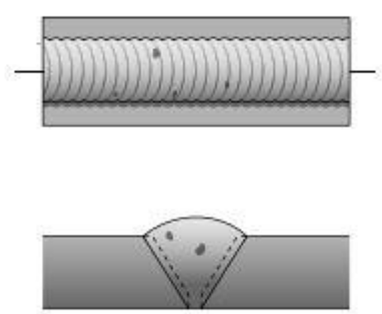


If you're working on a multilayer braze weld, flux inclusion can occur when you fail to remove the slag or glass on the surface of the braze before you apply the next layer. When you're soldering, flux inclusion can be a problem if you're not using enough heat. These inclusions are usually closely spaced, and they can cause a soldered joint to leak. If you want to avoid flux inclusions (and believe me, you do), make sure you do the following:

✓ Clean your weld joints properly after each pass. This task is especially important when you're brazing.
✓Don't go overboard with your use of flux.
✓ Make sure you're using enough heat to melt the filler or flux material.

Porosity

If you read very much of this book, you quickly figure out that porosity(tiny holes in the weld) can be a serious problem in your welds (especially stick or mig welds). Your molten puddle releases gases like hydrogen and carbon dioxide as the puddle cools; if the little pockets of gas don't reach the surface before the metal solidifies, they become incorporated in the weld, and nothing can weaken a weld joint quite like gas pockets. Take a gander at Figure for an example of porosity.



Following are a few simple steps you can take to reduce porosity in your welds:

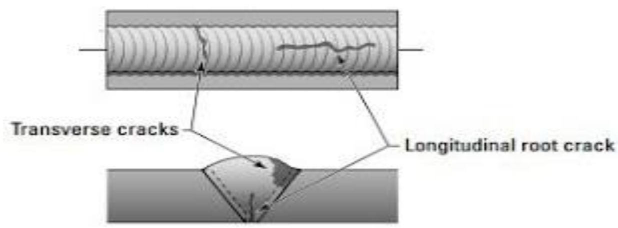
✓ Make sure all your materials are clean before you begin welding.

✓ Work on proper manipulation of your electrode.

✓ Try using low-hydrogen electrodes.

Cracks

Cracks can occur just about everywhere in a weld: in the weld metal, the plate next to the weld metal, or in any other piece affected by the intense heat of welding. Check out the example of cracking in Figure.



Here are the three major types of cracks, what causes them, and how you can prevent them.

✓ **Hot cracks:**

This type of crack occurs during welding or shortly after you've deposited a weld, and its cause is simple: The metal gets hot too quickly or cools down too quickly. If you're having problems with hot cracking, try preheating your material. You can also postheat your material, which means that you apply a little heat here and there after you've finished welding in an effort to let the metal cool down more gradually.

✓ **Cold cracks:**

This type of crack happens well after a weld is completed and the metal has cooled off. (It can even happen days or weeks after a weld.) It generally happens only in steel, and it's caused by deformities in the structure of the steel. You can guard against cold cracking by increasing the thickness of your first welding pass when starting a new weld. Making sure you're manipulating your electrode properly, as well as pre- and post-heating your metal, can also help thwart cold cracking.

✓ **Crater cracks:**

These little devils usually occur at the ending point of a weld, when you've stopped welding before using up the rest of an electrode. The really annoying part about crater cracks is that they can cause other cracks, and the cracking can just kind of snowball from there. You can control the problem by making sure you're using the appropriate amount of amperage and heat for each project, slowing your speed of travel, and pre- and postheating.

Warpage

If you don’t properly control the expansion and contraction of the metals you work with, warpage(an unwanted distortion in a piece of metal’s shape) can be the ugly result. Check out an example in Figure.

If you weld a piece of metal over and over, the chances of it warping are much higher. You can also cause a piece of metal to warp if you clamp the joints too tightly. (If you allow the pieces of metal that make the joint to move a little, there’s less stress on them.) Say you’re welding a Tjoint. The vertical part of the Tsometimes pulls itself toward the weld joint. To account for that movement, simply tilt the vertical part out a little before you weld, so that when it tries to pull toward the weld joint, it pulls itself into a nice 90 degree angle! The more heat you use, the more likely you are to end up with warpage, so be sure to use only the amount of heat you need. Don’t overdo it. Opting for a slower speed of travel while welding can also help to cut down on warpage.

Spatter

Spatter(small particles of metal that attach themselves to the surface of the material you’re working on.) is a fact of life with most kinds of welding; no matter how hard you try, you’ll never be able to cut it out completely. You can see it in all its glory .You can keep spatter to a minimum by spraying with an anti-spatter compound (available at your welding supply store) or by scraping the spatter off the parent metal surface.

Classification of Internal Combustion Engines:

Today’s IC engines can be classified in several ways. Some of the ways of classification of Internal Combustion (IC) engines is listed below:

1. Based on application

- Automobile Engine
- Aircraft Engine
- Locomotive Engine
- Marine Engine

- Stationary Engine

2. Based on basic engine design

- Reciprocating: Single cylinder, Multi-cylinder In-line, V, radial, opposed cylinder, Opposed Piston.
- Rotatory: Single motor, Multi motor

3. Based on operating cycle

- Atkinson (For complete expansion SI Engine)
- Diesel (For the Ideal Diesel Engine)
- Dual (For the Actual Diesel Engine)
- Miller (For Early/Late Inlet valve closing type SI Engine)
- Otto (For the Convectional SI Engine)

4. Based on working cycle

- Four stroke cycle
- Two stroke cycle
    - Scavenging ; direct/crankcase/cross flow; back flow/loop; Uni flow
    - Naturally aspirated or turbocharged

5. Based on Valve/port design and location

- Design of valve/port
    - Poppet valve
    - Rotatory valve
- Location of valve/port
    - T-head
    - L-head
    - F-head
    - L-head

6.Based on Fuel

- Convectional
    - Crude oil derivatives; Petrol, diesel
    - Other sources; coal, bio-mass, tar stands, shale

- Alternative
  - Petroleum derived: CNG, LPG
  - Bio-mass derived: alcohols, vegetable oils, producer gas, biogas and hydrogen
- Blending
- Bi-fuel and dual fuel

7. Based on mixture preparation

- Carburetion
- Fuel injection

8. Based on ignition

- Spark ignition
- Compression Ignition

9. Based on stratification of charge

- Homogeneous Charge
- Stratified charge
  - With carburetion
  - With fuel injection

10. Based on combustion chamber design

- Open chamber: Disc, wedge, hemispherical, bowl-in-piston, bath tub.
- Divided chamber:
  - (For CI) 1. Swirl chamber, 2. Pre-chamber
  - (for SI) 1. CVCC, 2. Other designs

11. Based on cooling system

- Air-cooling system
- Water-cooling system

ENGINE&WORKINGPRINCIPLES

Aheatengineisamachine,whichconvertsheatenergyintomechanicalenergy.Thecombustionoffuel suchas coal,petrol,dieselgeneratesheat.Thisheatissuppliedtoaworkingsubstanceathightemperature.Bytheexpansionofthissubstanceinsuitablemachines,heatenergyisconvertedintousefulwork.Heatenginescanbefurtherdividedintotwotypes:

(i) Externalcombustionand

(ii) Internalcombustion.

Inasteamenginethecombustionoffueltakesplaceoutsidetheengineandthesteamthusformedisusedtoruntheengine.Thus,itisknownasexternalcombustionengine.Inthecaseofinternalcombustionengine,thecombustionoffueltakesplaceinsidetheenginecylinderitself.

TheICenginecanbefurtherclassifiedas:(i)stationaryormobile,(ii)horizontalorverti-caland(iii)low,mediumorhighspeed.ThetwodistincttypesofICenginesusedforeithermobileorstationaryoperationsare:(i)dieseland(ii)carburettor.

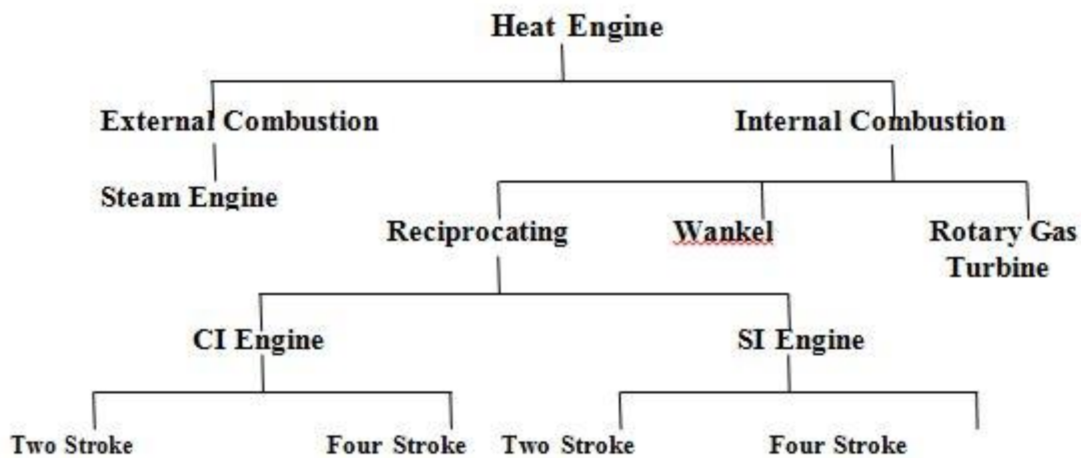


Chart 1. Types of Heat Engines

SparkIgnition(CarburettorType)ICEngine

Inthisengineliquidfuelisatomised,vaporizedandmixedwithairincorrectproportionbeforebeingtakentotheenginecylinderthroughtheintakemanifolds.Theignitionofthemixtureiscausedbyanelectricsparkandisknownassparkignition.

CompressionIgnition(DieselType)IC Engine

Inthisonlytheliquidfuelisinjectedinthecylinderunderhighpressure.

CONSTRUCTIONALFEATURESOFICENGINE:

ThecrosssectionofICengineisshowninFig.1.Abriefdescriptionofthesepartsisgivenbelow.

Cylinder:

ThecylinderofanICengineconstitutesthebasicandsupportingportionoftheenginepowerunit.Itsmajorfunctionistoprovidespaceinwhichthepistoncanoperatetodrawinthefuelmixtureorair(dependinguponsparkignitionorcompressionignition),compressit,allowittoexpandandthusgeneratepower.Thecylinderisusually madeofhigh-gradecastiron.Insomecases,togivegreaterstrengthandwearresistancewithlessweight,chromium,nickelandmolybdenumareaddedtothecastiron.

Piston:

Thepistonofanengineisthefirstparttobeginmovementandtotransmitpowertothecrankshaftasaresultofthepressureandenergygeneratedbythecombustionofthefuel.Thepistonisclosedatoneendandopenontheotherendtopermitdirectattachmentoftheconnectingrodanditsfreeaction.

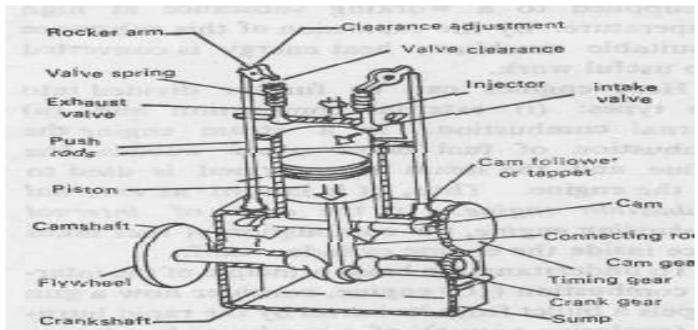


Fig.1Cross-sectionofadieselengine

Thematerialsusedforpistonsaregreycastiron,caststeelandaluminumalloy.However,themoderntrendistouseonlyaluminumalloypistonsinthetractorengine.

PistonRings:

Thesearemadeofcastirononaccountoftheirabilitytoretainbearingqualitiesandelasticityindefinitely.Theprimaryfunctionofthepistonringsistoretaincompressionandatthesametimereducethecylinderwallandpistonwallcontactareatoa minimum, thus reducingfrictionlossesandexcessivewear.The otherimportantfunctionsofpistonringsare thecontrolofthelubricatingoil,cylinderlubrication,andtransmissionofheatawayfromthepistonandfromthecylinderwalls.Pistonringsareclassedascompressionringsandoilringsdependingontheirfunctionandlocationonthepiston.

Compressionringsareusuallyplainone-pieceringsandarealwaysplacedinthegroovesnearestthepistonhead.Oilringsaregroovedorslottedandarelocatedeitherinthelowestgrooveabovethepistonpinorinagroovenearthepistonskirt.Theirfunctionistocontrolthedistributionofthelubricatingoiltothecylinderandpistonsurfaceinordertopreventunnecessaryorexcessiveoilconsumptionion.

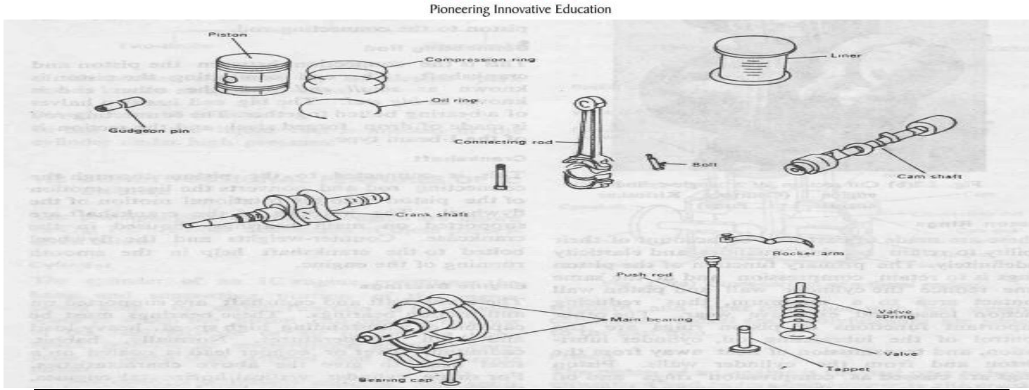


Figure2.Componentsofthedieselengine

PistonPin:

Theconnectingrodisconnectedtothepistonthroughthepistonpin.Itismadeofcasehardenedalloysteelwith precisionfinish.Therearethreedifferentmethodstoconnectthepistontotheconnectingrod.

ConnectingRod:

Thisistheconnectionbetweenthepistonandcrankshaft.Theendconnectingthepistonisknownas*smallend* andtheotherendisknownasbig*end.*Thebigendhastwohalvesofabearingboltedtogether.Theconnectingro dismadeofdropforgedsteelandthesectionisoftheI-beamtype.

Crankshaft:

Thisisconnectedtothepistonthroughtheconnectingrodandconvertsthelinearmotionofthepistonintother otationalmotionoftheflywheel.Thejournalsofthecrankshaftaresupportedonmainbearings,housedinthe crankcase.Counter-
weightsandtheflywheelboltedtothecrankshafthelpinthesmoothrunningoftheengine.

EngineBearings:

Thecrankshaftandcamshaftaresupportedonanti-
frictionbearings.Thesebearingsmustbecapableofwithstandinghighspeed,heavyloadandhightemperatur es.Normally,cadmium,silverorcopperleadiscoatedonasteelbacktogivetheabovecharacteristics.Forsingle cylindervertical/horizontalengines,thepresenttrendistouseballbearingsinplaceofmainbearingsofthethi nshelltype.

Valves:

Toallowtheairto*enterinto*thecylinderortheexhaust,gasestoescapefromthecylinder,valvesareprovided,k nownas*inlet*and*exhaust*valvesrespectively.Thevalvesaremounted*eitheron*thecylinderheadoronthecylin derblock.

Camshaft:

Thevalvesareoperatedbytheactionofthecamshaft,whichhasseparatecamsfortheinlet,andexhaustvalves .Thecamliftsthevalveagainstthepressureofthespringandassoonasitchangespositionthespringclosesthev alve.Thecamgetsdrivethrough*eitherthe*gearorsprocketandchainsystemfromthecrankshaft.Itrotatesath alfthespeedofthecamshaft.

Flywheel

Thisisusuallymadeofcastironanditsprimaryfunctionistomaintainuniformenginespeedbycarryingthecran kshaftthroughtheintervalswhenitisnotreceivingpowerfromapiston.Thesizeofthe*flywheelvaries*withthe numberofcylindersandthetypeandsizeoftheengine.Italsohelpsinbalancingrotatingmasses.

Materialsusedforengineparts:

S.No.	NameoftheParts	MaterialsofConstruction
1.	Cylinderhead	Castiron,CastAluminium
2.	Cylinderliner	Caststeel,Castiron
3.	Engineblock	Castiron,Castaluminum,Weldedsteel
4.	Piston	Castiron,Aluminiumalloy
5.	Pistonpin	Forgedsteel,Casehardenedsteel.
6.	Connectingrod	Forgedsteel.Aluminiumalloy.
7.	Pistonrings	Castiron,Pressedsteelalloy.
8.	Connectingrodbearings	Bronze,Whitemetal.
9.	Mainbearings	Whitemetal,SteelbackedBabbittbase.
10.	Crankshaft	Forgedsteel,Caststeel
11.	Camshaft	Forgedsteel,Castiron,caststeel,
12.	Timinggears	Castiron,Fiber,Steelforging.
13.	Pushrods	Forgedsteel.
14.	Enginevalves	Forgedsteel,Steel,alloy.
15.	Valvesprings	Carbonspringsteel.
16.	Manifolds	Castiron,Castaluminium.
17.	Crankcase	Castiron,Weldedsteel
18.	Flywheel	Castiron.
19.	Studsandbolts	Carbonsteel.
20.	Gaskets	Cork,Copper,Asbestos.

PRINCIPLESOFOPERATIONOFICENGINES:FOUR-STROKECYCLEDIESELENGINE

Infour-strokecycleenginestherearefourstrokescompletingtworevolutionsofthecrankshaft.Thesearerespectivel y,thesuction,compression,powerandexhauststrokes.InFig.3,thepistonisshowndescendingonitssuctions troke.Onlypureairisdrawnintothecylinderduringthisstrokethroughtheinletvalve,whereas,theexhaustval veisclosed.Thesevalvescanbeoperatedbythecam,pushrodandrockerarm.Thenextstrokeisthecompressi onstrokeinwhichthepistonmovesupwithboththevalvesremainingclosed.The air,whichhasbeendrawnintothecylinderduringthesuctionstroke,isprogressivelycom-pressedasthepistonascends.Thecompressionratiousuallyvariesfrom14:1to22:1.Thepressureattheendof thecompressionstrokerangesfrom30to45kg/cm^2.Astheairisprogressivelycompressedinthecylinder,itstemperatureincreases,untilwhenneartheendofthecompressionstroke,itbecomessufficientlyhigh(650-80O^{o}C)toinstantlyigniteanyfuelthatisinjectedintothecylinder.Whenthepistonisnearthetopofitscompressionstroke,a liquidhydrocarbonfuel,suchasdieseloil,issprayedintothecombustionchamber**underhighpressure(140-160kg/cm^2)**,higherthanthatexistinginthecylinderitself.Thisfuelthenignites,beingburntwiththeoxygenof thehighlycompressedair.

Duringthefuelinjectionperiod,thepistonreachestheendofitscompressionstrokeandcommencestoreturnonitsthirdconsecutivestroke,viz.,**powerstroke**.Duringthisstrokethehotproductsofcombustionconsistingchieflyofcarbondioxide,togetherwiththe nitrogenleftfromthecompressedairexpand,thusforcingthepistondownward.Thisisonlytheworkingstrokeofthecylinder.

Duringthepowerstrokethepressurefallsfromitsmaximumcombustionvalue**(47-55kg/cm^2),**whichisusuallyhigherthanthegreatervalueofthecompressionpressure(45kg/cm^2),toabout**3.5-5kg/cm^2**neartheendofthestroke.Theexhaustvalvethenopens,usuallyalittleearlierthanwhenthepistonreachesitslowestpointoftravel.Theexhaustgasesaresweptoutonthefollowingupwardstrokeofthepiston.Theexhaustvalveremainsopenthroughoutthewholestrokeandclosesatthetopofthestroke.

Thereciprocatingmotionofthepistonisconvertedintotherotarymotionofthecrankshaftbymeansofaconnectingrodandcrankshaft.Thecrankshaftrotatesinthemainbearings,whicharesetinthecrankcase.Theflywheelisfittedonthecrankshaftinordertosmoothenouttheuneventorquethatisgeneratedinthereciprocating engine.

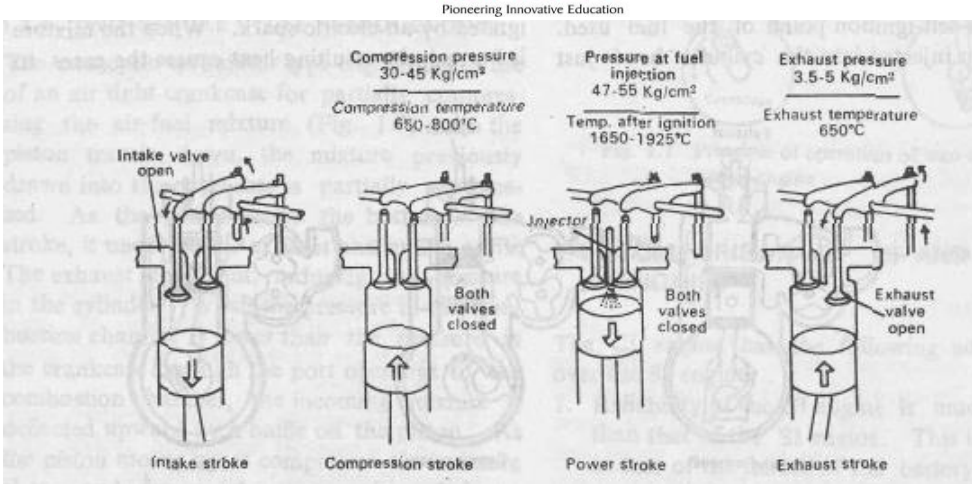


Fig.3.Principleoffour-strokeengine

TWO-STROKECYCLEDIESELENGINE:

Thecycleofthefour-strokeofthepiston(thesuction,compression,powerandexhauststrokes)iscompletedonlyintwostrokesinthecaseofatwo-strokeengine.Theairisdrawnintothecrankcaseduetothesuctioncreatedbytheupwardstrokeofthepiston.Onthedownstrokeofthepistonitiscompressedinthecrankcase,Thecompressionpressureisusuallyverylow,beingjustsufficienttoenabletheairtoflowintothecylinderthroughthetransferportwhenthepistonreachesnearthebottomofitsdownstroke.

Theairthusflowsintothecylinder,wherethepistoncompressesitasitascends,tillthepistonisnearlyatthetopofitsstroke.Thecompressionpressureisincreasedsufficiently hightoraisethetemperatureoftheairabovetheself-ignitionpointofthefuelused.Thefuelisinjectedintothecylinderheadjustbeforethecompletionofthecompressionstrokeandonlyforashortperiod.Theburntgasesexpandduringthenextdownwardstrokeofthepiston.Thesegasesescapeintotheexhaustpipetotheatmospherethroughthepistonuncoveringtheexhaustport.

ModernTwo-StrokeCycleDieselEngine

Thecrankcasemethodofaircompressionisunsatisfactory,astheexhaustgasesdonotescapethecylinderduringportopening.Alsothereisalossofairthroughtheexhaustportsduringthecylinderchargingprocess.Toovercomethesedisadvantagesblowersareusedtopre-compresstheair.Thispre-compressedairentersthecylinderthroughtheport.Anexhaustvalveisalsoprovidedwhichopensmechanicallyjustbeforetheopeningoftheinletports(Fig.4).

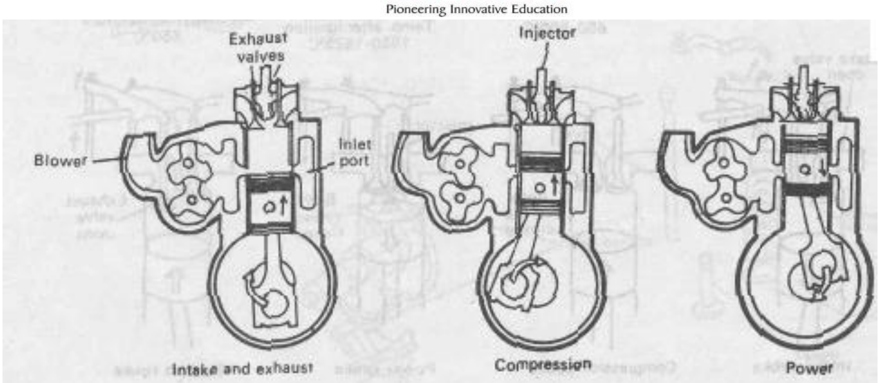


Fig.4Principleoftwo-strokecycledieselengine

FOUR-STROKESPARKIGNITIONENGINE

Inthisgasolineismixedwithair,brokenupintoamistandpartiallyvaporizedinacarburettor(Fig.5).Themixtureisthensuckedintothecylinder.Thereitiscompressedbytheupwardmovementofthepistonandisignitedbyanelectricspark.Whenthemixtureisburned,theresultingheatcausesthegasestoexpand.Theexpandinggasesexertapressureonthepiston(powerstroke).Theexhaustgasesescapeinthenextupwardmovementofthepiston.Thestrokesaresimilartothosediscussedunderfour-strokedieselengines.ThevarioustemperaturesandpressuresareshowninFig.6.Thecompressionratiovariesfrom4:1to8:1andtheair-fuelmixturefrom10:1to20:1.

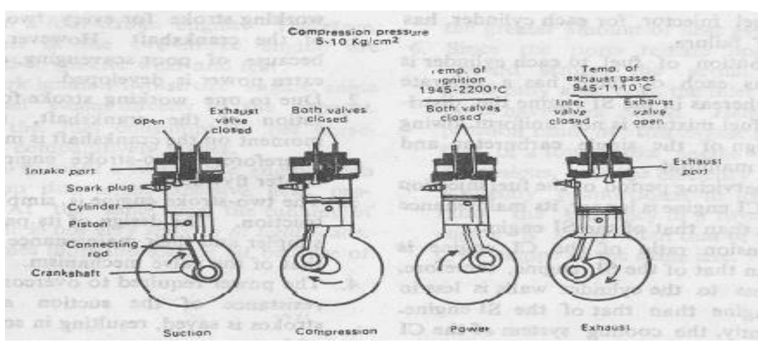


Fig.5.Principleofoperationoffour-strokepetrolengine

TWO-STROKECYCLEPETROLENGINE

Thetwo-cyclecarburettortypeenginemakesuseofanairtightcrankcaseforpartiallycompressingtheair-fuelmixture(Fig.6).Asthepistontravelsdown,themixturepreviouslydrawnintothecrankcaseispartiallycompressed.Asthepistonnearsthebottomofthestroke,ituncoverstheexhaustandintakeports.Theexhaustflowsout,reducingthepressureinthecylinder.Whenthepressureinthecombustionchamberislowerthanthe pressureinthecrankcasethroughtheportopeningstothecombustionchamber,theincomingmixtureisdeflectedupwardbyabaffleonthepiston.Asthepistonmovesup,itcompressesthemixtureaboveanddrawsintothecrankcasebelowanewair-fuelmixture.

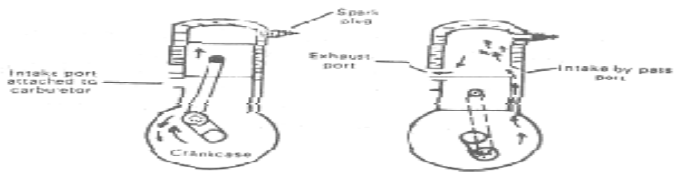


Fig.6Principleofoperationoftwostrokepetrolengine

The,two-strokecycleenginecanbeeasilyidentifiedbytheair-fuelmixturevalveattachedtothecrankcaseandtheexhaustPortlocatedatthebottom*of*thecylinder.

COMPARISONOFCIANDSIENGINES

TheCIenginehasthefollowingadvantagesovertheSIengine.

1. ReliabilityoftheCIengineismuchhigherthanthatoftheSIengine.Thisisbecauseincaseofthefailureofthebattery,ignitionorcarburettorsystem,theSIenginecannotoperate,whereastheCIengine,withaseparatefuelinjectorforeachcylinder,haslessriskoffailure.
2. Thedistributionoffueltoeachcylinderisuniformaseachofthemhasaseparateinjector,whereasintheSIenginethedistributionoffuelmixtureisnotuniform,owingtothedesignofthesinglecarburetorandtheintakemanifold.
3. SincetheservicingperiodofthefuelinjectionsystemofCIengineislonger,itsmaintenancecostislessthanthatoftheSIengine.
4. TheexpansionratiooftheCIengineishigherthanthatoftheSIengine;therefore,theheatlosstothecylinderwallsislessintheCIenginethanthatoftheSIengine.Consequently,thecoolingsystemoftheCIenginecanbeofsmallerdimensions.
5. ThetorquecharacteristicsoftheCIenginearemoreuniformwhichresultsinbettertopgearperformance.
6. TheCIenginecanbeswitchedoverfrompartloadtofullloadsoonafterstartingfromcold,whereastheSIenginerequireswarmingup.
7. Thefuel(diesel)fortheCIengineischeaperthanthefuel(petrol)forSIengine.
8. ThefireriskintheCIengineisminimizedduetotheabsenceoftheignitionsystem.
9. Onpartload,thespecificfuelconsumptionoftheCIengineislow.

The Basic Principle

The basic principle of refrigeration is simple. You simply pass a colder liquid continuously around the object that is to be cooled. This will take heat from the object. In the example shown, a cold liquid is passed over an apple, which is to be cooled. Due to the temperature difference, the apple loses heat to the refrigerant liquid. The refrigerant in turn is heated due to heat absorption from the apple.

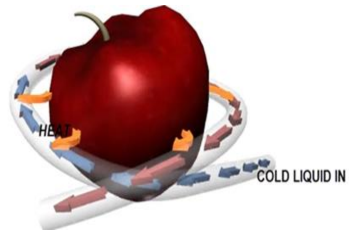


Fig.1 Basic principle of refrigeration is illustrated in this figure

It is clear that, if we can produce cold liquid refrigerant continuously, we can achieve continuous refrigeration. This simple fact forms the core of the refrigeration technology. We will next see how this is achieved.

Components of Refrigerator & Working

An inside view of a refrigerator is shown.

Fig.2 An inside view of a refrigerator

It has 4 main components: compressor, condenser, evaporator, and throttling device. Of these components, the throttling device is the one that is responsible for the production of the cold liquid. So we will first analyze the throttling device in a detailed way and move on to the other components.

Throttling Device

The throttling device obstructs the flow of liquid; cold liquid is produced with the help of this device. In this case, the throttling device is a capillary tube. The capillary tube has an approximate length of 2 m and an inside diameter of around 0.6 mm, so it offers considerable resistance to the flow.

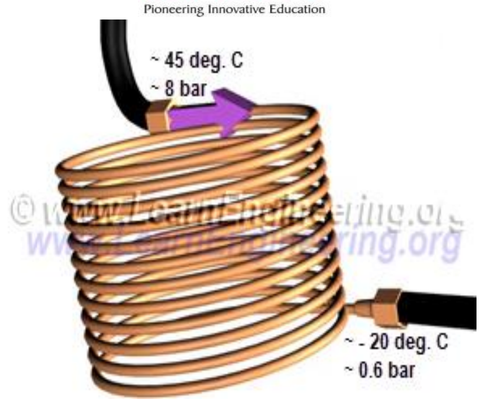


Fig.3 A Capillary tube: This results in sudden drop in pressure and temperature

For effective throttling at the inlet, the refrigerant should be a high-pressure liquid. The throttling device restricts the flow, which causes a tremendous pressure drop. Due to the drop in pressure, the boiling point of the refrigerant is lowered, and it starts to evaporate. The heat required for evaporation comes from the refrigerant itself, so it loses heat, and its temperature drops. If you check the temperature across the throttling device, you will notice this drop.

It is wrong to say that the throttling is a *process*. We know only the end points of throttling, that is, the states before and after throttling. We don't know the states in between, since this is a highly irreversible change. So it would be correct to call throttling a phenomenon rather than a process.

Evaporator - Heat Absorption Process

The next phase is simple: this cold liquid is passed over the body that has to be cooled. As a result, the refrigerant absorbs the heat. During the heat absorption process, the refrigerant further evaporates and transforms into pure vapor. A proper heat exchanger is required to carry the cold refrigerant over the body. This heat exchanger is known as an evaporator.

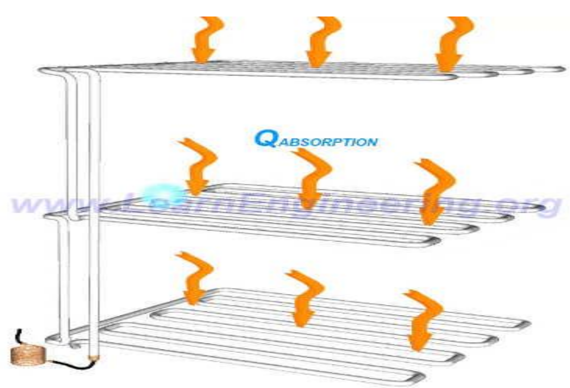


Fig.4 Cold liquid is passed through a heat exchanger know as evaporator for absorbing heat from the

refrigerator

So we have produced the required refrigeration effect. If we can return this low-pressure vapor refrigerant to the state before the throttling process (that is the high-pressure liquid state), we will be able to repeat this process. So first step, let's raise the pressure.

Compressor

A compressor is introduced for this purpose. The compressor will raise the pressure back to its initial level. But since it is compressing gas, along with pressure, temperature will also be increased. This is unavoidable.

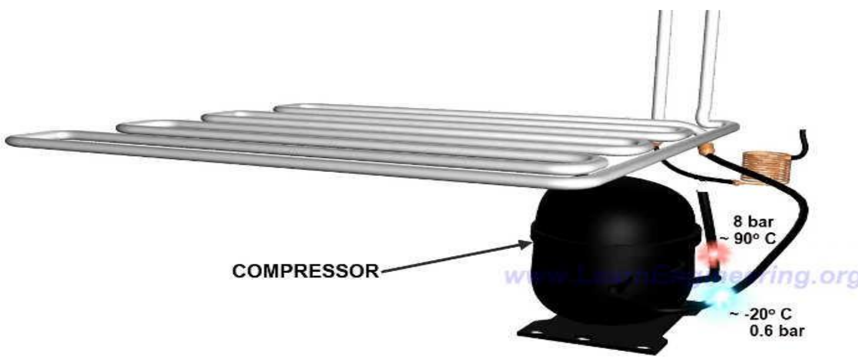


Fig.5 A compressor is used to raise pressure of the refrigerant

Now the refrigerant is a high-pressure vapor. To convert it to the liquid state, we must introduce another heat exchanger.

Condenser

This heat exchanger is fitted outside the refrigerator, and the refrigerant temperature is higher than atmospheric temperature. So heat will dissipate to the surroundings. The vapor will be condensed to liquid, and the temperature will return to a normal level.

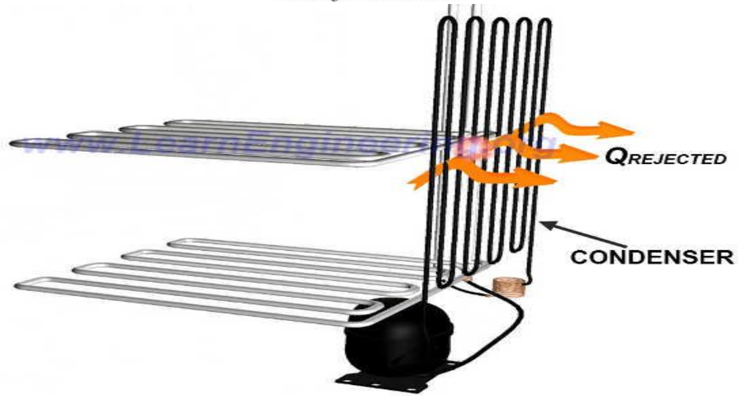


Fig.6 Condenser heat exchanger is fitted outside the refrigerator so it will reject heat to the surroundings

So the refrigerant is back to its initial state again: a high-pressure liquid. We can repeat this cycle over and over for continuous refrigeration. This cycle is known as the ***vapor compression cycle***. Refrigeration technology based on the vapor compression cycle is the most commonly used one in domestic and industrial applications.

Refrigeration Accessories

You can find more details on refrigerator components here. Evaporators and condensers have fins attached to them. The fins increase the surface area available for convective heat transfer and thus will significantly enhance heat transfer.

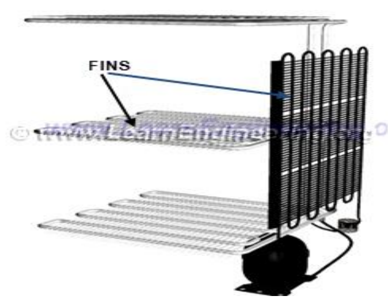


Fig.7 Fins attached to the condenser and evaporator

Since the evaporator is cooling the surrounding air, it is common that water will condense on it, forming frost. The frost will act as an insulator between the evaporator heat exchanger and the surrounding air. Thus it will reduce the effectiveness of the heat removal process. Frequent removal of frost is required to enhance the heat transfer. An automatic defrosting mechanism is employed in all modern refrigerators.

More on Compressor

Apart from raising the pressure, the compressor also helps maintain the flow in the refrigerant circuit. Usually, a hermetically sealed reciprocating type compressor is used for this purpose. You might have noticed that, your household refrigerator consumes a lots of electricity compared to the other devices.

In a vapor compression cycle, we have to compress the gas; compressing the gas and raising pressure is a highly energy intensive affair. This is the reason why the refrigerator based on the vapor compression refrigeration technology consumes a lot of electricity.

Coefficient of Performance

The heat and power transfer happening in a vapor compression refrigeration circuit is shown below.

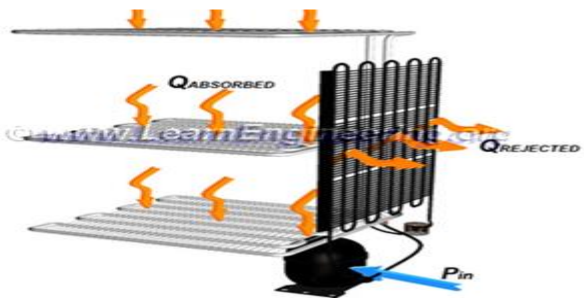


Fig.8 Energy interaction happening in a refrigeration system

A simple energy balance of the system yields the following relationship.

$$P_{in} + Q_{ABSORBED} = Q_{REJECTED}$$

It is often required to evaluate performance of a refrigerator or compare between different refrigeration technologies. A term called Coefficient of Performance (C.O.P) helps in doing this. To understand this term completely, we need to know what is the input and output of a refrigeration system. What we need from a refrigerator is the cooling effect. Or $Q_{ABSORBED}$ is the output of a refrigeration cycle. Input to the refrigerator is the power given to the compressor. So the term C.O.P can easily be defined as output by input and is expressed as follows.

$$C.O.P = \frac{Q_{ABSORBED}}{P_{in}}$$

Belt Selection Considerations

Environmental conditions in which the belt will operate, such as: exposure to oil and grease, range of operating temperatures, abrasive dust and chemical conditions, sunlight, and other weather conditions.

Other considerations include:

- Type of drive required
- Driver/Driven Revolutions Per Minute (RPM)
- Horsepower requirements
- Pulley diameters and center distance
- Take-up allowances and take-up design
- Space limitation for operation
- Pulsating or shock load conditions
- Static dissipation problems
- Belt availability and inventory considerations
- Belt construction and service life

Belt Drive Advantages

- Wide range of speeds available.

- Belts permit flexibility ranging from high horsepower drives to slow speed and high speed drives.
- Belt drives are less expensive than chain drives for low horsepower and low ratio applications.
- Belts require no lubrication.
- Single belt drives will accept more misalignment than chain drives.
- Flat belts are best for extremely high speed drives.
- Belt drives cushion shock loads and load fluctuations.

- Belts will slip under overload conditions, preventing mechanical damage to shafts, keys, and other machine parts.

Belt Drive Disadvantages

- Belts cannot be used where exact timing or speed is required because slippage does occur (only timing belts can be used).
- Belts are easily damaged by oil, grease, abrasives, some chemicals, and heat.
- Belts can be noisy; also loose or worn belts can be a major cause of machinery vibration.

Belt Drive Principles

Flat belts and V-belts transmit power by their grip on the pulley or sheave.

Three major factors determine the potential of the grip:

1. Area of contact
2. Belt tension
3. Friction between the belt and pulley or sheave surface (coefficient of friction)

Area of Contact

The area of contact is determined by width and the arc of contact. The arc of contact with pulleys of equal diameters is 180 degrees on each pulley, as shown in Figure 1.

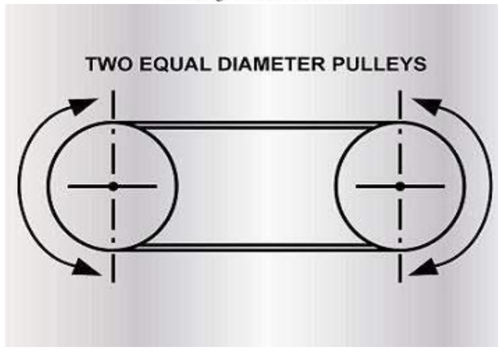


Figure 1: Area of Contact

Pulleys of equal size are not always used. With pulleys of unequal diameter, the arc of contact is less than 180 degrees on the smaller pulley. Under most conditions, this small pulley is the driver. An example is shown in Figure 2.

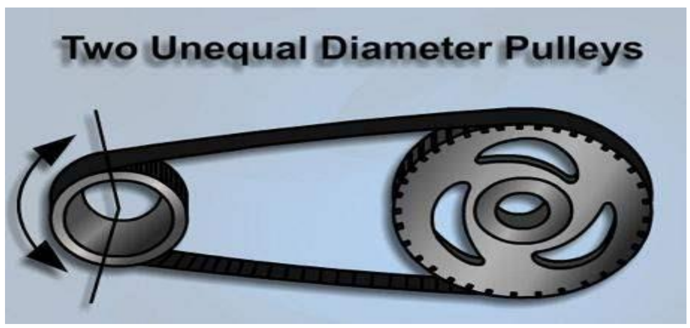


Figure 2: Unequal Pulleys

An arc of contact greater than 180 degrees can be obtained three ways:

1. A crossed belt drive.
2. Moving the input and output shafts farther apart.
3. Using an idler or snub pulley.

Crossed Belt Drive

A crossed belt drive, as shown in Figure 3, is not usually recommended for V-belts. In the crossed position, the center-to- center distance between the pulleys must be long enough to limit the internal stress in a belt. Crossed belt drives make the pulleys rotate in opposite directions to each other.

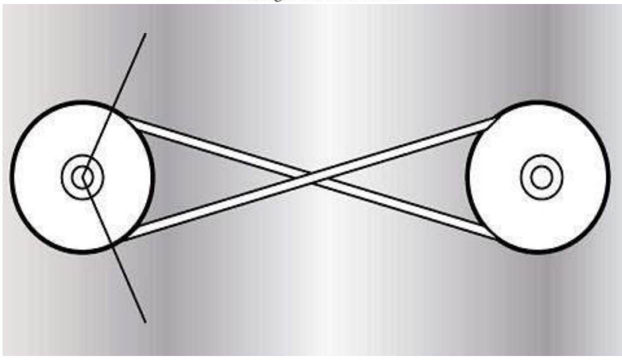


Figure 3: Crossed Belt Drive

Pulley Center-to-Center Distance

For maximum power transfer on the belts and pulleys, the pulley ratio should be 3 to 1 or less as shown in Figure 4 Top. Higher ratios, as in Figure 4 Bottom, lessen the arc of contact, causing slippage and loss of power.

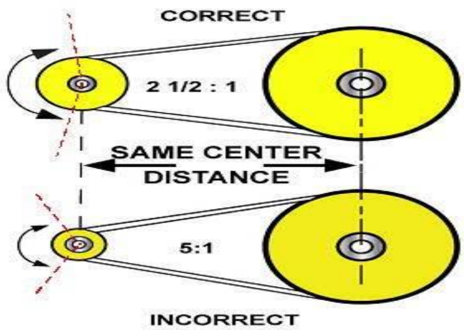


Figure 4: Pulley Center to Center Distance

The arc of contact on the critical smaller pulley may be increased if the shafts are moved farther apart as shown in Figure 5. Where a high ratio is required, a two-step drive (counter-shaft) can be used to avoid excessive single-step ratios or undersize pulleys.

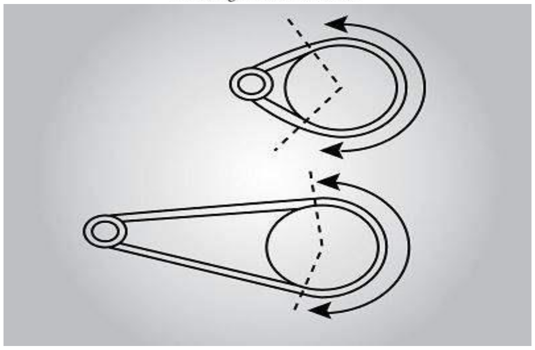


Figure 5: Increase Arc of Contact

Idler Pulleys

A properly designed V-belt drive does not require an idler to deliver fully rated horsepower if proper belt tension and area of contact are maintained. Idlers put an additional bending stress on the belt, which reduces belt life. Also, the smaller the idler pulley, as shown in Figure 6, the greater reduction in belt life.

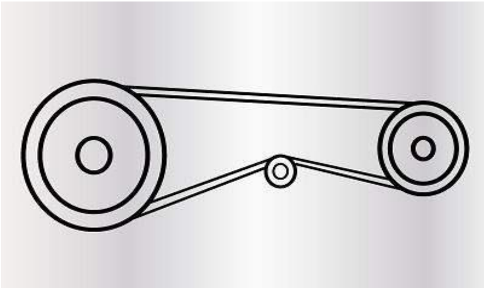


Figure 6: Idler Pulley

The best location for an inside idler is on the slack side of the drive. Figure 7 Top shows a backside idler that is commonly used to help increase the arc of contact on both pulleys. This idler forces a backward bend in the belt, which decreases belt life. The idler puts additional strain on the bottom portion of the belt, which may crack that section.

The diameter of the flat idler pulley should be at least 1.5 times the diameter of the smallest sheave located as close as possible to the small sheave.

Figure 7 Middle shows an inside idler. An inside idler reduces the arc of contact but the amount of take-up is unlimited. The smaller arc of contact will decrease the horsepower rating of each belt.

Figure 7 Bottom shows a backside idler, which is located as close as possible to the driven pulley. In this example, the idler helps to increase the arc of contact on the large diameter pulley, which reduces belt slippage problems that may be encountered on the driven side.

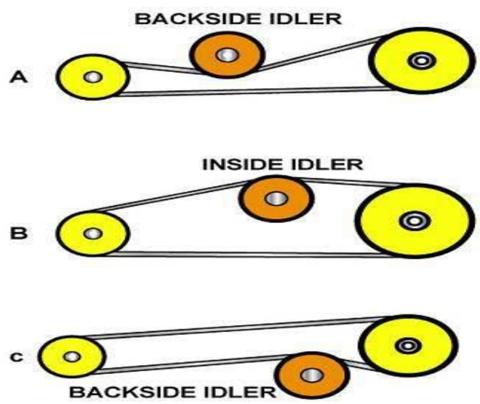


Figure 7: Idler Positions

Belt Tension

The best tension for a V-belt is the lowest tension at which the belts will not slip under full load. Other belt tension recommendations are:

- Check the belt tension frequently during the first 24 to 48 hours of run-in operation.
- Maintain sheave alignment while tensioning the drive.
- Make V-belt drive inspections periodically checking belt tension.
- Keep all belts free from foreign material, which can cause slippage.
- Over-tensioning belts will lead to reduced belt and bearing life.