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Contents

Advances in the Shaft Sealing System of Centrifugal Pumps

V.K. Sharma

Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India

Email: vinay272002@yahoo.co.in

Abstract

Shaft sealing system is very critical for any Centrifugal Pump because its frequent failure will result in leakage of expensive / inflammable / hazardous / toxic pumping fluid to the atmosphere causing various safety hazards to the people working around. In addition to above we can well imagine the losses due to expensive fluid being drained & frequent expensive maintenance / replacement of shaft sealing system. This paper describes about the understanding of various shaft sealing systems which are available.

1. Introduction

Initially gland packing was used as a shaft sealing system for centrifugal pumps but handling of various types of inflammable / hazardous fluids necessitated the use of a better shaft sealing system so that leakage of fluid is eliminated to minimise the various safety hazards to the people working around the equipment as well as to save the money from going to drain. As a result of continuous R & D efforts in this field now better shaft sealing systems are available which give a longer service life with minimum maintenance. However understanding of these systems with their merits & demerits will go a long way in selecting a suitable shaft sealing system for getting trouble free service.

2. Gland Packing

We all are aware that conventional shaft sealing was carried out by means of gland packing. The problems associated with conventional gland packing is summarised as under:

2.1 Product Loss:

Gland packing works on a principle of controlled leakage. For proper life, every packing ring should get enough lubrication to avoid excessive heating & subsequent burn out. In short, a gland packing has to leak to perform. It is normally seen that a steady stream of leakage is always observed through the gland packing. The product loss resulting from this leakage can be quantified as under:

- One drop every 5 seconds   550 litres / year
- Two drops per second   5500 litres / year
- Steady stream leakage   40,000 litres / year

The cost per litre of the liquid multiplied by the above quantities would give staggering figures of product loss due to gland leakage. These figures would automatically justify the use of a better sealing methods even for water pumps where second or third of the above conditions usually prevail.

2.2 Frequent Adjustments:

The gland packing has to be frequently tightened to control the leakage.

2.3 Excessive Wear on Shaft Sleeve:

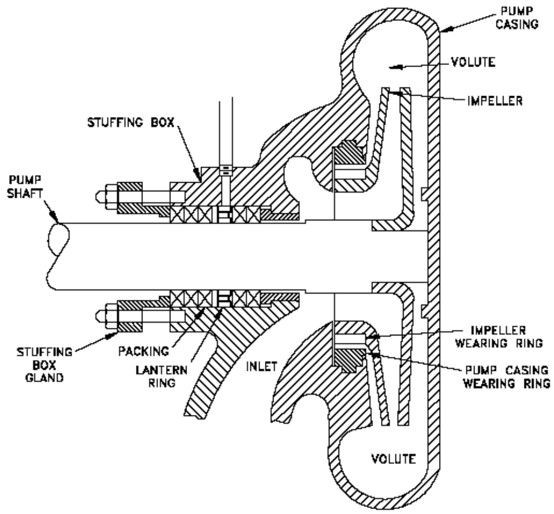
It is experienced that on an average, gland packed sleeve needs replacement at least once every year.

2.4 Energy Loss:

It is estimated that energy loss due to gland friction is usually up to 8% of the output of the motor.

Apart from the above there are numerous other factors like hazardous & toxic nature of the liquid, high man hour cost of maintenance staff, frequent bearing failures, corrosion of pump parts & base frames etc. which weigh heavily against the use of conventional packing.

A centrifugal pump with conventional gland packing is shown as under:

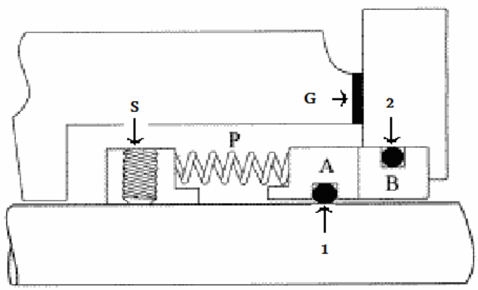


3. Mechanical Seals

In order to overcome various above stated problems associated with gland packing, Mechanical Seals were developed. Mechanical Seals offers following advantages:

- Positive Seal : Practically there is zero leakage.
- Saving in Power : Needs negligible power (max. 1%) as compared to Pump with gland which consumes about 8% of the total power.
- Pollution & Safety : Mechanical Seal incorporates all the safety features which are important while handling toxic and inflammable fluids.
- Loss of Expensive fluid : Saving in the loss of expensive fluid being handled
- Reduction in maintenance cost : Wear of shaft sleeve is eliminated. The down time due to seal problem is reduced

	A Rotating face (primary seal face)
	B Stationary face(primary seal face)
	P Spring (mechanical hardware)
	S Set Screw (mechanical hardware)
	G Gasket
	1 Shaft Packing (secondary seals)



2 'O' Ring(secondary seals)

As shown above a conventional mechanical seals have following three basic components:

a) A set of primary seal faces consisting of Rotating & Stationary faces.
b) A set of secondary seals consisting of Shaft packing & O Rings
c) Some mechanical hardware consisting of Compression unit having springs, Set Screw etc.

3.1 Classification of Mechanical Seals

3.1.1 Pusher type seals
- 3.1.1.1 Unbalanced seals
- 3.1.1.2 Balanced seals
- 3.1.1.3 Double Mechanical seals

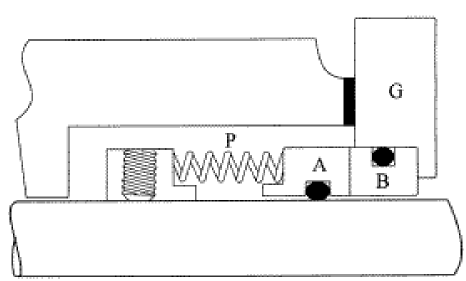
3.1.2 Non Pusher type seals
- 3.1.2.1 Metal Bellows seal
- 3.1.2.2 Teflon Bellows seal

3.1.1 Pusher Type Seals:

In these type of seals, as the seal face wears out, secondary seal is pushed out along the shaft in the direction of wear. The elastomer which slides in the process is called dynamic elastomer.

3.1.1.1/ 3.1.1.2 Unbalanced vs. Balanced Mechanical Seals

Hydraulic balance is very easy to understand; let us look at the following diagram:



A = The spring loaded face with an area of 6 cm^2
B = The stationary face held to the front of the stuffing box by gland "G"

P = The hydraulic pressure in the stuffing box is given as 10 Kg. /cm^2
Pressure (Kg/cm^2) x Area (cm^2) = Force (Kg. *)

There are at least two forces closing the seal faces:

- The mechanical spring force.
- The hydraulic force caused by the stuffing box pressure acting on the seal face area.

There are at least three forces trying to open the seal faces:

- A hydraulic force is created any time there is fluid between the seal faces.
- A centrifugal force created by the action of the fluid being thrown outward by the rotation of the pump shaft.
- A hydrodynamic force created because trapped liquid is, for all practical purposes, non compressible.

Let's look at these forces individually and in a little more detail

First we'll look at the closing forces:

- A spring load of 2 Kg/cm^2 is an industry standard when the seal face is new and a load of 0.7 Kg/cm^2 should still available when the carbon seal face has worn away. We need this minimum load to prevent normal vibration from opening the lapped faces. We set this load by installing the mechanical seal with the proper amount of compression.
- Since the definition of hydraulic force was given as pressure x area , closing hydraulic force works out to be 10 Kg/cm^2 x 6 cm^2 = 60 Kg

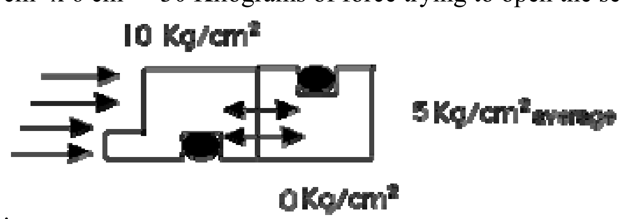
Now we'll look at the opening forces

1. First the hydraulic force:

- Testing shows that some times there is a film of liquid between the faces, some times there is only vapour, some times there is nothing at all, and some times there is a combination of all three. This means that if there is liquid or vapour between the faces, it is under pressure trying to force the lapped faces apart. The stationary face (B) cannot move because it's being held by gland "G", but the spring loaded face (A) will respond to this force.

Let us have a look on the following diagram: If we assume a straight line or linear pressure drop across the seal faces, we would get an average of:

5 Kg/cm^2 x 6 cm^2 = 30 Kilograms of force trying to open the seal faces



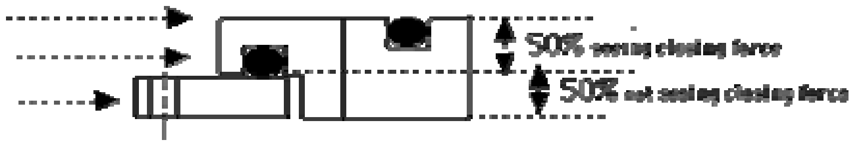
2. Centrifugal force is acting on the spring loaded face (A) trying to spin it perpendicular to the rotating shaft.

- Stationary face (B) is not perpendicular to the shaft because it is referenced against the stuffing box face which is a casting that is not perpendicular or square to any thing.. Testing has shown that a surface speed of 25 meters per second centrifugal force is powerful enough to open most mechanical seal faces.

3. Seal faces are lapped to within three helium light bands or slightly less than one Micron. This slight waviness is enough to generate hydrodynamic lifting forces as we try to compress non-compressible liquid trapped between the lapped faces.

Two forces close and three forces open the seal faces. If the closing forces are the greater forces, the seal will generate heat that is often destructive, but always a waste of energy and pump efficiency. If the opening forces are the greater forces the seal will leak and that's never desirable.

A balanced seal, by definition, balances these opening and closing forces so that the seal will not get hot and it will not leak. How is that accomplished? Since the hydraulic closing forces were twice the opening forces (10 Kg/cm^2 vs. 5 Kg/cm^2) we have installed a sleeve inside the seal to reduce the closing area and reduce the closing force. Let us see the following diagram for explanation:



We can now see that 10 Kg/cm^2 is now pushing on only 3 cm^2 because the inner sleeve is attached to the shaft and cannot move. The opening force remains the same. The numbers look like this:

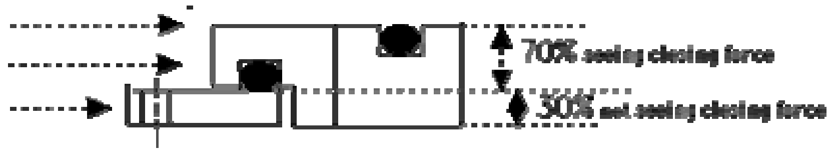
- 10 Kg/cm^2 x 3 cm^2 = 30 Kg. Closing
- 5 Kg/cm^2 x 6 cm^2 = 30 Kg. Opening

It can seen that we have eliminated the hydraulic forces from acting to open or close the seal faces. This leaves only the spring force to close the seal and the hydrodynamic and centrifugal forces to try to open the seal faces.

The final design solves the problem by overbalancing the closing hydraulic forces to compensate for:

- The non-linear pressure drop across the seal faces.
- The hydrodynamic opening forces
- Centrifugal opening force.

Let us see the following diagram for the final result



Seventy percent (70%) of the seal face area is exposed to the hydraulic closing force instead of the fifty percent (50%) shown in the previous drawing. This is the standard 70-30 balance used by most mechanical seal companies. The seal designer can increase or decrease the percentage of over balance by changing the stepped sleeve diameter.

3.1.1.3 Double Mechanical Seals

Double mechanical seals are recommended for a variety of purposes that include:

- To prevent a costly product from leaking.
- To prevent a dangerous product from leaking to the atmosphere.
- To prevent a pollutant from escaping to the atmosphere.
- As a back up seal to prevent costly down time when the first seal wears out or fails. This is an important element in any predictive maintenance program.

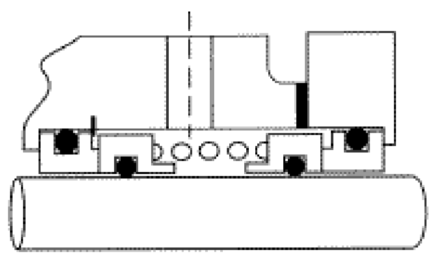
Double mechanical seals can be installed in the following different configurations.

- Back to back or facing in opposite directions
- Tandem or facing in the same direction

The fluid that circulates between the seals is called barrier fluid if it is higher than stuffing box pressure. It is called buffer fluid if it is lower than stuffing box pressure. It can be circulated between the two seals by:

- Natural convection using a convection tank. Insulated piping coming from the top of the gland to the convection tank and finned piping coming out of the tank will aid convection if heat removal is a problem.
- Introducing the fluid between the seals, from an external source. Be sure to bring the fluid in at the bottom of the gland and out the top to prevent an air pocket from forming in the gland.

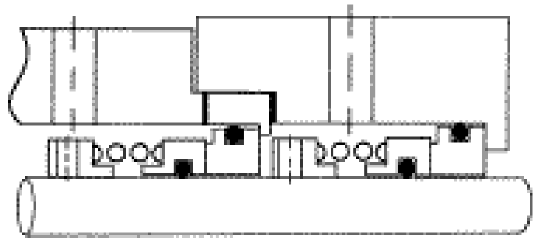
First we will look at the back to back version of a rotating seal:



The rotating back to back version would be the worst possible choice. Here are some of the reasons :

- This configuration requires a higher barrier fluid pressure between the seals. This means that an inner seal leak will cause a dilution of the product. There will be no visible evidence of this happening unless someone notices a change in the product concentration or tank level.
- In operation the outboard seal is carrying the higher differential pressure and should be the first seal to wear out or fail. When this occurs, the barrier fluid pressure will drop and the inner seal can blow open. In other words, if the seal works as designed, both seals will fail at the same time.
- If a connection in the barrier fluid system is ruptured the inner seal can blow open, dumping the pump contents to the environment. The second seal would be of no use.
- This seal is often used in slurry applications. Centrifugal force will throw the slurry into the inner faces causing excessive carbon wear. The slurry will then pack in front of the moveable face preventing it from moving as it tries to slide forward to compensate for normal face wear, thermal growth, most impeller adjustment and shaft end play.

Tandem is the next version. This is the configuration which is found in most Oil Refinery applications.



Here are a few comments about this version:

- It takes the most axial space of all the three types and as a result is seldom found in the process industry, although newer designs are being made shorter as a result of computer finite analysis programs.
- We need two glands and this adds to the cost as well as the axial space required.
- A low pressure buffer fluid is circulated between the seals, eliminating the possibility of product dilution.
- A loss of buffer fluid will not cause the seal faces to open.

We have many choices when it comes to the choice of the buffer or barrier fluid:

- A fluid compatible with the product is often used.
- We might consider a cleaner or solvent that will be used to clean the system.
- If a flush is being used in the system we can always use that as a barrier fluid.
- Once again, try to avoid using any type of mineral, petroleum or vegetable oil as a barrier fluid. Oil has a low specific heat and poor conductivity that can cause varnishing and coking problems between the seals. Some of the newer synthetic and heat transfer oils can be used if the temperate is not too high.

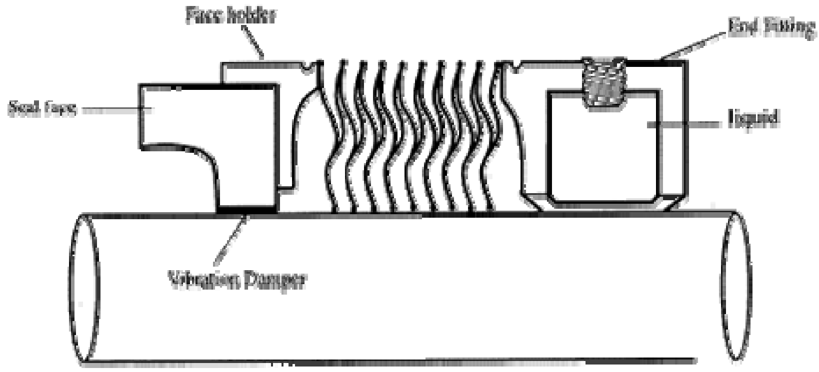
3.1.2 Non Pusher Type Seals

Non pusher type seal by virtue of their design have no sliding elastomers. Non pusher seals are essentially bellow type (metal or Teflon) seals.

Metal bellows seals perform many functions.

- They can be used to eliminate elastomers (rubber like parts) in the chemical process industry. Most solvents present a real problem for elastomer selection. Expensive materials like Kalrez and Chemraz are often the only solution. We would be better off if we could eliminate these special materials all together
- Metal bellows are also used to eliminate elastomers because of temperature limits. All elastomers have both an upper and lower temperature limit that prevents them from sealing many hot resins, polymers and cryogenic applications. Hot oils are another high temperature sealing problem, but their "coking" characteristics dictates cooling of the stuffing box area.

In the following drawing names of the individual parts of a typical "nested convolution" bellows seal are indicated.



Some of the advantages of Bellow Seals are as under:

- Wide service range from cryogenics to heat transfer liquids and corrosive chemicals.
- Long service life, only one moving part
- Flexible bellows construction eliminates seal hang up due to solids or dirt in pumping fluid
- Built-in hydraulic balance eliminates step in shaft or sleeve.
- Available for either inside or outside mounting.

4. Non-contacting Seals

The latest development in shaft sealing technology is development of Gas Seals. There are presently two types of non contacting seals available for fugitive emission and gas sealing:

4.1 Hydrodynamic or lift off seals that float on a cushion of gas.

4.2 Hydrostatic seals where the seal faces are separated by controlling the opening and closing forces acting on the faces.

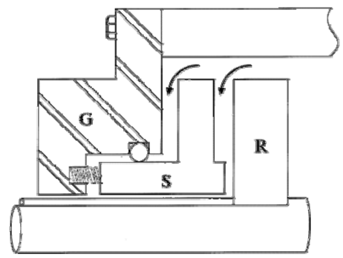
Non-contacting seals have a couple of advantages over conventional face seals:

- The product we are trying to seal does not have to be a lubricant. Gases or hot water are examples of typical non-lubricating fluids. A non-lubricant is defined as a fluid that will not maintain a film thickness of one micron or more at its operating temperature and load.
- There is little to no heat being generated at the seal faces. Heat causes all sorts of expansion and other problems. The non-contacting seal eliminates many of these problems.
- Except for some possible erosion, we should not experience any face wear.
- Dual versions of these seals can use an inert gas as a barrier fluid and eliminate the possibility of any fugitive emissions escaping to the atmosphere.

We will maintain a very small, constant separation between the seal faces regardless of any shaft movement, thermal expansion or face distortion caused by pressures that might be present. We will accomplish this by controlling the opening and closing forces between the seal faces to maintain the desired separation.

4.1 Hydrostatic Gas Seals

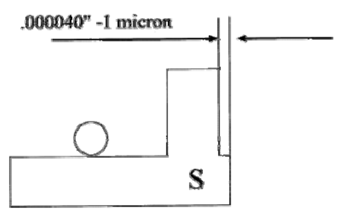
Let us have a look at the following drawing which is a typical hydrostatic seal:



Let's check out at the individual parts:

- S = Spring loaded stationary seal face.
- R = Rotating face. It is held to the shaft shoulder by a clamping sleeve. A gasket would be located on either side of the rotating face.
- G = Gland

Although this drawing looks like a conventional mechanical face seal we will learn that the seal faces never do come into contact. In the next sketch we will look at a detail of the stationary face.

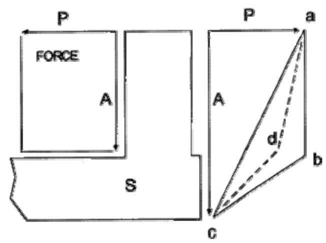


The thing to notice in this sketch is the width of the channel leading to the stationary nose piece. As can be seen we are talking about a distance that is not visible to the human eye.

The smallest object that can be seen with the human eye is forty (40) microns and we are talking about a distance of one micron. This dimension is lapped, not machined into the stationary face in the same way we lap conventional seal faces.

We are going to use this small width to develop a two stage pressure drop across the seal face. This is different than a conventional mechanical seal where we experience one pressure drop from the outside to the inside of the extended nose.

In the next drawing we will look at the forces acting on the stationary face and learn how we are able to obtain the desired face separation by experiencing two pressure drops.



Let's look at the force generated on the back of the stationary face:

- The force on the back of the stationary face (S) is represented by the rectangle formed when the pressure was multiplied by the area (Closing force = P x A)
- This closing force is in addition to the spring load and is not affected by the axial position of the stationary face. The area remains a constant. The closing force changes with the system pressure.

Now we will look at the force generated between the faces:

- The stationary face (S) has a larger area (A)
- The pressure between the seals (P) starts out the same as on the back of the stationary face (S) but:
- If the rotating face should try to come into contact with the stationary face the pressure would be felt to point (b) and then we would experience a pressure drop across the extended nose on stationary face (S). This would cause a larger force between the faces, causing the stationary face to move away from the rotating face.
- If the rotating face should move away from the stationary face too far a distance, we would take a single pressure drop from point (a) to point (c). This would cause a reduction of the force between the faces causing the stationary face (S) to move towards the rotating face (R)

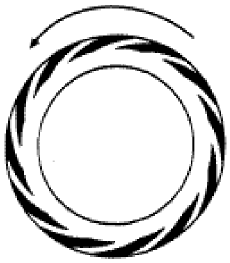
- Somewhere between these two extremes is where the opening and closing forces equalize. It is shown by the dotted line (a-d-c). In this position we take a slight pressure drop from (a-d) and another pressure drop from (d-c). It is at this point that the opening and closing forces are in equilibrium.

If the shaft moves axially and the hydrostatic faces try to come together the opening force builds up and separates the faces, but as they begin to separate we lose the two pressure drop concept and take a linear pressure drop between the faces, causing them to close again. In practice the faces do not move once they have found the correct separation.

The result of all of this is a very stiff and stable system. If the fluid you are sealing is an inert gas the leak rate will be very low and in the order of a portion of a standard cubic foot per hour (not minute). This is more than acceptable in most applications.

4.2 Hydrodynamic Gas Seals

The idea is very simple. Let the seal faces ride on a film of gas either pumped to, or flowing between the seal faces. Unlike hydrostatic seals that create a balanced opening and closing force to maintain just the right amount of seal face separation, the hydrodynamic seal depends upon the generation of a lifting force to separate the seal faces. Please take a look at the following illustration:

	The hydrodynamic lifting force is created by the seal face geometry (shape or configuration). The shaft must be rotating at a reasonable rpm to provide the proper lifting force.

Hydrodynamic forces are generated by the viscous shear of the gas film when the smooth face is rotating, so unlike the hydrostatic version these seals operate effectively only while the pump shaft is turning.

Unlike liquids, gases are compressible, but you can generate a similar lifting force if the face geometry is designed and built correctly. The idea is to direct the gas into a narrow channels that will increase the gas pressure causing the face separation.

Gas seals have become very popular in recent years for a variety of reasons:

- A growing market for fugitive emission sealing.
- The increasing use of two seals in a pump opens the possibility of contaminating the process fluid with the barrier fluid circulating between the dual seals.
- Non-contacting gas seal have the potential to generate less heat than conventional face seals.
- Some pumps experience dry running periods that might damage lapped seal faces.
- Nitrogen is the most popular gas used in these applications.
- The gas leak rate is proportional to the cube of the gap between the sealing faces. This gap is normally in the order of less than one helium light band (0, 3 microns) creating a leak rate of less than one standard cubic foot per minute.

Hydrodynamic gas seals also present a few problems to the user:

- We have to have a continuous supply of inert gas on hand.
- The shaft has to be tuning at a reasonable rpm to provide the proper dynamic lifting forces. Many turbine driven pumps are rolled or rotated at a slow speed to keep the turbine and piping warm. This can cause destructive wear to the seal face geometry.
- The dimensions required are very critical. We need seal face materials that do not distort over a wide range of temperature and pressure. This can be a serious problem with most conventional seal face materials.
- Any gas that gets into the system could cause cavitation problems within the pump if the gas volume exceeds 3%.
- There should be some facility available to remove any excess gas that might leak into the system.
- Some consumers complain of excessive noise in the gas lines.
- In some dual seal applications, the barrier or buffer fluid is used to regulate the temperature at the seal faces. Gas doesn't do this very well because of its poor thermal conductivity.

Conclusion

An effort has been made to explain various shaft sealing systems available for a centrifugal pump so that designer can choose a suitable system depending upon the techno commercial analysis. However in addition to above selection of compatible material (with the pumping fluids) for various seal parts is also required to be carried out for trouble free service of shaft sealing system.

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Ecological Optimization of Brayton Heat Engine Cycle

Rajesh Arora

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India
Email: - rajesharora1219@rediffmail.com

Abstract

Finite-Time Thermodynamics has been applied to optimize the power output of closed Endo-reversible, Irreversible, and Regenerative Brayton Cycles for infinite thermal capacitance rates of the heat reservoir. The optimum values of power, thermal efficiency and second law efficiency of Brayton cycles are presented. The ratio of ecologically optimum power to maximum power is independent of number of transfer units of the hot side and cold side heat exchangers, and this ratio is much higher than the ratio of the entropy generation rate at maximum ecological function to that at maximum power. With the introduction of the ecological function, the improvement in second law efficiency and in thermal efficiency is evident, especially for low hot-cold temperature ratios. Moreover, the thermal efficiency at maximum ecological function is about the average of the maximum power efficiency and the reversible Carnot efficiency.

1. System Description

The way to operate a gas-turbine power plant is in a Brayton Cycle. The gas turbine power plant is used for meeting peak-load demands, while the Rankine cycle plant is sized to provide the base load power requirements. Another application that is quite well-suited to gas turbines is providing emergency power. Gas turbines can be started and be operating at full power in a few minutes, while it will usually take several hours for a Rankine-cycle power plant to be at full power from a cold start.The schematic and T-S diagram of Brayton cycle coupled to a heat source and heat sink with infinite thermal capacitance rates is sketched resp. in Fig. 1.1 and Fig. 1.2, where T_H is the hot reservoir temperature and T_L is the cold reservoir temperature.

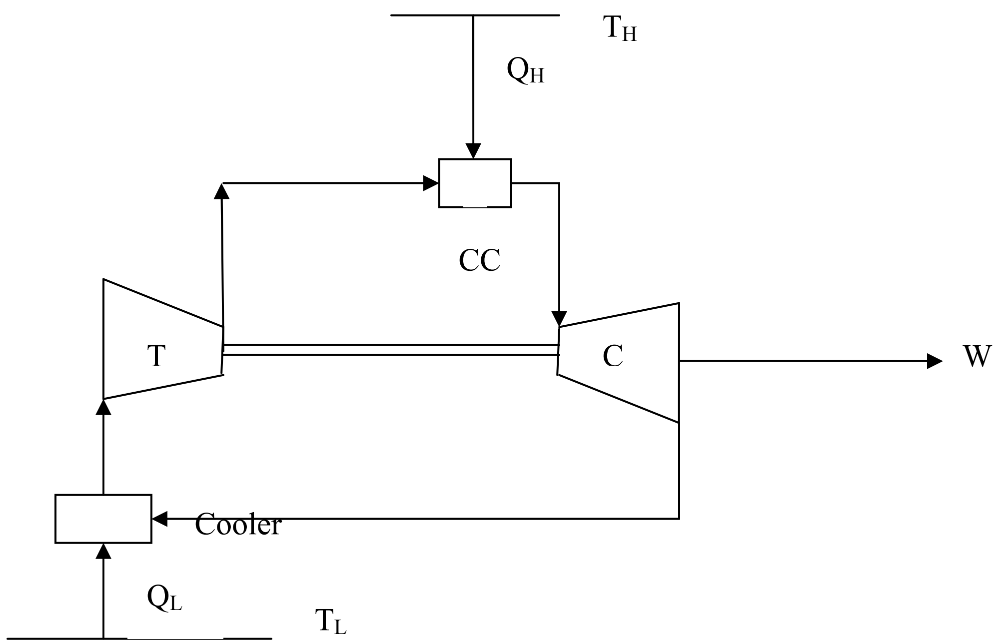

Fig. 1.1 Schematic of Endoreversible Brayton heat engine cycle

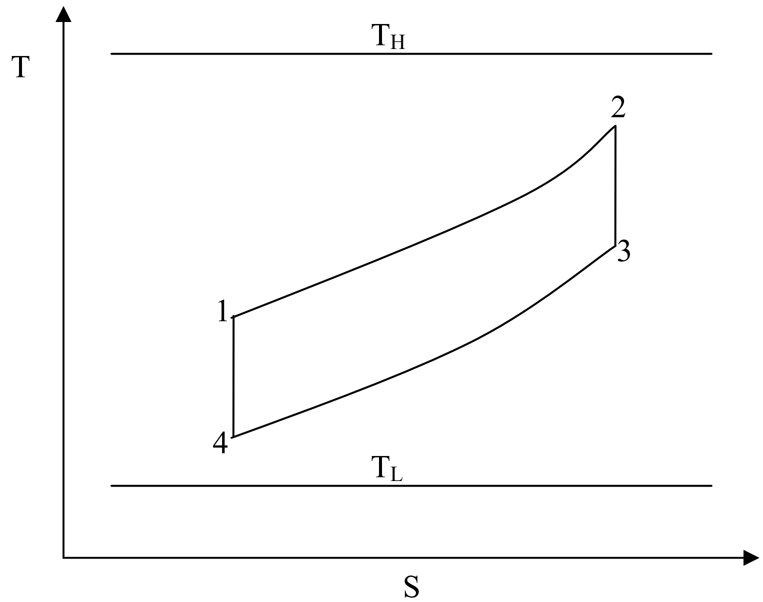

Fig. 1.2 T-S diagram of Endoreversible Brayton Heat Engine cycle

2. Optimization Analysis

The rates at which heat (Q_H) is supplied, is given by

Q_H $= U_HA_H \{(T_H - T_1) - (T_H - T_2)\} / \ln \{(T_H - T_1) / (T_H - T_2)\}$

$= C_W (T_2 - T_1)$ (1)

The rates at which heat (Q_H) is supplied, is given by

Q_L $= U_LA_L \{(T_3 – T_L) - (T_4 – T_L)\} / \ln \{(T_3 – T_L) / (T_4 – T_L)\}$

$= C_W (T_3 – T_4)$ (2)

Where U_HA_H and U_HA_H are, respectively, the hot side and cold side heat exchanger conductances (heat transfer coefficient-area product), and C_W is the capacitance rate of the working fluid.

From equations (1) and (2), we have

Q_H $= C_W\varepsilon_H (T_H - T_1)$

$= C_W (T_2 - T_1)$ (3)

Q_L $= C_W\varepsilon_L (T_3 – T_L)$

$= C_W (T_3 – T_4)$ (4)

The effectiveness of the hot-side heat exchanger ε_H and cold-side heat exchanger ε_L for counter flow heat exchangers are defined as

ε_H $= 1 – \exp(-N_H)$ (5)

ε_L $= 1 – \exp(-N_L)$ (6)

Where the numbers of heat transfer units are based on the minimum thermal capacitance rates

N_H $= U_HA_H / C_W$

And

N_L $= U_LA_L / C_W$

Equations (3) and (4) gives

T_2 $= \varepsilon_HT_H + (1 - \varepsilon_H)T_1$ (7)

T_4 $= \varepsilon_LT_L + (1 – \varepsilon_L)T_3$ (8)

From the first law of thermodynamics, the power output is given by

W $= Q_H – Q_L$

$= C_W\varepsilon_H (T_H - T_1) - C_W\varepsilon_L (T_3 – T_L)$ (9)

From equation (9), we can find

T_3 $= \varepsilon_HT_H / \varepsilon_L + T_L + \varepsilon_HT_1 / \varepsilon_L – W/ C_W\varepsilon_L$ (10)

Substitution of equation (10) into equation (8) gives

$T_4 = \varepsilon_H T_H (1 - \varepsilon_L) / \varepsilon_L + T_L - \varepsilon_H T_1 (1 - \varepsilon_L) / \varepsilon_L – W (1 - \varepsilon_L) / C_W\varepsilon_L$ (11)

From the second law of thermodynamics, the following equation is obtained:

$T_1T_3 = T_2T_4$ (12)

Substituting the values of equations (7) , (10) and (11) into equation (12) gives

$\varepsilon_H T_1^2 (\varepsilon_H\varepsilon_L - \varepsilon_H - \varepsilon_L) / \varepsilon_L + (A W + B) T_1 + CW + D = 0$ (13)

Where

$A = (\varepsilon_H\varepsilon_L - \varepsilon_H - \varepsilon_L) / C_W\varepsilon_L$

$B = \varepsilon_H T_H (\varepsilon_H + 2\varepsilon_L\varepsilon_H + \varepsilon_L) / \varepsilon_L$

$C = \varepsilon_H T_H (1 - \varepsilon_L) / C_W\varepsilon_L$

$D = -\varepsilon_H^2 T_H^2 (1 - \varepsilon_L) / \varepsilon_L - \varepsilon_H T_H T_L$

Therefore, T_1 can be expressed as a function of W , T_H, T_L, C_W , ε_H and ε_L

$T1 = \{-AW – B – [(AW + B)^2 – 4E(CW + D)]^{1/2}\} / 2E$ (14)

Where

$E = \varepsilon_H (\varepsilon_H\varepsilon_L - \varepsilon_H - \varepsilon_L) / \varepsilon_L$ (15)

The objective function for optimization is defined as

$E = W – T_0S_{gen}$ (16)

Where T_0 is the environment temperature and S_{gen} is the entropy generation rate. The optimization of the function E represents the best compromise between power output W and power loss T_0S_{gen} , which is produced by entropy generation
in the system and its surroundings. Substituting of equations (3) , (4) and (10) into equation (15) gives

$E = W – \{Q_L / T_L – Q_H / T_H\}$

$= (1 + T_0 / T_L)W + C_W \varepsilon_H T_0 T_1(1 / T_H – 1 / T_L) + C_W \varepsilon_H T_0(1 – T_H / T_L)$

Maximizing E with respect to W by setting

$ðE / ðW = 0$

Which gives

$(1 + T_0 / T_L) + C_W \varepsilon_H T_0(1 / T_H – 1 / T_L) ðT_1 / ðW = 0$ (17)

Substituting of equation (14) into equation (17) gives,

$F W^2 + G W + H = 0$ (18)

Where

$F = A^2(JA – 2EI)^2 – A^4J^2$

$G = (2AB – 4CE)(AJ – 2EI)^2 – 2A^2J^2(AB – 2CE)$

$H = (B^2 – 4DE)(AJ – 2EI)^2 – J^2(AB – 2CE)^2$

Thus the optimal power corresponding to the maximum objective function is given by

$W_{opt} = \{-G – (G^2 – 4FH)^{1/2}\} / 2F$ (19)

Using equation (14) and (19), we can obtain

$T_{1opt} = \{-AW_{opt} – B – [(AW_{opt} + B)^2 – 4E(CW_{opt} + D)]^{1/2}\} / 2E$ (20)

Then from the above equations, we can get the optimum cycle temperatures T_{2opt} , T_{3opt} and T_{4opt}. The optimum power W_{opt} and the corresponding heat transfer rates Q_{Hopt} and $Q_{L\ opt}$ are also calculated. The thermal efficiency at maximum objective function can be expressed as

$\eta_{opt} = W_{opt} / Q_{\ Hopt}$ (21)

If $T_0 = T_L$, the second law efficiency at maximum ecological function is given by

$\eta_{IIopt} = \eta_{opt}T_H / (T_H - T_L)$ (22)

For comparison, the maximum power and the corresponding thermal efficiency for Brayton cycle given by Ibrahim et al. are given as

$Wm = C_W\varepsilon_L\varepsilon_H / (\varepsilon_L + \varepsilon_H - \varepsilon_L\varepsilon_H)$ (23)

$\eta_m = 1- (T_L / T_H)^{1/2}$ (24)

3. Discussion of Results

The dimensionless power at maximum objective function W_{opt} / C_WT_H and the dimensionless entropy generation rate at maximum objective function S_{gen} / C_W as a function of the numbers of transfer units of the hot-side and cold-side heat exchangers, N_H and N_L, are plotted in Fig. 1.3 and

Fig. 1.4. Both the power output and rate of entropy generated increase rapidly at low N_H and N_L,while slowly as N_L and N_H becomes greater.

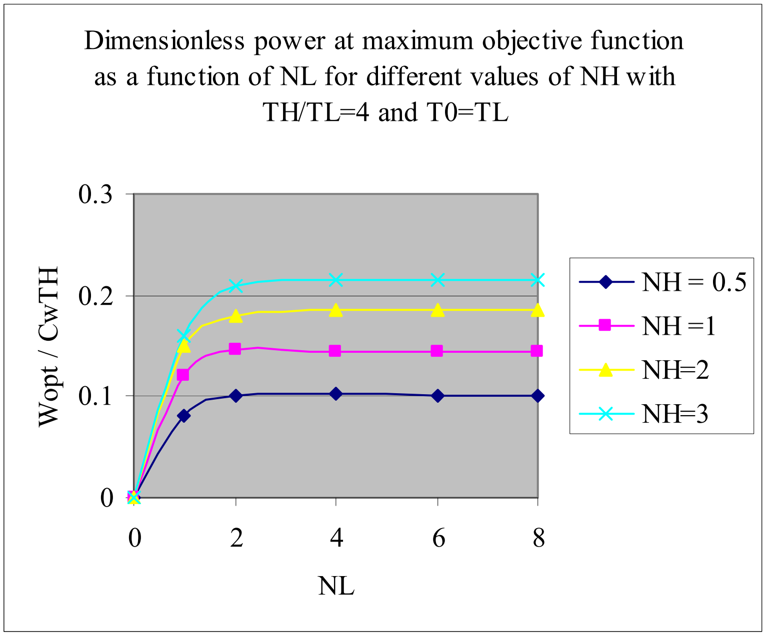

Fig. 1.3 Dimensionless power at maximum objective function as a function of N_L for different values of N_H with T_H/T_L=4 and $T_0 = T_L$

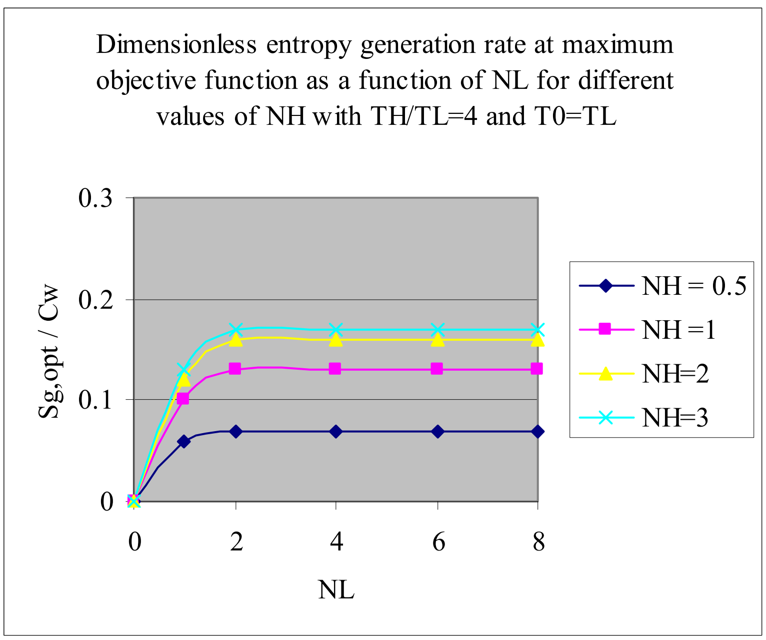

Fig. 1.4 Dimensionless entropy generation rate at maximum objective function as a function of N_L for different values of N_H with T_H/T_L=4 and $T_0 = T_L$

The dimensionless power W_{opt} / $C_W T_H$ at maximum ecological function and the dimensionless entropy generation rate S_{gen} / C_W as functions of the hot-cold reservoir temperature ratio T_H / T_L are sketched in Fig. 1.5 and Fig. 1.6. It is shown that both the power output and the rate of entropy generated increase monotonically as this temperature ratio is increased.

In Fig 1.7-1.9, it is interesting to find that the plots that represent the three cases of different values of N_H are overlapped by the same straight line. These figures show that the ratio of the power output at maximum objective function to the maximum power output W_{opt} / W_m , the ratio of the entropy generation rate at maximum objective function to the entropy generation rate at maximum power $S_{gen,opt} / S_{gen,m}$ and the thermal efficiency at maximum objective function are independent of number of heat transfer units of the hot side and cold side heat exchangers N_H and N_L. With the reservoir temperature ratio $T_H / T_L = 4$, the maximum objective function power is about 90 % of the maximum power; however, the entropy generation rate at maximum objective function is only 40% of that at maximum power. Moreover, the thermal efficiency at maximum objective function is about 1.2 times that at maximum power. Therefore, with a little sacrifice in power output, we can have a substantial reduction in the entropy generation rate and an increase in thermal efficiency.

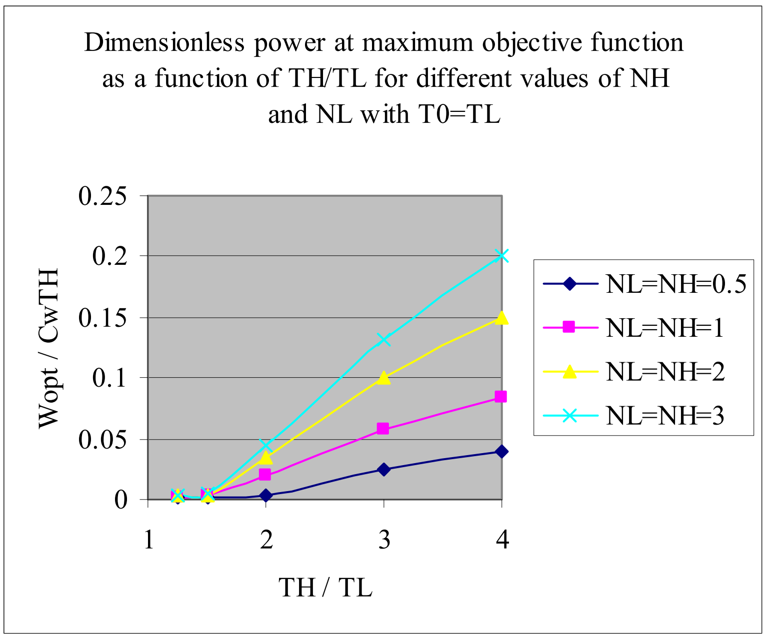

Fig. 1.5 Dimensionless power at maximum objective function as a function of T_H / T_L for different values of N_H and N_L with $T_0 = T_L$

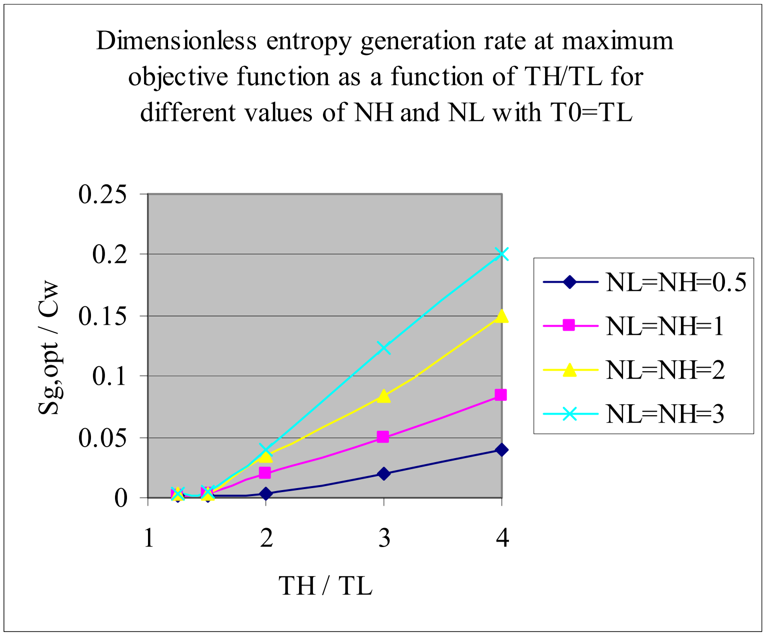

Fig. 1.6 Dimensionless entropy generation rate at maximum objective function as a function of T_H / T_L for different values of N_H and N_L with T_0 = T_L

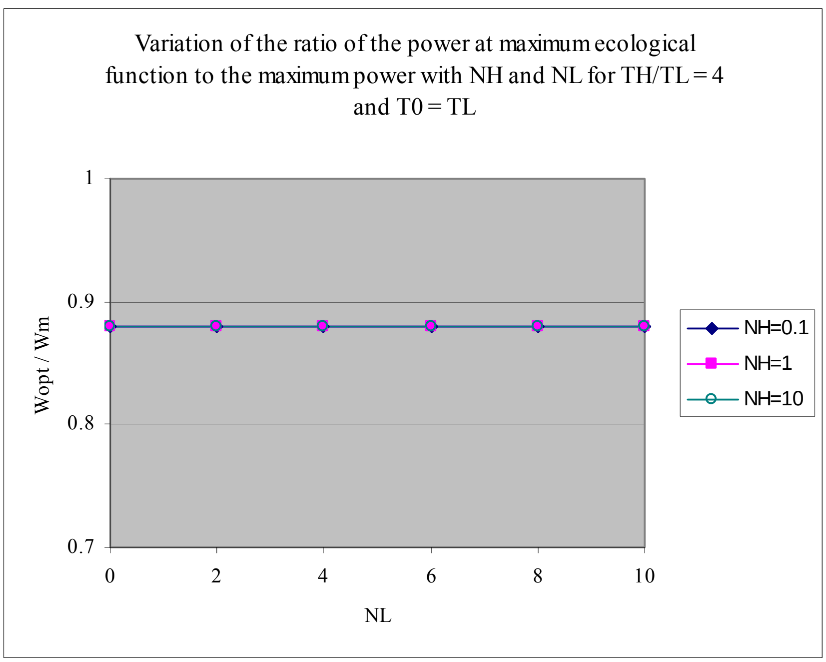

Fig. 1.7 Variation of the ratio of the power at maximum objective function to the maximum power with N_H and N_L for T_H/T_L =4 and T_0=T_L

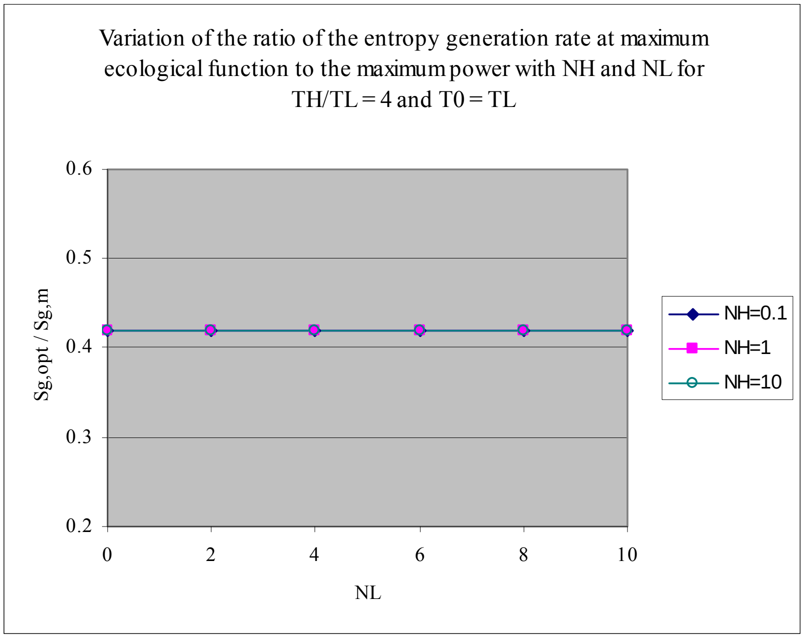

Fig. 1.8 Variation of the ratio of the entropy generation rate at maximum objective function to the entropy generation rate at maximum power with N_H and N_L and for T_H/T_L =4 and T_0=T_L

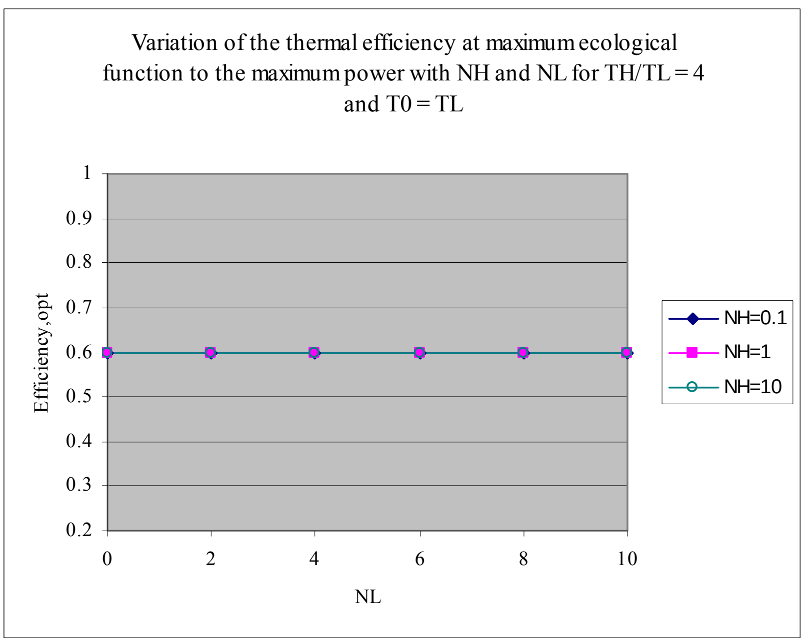

Fig. 1.9 Variation of the thermal efficiency at maximum objective function with N_H and N_L for $T_H/T_L = 4$ and $T_0 = T_L$

The relationship between the ratio of the power output at maximum objective function to the maximum power output W_{opt} / W_m and the hot-cold reservoir temperature ratios T_H / T_L is illustrated in Fig. 1.10. The result show that the ratio of the power output at maximum objective function to the maximum power output increases as the hot-cold reservoir temperature ratio is increased.

The variation of the ratio of the entropy generation rate at maximum objective function to the entropy generation rate at maximum power Sgen,opt / Sgen,m with the hot-cold temperature ratio

T_H / T_L is also plotted in Fig. 1.11. The ratio of the entropy generation rate at maximum objective function to the entropy generation rate at maximum power increases with the increase of temperature ratio. It is noted that the higher power output ratio W_{opt} / W_m is always in company with the relatively lower entropy generation rate ratio $S_{gen,opt}$ / $S_{gen,m}$.

The variation of the thermal efficiency at maximum objective function and the thermal efficiency at maximum power with the hot-cold reservoir temperature ratio T_H / T_L is plotted in Fig. 1.11. For Brayton cycle, the thermal efficiency at maximum objective function increases monotonically with the hot-cold temperature ratio. The thermal efficiency at maximum objective function is much higher than the thermal efficiency at maximum power. It is evident that this efficiency is almost equal to the average of the reversible Carnot efficiency and the maximum power efficiencies for low hot-cold reservoir temperature ratios.

The variation of the second-law efficiency at maximum objective function and the second law efficiency at maximum power with the hot-cold reservoir temperature ratio T_H / T_L is plotted in Fig. 1.12. The second law efficiency at maximum objective function increases with the increase of the hot-cold reservoir temperature ratio. The second law efficiency at maximum objective function is much higher than the second law efficiency at maximum power. With the introduction of the objective function, the improvement in second-law efficiency and in the thermal efficiency is clearly found, especially for low hot-cold reservoir temperature ratio.

A = curve for the ratio of the power at maximum ecological function to the maximum power W_{opt} / W_m;
B = curve for the ratio of the entropy generation rate at maximum objective function to the entropy generation rate at maximum power $S_{g,opt}$ / $S_{g,m}$

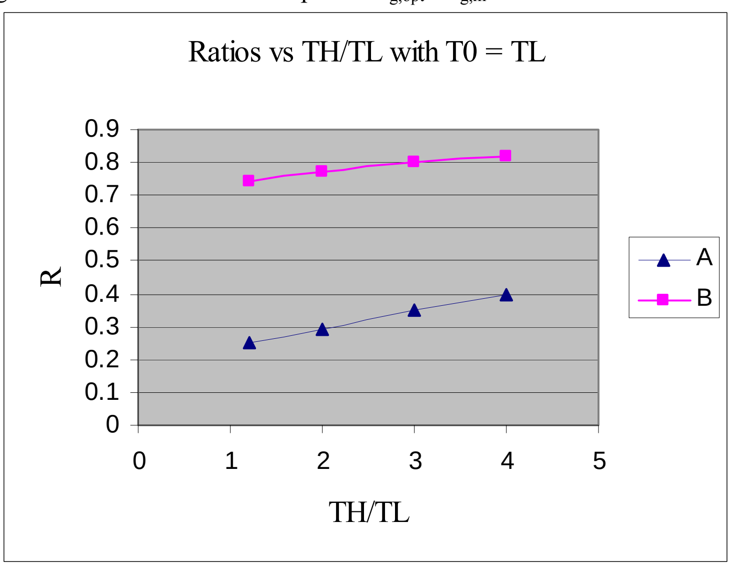

Fig. 1.10 Ratios vs T_H / T_L with $T_0 = T_L$
A = curve for the thermal efficiency at maximum objective function
B = curve for the thermal efficiency at maximum power
C = the average of the reversible carnot and the maximum power efficiencies

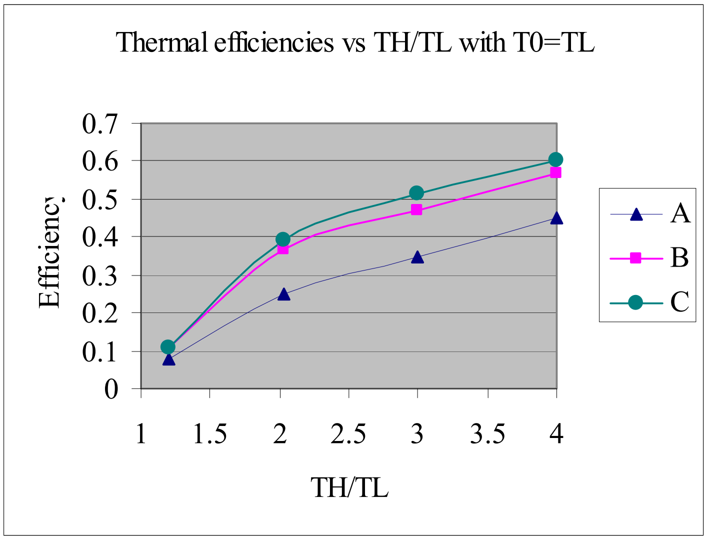

Fig.1.11 Thermal efficiencies vs T_H / T_L with T_0 = T_L
A = curve for the second-law efficiency at maximum objective function
B = curve for the second-law efficiency at maximum power

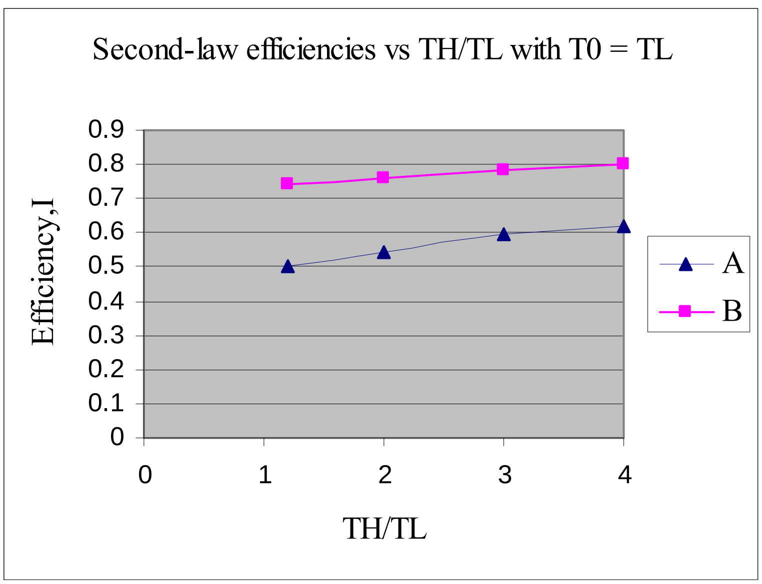

Fig. 1.12 Second-law efficiency vs T_H / T_L with T_0 = T_L

Conclusion

Finite-time thermodynamics has opened the promising perspective of finding answers, within a theoretical framework, for a wide spectrum of questions related to real dissipative thermodynamic processes One such question is the problem of finding realistic bound for some process variables, such as work power, efficiency, and so on. Another important issue is to find the best mode of operation of heat engines under more realistic conditions than reversible ones. Diverse criteria of optimization have been proposed using finite-time thermodynamic approach, which maximize the difference between the power produced and power lost. An analysis based on this criterion has been done for the endoreversible Brayton heat engine cycles coupled with constant temperature thermal reservoirs.The thermal efficiency at maximum ecological function is equal to the average of the reversible carnot and maximum power efficiencies for low TH/TL value in case of endo-reversible Brayton heat engine cycle. Hence with a little sacrifice in power output we can increase the thermal efficiency of endoreversible Brayton heat engine cycle.

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Total Quality Management

Achin Srivastava

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India
achin.srivastav@rediffmail.com

Abstract

In recent years, quality has become an important competitive strategy in the global market. In near future, due to World Trade Organization agreements, globalization and competitiveness, organizations have no choice other than adopting Total Quality Management for their survival. This paper provides problem identification, solving and prevention tools for successful implementation of TQM culture. A case study of service sector implementing TQM is discussed.

1 INTRODUCTION

With demanding customers, increasing competition, changing business condition, globalization and increasing complexity of products & markets that buy these products has created a scenario where companies need TQM, to help product costs down without compromising on quality. The present study has made an attempt to understand Total Quality Management approach. In this paper concept of TQM, background of TQM, principles of TQM, tools of TQM, implementation of TQM and a case study of TQM is covered. Lastly the benefits for implementing TQM are discussed.

2 TOTAL QUALITY MANAGEMENT

TQM is management strategy aimed at embedding awareness of quality in all organizational processes. TQM provides an umbrella under which everyone in the organization can strive and create customer satisfaction and meet organizational objectives [1]. TQM is a structural system for creating organization wide participation in planning and implementing a continuous improvement process that exceeds customer expectation

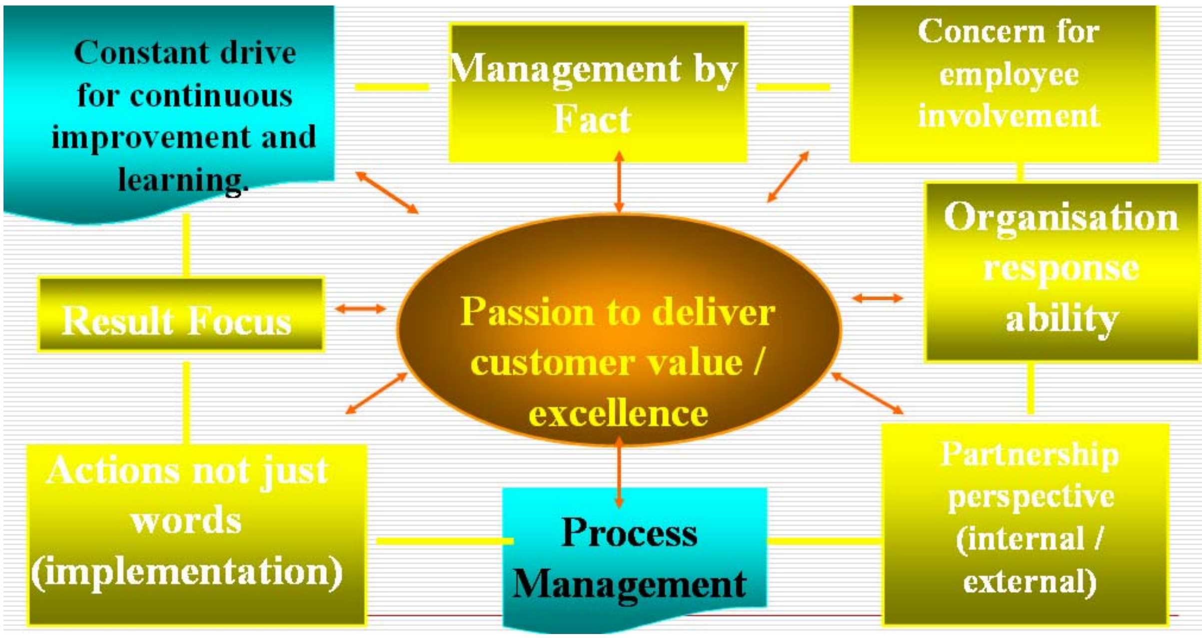

Figure 1 Concept of TQM

3 BACKGROUND OF TQM

As noted by Deming (1982) , in 1950 Japan's net worth was negative, it had no significant natural resources and had a reputation for producing cheap , shoddy consumer goods . forty years later Japan's manufactured products are the envy of the world and are of high quality . Their approach to, management of resources is completely different from traditional approach. TQM, having being established in manufacturing industries has continued to grow and is now pervasive throughout enterprise in the world.

4 TRADITIONAL APPROACH TO QUALITY CONTROL

Quality Control has been an important function in organization producing goods for sale where product specifications are important [2]. The approach to quality control usually followed this sequence

1 Produce product with major emphasis on cost & Quality

2 Measure the product after it is produced to determine whether it meet product specification.

3 Ship product meeting specification and reject products not meeting specification

In operations where quality is not a concern at the point of sale, the sequence generally skips step numbers two and three in the list above.

Traditional Approach	**NonTraditional Approach**
Market Share Focus	Customer Focus
Individuals	Cross Functional Teams
Focus on 'Who' & 'Why'	Focus on 'How' & 'What'
Short term focus	Long term Focus
Status Quo	Continuous Improvement
Product Focus	Process Improvement focus
Innovation	Incremental improvements
Fire Fighting	Problem solving

Table 1 : Traditional v/s Nontraditional Approach

In the traditional management approach, quality control is generally thought to result in higher marginal costs of production. Tighter control requires more scrutiny, which requires more inspectors. Tighter controls also result in additional production costs because productivity is decreased as a result of additional controls in the production process. Where quality control is not practiced, costs would be the least since these controls would not be required. For this reason, operating managers, quite naturally, are most interested in avoiding additional emphasis on quality. This is particularly true when there is no requirement for quality control at the point of sale.

5 TOTAL QUALITY MANAGEMENT: A NON-TRADITIONAL APPROACH

To maximize quality, variation must be minimized. Variation is sometimes called the fundamental cause of poor quality (Evans, 1989). Variation can also be called the fundamental cause of high unit costs. The total quality management approach concentrates on reducing variation in the production process. To the degree this is successful it improves quality and unit costs at the same time. Therefore, the TQM is essential not only to improve quality but to optimize production cost[10].

6 PRINCIPLES OF A TOTAL QUALITY MANAGEMENT PROGRAM

The following elements are essential in any successful quality management program:

1 Management Commitment
2 Employee Empowerment
3 Fact-Based Decision Making
4 Continuous Improvement
5 Customer Focus

First, top management is the driving force. Quality is a strategic issue. Senior management sets the environment, provides the resources and leads by example.

Second, cross-functional management is essential existing vertical organisational structures and independent operational units may be retained, but new structures for horizontal coordination are often required, and *internal customer* relationships are commonly created.

Third, middle managers are the *quality champions*, the implementers of quality systems. Standing at the crossroads of vertical and horizontal structures, middle managers are the dominant quality controllers in most organisations, and the maximum possible responsibility should be devolved to this level. In flat organisational structures, with no middle management, team leaders are the quality champions.

Fourth; question, test, and measure. Rigorous and systematic issue -identification and problem-solving, using statistical methods, cost/benefit and cause and effect analysis, and decision-making techniques should be adopted, or at least understood, by all participants.

And **fifth**, the improvement process both creates and depends on cultural change within the organisation. Quality organisations are characterised by the internalisation of a commitment to quality, open communications, distributed (and collective) decision making, high levels of trust, entrenched quality systems, and a focus on the absolute priority of the customer.

.

7 TOOLS OF TQM

The following are some of the most common TQM tools in use today.

Pie Charts and Bar Graphs

Used to identify and compare data units as they relate to one issue or the whole, such as budgets,vault space available, extent of fonds, etc.

Histograms

To illustrate and examine various data element in order to make decisions regarding them.

Effective when comparing statistical, survey, or questionnaire results.

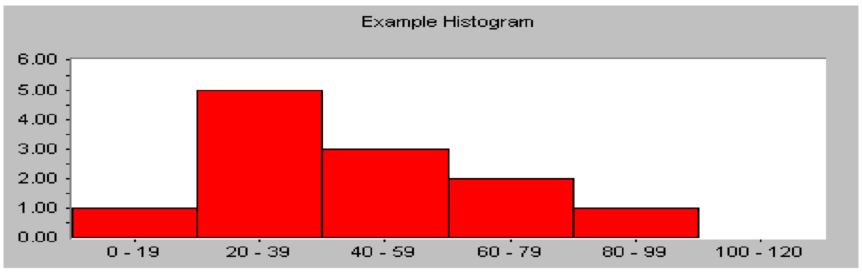

Figure 2 Histogram

Run Chart

Follows a process over a specific period of time, such as accrual rates, to track high and low points in its run, and ultimately identify trends, shifts and patterns.

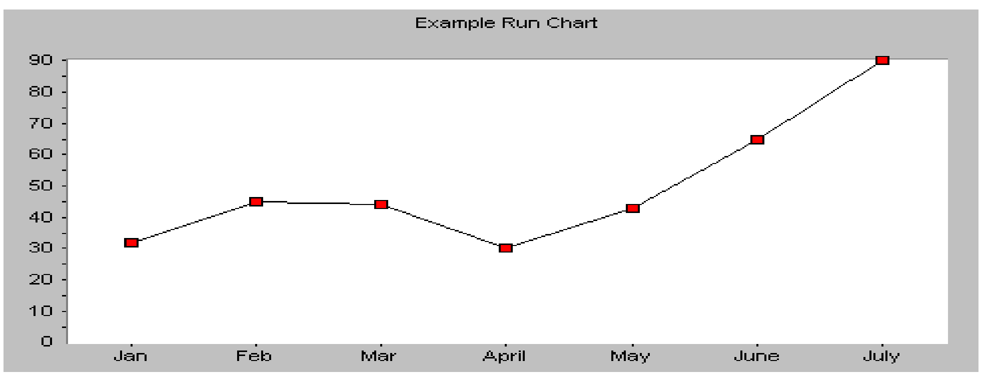

Figure 3 : Example Run Chart

Pareto Charts / Analysis (designed by Vilfredo Pareto)

Rates issues according to importance and frequency by prioritizing specific problems or causes in a manner that facilitates problem solving.

Identify groupings of qualitative data, such as most frequent complaint, most commonly purchased preservation aid, etc. in order to measure which have priority.

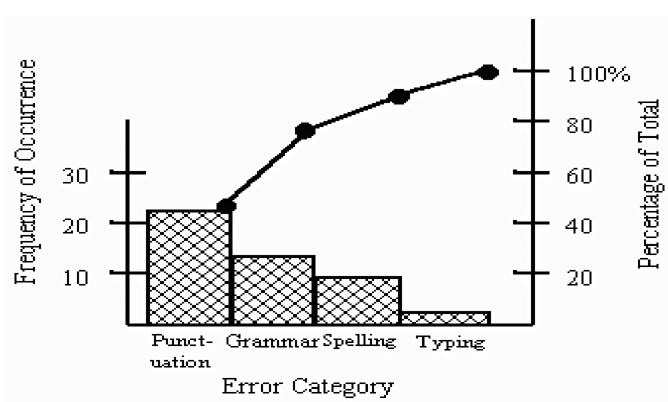

Figure 4: Pareto Charts

Force Field Analysis

To identify driving and restraining forces occurring in a chosen process in order to understand why that particular process functions as it does. For example, identifying the driving and restraining forces of catering predominantly to genealogists.

To identify restraining forces that need to be eradicated or driving forces that need to be improved, in order to function at a higher level of efficiency.

Cause and Effect, Ishikawa or Fishbone Diagrams (designed by Kauro Ishikawa)

Illustrates multiple levels of potential causes (inputs), and ultimate effects (outputs), of problems or issues that may arise in the course of business.

May be confusing if too many inputs and outputs are identified. An alternative would be a tree diagram, which is much easier to follow.

Focus Groups

Useful for marketing or advertising organizations to test products on the general public.

Consist of various people from the general public who use and discuss your product, providing impartial feedback to help you determine whether your product needs improvement or if it should be introduced onto the market.

Brainstorming and Affinity Diagrams

Teams using creative thinking to identify various aspects surrounding an issue.

An affinity diagram, which can be created using anything from enabling software to post-it notes organized on a wall, is a tool to organize brainstorming ideas.

Tree Diagram

To identify the various tasks involved in, and the full scope of, a project.

To identify hierarchies, whether of personnel, business structure, or priorities.

To identify inputs and outputs of a project, procedure, process, etc.

Flowcharts and Modelling Diagrams

Assist in the definition and analysis of each step in a process by illustrating it in a clear and comprehensive manner.

Identify areas where workflow may be blocked, or diverted, and where workflow is fluid.

Scatter Diagram

To illustrate and validate hunches

To discover cause and effect relationships, as well as bonds and correlations, between two variables

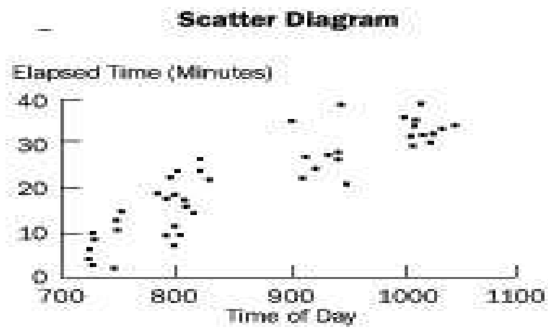

Figure 5 : Scatter Diagram

IMPLEMENTATION OF TQM

1 PLAN

Plan a change to the process. Predict the effect this change will have & plan how the effects will be measured.

2 DO

Implement the change on a small scale and measure the effects

3 CHECK

Study the results to learn what effect the change had, if any.

4 ACT

Adopt the change as a permanent modification to the process, or abandon it.

TQM Process Improvement and Problem Solving Sequence					
PLAN (PLAN A CHANGE)			DO (IMPLEMENT THE CHANGE)	CHECK (OBSERVE THE EFFECTS)	ACTION (EMBED THE FIX INTO THE PROCESS FOR GOOD)
DEFINE THE PROBLEM	IDENTIFY POSSIBLE CAUSES	EVALUATE POSSIBLE CAUSES	MAKE A CHANGE	TEST THE CHANGE	TAKE PERMANENT ACTION
1. Recognize that what you are doing is a "PROCESS" 2. Identify the commodity being processed. - Process Inference 3. Define some measurable characteristics of value to the commodity. 4. Describe the "PROCESS" o Process Flow Analysis's o Flow charts o List of steps 5. Identify the "Big" problem o Brainstorming o Checklists o Pareto analysis	6. "BRAINSTORM" what is causing the problem. 7. Determine what past data shows. o Frequency distribution o Pareto charts o Control charts - sampling	8. Determine the relationship between cause and effect o Scatter diagrams o Regression analysis 9. Determine what the process is doing now o Control charts - sampling	10. Determine what change would help • Your knowledge of the process • Scatter diagrams • Control Charts - sampling • Pareto analysis ****Then make the change.	11. Determine what change worked (confirmation). • Histograms • Control charts - sampling • Scatter diagrams	12. Ensure the fix is embedded in the process and that the resulting process is used. Continue to monitor the process to ensure: A. The problem is fixed for good. and B. The process is good enough o Control charts - sampling ****To ensure continuous improvement, return to step 5.

Table 1 : TQM PROCESS IMPROVEMENT

9 CASE STUDY(Jet Airways)

Indian aviation is the fastest growing aviation industry in the world. Aviation industry in India has undergone a rapid change due to liberalization of Indian aviation sector. Private airlines account for almost 75% of domestic aviation market share . With Jet Airways sharing about one third of total market.

Figure 8:Indian Market Share

9.1 Service Process at Jet

The process of travelling on airline is divided into three stages : pre-flight, inflight and post flight experiences. The service start from buying ticket- check-in- boarding- departure-flying- arrival- baggage claim. The key areas of quality management are on time, delay announcements, good in flight service, good in flight food, waiting time for baggage , baggage loss, compensate for baggage loss, good ground service, refreshments on delay, accommodation on delay, online booking, discounted fare, real benefits for frequent fliers & maintenance of aircraft and other equipments.

Jet Airways was founded by Mr. Naresh Goyal in 1974 and today it has become frontrunner in domestic aviation market, due implementation of TQM.

9.2 TQM Techniques at Jet

Jet airways formulated a Quality Management System for In-flight Services in 2001 as a part of comprehensive exercise to implement ISO in selective operational areas. They also implement KAIZEN techniques to improve the services of their employees through continuous training programs.

FSC / ServQual Dimensions	Jet Airways Rankings	Kingfisher Airlines Rankings	Indian Airlines Rankings
Reliability	1	2	3
Assurance	1	2	3
Tangibles	2	1	3
Empathy	1	2	3
Responsiveness	1	2	3

Table 2 : Comparison of Major Airlines

9.3.1 Cost Reduction Measures

- Jet and Kingfisher put aside their differences and joined hands to cut cost through cost sharing and combining ticketing and ground services.
- The airline leased two of its Boeing 737s to a Japanese company, and implemented a number of workforce productivity measures.
- Salary cut of employees.

9.4 Result

- The adoption of TQM techniques has placed Jet airways in top in almost all aspects as compare to other major airlines. Jet Airways has won the 2008 Galileo Express Travelworld "best domestic full service airline" award for the sixth year in a row.

CONCLUSION

To economically compete in the future, companies will need to take the next step in optimizing product quality and minimizing operating costs. This step cannot be taken without a commitment to total quality management incorporating statistical process control. Using Total Quality Management not only eliminates product and service defects, but it as well enhances product design, speeds service, reduces costs, and, above all, changes the culture of organizations and improves the quality of work life. There is a distinction between conceptual TQM journey and execution TQM journey. Conceptual journey is rather straightforward. The execution journey, however, presents two options on many critical issues. The success of TQM is dependent on the prudent choices. The choices must be made between the two options at the juncture between the end of TQM conceptual journey and the beginning of TQM implementation. The paper has reasoned in favour of strategically superior choices.

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Digital Manufacturing

Dharmender Saini

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India
Email: dharmender82@gmail.com

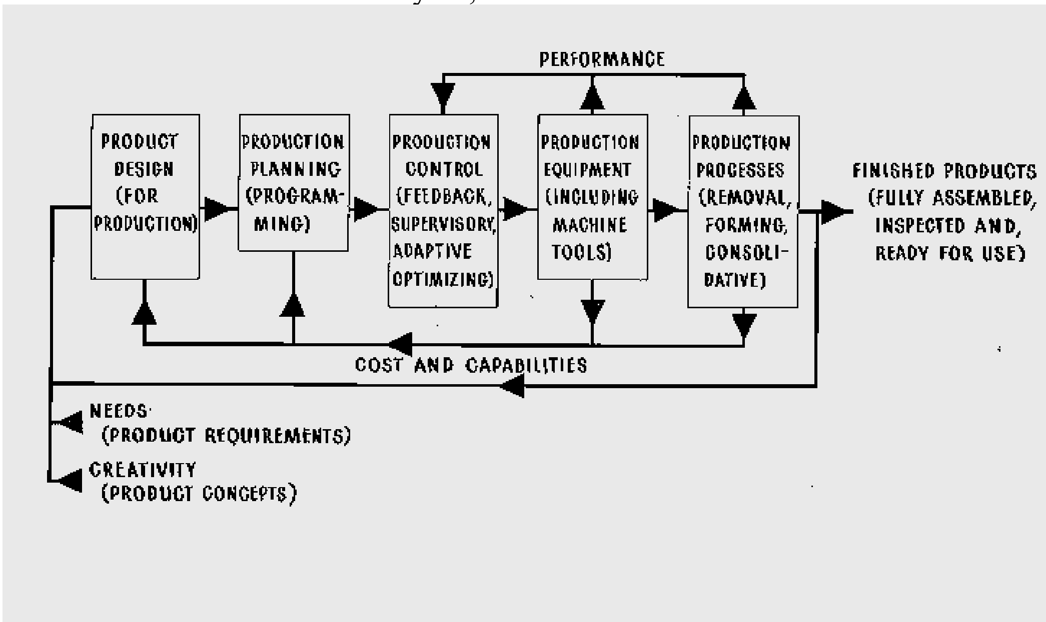
Abstract
The paper represent the digital manufacturing importances The practical reasons for adopting digital manufacturing are fairly obvious – no paper revisions, no prototypes, more collaboration, and more output. However, consider the effects that it can have on the scale and reach of projects. With digital manufacturing designers are no longer constrained by space or volume limitations. They can build greener, smaller plants and experiment with all types of new materials, layouts and equipment. What would've seemed extremely tedious and time-consuming a year ago (such as designing a production line) can now be done in a fraction of the time. Being able to simulate the designs online, collaboratively, provides unlimited potential.

1. Introduction

Everyone is looking for a magic bullet that would make their company more productive and retain costs, but thus far – unless you have a sixth sense – it hasn't been found. Until it is, one practice that has been tremendously successful on both fronts is "digital manufacturing."The term has been bandied about for quite some time now, advertised as an example of corporate social responsibility, an eco-conscious way to do business, the manufacturing buzzword du jour. And undoubtedly, digital manufacturing encompasses all of those things and it is a step in the right direction for saving our planet, but let's examines some equally pressing issues. The economy is in dire straits, and highly respected global manufacturing companies are laying off plant workers by the thousands. Suppliers are shutting their doors due to devastating decreases in consumer and OEM demand. Right now, the question on every manufacturer's mind is, "How do we stay competitive?"The answer to that question is also digital manufacturing. It turns out that in this case, helping the environment can dramatically help the bottom line. By delivering a high return on investment and contributing to revenue increases, digital manufacturing can save companies money, time and make them even more attractive as a potential business partner and it doesn't require putting solar panels on plant stacks. Digital manufacturing is becoming a major element of product life-cycle management (PLM). It's the process by which companies can define and optimize manufacturing processes, manage manufacturing data, and encourage collaboration between different types of engineers by incorporating both digital and plant product definitions. Digital manufacturing presents a view of product and process design holistically, as part of the product life cycle, and allows products to be designed in a way that adjusts for process capabilities or limitations. According to a CIMdata report entitled "The Benefits of Digital Manufacturing," organizations using digital manufacturing technologies can realize tremendous production improvements and reductions in resource waste, including a 30 percent reduction in time-to-market; a 40 percent reduction in process planning; a 15 percent increase in production throughput; a 13 percent decrease in overall production cost; and a 40 percent reduction in equipment costs.

2. Evaluation of Digital Manufacturing

Digital Manufacturing sets the criteria by which manufacturing planning and execution are tightly integrated and model/configuration driven, and where rich data that is associative to product and process information, drives downstream processes. Furthermore, a rich set of integrated simulation and validation tools ensure product quality and reliability as well and throughput and operational efficiencies from the start Digital Manufacturing has been known by many different names in the past including: Manufacturing Process Management, Collaborative Manufacturing Process Management, and Computer-Aided Process Planning (CAPP). Solutions that support manufacturing process planning collaboration among engineering disciplines, from product design to manufacturing. The solutions use best practice processes and allow access to the full digital product definition, including tooling and manufacturing process designs. Digital manufacturing is, in practice, an integrated suite of tools that work with product definition data to support tool design, manufacturing process design, visualization, simulation, and other analyses necessary to optimize the manufacturing process."… (CIMData, 2006). Digital Manufacturing is a combination of open software and manufacturing methods that transforms production processes and business initiatives. It provides a solution that links all manufacturing disciplines including: manufacturing process design; process simulation/engineering and production management. By doing so, Digital Manufacturing results in companies not only getting much more from their production operations, but more from product design investments and supply chain partnerships". Digital Manufacturing, data management and CAD tools provide solutions that integrate the definitions of products, processes, practices, plants, tools, and resources into a consistent manufacturing solution It delivers innovation by linking all manufacturing disciplines with product engineering including: process layout and design, process simulation/engineering and production management through manufacturing backbone that keeps all necessary updated files necessary for the overall product design and realization (Siemens UGS Tecnomatix, 2007). Digital manufacturing is a term that has been thrown around by software vendors and machine marketers for years, but it is only recently that it has become something that is available to almost anybody in the manufacturing supply chain. The rise of affordable software combined with the acceptance of the Internet means that many companies are doing digital manufacturing without fanfare and almost without noticing that their processes are evolving. Whoever you ask will give a slightly different definition of "digital manufacturing." Based on responses from many people in the industry, here's a definition: Digital manufacturing is the ability to describe every aspect of the design-to-manufacture process digitally—using tools that include digital design, CAD, Office documents, PLM systems, analysis software, simulation, CAM software and so on. The ideal is that the passing of data from one department to another should be seamless so that the data created is immediately reusable. By doing so, Digital Manufacturing results in companies not only getting much more from their production operations, but more from product design investments and supply chain partnerships" (Dalton-Taggart, 2007). Digital manufacturing is the technology to provide rapid and efficient product development and production by composing an accurate and integrated computer model of physical and logical elements in the manufacturing system, and utilizing various computer technologies such as 3D CAD and simulation as the means of detecting errors in earlier stages and performing efficient decision making over the whole process of manufacturing (Kim, 2002, Shukla et al, 1997). Digital manufacturing is an initiative to define manufacturing processes, manage manufacturing process information and support effective collaboration among engineering disciplines by using full digital product definition. It supports visualization, manufacturing simulation, ergonomic and human factor analyses, and other engineering analysis tools necessary to optimize the manufacturing process design. It also facilitates the holistic view of product and process design as integral components of the overall product life cycle and enables product design to be sensitive to process constraints and capabilities (Chrisman, 2007).

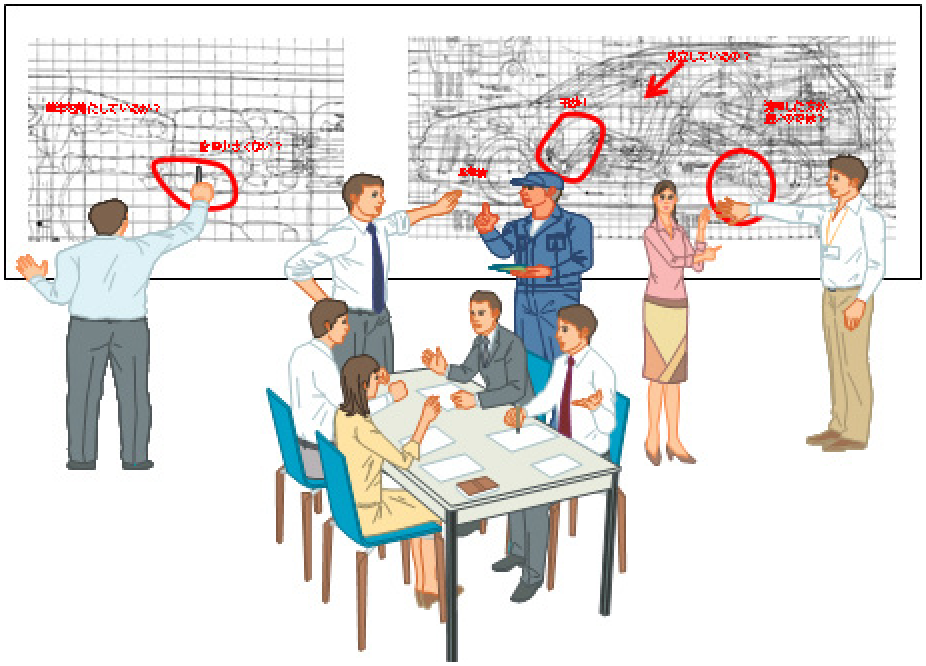


2.1 Digital Manufacturing Design

Whenever a product of any kind is developed, diligent manufacturers have to establish a consistent, strong design review process to ensure that the product meets all standards for design, engineering, manufacturing, safety and branding. According to 6 Sigma SPC, design review is, “[An] official review, usually by a team or by one’s peers, or both, of the most important targets in a program’s, procedure’s, service’s and/or a project’s design, or process, thus ensuring the optimum plan prior to the start of project.”These are systematic, comprehensive, and documented analyses of a design to determine its capability and adequacy to meet its requirements. A design review also serves to identify present and potential problems. Design Review is scheduled to occur at specific milestones, for example when concept design has completed and prior to the product going to detail design. Another key milestone review often occurs after detail design but prior to releasing drawings to production. This process allows a product to be visually assessed and assured at each stage prior to going into production, and certain stages will often also involve physical prototypes. In older, traditional processes for design review in manufacturing, paper drawings would be shared with peers, who would use them to visually observe and identify conflicts with corporate standards, design problems, and potential problems with manufacture and production. Design review in a Digital Manufacturing environment already occurs, but is often bogged down by unanticipated barriers that eradicate the benefits of digital manufacturing. To help understand the barriers, we will first look at traditional design review processes, then at how manufacturers try and address it in 3D CAD, and finally the XVL solutions for accurate, rapid and robust digital design review.

2.2 How does Traditional design review occur?

For design review to have any significant value, design drawings have to be viewed and assessed by peers, typically by those that have a stake within the design-to-manufacture process. As a design is poised to be released from, say, concept design to detail design, so paper drawings, parts lists and all related data is delivered to the design review group. This group will visually identify issues and errors, and manually note errors that may exist. Prior to releasing the design to the next phase, any issues identified during design review must be tackled by the originating designers or engineers. A second design review to ensure the issues have been solved will be conducted prior to releasing the design to its next phase. Typically, a standard manufactured product will have at least 3 milestone Design Reviews during the process of design to manufacture.



2.3 How critical is design review

Design Review of a product as it passes from phase to phase is critical to reduce errors in all aspects of the design. An incorrect choice of material could delay manufacturing; an erroneous thickness on a sheet metal part could make the design unproduceable. And any delay, or change to a design becomes more costly the later it is identified and changed. It has long been understood that the cost to a manufacturer of changing a product design when it is going into production is 10 times higher than the cost that would have been incurred for the same change during product design. It is 100 times more costly to make that same change during the assembly phase. [source: "The Machine that Changed the World." MIT 1990.As manufacturers have to face huge global competition, deal with rapidly changing consumer expectations, environmental issues, and increased raw material costs, so the need to create and deliver a product on time and within budget becomes more and more critical. This means that Design Review processes are key for any product to be manufactured, and the more diligent they are, the lower the cost of the product will be.

3. Design Review in a Digital Design process

In an ideal world, every piece of technology used would work as advertised – CAD systems would deliver seamless design-to-manufacture processes at the touch of a button; PLM systems would truly handle product design data all the way from concept through to end of life of the product; and CAD file formats would not change, ever. Unfortunately, life is never quite that ideal! Now, don't be mistaken – 3D CAD has revolutionized design and manufacture processes, making design more precise, shared across a global network, and allowing products to be delivered to market faster than ever before. However, when a manufacturer embarks on 3D digital manufacturing or digital prototyping for its design-to-manufacture process, they can quickly find out that what seemed to be a simple implementation can be fraught with unanticipated, and poorly solved, challenges. These can include:• Proprietary CAD file formats that prevent data being shared and used seamlessly• The rapidly increasing size of 3D CAD assemblies brings up needs for new, better hardware and more CAD seats• And the CAD systems themselves simply do not have many of the tools needed for actual, seamless design-to- manufacture process, including fast, accurate design review. These factors mean that often older, traditional techniques are still being deployed, even in an otherwise digital manufacturing workflow. And design review is no exception

3.1 Design Review processes using only 3D CAD

There are many merits to the ideal of using 3D CAD data in critical areas such as design review. sentially - and in principle - 3D is more straightforward and more descriptive than 2D, allowing people to rotate, view and zoom into the design, quickly understand possible movement of parts and easily understanding details. By having digital data, more people can gain access to it, and this saves time and effort by not printing paper drawings and shipping them to recipients. However, as 3D becomes accepted as a standard within the organization, so problems can occur, making use of the 3D CAD system as a design review platform inappropriate:- As assemblies are created in 3D, so the size of that data rises, often to uncontrollable levels; When a product has many thousands of parts, so viewing, using, and sharing an entire assembly becomes almost impossible; In this situation, anyone wishing to work on the data will be forced to use very high end, expensive computer hardware to deal with these massive files. Alternatively, users can break up a 3D assembly for review, but this also brings the opportunity for critical errors and problems that are missed when using sub-assemblies and discrete parts, rather than the complete assembly. Notwithstanding the need for more powerful computers on which to run large assembly design, so undertaking design review processes directly on a 3D CAD platform consumes costly CAD licenses that are often needed for other critical design tasks. Most 3D CAD systems do not easily integrate 3D CAD data from other systems and sources, meaning that entire assemblies might be difficult to combine from various parts and sub-assemblies. This can result in unanticipated and costly errors and clearance problems that might only be found during the expensive production phases. And ultimately, the design review tools within 3D CAD systems are typically inadequate for the needs of the design team, resulting in poor design review results that have to be supported by tedious visual checking. 3D CAD viewers can assist with visual checks and redlining but are very limited in terms of mathematical checks of data. On the positive side, design review that is performed on a 3D CAD system can allow the data to be modified immediately. This means that for casual design review, 3D CAD systems can be a useful tool, but are woefully inadequate for the critically important milestone reviews.

3.2 Design Review processes using XVL

XVL applications from Lattice Technology deliver design review tools that eliminate all the barriers previously discussed. XVL formats compress 3D data with no loss of accuracy, so that mathematically correct design review can occur easily and quickly. XVL applications deliver the tools for accurate interference, clearance, contact and gap checking, and provide automated reporting to allow errors and issues to be documented, tracked and resolved. XVL Studio identifies all errors found across parts and assemblies, listing each error found with a corresponding marker displayed on the 3D data. And the user can quickly zoom, pan and rotate down to the smallest detail to view each error in 3D and in 2D cross-sections.3D data in XVL delivers the industry's most highly compressed format but maintains mathematical accuracy, allowing the data to be easily exchanged, loaded, viewed and validated by the XVL applications.These tools deliver benefits that include much faster and earlier identification of errors, more opportunities for design review throughout the process, highly accurate design review and time savings for product design.

Conclusion

The use of 3D data throughout enterprises is growing rapidly. Simultaneous to that growth is the increase in size of 3D assemblies, as digital manufacturing, PLM and digital prototyping processes are established within an operation. However, there are barriers to using that data that are not readily anticipated prior to implementing such a process. These barriers include:• Huge data size preventing re-use of the data in any way• Lack of interoperability of the data across many disciplines• Lack of tools to adequately test, simulate and animate the data for useful testing and reporting

Applications

The present study can be made useful in the following some applications which are listed below

i. Product design
ii. Process Planning
iii. Time management & Business Applications
iv. Factory Layout Planning
v. Ergonomics
vi. Simulation of Robot Usage
vii. Production Process Simulation
viii. PLM systems
ix. Analysis Software
x. CAM software

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Biodiesel Technology

Geetha Varma.V

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India
Email: geethavarmamurali@yahoo.com

Abstract

Biodiesel refers to the diesel equivalent of fossil fuel-derived diesel and originates from recent biological sources. Biodiesel can be created from a number of vegetable oils or animal fats. Biodiesel is the only alternative fuel to have fully completed the health effect testing requirements of the clean air act. The use of biodiesel in a conventional diesel engine results in substantial reductions of unburned hydrocarbons, carbon monoxide and particulate matter compared to emissions from diesel fuel

1. Introduction

The growing environmental concern has engaged the worlds' brightest minds to come up with a perfect answer to soaring fuel prices and automotive pollution. Biodiesel is an alternative fuel produced from renewable resources i.e. nonedible oilseeds like jatropha, neem, and karanj[4]. Biodiesel contains no petroleum, but it fully replaces petroleum diesel or can be blended with petroleum diesel to create a biodiesel blend. It can be used in diesel engines with no modifications. Biodiesel is simple to use, biodegradable, nontoxic and essentially free of sulfur and aromatics. Specially grown crops producing straight vegetable oil (SVO) or waste vegetable oils (WVO) can be refined into biodiesel that can be used directly in standard diesel engines[1]. The production process for biodiesel from waste oils is relatively simple and can be converted at a wide range of scales

Biodiesel can be used in diesel vechicle like cars, trucks, construction equipments, D.G.Sets. In most cases you can start using biodiesel immediately without any modification. Biodiesel is having very high solvent like cleaning a property, as a result it cleans the entire fuel system. Regular use of Biodiesel makes the entire fuel system free from harmful deposits that accumulate as a result of long-term usage of diesel. This powerful cleaning effect can be seen within few hours of driving/running a diesel engine on Biodiesel. All these deposits can be seen on fuel filter. It is recommended that fuel filter with accumulated dirt/deposits should be changed after 500 KMS of running on biodiesel[3].

2.Production of Biodiesel

Straight animal fats or vegetable oils have to undergo a chemical reaction, known as transesterification, in which the fat or oil is purified and reacted with alcohol to form esters and glycerol. Chemically, triglycerides consist of three long-chain fatty acid molecules joined by a glycerine molecule. The biodiesel process uses a catalyst (lye) to break off the glycerine molecule and combine each of the three fatty-acid chains with a molecule of methanol, creating mono-alkyl esters, or Fatty Acid Methyl Esters (FAME) -- biodiesel. The glycerine sinks to the bottom and is removed. The **lye** catalyst can be either potassium hydroxide (KOH) or sodium hydroxide (caustic soda, NaOH)[9].

3.Blends of Biodiesel

Biodiesel is safe and can be used in diesel engines with little or no modification needed. Although biodiesel can be used in its pure form, it is usually blended with standard diesel fuel. Blends are indicated by the abbreviation Bxx, where xx is the percentage of biodiesel in the mixture. For example, the most common blend is B20, or 20 percent biodiesel to 80 percent standard. So, B100 refers to pure biodiesel.

4. Advantages of Biodiesel

Biodiesel is an oxygenated fuel, so it contributes to a more complete fuel burn and a greatly improved emissions profile. The more biodiesel used in a blend, the higher the emission reductions. Bio-diesel improves overall cetane number of blended diesel fuel, hence the ignition becomes better after using biodiesel blended with petroleum diesel.

Biodiesel is the only alternative fuel to have fully completed the health effect testing requirements of the clean air act. It reduces greenhouses gases considerably as it recycles the CO2. The use of biodiesel in a conventional diesel engine results in substantial reductions of unburned hydrocarbons, carbon monoxide and particulate matter compared to emissions from diesel fuel. Biodiesel removes the carbon deposited on the walls of tank by the use of petroleum diesel. It has a higher flashpoint than petroleum diesel, making it a safe fuel to use and store. Biodiesel is not superior to petroleum diesel only in terms of quality but also in terms of price. It is cheaper as compared to petroleum diesel making it a very viable option for the user.

Traditional diesel engines have a much higher rate of engine wear (lubricity). Lubricity levels are improved even at low biodiesel concentration levels. New regulations requires petrodiesel engines to lower sulfur emissions considerably, making biodiesel blends much more attractive as a practical fuel to use. Biodiesel also offers a higher cetane ignition rating, which means that there is less engine noise pollution .

Generations of electricity through biodiesel fueled generators considerably reduce the harmful emission and the noise pollution compared to petroleum diesel. Use of biodiesel in tractors, passenger vehicles and transporation fleets leads to reduction in engine wear and tear. Use of biodiesel in school buses has a positive impact on the health of kids, as it is a clean, fuel .Biodiesel can be used efficiently in heavy vehicles involved in mining operations.

5. Emissions

The emissions of various gases by using blends of biodiesel B100 and B20 are given in Table 1[6]. Table-2 gives greenhouse emissions of biodiesel compared to a mile driven on diesel.

Emission	**B100**	**B20**
Carbon monoxide	-43.2%	-12.6%
Hydrocarbons	-56.3%	-11.0%
Pariculates	-55.4%	-18.0%
Nitrous oxides	+5.8%	+1.2%

Aix Toxics	-60%-90%	-12%-20%
Mutagenicity	-80%-90%	-20%

Table-1- Emissions of various gases using B100 and B20.

Fuel	Greenhouse Gases	Particulates	Nitrous Oxides	Volatile Organic Compounds	Carbon Monoxide
Gasoline	+35	-70	-55	+170	+415
CNG	+20	-80	-45	-30	+190
LPG	+20	-80	-60	0	+210
Ethanol 85%	0	-75	-55	+130	+210
Diesel	0	0	0	0	0
Biodiesel 20%	-15	-20	0	-10	-15
Hybrid	-30	-20	-20	-20	-20
Electric	-45	-80	-95	-100	-100
Biodiesel 100%	-70	-55	+5	-55	-45

Table 2. Green house gas emissions per mile for a passenger car

6.Applications of Biodiesel

Generations of electricity through biodiesel fueled generators considerably reduce the harmful emission and the noise pollution compared to petroleum diesel. Use of biodiesel in tractors, passenger vehicles and transporation fleets leads to reduction in engine wear and tear. Use of biodiesel in school buses has a positive impact on the health of kids, as it is a clean fuel . Biodiesel can be used efficiently in heavy vehicles involved in mining operations.

7. Usage of Biodiesel

Biodiesel, in theory, can go into all diesel engines as the diesel engine itself was designed to run on plant oil. However it is the parts *attached* to the diesel engine which could potentially cause problems although the vast majority of diesels on the road are fine running on 100% biodiesel.

8. Standards of Biodiesel -*Technical Details & Standards*

There are three existing specification standards for diesel & Biodiesel fuels (EN590, DIN 51606 & EN14214). EN590 describes the physical properties that all diesel fuel must meet if it is to be sold in the EU, Czech Republic, Iceland, Norway or Switzerland[7]. It allows the blending of up to 5% Biodiesel with 'normal' DERV - a 95/5 mix. In some countries such as France, all diesel sold routinely contains this 95/5 mix.

DIN 51606 is a German standard for Biodiesel, is considered to be the highest standard currently existing, and is regarded by almost all vehicle manufacturers as evidence of compliance with the strictest standards for diesel fuels. The vast majority of Biodiesel produced commercially meets or exceeds this standard.

EN14214 is the standard for biodiesel now having recently been finalized by the European Standards organisation CEN. It is broadly based on DIN 51606.

9.Biodiesel In India

The Gujarat Chief Minister Narendra Modi flagged off four state transport buses running on biodiesel supplied by Indian Oil Corporation of India. Indian Railway had already awarded the tender of 50,000 kilolitres for supply and use of Bio-diesel in the railway engines. TNT, a leading logistics company, has begun an exercise that is aimed to introducing biodiesel in its fleet of about 1,400 trucks. Mahindra & Mahindra, the leading Indian automotive manufacturer for over 60 years announced its emphasis on bio-diesel and unveiled the bio-diesel scorpio with indigenously developed CRDE technology to run on 100% bio-diesel. Major application of biodiesel is in transport sector as an alternate to petroleum diesel. Major automobile manufacturers like Ford, John deere, Massey-Fergson, Mercedes, BMW, Volkswagon, Volvo etc have accepted Bio-Diesel as the fuel suitable for their vehicles in the existing diesel engines

The bio-diesel fuel for cars has been developed by Bhavnagar-based Central Salt and Marine Chemicals Research Institute (CSMCRI). CSMCRI's bio-diesel developed from seeds of Jatropha plant had very similar properties to diesel (fossil fuel) and is superior to other forms of bio-diesel developed in other countries.

The new biofuel policy was announced recently which makes blending of 10 percent bio-fuel with diesel mandatory from the year 2012. It will be hiked to blending of 20 percent from the year 2017. All the major auto companies have started to design new plans for their future launches . Central pollution control board has published comprehensive report on biodiesel certifying that it is a better fuel than petroleum diesel

10. Disadvantages of Biodiesel

Unburnt carbon particles act as abrasive material & are significantly responsible for engine wear. Biodiesel that uses certain yellow greases can clog filters and cause the engine to stop.It is expensive to grow the vegetables and feed the animals that produce the renewable fats and oils. Since biodiesel is an effective solvent and cleans residues deposited by mineral diesel, engine filters may need to be replaced more often, as the biofuel dissolves old deposits in the fuel tank and pipes. It is having lower energy content – 6-9% less energy per unit volume for B100. Soybean oil is widely used for making biodiesel. It is available but expensive.

Conclusion

The dwindling energy resources lead to the search for renewable fuels. Alternative fuels are going to be a fact of life now and in the future . Biodiesel is made from renewable sources.It is simple to use, biodegradable, nontoxic, and essentially free of sulfur and is 100 % carbon neutral in its lifecycle. It can be widely used as an alternative fuel.

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Product Life cycle Management

Umang Soni

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India

Email: umang_soni2000@yahoo.com

Abstract

All product companies are now looking for ways to bring higher quality products to the market faster, at lower cost and at the same time are faced with increasing competition, pricing pressure, globalization and most importantly changing customer demand. It is imperative for everyone to be innovative and PLM facilitates just that by adopting PLM strategies, it will be possible for companies to bring more and more of their ideas into real products. In addition to providing an integrated collaborative environment, it increases the company's flexibility to respond quickly to changes in the market. As a result, PLM aligns to the company's roadmap and product strategies. A product's lifecycle goes though many phases & involves various professional disciplines and requires many skills, tools and processes. Product Lifecycle Management (PLM) is more to do with managing descriptions and properties of a product through its development and useful life, mainly from a business/engineering point of view essentially, PLM is to a company's product value chain what ERP is to its inventory and manufacturing processes. However, a well thought-out PLM strategy enables a company to adopt new improvements to its product development processes over time in order to avoid the lengthy, costly and complicated implementations that have been associated with ERP. PLM represents the single version of the truth that enables a company's value chain to most effectively collaborate to bring better products to market faster and more cost effectively.

1. Introduction

Product lifecycle management (PLM) is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal. PLM is a framework that enables an enterprise to effectively and efficiently innovate & manage its products and associated services throughout the entire business lifecycle. It is one of the four cornerstones of a corporation's IT digital structure. All companies need to manage communications and information with its customers (CRM), its suppliers (SCM) and the resources within the enterprise (ERP). In addition, manufacturing engineering companies must also develop, describe, manage and communicate information about their products (PLM).

1.1 *Who controls PLM?*

PLM vision and strategies are typically defined by the Engineering / Business / CTO. Product development processes, data control and management, compliance needs, design, analysis and process control are best known only to the Business organization. Once the PLM vision and strategy are defined, the CTO's office with the help of the CIO office selects the solution and defines the roadmap. In some organizations, PLM implementation is completely driven by the CTO of the organization and once deployed, the sustenance is taken care of by the CIO of the organization. Even in organizations where CIO drives the PLM implementation, CTO will be involved as a key decision maker.

1.2 *Can PLM also be applied to the Service industry?*

PLM can definitely be applied to the Service industry. Information and processes related to services also can be controlled and managed using PLM strategies. Due to changing customer expectation and competition, even services need to be better, faster & cheaper. Services too have a lifecycle similar to products where they get conceptualized, launched and serviced. They go through revisions and reuse of information and avoidance of non-value added activities is critical to be competitive and to increase customer satisfaction. There are specific PLM solutions available for service industries.

1.3 *PLM Service Offerings:*

Consulting – Domain Specific Consulting, Business Process Consulting & Mapping, PLM Product Selection, Business case and ROI development.

Implementation- Business/Data Modeling, Configuration and Customization, Leverage productivity improvement tools.

Data Migration-Migration of Native/Legacy System Data, Migration of data for upgrades, Migration Tools, Utilities and Best Practices.

Integration-Integration with PLM/ERP/SCM and other enterprise systems, CAD/Authorization tool Integration, EAI and Point-to-Point Solutions.

Sustenance-Ongoing Maintenance, L1, L2 & L3 Support, 24*7 Supports.

Application Upgrade-Version Upgrade, Data Migration and Carry forward customization

2. Managing Manufacturing Processes in PLM

Outsourcing has changed the dimensions of manufacturing operations for the OEM worldwide. Most OEMs are no longer investing on establishing newer plants & equipments, but instead are outsourcing most component/platform manufacturing to contract manufacturers retaining only critical core components of a product. Instead they are now focused on new product development methods to launch more quality products faster to the market.

Traditionally, Product Engineers/Designers are used to viewing Product Bill-of-Materials from a top to bottom perspective; hence, Engineering Bill-of-Materials (EBOM) is built with such a view. This results in expanding the product structure from top assembly (system) to sub-assemblies (sub-systems) to further down to the leaf components. However, during manufacturing of the product, manufacturing engineers need the exact opposite view of what EBOM provides - a bottom to top approach. They are mostly concerned with the process of assembling subassemblies or manufacturing the components in a batch/serial mode. In addition, they require creating kits/sets/pairs/RH-LH components and planning the raw materials consumption accordingly. They also have to plan the production quantities based on machine capacity/ stock consumption. Hence, they derive the manufacturing view called MBOM from the EBOM for every product to be manufactured. It is noted that manufacturing engineers spend at least 50% of their day identifying changes in Engineering Bill-of-Materials (EBOM) using manual interrogation methods and rebuilding Manufacturing BOM (MBOM) from scratch based on these changes.

It is estimated that 60%-80% of the manufacturing costs are committed during design in any product development. Thus, any isolated design decision will have a big impact on the manufacturing processes affecting the overall profitability of the product. Due to this reason, companies are now trying to assess the impact of any product changes or introductions on the manufacturing plants, existing lines & job shops during the design phase rather than at a later stage.

Design for Manufacturability (DFM) practices help organizations to interconnect their product engineering information with detailed manufacturing processes & plans to identify quality issues, yield problems, mitigate retooling expenses and avoid unexpected manufacturing issues that can

delay production readiness. However, implementation of DFM practices is not easy. Organizations will have to invest on collaboration between the engineering & manufacturing teams even when the manufacturing teams are external. As a leader in standardized processes, Toyota created a global design data sharing system that interconnects digitized 3D drawings for all parts used in all car models of the company. Such centralized source of information will enable design engineers, line staff, and supplier partners from around the world to visually reference detailed part drawings and regularly scrutinize them for manufacturability concerns. In addition, such a centralized source provides numerous benefits including version control, traceability and part standardization.
Based on this industry best practice, leading PLM Vendors are providing integrated manufacturing process management (MPM) solutions that digitally coordinate engineering changes and the associated impacts on shop floor details like part and assembly process plans, work cell and tooling designs, and operator work instructions. PLM takes away the problems involved in generating MBOM from EBOM by managing the engineering data in the centralized data source. Manufacturing engineers can create their view of the EBOM without the hassles of manual interrogation. In some cases, MPM process in PLM is customized to adopt a higher level, project-oriented approach to DFM coordination. In such cases, manufacturing processes are tightly integrated in all aspects of product development planning from tracking project status and issues through stage-gate reviews. This approach ensures timely completion of both products engineering and manufacturing reviews and promotes shared ownership of product development process.
MPM provides features to manage product, process, and resource and plant data, MBOM Management with phantom parts, assembly instructions management, Manufacturing change and workflow management. In addition, it provides seamless integrations with other PLM modules such as Part Design, Project Management, Requirements Management, Resource Management and external interfaces like MES/ERP Systems. MPM provides ability for the organizations to identify plant-specific BOM for manufacturing with appropriate effectively dates for changed components & systems.
In addition, ability of PLM Tools to provide simulation & digital mock-up also becomes a basis for improving collaboration between the teams. Engineering & manufacturing teams can enter into virtual meetings to discuss on virtual prototype of the product to validate the assembling patterns & instructions, checking for interferences without needing to build costly physical prototypes.
PLM Solutions from leading PLM Vendors have incorporated most of the MPM features.

3. Benefits of Manufacturing Process Management in PLM

Managing Manufacturing Process in PLM provides following benefits to organizations:

- Systematic capturing of production concerns and quality problems, can continuously feed more corrective actions and improvements back to product designers
- Tighter integration between process plans and equipment controls supports more concurrent development of PLC code during validation, enabling “virtual commissioning” and accelerating ramp up
- Make better decisions with the right information, in the right context due to enhanced collaboration between various cross functional teams
- Early involvement of manufacturing teams in the product development phase reduces costly component redesign during manufacturing
- Early involvement of manufacturing also enables them to make better decision regarding the changes to the tools, jigs & fixtures
- Improve productivity with parallel execution across the engineering and manufacturing domains and streamlines manufacturing processes
- Drive key Manufacturing initiatives like Lean and Design for Manufacture
- Easier generation of plant specific MBOM from EBOM
- Reduce total cost of ownership and capital asset investment from program to program

Case Study: Improving NPI Timelines using PLM:

A leading Japanese Optics manufacturer was facing problems related to high inventory, longer cycle time for component development, high NPI timelines (4 to 5 years for new product launch) resulting in loss of market share and reduced profitability. They wanted to eliminate design chain inefficiencies and reduce the NPI timelines to 2.5yrs by using PLM.

Wipro using a joint team of senior consultants from PSA, PES and PLM groups helped the client to redefine the design chain & innovation processes based on industry best practices to streamline the new product development & introduction. PLM was identified as the base solution to help the client to manage their innovation processes by capturing voice of customer, enabling short-term & long-term technology management, product portfolio management, concept identification & development. This is expected to help the customer to effectively collaborate between the sales & marketing teams, strategy teams and R&D Teams in identifying newer opportunities in the market rather than targeting competitor's product lines.

In addition, Wipro refined the design chain by redefining some of the processes and by implementing PLM to manage the product data, designs, task deliverables and enable project & program management. PLM will also help the client to manage the manufacturing processes of various components like mechanical parts, optical parts and electronic parts. In addition, various metrics are captured during the course of product innovation & development to help the client to clearly measure the success of the implementation as well as the products.

In addition, Wipro also evaluated various PLM solutions available in the market based on the requirements of the client, capabilities of the solution to meet these requirements and various other parameters. Wipro also helped the client to manage their RFQ processes for selecting the best suited PLM Solution.

Conclusion

Product Lifecycle Management (PLM) is a viable option for extending profitability, and there are several methods for approaching PLM effectively. What is crucial, however, is to plan for it early on, even, if possible, before the product actually enters the market. The key to successful Product Lifecycle Management is to create and evolve a proactive strategy for the product throughout its entire useful life, from its launch through to its long-term growth and acceptance in the market

Organizations have to release new products faster or release product variants consistently to have sustainable competitive advantage in the market. When it comes to launching new products, companies can choose to either launch "New Products" in an existing market or launch a "New Product Category" itself. New Product Development & Introduction (NPDI) is the process of identifying opportunities, developing concepts & launching of newer products. In addition, it is about defining the product strategy, managing the overall product program, and monitoring all the projects and activities needed to drive the NPDI process. NPDI involves complex, collaborative process that requires coordination between various functions within an organization. Most departments of the company get involved in NPDI at some time or another, including marketing, engineering, supply management, manufacturing, finance, and so on. In addition, external organizations like suppliers & partners may also get involved early in the NPI process to have better control on costs and make new products successful.

Each new product can contain hundreds to thousands of new components with unique design specifications, development or manufacturing processes. In fact, a new product can be defined as a new idea, which houses various new ideas targeting to satisfy various needs of the customer. Various business units or individuals may be responsible for one or more aspects of the product with few of these aspects being independent and most of them being interdependent. Hence, it becomes very important for all the teams to be involved in making right choices and decisions. In addition, time-to-market (TTM) is an important measure for new products. Faster the TTM, higher is the chance of success and profitability. Products that do not have direct competition usually commands premium in the market there by increasing product profitability. By the time competitors come out with the alternative, organization will usually have an upper hand and can enter into price wars or other use other pricing strategies. PLM helps organizations to manage their NPDI processes better by providing single source of product data than using disparate systems to manage each process.

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JUST IN TIME PRODUCTION

Neeta Sharma

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India

Email: neeta_sharma44@yahoo.com

Abstract

The objective of this paper is to introduce the basic concepts of a Just-in-Time (**JIT**) production system. This paper is compiled in a way to provide the reader with a basic overview of **JIT** production. Planning for JIT, critical elements in JIT manufacturing, Integrated process control, quality in JIT are the issues which are covered in the paper.

1. Introduction

Just in Time manufacturing is a systems approach to developing and operating a manufacturing system. It is based on the total elimination of waste. **JIT** is not a new concept. It has been part and parcel of the Japanese manufacturing industry adopted approach for quite some time. It requires that equipment, resources and labor are made available only in the amount required and at the time required to do the job. It is based on producing only the necessary units in the necessary quantities at the necessary time by bringing production rates exactly in line with market demand. In short, **JIT** means making what the market wants, when it wants it. **JIT** has been found to be so effective that it increases productivity, work performance and product quality, while saving costs .

2. Planning for JIT

Defining the planning process for a **JIT** manufacturing system requires an understanding of the objectives of **JIT**, and the goals and objectives of the JIT system. After the objectives are established for the manufacturing, the process of planning becomes one of determining what is required to meet those objectives.

The goal of a **JIT** approach is to develop a system that allows a manufacturer to have only the materials equipment and people on hand required to do the job. Achieving this goal requires six basic objectives[1]:

- Integrating and optimizing every step of the manufacturing process
- Producing quality product
- Reducing manufacturing cost
- Producing product on demand
- Developing manufacturing flexibility
- Keeping commitments and links made between Customers and Suppliers

It should be noted that obtaining these objectives does not automatically make a company a **JIT** manufacturer, on the other hand failing to achieve even one of these objectives will prevent a manufacturer from establishing a successful **JIT** system.

2.1 Integrating and Optimizing

The manufacturing system is a continual process of reducing the number of discrete steps required to complete a particular process rather than plateaus of steps. Removal of *bottlenecks* in the manufacturing process is a critical step in integration. One of the best ways to accomplish this objective is to plan for 100 % defect free quality.Integrating and optimizing will involve reducing the need for unnecessary functions and systems such as inspection, rework loops and inventory.

2.2 Producing a Quality Product

"Total Quality Control" is one of the fundamental goals in **JIT** manufacturing. Total Quality Control (TQC) emphasizes the quality at every stage of manufacture including product design down to the purchase of raw materials. Quality control is carried out at every stage of the manufacturing steps; from the source to the final step rather than relying on a single processing stage which implements quality control on the final product. Each individual and function involved in the manufacturing system must, therefore, accept the responsibility for the quality level of its products. This concept introduces the correction of the problem before many other defective units have been completed.

2.3 Reducing Manufacturing Cost

Designing products that facilitate and ease manufacturing processes helps to reduce the cost of manufacturing and building the product to specifications. One aspect in designing products for manufacturability is the need to establish a good employer and employee relationship. This is to cultivate and tap the resources of the production experts (production floor employee), and the line employees to develop cost saving solutions. Participatory quality programs utilize employee knowledge about their job functions and review the department performance, encouraging with rewards for suggested cost saving solutions.

2.4 Producing product on demand

The fundamental principle of **JIT** is the concept of producing product only as needed or on demand. This implies that product is not held in *inventory*, and production is only initiated by demand. Adopting the produce-on-demand concept will ensure that only materials that are needed are processed and that labour will be expended only on goods that will be shipped to a customer. At the end of the production cycle, there would be no excess inventory.

2.5 Developing Manufacturing Flexibility

Manufacturing flexibility is the ability to start new projects or the rate at which the production mix can be adjusted to meet customer demand. Planning for manufacturing flexibility requires the understanding of the elements in the manufacturing process and identifying elements in the process that restrict flexibility and improving on these areas. The unique feature of **JIT** is the change from a PUSH to a PULL system. The idea behind this concept is that work should not be pushed on to the next worker until that worker is ready for it. As such manufacturing flexibility requires production managers to consider the following aspects in scheduling and manufacturing flexibility improvement:

- supplier lead time
- the need to ensure fast and reliable delivery of finished goods to the customer
- production process time

- process setup time
- bottlenecks in production process should be reduced and resources (e.g. workers, machines should be fully utilized.

2.6 Keeping Commitments and Links made between Customers and Suppliers

The corporate commitment to developing the internal structures and the customer and supplier bases to support **JIT** manufacturing is the primary requirement for developing the **JIT** system. Trust and commitment between the supplier and the customer is a must, because every Just-in-Time operation relies on it. Failure to keep the commitments is a serious form of break-down in a **JIT** system.

3. Critical Elements in JIT manufacturing [2]

- Partnerships
- Commitments
- Contracts Supporting Partnerships
- Developing JIT Suppliers
- Partnerships - A Mutually Beneficial System
- Customer-Supplier proximity

3.1 Partnerships

In the past companies were capable of remaining independent and competitive when they had the capability and resources necessary to produce a product. This is no longer possible. As technology increases in complexity, companies overcome capital limitations or *labor intensive* requirements by becoming dependent on suppliers to provide services. Many services and Original Equipment Manufacturing (OEM) suppliers have evolved as the result. Companies now appreciate that long-term success relies on the quality of the customer-supplier relationship established so that they will develop successful partnerships. Hence, successful partnerships require the development of mutually beneficial programs.

3.2 Commitments

To enable suppliers to deal with customers in a confident manner, they must be backed by the level of commitment given by manufacturers. Without a partnership between the customer and supplier, there will always be hesitation instead of trust. The concept of trust and commitment in **JIT** is used to build partnerships and to reduce the needs for materials-production control, receiving inspection or inventory buffers that many companies have constructed. Contracts used by **JIT** manufacturing company to record the details of an agreement usually stress the level of commitments.

3.3 Contracts Supporting Partnerships

By ensuring fair and equitable contracts, many of the problems in developing customer-supplier relationships are overcome by **JIT** manufacturers. The goal of **JIT** is to make long-term contracts with suppliers. A long-term contract gives the supplier a job security for as long as the supplier remains competitive and committed. Long-term contracts usually extend for one or more years and can consist of one or more part requirements.

3.4 Developing JIT Suppliers

It is important to develop a link between the companies so to ensure a long-term business relationship. This will provide both companies with the stability required to optimize the profit potential. There are four needs that affect the supplier's ability to perform : trust, communications, linearity of production, and time and visibility to make changes.

3.4.1 Trust

The most basic need of suppliers is to be able to trust that the customer will provide stability if the supplier meets requirements. This will allow the two organizations to work much more closely than they would based just on a contract.

3.4.2 Communications

To successfully manage the communication link between customers and suppliers can be done in two ways:

Supplier contacts: To overcome the complexity of the communication problem, some companies assign a buyer-quality engineer team to be the contact for each supplier. The advantage of this solution is that it provides a formal communication channel for the supplier and reduces the potential for miscommunications.

Supplier programs: Supplier programs keep the supplier informed on topics of mutual interest and ensure the supplier access to information that will have an effect on the supplier's production. These programs strengthen supplier relationships by opening communications and providing an understanding of one anothers needs.

*3.4.3*Linear Production Schedules

Linear production schedules contribute to improving the performance of manufacturing. In a **JIT** system, the need for the supplier to track the customers needs closely is important. For this to occur, the supplier must reduce lead time to the minimum. This consists of isolating the bottlenecks in the operation, balancing the production system, and reducing setup-time.

*3.4.4*Time and visibility to make changes

Most suppliers can respond to changes in customer demand, but they must have enough time to make the changes. The types of changes suppliers must make are purchasing materials, adding equipment, establishing work shifts, and hiring and training labor. With better schedule visibility, suppliers could react more quickly to changes in production requirements.

3.5 Partnerships - A Mutually Beneficial System

A mutually beneficial system requires that the supplier and customer work in cooperation to achieve a greater benefit than they would have individually. Three mutually beneficial systems are [3]:

- Early supplier involvement
- Just-in-Time materials shipment
- Invoicing systems

3.5.1 Early supplier involvement

Involving the supplier early in the design phase of a new product can obtain the best performance from a supplier. Suppliers will often make suggestions that can improve the design of the product. Supplier feedback provides avenues for improvement in cost, quality, and scheduling.

3.5.2 Just-in-Time materials shipments

Deliveries can cause traffic problems. In addition, there are the problems of unloading material, unpacking it, and moving it to the production-line. Several systems have been developed to improve the efficiency of deliveries to customer. An example is the "Bus Route" system installed by Xerox Corporation. The bus routes system improves material flow, communications, and the interaction of companies.

3.5.3 Invoicing systems

JIT requires frequent deliveries. There are solutions to handling increased invoice load. Electronic invoicing will work where compatible equipment transmits customers accounts directly. Another solution is to pay suppliers based on purchasing records that have completed the assembly process. A third possibility is to batch invoices and submit them on a bimonthly or monthly schedule. A company can also invoice the monthly deliveries on one invoice, hence decreasing the amount of paperwork

3.6 Customer-Supplier Proximity

Customer-supplier partnerships can be formed irrespective of the physical distance between two companies. Close proximity, however, offers three advantages : early supplier involvement, line problems are easier to resolve, and communications are easier. The criteria for determining supplier selection are based on suppliers ability, location and price.

4. Integrated Process Control (IPC)

In most cases, the typical goals of manufacturing consist of meeting production schedules, cost projections, and product specifications. However, two key points are usually overlooked : optimizing the production process and meeting customer requirements concurrently. The company must be aware of changes in requirements and continually improve the production process. Integrated Process Control (IPC) achieves the goals of **JIT** manufacturing by optimizing production to meet both manufacturer and customer requirements. In IPC, two concepts control the process of continual improvement. They are:

- First, the process of continual improvement is directed toward producing product of quality at low cost.
- The second concept is that customers needs have to be continually monitored since they change regularly.

5. Detect Defects before they Affect...

Improving the production process is streamlining and integrating the production system to achieve an efficient and simple product flow. Continuous improvement implies that the manufacturing system will continue to include both process and product improvement. The process of continual improvement is aimed at reducing the need for gate inspection, rework, scrap, and test. IPC is an economical tool to minimize these costs. The results of using IPC is the prevention of defects before they occur.

6. Quality for JIT

Quality is an integral part of a **JIT** program. Quality control concentrates on quality at every stage of manufacture including the purchase of raw material. To increase the supplier quality two methods are used in a **JIT** system; supplier quality engineering (SQE) and receiving inspection (RI).

Supplier quality engineering is used to evaluate supplier capability, help suppliers develop process control, resolve quality issues with suppliers, and certify that suppliers qualify for **JIT** production. Receiving inspection provides an inspection service for purchasing.

6.1Delivery of Purchased Material

On time delivery, frequency of delivery, and receiving and stocking the material are three major aspects that are important in purchasing[4].

On-time material delivery means that the work stations receive the material just before it is required. A suppliers ability to deliver on time is a combination of factors ; transportation, raw material availability, price, holidays, etc. If a factor arises that could affect the delivery schedule, the company should be able to increase production schedules and establish enough inventory to see them past the expected disruption.

Frequent delivery is required if dependency on inventory is to be minimized. The suppliers' ability to make frequent deliveries depends on the suppliers ability to produce product at the rate the customer requires delivery. Local suppliers usually have an advantage in being able to deliver daily. Frequent delivery means that a loss of one small shipment will have less significance than the loss of a large shipment in on time delivery.

Material shipping and handling requirements: Costs associated with material shipping includes packaging and handling costs. Packaging costs mainly include material handling, shipping damage, and the cost of packaging materials. Handling costs include receiving, unpacking, counting, repacking, stocking, kitting and moving the material to the production area. Reusable packaging material, packing containers that can be used on the production line, and standardised containers that eliminate counting are ways to reduce costs and damage in transporting. These cost reducing methods are then reviewed with the supplier to determine how the supplier can best meet these needs.

Scheduling : A major concern of purchasing managers is the process of coordinating the manufacturing need for materials. The process is complicated by periodic changes in product mix and volume requirement and the continual introduction of new products. Companies solve the problem of how much material to order and when to order by placing contracts based on order requirements supplied by material control. Material control makes its decisions based on the master schedule less current inventory. In a **JIT** system the supplier picks up the information on the next production requirements every time a delivery is made.

Reasonable Cost Price of purchased material is an important issue. Material that cause or require additional production costs reduce company profits. Every extra inspection or test step, rework requirement or item scrapped represents a reduction in company profit. These additional costs are remedied by purchasing products that meet both specification and production needs

Conclusion

Hence we can see that to have a Total **JIT** production system, a company-wide commitment, proper materials, quality, people and equipments must always be made available when needed. In addition; the policies and procedures developed for an internal **JIT** structure should also be extended into the company's supplier and customer base to establish the identification of duplication of effort and performance feedback review to continuously reduced wastage and improve quality. By integrating the production process; the supplier, manufacturers and customers become an extension of the manufacturing production process instead of independently isolated processes where in fact in clear sense these three sets of manufacturing stages are inter-related and dependent on one another. Once functioning as individual stages and operating accordingly in isolated perspective; the suppliers, manufacturers and customers can no longer choose to operate in ignorance. The rules of productivity standards have changed to shape the economy and the markets today; every company must be receptive to changes and be dynamically responsive to demand. In general, it can be said that there is no such thing as a KEY in achieving a **JIT** success; only a LADDER; where a series of continuous steps of dedication in doing the job right every time is all it takes.

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Recent Development in Electrochemical Micromachining

Neha chauhan

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India

Email: nehachauhan_4u@yahoo.co.in

Abstract

Electrochemical Micro-Machining appears to be very promising as a future micro and nano machining technique since in many areas of applications it offers several advantages. In this paper, a review is presented on current research, development and industrial practice of micro-ECM for micro and nano fabrication. New developments in the area of electrochemical micro-machining e.g. micro-electrochemical milling, wire-ECM, solid electrochemical machining, surface structuring and OFLL etc. have also been reported. Future trend of research in the area of utilization of anodic dissolution method for manufacturing of nano range products are also highlighted. The Electrochemical micro machining can effectively be used for high precision machining operations. Further research activities of ECM will open up many challenging opportunities for effective utilization of ECM in the micro machining and nano fabrication domain.

1. Introduction

Electrochemical machining (ECM) has seen a resurgence of industrial interest within the last couple of decades due to its many advantages such as no tool wear, stress free and smooth surfaces of machined product and ability to machine complex shape in electrically conductive materials, regardless of their hardness. When this ECM process is applied to the micromachining range for manufacturing ultra-precision shape, it is called electrochemical micro-machining (EMM). Micromachining may literally mean the machining of the dimension between 1 and 999 mm. However, as a technical term, it also means the smaller amount of machining that cannot be achieved directly by a conventional technique. Advanced micro machining may consist various ultra precision activities to be performed on very small and thin work pieces in large numbers. Sometimes, when these things are performed with conventional machining techniques, the problem one usually encounters is high tool wear, rigidity and heat-affected zone. In nonconventional machining most of the machining processes are thermal oriented, e.g. Electro Discharge machining (EDM), Laser beam machining (LBM), Electron beam machining (EBM) etc. Chemical machining and Electrochemical machining are thermal free processes, but chemical machining cannot be controlled properly in the micro-machining domain. ECM process is applied to the micro machining range of applications for manufacturing ultra precision shapes; it is called Electrochemical micro machining (EMM). EMM appears to be a very promising micro machining technology due to its advantages that include high MRR, better precision and control, rapid machining time, reliable and environmentally acceptable. In recent years, ECM has received much attention in the fabrication of micro parts [1]. Fig.1 shows the schematic view of EMM system set up, which consists of pulsed DC power supply, machine controller, micro tool drive unit, mechanical machining unit and electrolyte flow system etc. Recent research establishes the fact that electrochemical process of metal removal can also be effectively utilized for nano machining Research attempts have been made by the electromechanical consumer product industries as well as T.J.Watson research center of IBM apart from other research institutions. To exploit full potential of EMM, research is still needed to improve accuracy and compactness. In this paper, a review is presented on current research, development and industrial practice in micro-ECM. An attempt has also been made to report the latest development of ECM in the field of nanofabrication.

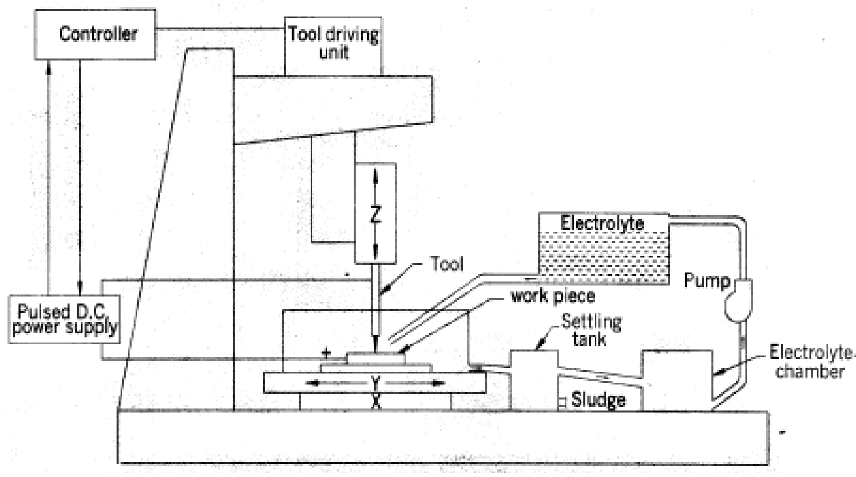

Fig 1 Schematic view of EMM

2. Material Removal and Machining Accuracy in EMM

Various predominant process parameters such as current density, Inter Electrode Gap (IEG), electrolyte and also the anode reactions etc influence the machining performance of EMM. Experimental results proved that the addition of the magnetic field causes increase in material removal rate (MRR) and accuracy. When interelectrode current is 6A, MRR is 37 mg/min but by the addition of magnetic field, MRR increases to 55 mg/min [2]. The MRR is expressed in terms of unit removal (UR) in micro machining domain [1]. UR is defined as a unit of work piece removed during one cycle/pulse of machining action. UR is basically dependent on three important factors (i) mass transport effect, (ii) current distribution and shape control, (iii) passive oxide films and transpassive dissolution.

3. Power Supply for EMM

EMM using pulsed current offers considerable potential for enhancement of ECM process. The high current density required for proper operation of EMM process, may give high concentration of reaction products, which can only be partly removed by the electrolyte, especially if the inter electrode gap is narrow. The increasing contamination can cause a deposition to form on the tool, so the work piece material no longer dissolves uniformly. This type of problems can be largely avoided by applying a pulsed voltage [3]. The anodic electrochemical dissolution occurs during the short pulse on-time, each ranging from 0.1 to 5 ms. The dissolution products can be flushed away from the inter electrode gap by the flowing of electrolyte during the pulse off times. For further improvement of micro machining accuracy, piezoelectric transducer is used to retract the tool from the work piece during pulse off time to enlarge the gap by means of vibration so as to intensify the electrolyte flushing [4]. Short duration pulses have great potential to achieve higher dimensional accuracy due to small amount of material removal per pulse. In this area, lot of research is going on and still it needs more.

4. Development of Micro Tools

Development micro-tools remains a major challenge for manufacturing micro-feature by EMM [5]. Tool design mainly deals with the determination of tool shape. In addition to tool design, suitable development of micro tool is required for successful machining. In general material for micro tool should consists of a chemically inert material, good electrical conductivity and easily machinable. Micro-tools can be developed by applying small hall ECM, EDG, ELID grinding and WEDM. Fig. 2 shows micro-tool manufacture by Electrolytic in-process dressing (ELID) grinding. For reducing the effect of stray current, the micro tool should be insulated with SiC /Si3N4 by means of a chemical vapour deposition (CVD) process so that current only flows through the front face. Further research is still needed in the area of micro tool design and development.

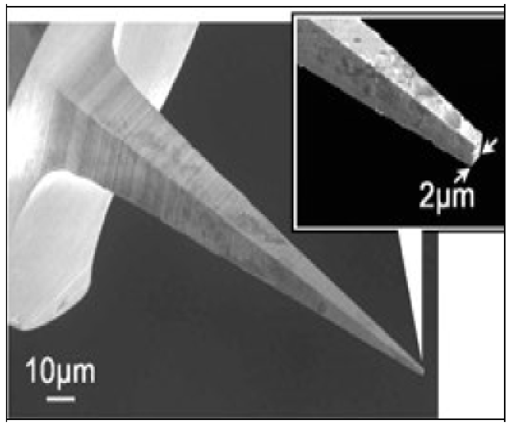

Fig. 2 Micro-tool manufacture by ELID grinding

5. Role of Inter Electrode Gap (IEG)

If the inter-electrode gap is narrowed down to a bare minimum level then the resolution of machined shape becomes better and the possibility of applying ECM to micro machining increases. Maintaining the specific IEG uniformly is an important requirement to achieve high accuracy and surface finish. Around 1V can be applied between the tool and the work piece, for measuring the current in such a way that the electrical contact of the micro tool with the work piece can be checked [6]. In pulsed EMM system, the IEG and tool position monitoring can be conducted during pulse off time. A unique hybridized EMM set-up has been developed with a microtool vibration system. Piezo-electric transducer (PZT) has been used for vibrating micro-tools, which creates acoustic waves and cavitation in narrow IEG and improves the circulation of electrolyte that may result in reduction or elimination of micro-spark generation. The influence of micro-tool vibration frequencies on accuracy is shown in Fig. 3 during EMM operation. Attention to be needed in the area of dynamic gap measurement and control for effective metal removal.

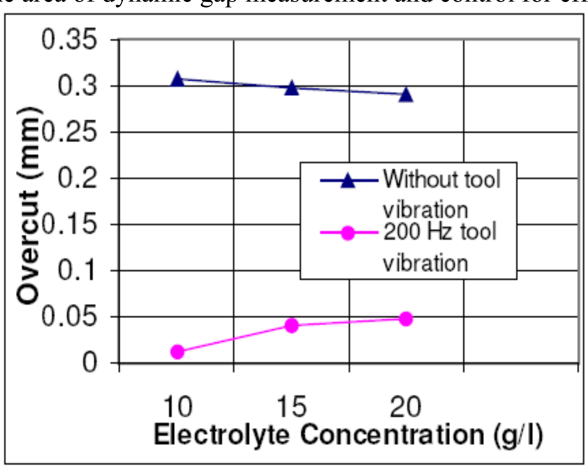

Fig. 3 Machining accuracy with and without tool vibration

6. Electrolyte for EMM

Electrolytes play a vital role for precise control of metal removal in microscopic domain. Generally anodic films are allowed to form on work piece surface which helps to achieve anodic smoothing, finally sometimes it may cause for short circuiting during EMM due to smaller IEG. Hence it is advisable to use fresh and clean electrolyte for micro machining. The electrolyte carries away the heat and reaction products from the zone of machining. Electrolyte must possess less throwing power apart from basic properties, to increase the accuracy. ECM electrolytes are classified into two categories: passivating electrolytes containing oxidizing anions i.e. sodium nitrate, sodium chlorate and non-passivating electrolytes containing relatively aggressive anions such as sodium chloride. Passivating electrolytes are known to give better machining precision [4]. It may be observed during micro holes generation on the metallic foils by EMM process that the lower value of electrolyte concentration with higher machining voltage and moderate value of pulse on time will produce a more accurate shape with less over cut at moderate MRR.

7. Applications

In this section, typical applications of EMM technologies for microfabrication of components are introduced.

7.1 Nozzle Plate For Ink Jet Printer head

Pulsating current/voltage permits a better control over electrochemical micro machining of thin films and foils for applications in micro fabrication. Through mask EMM was used to fabricate series flat-bottomed v-shaped nozzles in a metal foil as shown in Fig. 4 [7]. The process is applicable to various materials including high strength corrosive resistant materials such as conducting ceramics.

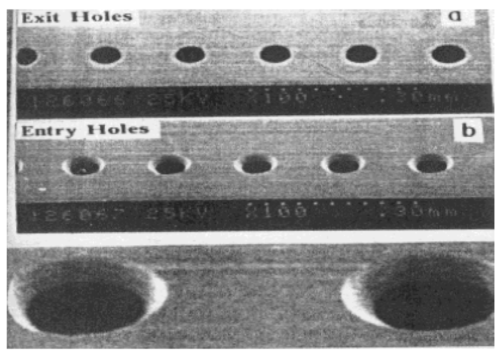

Fig. 4 An Array of V Shaped Nozzles

7.2 3D Micromachining

3-dimenional EMM is shown in Fig. 5, SEM micrograph of a machined component of an electronic circuit board in which platinum wire of 10-µm diameter was used as a tool on the copper sheet by the application of 2 MHz frequency of 50 ns, 1.6 V pulses. To obtain delicate 3D copper structure i.e. 5µmX10µmX12µm in the middle of the hole sitting on a base, i.e. 15µmX15µmX10µm, the microtool is first fed vertically 12 µm deep into the work piece. After this vertical machining, the microtool is moved laterally along the prescribed path in the copper sheet. The outer rectangular trough is dissolved to a dimension of 22µmX14µm. During the process, the microtool feed rate is adjusted to 0.5µm by monitoring the peak current transient of the inter electrode gap [7].

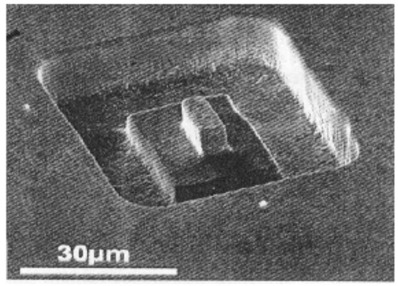

Fig. 5 3D-electronic circuit board component

Attempts have been made to utilize micro and nanoscopic anodic dissolution of metals for fabrication of micro and nano features. Principles of ECM have already been successfully demonstrated to machine micro scale features using ultra short pulses. Some of the latest developments in this area are Micro electrochemical milling, Wire electrochemical milling, Solid electrochemical milling, Oxide film laser lithography (OFLL) by EMM and EMM for nano-fabrication etc.

Conclusion

The paper presents research achievements and industrial applications created in micro and nanoscale machining using ECM. Results of recent research indicate the applications of electrochemical metal removal in micro and nano-machining offers many opportunities that have been unexplored till now. Further research activities in the area of ECM for effective utilization in micro and nano-fabrication require improvements in tool design and development, monitoring and control of the inter electrode gap, control of material removal and accuracy, efficient power supply, elimination of micro sparks in IEG and selection of suitable electrolyte which are expected to enhance the applications of ECM technology in modern manufacturing industries engage in ultra precision machining. Extensive research efforts and continuing advancements in this area will make the process more efficient and effective. The increasing demands for precision manufacturing of microparts and nano-features for biomedical components, automotive components and IT applications will lead modern manufacturing engineers to utilize ECM technique more successfully considering its advantages. Electrochemical micro-machining will be more popular in the near future in the area of micro and nano fabrication due to its quality, productivity and ultimately cost effectiveness.

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Design of 4+2 stroke Petrol Engine

Shiva Kumar Gupta

Assistant Professor, Department of Mechanical Engineering, Dronacharya College of Engineering, Gurgaon-123504, India

Email: shiva101084@gmail.com

Abstract
As we know that in the coming years, there will be a big problem of fuels like: petrol, diesel etc. and also the conventional IC engines (2 strokes or 4strokes) are not so efficient. A lot of harmful gases are emitted by these engines, which would increase the threat due to "Green House Effect". In this work a "4+2 Stroke Engine" will be designed which comparatively would be more fuel efficient, powerful, simpler in design, less expensive in manufacturing and tooling. It would emit less quantity of harmful gases. This "4+2 Stroke Engine" replaces the conventional 4 stroke engine cylinder head with an "Overhead short stroke crankshaft and piston arrangement" which opens and closes inlet and exhaust ports leading through the upper cylinder head liner. The top and bottom crankshaft are connected via a drive chain or toothed belt. The top crankshaft and piston become positive power and contributes to the overall power output and thus increasing the amount of power/torque generated. The absence of "Cams, Valves, springs and other power absorbing driven components results in more output power. Absence of these components also reduces the failure due to wearing of parts and thus increasing the service life of engine and decreasing the maintenance cost.

1. INTRODUCTION
An internal combustion engine plays a vital role in our day-to-day life in converting chemical energy to useful mechanical work. A lot of modifications have been done in the engine design; its construction as per the requirements and still the development is going on in this field. The present day engines have to satisfy the strict environmental constraints and fuel economy standards in addition to meeting the competitiveness of the world market. Today the internal combustion engine has synthesized the basic knowledge of many disciplines – thermodynamic fluids flow combustion, chemical kinetics and heat transfer as applied to a system with both spatial and temporal variations in a state of a non-equilibrium with the availability of sophisticated computer's art of multi-dimensional mathematical modeling and electronic instrumentation have added new refinements to the engine designs. The conventional internal combustion engines are broadly classified as 2- Stroke and 4-Stroke In a four-stroke engine the cycle of operations is completed in four strokes of the piston or two revolutions of the crankshaft. During the four strokes there are five events to the completed, viz., suction, compression, combustion, expansion and exhaust. Each stroke consists of 180° of crankshaft rotation and hence a four-stroke cycle is completed through 720° of crank rotation. The cycle of operation for an ideal four-stroke SI engine consists of the following four strokes:

[1] suction or intake stroke;
[2] compression stroke;
[3] expansion or power stroke and
[4] exhaust stroke.

As already mentioned if the two unproductive strokes, viz., the suction and exhaust could be served by an alternative arrangement, especially without the movement of the piston then there will be a power stroke for each revolution of the crankshaft. In such an arrangement, theoretically the power output of the engine can be doubled for the same speed compared to a four stroke engine. It is an Internal Combustion engine in which the basic processes (intake, compression, power and exhaust) are completed in two strokes. This is accomplished by using the beginning of the compression stroke and the end of the power stroke to perform the intake and exhaust functions. This allows a power stroke for every one revolution of the flywheel. For this reason, two-stroke engines provide high specific power. There are ports for intake, transfer and exhaust in this engine. Looking towards the urgent need of petrochemicals in the future, there is a great requirement of such an engine, which is so efficient that it not only requires less fuel but also should be simpler and require low maintenance. Thus, we have 4+2 Stroke Engine. This "4+2 Stroke Engine" replaces the conventional 4 stroke engine cylinder head with an "Overhead short stroke crankshaft and piston arrangement" which opens and closes inlet and exhaust ports leading through the upper cylinder head liner. The top and bottom crankshaft are connected via a drive chain or toothed belt. The top crankshaft and piston become positive power and contributes to the overall power output and thus increasing the amount of power/torque generated. The absence of "Cams, Valves, springs and other power absorbing driven components results in more output power. Absence of these components also reduces the failure due to wearing of parts and thus increasing the service life of engine and decreasing the maintenance cost. The 4+2 Stroke engine name is based on its basic design i.e. a combination of a 4-Stroke Internal Combustion Engine as bottom end and a 2 Stroke Internal Combustion Engine resembling the top end, thus the name 4+2 Stroke Engine.

2. LITERATURE REVIEW

There are actually three modifications of a four-stroke engine. They are:

a. Bajulaz six stroke engine
b. Crower Six stroke engine
c. Beare Head
Our engine is based on the “Beare Head” type engine. The 4+2 Stroke Engine is originally the brainchild of Malcolm Beare, a resident of South Australia. He came up with this idea in 1973. The term “Six Stroke” was coined by the inventor of the Beare Head, Malcolm Beare. The technology combines a four stroke engine bottom end with an opposed piston in the head working at half the cyclical rate of the bottom piston. The head piston works in a ported cylinder closely resembling that of a two stroke, thus 4+2= Six Stroke. In 1994, he fabricated the 4+2 Stroke engine theory.

3. THEORY

The 2-stroke engine cylinder simply replaces the conventional 4 Stroke Engine’s Cylinder Head. The manufacturers 4 Stroke bottom end remains unchanged. The New Head utilizes an overhead short stroke Crankshaft and Piston arrangement which opens and closes Inlet and Exhaust Ports leading through the Upper Cylinder Liner. The top and bottom Crankshaft are connected via a drive chain or toothed belt. The top Crankshaft and Piston become positive power contributors to the overall power output, thus increasing the amount of power/torque generated. The Dual Opposed Piston 4+2 Stroke Engine results in having Two Pistons Operating and producing power within each cylinder. The absence of parasitic CAMS, valves, springs, retainers and guides; all up about 45 dependant and power absorbing driven components, mean that the 4+2 Stroke Engine’s bottom end has been freed up from laboring and is allowed to spin up producing more power. The additional torque and power further generated by the Top Piston/Crank of the New Cylinder Head is then channeled via the connecting drive chain to the Bottom Crank. The net result of the Dual Opposed Piston Engine, is Tractor type pulling torque never before realized from a 4 Stroke Internal Combustion Engine, the sort of steady locomotive type performance gained can only be likened to Steam Locomotives or Diesel Engines. Due to the radical hybridization of 2 and 4 Stroke Technology, this engine achieves increased torque and power output, better fuel economy and cleaner burning with reduced emissions, longer service intervals etc.

4. WORKING

Initially, the Main piston and the Head piston are at their TDC. Thus, compression is completed and air fuel mixture is ignited for combustion process, leading to Power stroke. After expansion Main piston reaches its BDC and Head piston is half way to its BDC or head crank is turned 90◦ simultaneously. Now the Exhaust Stroke starts. During Exhaust stroke the main piston moves from BDC to TDC and Head piston reaches its BDC. 4+2 Stroke Function Diagram Now Intake stroke initiates. During Intake stroke the main piston moves from TDC to BDC and Head piston reaches half way to its TDC (i.e. Head crank is turned 90◦ after BDC) simultaneously. After the Intake, Compression is completed as Main piston moves from BDC to TDC and Head piston reaches its TDC simultaneously.

5. DESIGN

This is a modification to the conventional 4-stroke engine. In this the construction of the 4- stroke engine is modified. In this the 2 stroke engine cylinder head simply replaces the head of a 4- stroke engine. The New Head utilizes an overhead short stroke Crankshaft and Piston arrangement which opens and closes Inlet and Exhaust Ports leading through the Upper Cylinder Liner. The top and bottom Crankshaft are connected via a drive chain or toothed belt. The top Crankshaft and Piston become positive power contributors to the overall power output, thus increasing the amount of power/torque generated. The 4+2 Stroke engine name is based on its basic design i.e. a combination of a 4 Stroke Internal Combustion Engine as bottom end and a 2 Stroke Internal Combustion Engine resembling the top end, thus the name 4+2 Stroke Engine. The designing of the engine is done on designing software CATIA V5R14. For designing we first studied the working of 2 and 4 stroke engines.
Then we calculated the dimensions for designing by consulting various machine designs books. After that we checked the dimensions of the engine by measuring them from a conventional 4- stroke engine using

various measuring instruments. Now for our project we have designed a modified 2 stroke cylinder as cylinder head using dimensions of a conventional 2 stroke engine. Now after creating all parts on computer we have assembled all the parts using Assembly design in CATIA. Finally we animated the whole assembly in CATIA. The design of the engine and new cylinder head is shown below.

6. ADVANTAGES

Various advantages of the "4+2 Stroke Engine" are as follows:
1. Power/torque increases Simpler and less expensive manufacturing and tooling. Reduction of cylinder head reciprocating parts. Lower maintenance costs due to less wearing parts (New Cylinder Head).
2. The New Head 4+2 stroke Engine is thermodynamically more efficient, because the change in volume of the 4+2 stroke Engine Power Stroke is greater than the intake, compression, & exhaust strokes.
3. Increased economy due to the New Head's ability to operate and produce full operating power of much higher AIR to FUEL ratios. Possible one piece engine block and head casting, saving more manufacturing costs.

6.1. BENEFITS OF NEW HEAD

The New Head offers an array of advantages, but it specifically offers a compact combustion chamber with a 50 per cent squish. Thus, the combustion in the center of the piston is concentrated, increasing the flame speed and the speed of combustion. In doing so the thermal stress on the piston is actually reduced. An added benefit of this configuration is that it allows a higher bore stroke ratio, due to a lesser expansion of the piston. As there are no cut outs for valves, the crown of the piston can be slightly domed for higher strength and less weight. The 50 per cent squish factor keeps the edges of the piston from being exposed to the flame. By doing so, it allows the use of a gapless L shaped compression ring to be implemented right to the top of the piston. Therefore ring flutter is reduced or even eliminated. Also, the hydrocarbon emissions are reduced due to reduction in crevices. Crevices are reduced due to the new head design of the engine. Crevices are narrow regions in the combustion chamber into which the flame cannot propagate because it is smaller than the quenching distance. Crevices are located around the piston, head gasket, spark plug and valve seats and represent about 1 to 2% of the clearance volume. The crevice around the piston is by far the largest; during compression the fuel air mixture is forced into the crevice (density higher than cylinder gas since gas is cooler near walls) and released during expansion.

CONCLUSION

The 4+2 stroke engine is thermodynamically more efficient than conventional IC engines. In this engine a higher compression ratio is achieved and hence higher power for same fuel is obtained. The engine has fewer components hence the engine is light and simple in construction. Due to lesser number of parts the maintenance is cheap and easy. A one-piece 4+2 stroke Engine casting from crankshaft to upper shaft becomes feasible. No head gasket needed, cheaper to tool and produce. The emissions from the engine are less and hence environmental pollution is less

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Vendor Evaluation –An AHP Based approach

JOHN POULOSE
ASSISTANT MANAGER, HLL LIFECARE LTD.

Abstract

Vendor Selection in Government of India supplies is crucial to the exchequer as the money & the quantities involved are very high. Selecting a vendor is based on several factors which include financial aspects, quality, price, technical compatibility, capacity of the firm, repustation, quality certifications, management outlook, delivery performance & so on. The procurement Agency/Department, hence has to evaluate all these factors which determine the competence of the vendors. Analytic Hierarchy Process(AHP) is an ideal technique which can be used to evaluate the vendors by suitably incorporating the relative importance of the factors with respect to each other according to the requirement /objectives of the Purchaser. The Utilization of AHP to optimize the selection of a vendor from numerous bidders participating in a National Competitive Bidding of the Procurement Agency is the basis of the study conducted vides this paper.

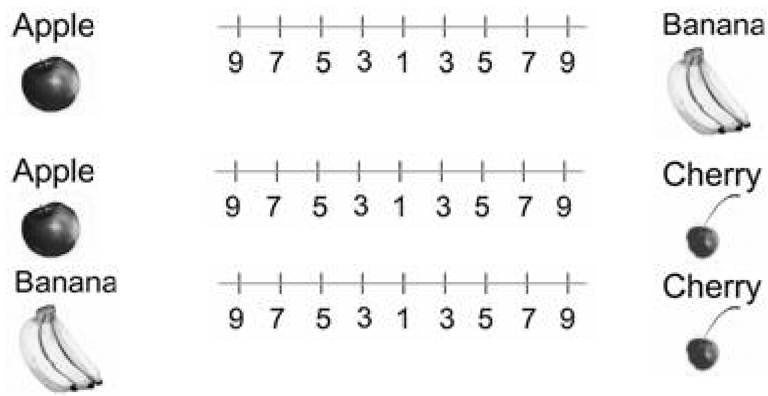
Introduction

The Procurement & Consultancy Services Division(P&CD) of HLL Lifecare Ltd. is a National Procurement Support Agency(NPSA) which procures on behalf of the Government Departments. The Division is mainly involved in the Procurement of Goods & Services for the various departments under the Ministry of Health & Family Welfare, Government of India. The type of Procurement Procedure to be adopted is based on the Value & the Nature of the item(s) to be procured. Competitive Bidding Process is commonly used method for procurement of goods having a value of over Rs.25,00,000.00. In the bidder evaluation, the lack of a proper technique which provides reasonable weightage/importance according to the requirements is evident. This is an ideal situation where the Analytic Hierarchy Process(AHP) can come to aid the Bid Evaluation Manager. The Analytic Hierarchy Process (AHP) is a structured technique for helping people deal with complex decisions involving multiple objectives. Rather than prescribing a "correct" decision, the AHP helps people to determine one that suits their needs and wants. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

Literature Review

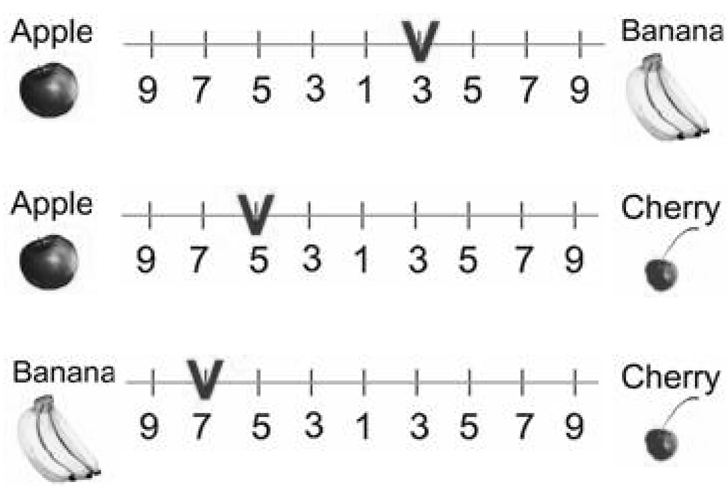
The various aspects of Analytical Hierarchy Process & its use in selection of a most optimum alternative from a set of alternatives are illustrated with the help of a simple example:

For example, suppose we have three choices of fruits. Then the pair wise comparison goes as the following



(Source: http://people.revoledu.com/kardi/tutorial/AHP/Priority%20Vector.htm)

Now, if XYZ has 3 kinds of fruits to be compared and he made subjective judgment on which fruit he likes best, like the following



(Source: http://people.revoledu.com/kardi/tutorial/AHP/Priority%20Vector.htm)

We can make a matrix from the 3 comparisons above. Because we have three comparisons, thus we have 3 by 3 matrix. The diagonal elements of the matrix are always 1 and we only need to fill up the upper triangular matrix. How to fill up the upper triangular matrix is using the following rules:

If the judgment value is on the left side of 1, we put the actual judgment value.

If the judgment value is on the right side of 1, we put the reciprocal value .

Comparing apple and banana, XYZ slightly favor banana, thus we put $^1/_3$ in the row 1 column 2 of the matrix. Comparing Apple and Cherry, John strongly likes apple, thus we put actual judgment 5 on the first row, last column of the matrix. Comparing banana and cherry, banana is dominant. Thus we put his actual judgment on the second row, last column of the matrix. Then based on his preference values above, we have a reciprocal matrix like this

$$A = \begin{array}{c} \\ \textbf{\textit{Apple}} \\ \textbf{\textit{Banana}} \\ \textbf{\textit{Cherry}} \end{array} \begin{array}{c} \begin{array}{ccc} \textbf{\textit{Apple}} & \textbf{\textit{Banana}} & \textbf{\textit{Cherry}} \end{array} \\ \begin{pmatrix} 1 & ^1/_3 & 5 \\ & 1 & 7 \\ & & 1 \end{pmatrix} \end{array}$$

To fill the lower triangular matrix, we use the reciprocal values of the upper diagonal. If a_{ij} is the element of row i column j of the matrix, then the lower diagonal is filled using this formula : $a_{ji} = 1/ a_{ij}$

Thus now we have complete comparison matrix

$$A = \begin{array}{c} \\ \textbf{\textit{Apple}} \\ \textbf{\textit{Banana}} \\ \textbf{\textit{Cherry}} \end{array} \begin{array}{c} \begin{array}{ccc} \textbf{\textit{Apple}} & \textbf{\textit{Banana}} & \textbf{\textit{Cherry}} \end{array} \\ \begin{pmatrix} 1 & ^1/_3 & 5 \\ 3 & 1 & 7 \\ ^1/_5 & ^1/_7 & 1 \end{pmatrix} \end{array}$$

Notice that all the element in the comparison matrix are positive, or $a_{ij} > 0$.

Having a comparison matrix, now we would like to compute priority vector, which is the normalized Eigen vector of the matrix. Suppose we have 3 by 3 reciprocal matrix from paired comparison

$$A = \begin{array}{c} \\ \textbf{\textit{Apple}} \\ \textbf{\textit{Banana}} \\ \textbf{\textit{Cherry}} \end{array} \begin{array}{c} \begin{array}{ccc} \textbf{\textit{Apple}} & \textbf{\textit{Banana}} & \textbf{\textit{Cherry}} \end{array} \\ \begin{pmatrix} 1 & ^1/_3 & 5 \\ 3 & 1 & 7 \\ ^1/_5 & ^1/_7 & 1 \end{pmatrix} \end{array}$$

We sum each column of the reciprocal matrix to get

$$\begin{array}{lccc} & \textbf{\textit{Apple}} & \textbf{\textit{Banana}} & \textbf{\textit{Cherry}} \\ \textbf{\textit{Apple}} & 1 & ^1/_3 & 5 \\ A= \textbf{\textit{Banana}} & 3 & 1 & 7 \\ \textbf{\textit{Cherry}} & ^1/_5 & ^1/_7 & 1 \\ \textbf{\textit{Sum}} & ^{21}/_5 & ^{31}/_{21} & 13 \end{array}$$

Then we divide each element of the matrix with the sum of its column, we have normalized relative weight. The sum of each column is 1.

Apple Banana Cherry

$$A = \begin{matrix} \textit{Apple} \\ \textit{Banana} \\ \textit{Cherry} \end{matrix} \begin{pmatrix} ^{5}/_{21} & ^{7}/_{31} & ^{5}/_{13} \\ ^{15}/_{21} & ^{1}/_{31} & ^{7}/_{13} \\ ^{1}/_{21} & ^{3}/_{31} & ^{1}/_{13} \end{pmatrix}$$

$$\textit{Sum} \quad 1 \quad 1 \quad 1$$

The normalized principal Eigen vector can be obtained by averaging across the rows

$$W = {}^{1}/_{3} \begin{pmatrix} ^{5}/_{12} + ^{7}/_{31} + ^{5}/_{13} \\ ^{15}/_{21} + ^{21}/_{31} + ^{7}/_{13} \\ ^{1}/_{21} + ^{3}/_{31} + ^{1}/_{13} \end{pmatrix} = \begin{pmatrix} 0.2828 \\ 0.6434 \\ 0.0738 \end{pmatrix}$$

The normalized principal Eigen vector is also called **priority vector.** Since it is normalized, the sum of all elements in priority vector is 1. The priority vector shows the relative weights among the things that we compare. In our example above, Apple is 28.28%, Banana is 64.34% and Cherry is 7.38%. John's most preferable fruit is Banana, followed by Apple and Cherry. In this case, we know more than their ranking. In fact, the relative weight is a ratio scale that we can divide among them. For example, we can say that XYZ likes banana 2.27 (=64.34/28.28) times more than apple and he also like banana so much 8.72 (=64.34/7.38) times more than cherry.

Criteria involved in the Evaluation of Bids (Serial Nos. A to P is allocated to each criterion)

A. Bid Form duly filled up should be submitted by the Bidder.

B. Power of Attorney in favor of signatory of TE documents should be submitted.

C. Performance Statement for last 3 years as per section VIII along with relevant copies of orders and end users' satisfaction certificate should be submitted.

D. Bid Security for 2.5% of the estimated contract value as stated in the Bid Document valid till 135 days from the date of Bid Opening should be submitted.

E. Bid Validity should be 90 days from date of Bid opening.

F. If the bidder is an SSI unit, the certificate of registration issued by Directorate of Industries/NSIC regarding the same must be enclosed.

G. Current ITCC (Income Tax Clearance Certificate) / PAN (Permanent Account Number) should be furnished.

H. Name and address of the Bidder's Banker (s) along with the Account Number.

I. Balance Sheet and Profit & Loss Account of the Bidder for last three years prior to the date of Tender opening should be submitted.

J. Certificate of not being De-registered, Debarred or Blacklisted by any Governmental Organization should be submitted.

K. Statement of No-Deviation from Technical & Commercial Conditions should be submitted.

L. The bidder shall furnish a brief write-up, packed with adequate data explaining and establishing his available capacity/capability (both technical and financial) to perform the contract (if awarded) within the stipulated time period, after meeting all its current/present commitments. Proforma'B' containing details of equipment & quality control.

M. Only manufacturers or his authorized agent (specifically against this invitation for bid for the subject goods) who had successfully executed contracts for similar and/or identical goods (similar and/or identical goods means Synthetic pyrethroids/ Insecticides/ Larvicides) for the past 3 years prior to the date of bid opening are qualified to quote.

N. The bidder or the manufacturer must have satisfactorily executed in any of the last 3 year period prior to the date of bid opening at least one single order of quantity of at least 25% of this present quantity of bid requirement in respect of the specific single schedule offered/quoted.

O. The bidder who is not a manufacturer and on whose behalf the bid is being made, must be the manufacturer of the product itself and must be in the business of the similar and/or identical goods at least for the last three years prior to the date of bid opening and must have manufactured and supplied at least one single order to the extent of at least 25% of the quantity.

P. The bidder should possess confirmed regular registration for Malathion with the Central Insecticides Board and should be licensed as manufacturer of respective product on the date of Tender opening.

Implementation of AHP in the Evaluation of Bids

A Questionnaire has to be handed out to the expert involved in the Bid evaluation to find out the priority that one criterion has over the other. The questionnaire has to be having choices so that the expert can easily tick on the preferred option. Although many scales can be used for quantifying Managerial Judgments, the scale given below is the standard used for AHP Analysis. The various options from 1 to 9 numerical values will have denominations as follows:

Numerical Value	Denomination
1	The two Criteria are equally favored
2	Intermediate Value between Numerical Values 1 & 3
3	One Criterion is slightly favored over the other.
4	Intermediate Value between Numerical Values 3 & 5
5	One Criterion is strongly favored over the other.
6	Intermediate Value between Numerical Values 5 & 7
7	One Criterion is very strongly favored over the other.
8	Intermediate Value between Numerical Values 7 & 9
9	One Criterion is extremely favored over the other.

Using the relative weights of one criterion with respect to another as provided in the questionnaire, we obtain a complete comparison matrix depicting the relative weight of one criterion with respect to another as shown below:

X =

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
A	1	5	5	1	1	9	9	9	3	5	6	5	1	3	3	2
B	1/5	1	1/3	1/7	5	7	9	9	4	5	3	5	1	1/5	1/5	1/7
C	1/5	3	1	1/3	1/2	9	9	9	5	3	3	5	1/3	1	1	1/3
D	1	7	3	1	1/3	9	9	9	5	5	5	6	1/2	1	2	1/2
E	1	5	2	3	1	8	9	9	5	6	4	7	1/2	1	1	1
F	1/9	1/7	1/9	1/9	1/8	1	1/3	1/2	1/5	1/5	1/6	1/5	1/6	1/7	1/7	1/8
G	1/9	1/9	1/9	1/9	1/9	3	1	1	1/3	1/5	1/5	1/4	1/9	1/8	1/8	1/9
H	1/9	1/9	1/9	1/9	1/9	2	1	1	1/5	1/5	1/6	1/6	1/9	1/9	1/9	1/9
I	1/3	1/4	1/5	1/5	1/5	5	3	5	1	1/3	1/3	1	1/5	1/4	1/4	1/8
J	1/5	1/5	1/3	1/5	1/6	5	5	5	3	1	1	1	1/3	1/3	1/4	1/5
K	1/6	1/3	1/3	1/5	1/4	6	5	6	3	1	1	1/2	1/2	1/3	1/4	1/7
L	1/5	1/5	1/5	1/6	1/7	5	4	6	1	1	2	1	1/5	1/6	1/5	1/7
M	1	1	3	2	2	6	9	9	5	3	2	5	1	1/2	1/2	1/3
N	1/3	5	1	1	1	7	8	9	4	3	3	6	2	1	2	1/5
O	1/3	5	1	1/2	1	7	8	9	4	4	4	5	2	1/2	1	1/6
P	1/2	7	3	2	1	8	9	9	8	5	7	7	3	5	6	1

We sum each column of the reciprocal matrix & subsequently divide each element of the matrix with the sum of its column &hence obtain a normalized relative weight, the sum of who's each column is 1. The normalized principal Eigen vector W can be obtained by averaging across the rows, i.e. adding up the values of each row & then dividing it by 16

A	0.13
B	0.07
C	0.06
D	0.1
E	0.11
F	0.01
G	0.01
H	0.01
I	0.02
J	0.03
K	0.05
L	0.02
M	0.08
N	0.08
O	0.07
P	0.15

W =

The priority vector shows relative weights among the criteria that we compared. The priority vector depicts the priority of one criterion over another. Hence, the percentage of importance of each criterion will be as follows:

Criterion	Percentage of Importance
A	13%
B	7%
C	6%
D	1%
E	11%
F	1%
G	1%
H	1%
I	2%
J	3%
K	5%
L	2%
M	8%
N	8%
O	7%
P	15%

The relative weight is a ratio scale that we can divide among them. For example, we can say that priority of Criterion A over Criterion B is (1.86=13/7) i.e. Criterion A 1.86 times more important than Criterion B.

Now, there were five Bidders who participated in the Tender for the procurement of Malathion, viz. 1) M/s Kamdhenu Pesticides, 2) M/s Rako Agrochem (P) Ltd, 3) M/s Coromandel Fertilisers Ltd, 4) M/s Prakash

Pulverising Mills & 5) M/s Kilpest India Ltd. The bidders & their corresponding 'Total percentage of Importance' are, there fore, as follows:

Sl. No.	Bidder	Total percentage of Importance
1.	M/s Prakash Pulverising Mills	84%
2.	M/s Kilpest India Ltd	84%
3.	M/s Rako Agrochem (P) Ltd.	84%
4.	M/s Coromandel Fertilisers Ltd.	83%
5.	M/s Kamdhenu Pesticides	56.5%

Results & Discussions

The Price Bid of the Bidder with the highest 'Total Percentage of Importance' has to be opened as it will be the most optimum Supplier. But in this case, as three of the five bidders have got equal scores in the 'Total Percentage of Importance' i.e. 84%, the price bids of M/s Prakash Pulverising Mills, M/s Kilpest India Ltd. & M/s Rako Agrochem (P) Ltd. have to be opened. On the Opening of the Price Bids, the following prices in the increasing order were found to be quoted:-

Ranking	Bidder	Quantity in Kilograms	Unit Price/Kg in Rs.	Total Price in Rs.
1	M/s Prakash Pulverising Mills,Alwar.	50,000	80.30	4015000.00
2	M/s Kilpest India Ltd,Bhopal. OR M/s Rako Agrochem (P) Ltd,Lucknow	50,000	80.519	4025950.00

Hence the optimum Bidder quoting the lowest purchase is M/s Prakash Pulverising Mills, the most eligible bidder, for the placement of the Purchase Order.

Conclusion

When a procurement agency is confronted with choosing the best bidder to deliver a good or service, the decision can often be very complex. The Bidder Evaluation problems are multi-objective problems which have many qualitative and quantitative concerns. This project has presented the AHP as a decision analysis tool in bidder evaluation problems. This project proposes a comprehensive AHP model to select the best supplier for a procurement agency. The AHP models a decision making framework using a hierarchical relationship among the various evaluation criteria. It ensures the incorporation of both qualitative & quantitative factors when assessing the bids. We concluded that M/s Prakash Pulverising Mills is the most optimum bidder to whom the Purchase Order can be placed.

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