Energy Audit and Analysis of Centrifugal Pumps Used for Tempcore Process in Light and Medium Merchant Mill

A project report submitted in partial fulfillment of the requirements for the award of the degree of

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IN

MECHANICAL ENGINEERING

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(Affiliated to Andhra University, Accredited by NBA & NAAC with 'A' grade)

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CERTIFICATE

This is to certify that the Project Report entitled **"Energy Audit and Analysis of Centrifugal Pumps Used for Tempcore Process in Light and Medium Merchant Mill"** is a bonafied work carried out by O.V.N. Sai Kumar (315126520159), P. Avinash (315126520171), N.V.S. SaiKumar (315126520154), S. Mujahid Ahmed (315126520205), R. Mahi Teja (315126520188), during the year 2018-2019 under the guidance of **Ms. K. V. Rukmini M.E., Assistant Professor** in the partial fulfillment of requirement for the award of Degree of Bachelor of Technology in Mechanical Engineering by Andhra University, Visakhapatnam.

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CONTENTS

ABSTRACT

After the industrial revolution the world has turned into a concrete jungle. For constructions, cement along with reinforced bars plays a prominent role. Reinforced bars are manufactured with required properties in a steel manufacturing industry. Tempcore process is used widely for production of reinforced bars.

Tempcore process plays a vital role in maintaining the properties of reinforced bars like strength, hardness etc. Tempcore process requires a coolant (usually water) for cooling of hot rolled bars. Centrifugal pumps are used to deliver water which is required for tempcore process. Energy Auditing on these centrifugal pumps leads to increase in efficiency of tempcore process.

Hence, the Energy Audit on the centrifugal pumps which are present in Light and Medium Merchant Mill of a steel plant is done by calculating pump characteristics such as head, flow rate, hydraulic power, shaft power and efficiency. Thus, by performing Energy Audit, the best combination of two pumps is found from a group of six pumps.

Using ANSYS Workbench, Modal Analysis is carried out on the SolidWorks model of centrifugal pump impeller to compare the natural frequencies with working frequencies of three different materials for their suitability to centrifugal pump impeller.

NOMENCLATURE

SYMBOL	DESCRIPTION	UNITS
h	Static head of a centrifugal pump	m
p_1	Inlet pressure to centrifugal pump	bar
p_2	Outlet pressure to centrifugal pump	bar
ρ	Density of fluid used in pump	kg/m^3
g	Acceleration due to gravity	m/sec^2
Q	Flow rate of fluid in pump	m^3/hr
V	Input voltage given to pump	volts
I	Input current given to pump	amps
$\cos \varphi$	Power factor	-
φ	Phase displacement angle	degrees
η_{motor}	Efficiency of motor	-
η	Efficiency of centrifugal pump	-

List of figures

List of tables

List of Graphs

CHAPTER 1

INTRODUCTION

Energy conscious centrifugal pump users are always interested in knowing the value of maximum attainable pump efficiency for the required capacity and head. This value can be used as a benchmark to facilitate:

- Selecting and purchasing an energy efficient pump
- Conducting an energy audit of pumps in an operating plant/refinery to make decisions about the replacement of energy inefficient pumps

The process known as Tempcore is used to produce high resistance rods by the formation of a surface layer of quenched and tempered martensite that surrounds a core made of ferrite and pearlite. Such a mixed structure is result of processing hot rolled rods through waters headers that reduce the temperature at the surface below that for the transformation into martensite. This structure is tempered by the heat flowing from the core of the rod, which transforms into ferrite and pearlite while the rod is in the cooling beds. Such processing produces a significant increase in yield and ultimate tensile strength, while maintaining adequate ductility. The economic advantages of this process are huge in comparison with those that require alloying elements or further metal working to improve mechanical properties.

This project deals with energy audit of centrifugal pumps used in tempcore process of a steel manufacturing industry and modal analysis of their impellers**.** Light and medium merchant mill (LMMM) is a type of rolling mill in the steel manufacturing industry which comprises of two mills, namely billet mill and bar mill. In billet mill, blooms 320×250 mm of 6mt length. The blooms are feed into a furnace where they are heated to 1150^{o}c-1200^{o}c and then passed into the rolling stands where reduction of cross sectional area takes place and finally billets of 125×125 mm are obtained. During rolling, the billets are sent through “**TEMPCORE BOXES**” in production of reinforcement bars in bar mill where “**TEMPCORE PROCESS**” takes place which is a very essential process to decide characteristics of reinforced bars. Tempcore process needs continuous water supply which is supplied by centrifugal pumps. Centrifugal pumps are used to induce flow or raise a liquid from a low level to a high level. A centrifugal pump converts rotational energy, often from a motor, to energy in a moving. The two main parts that are responsible for the conversion of energy are the impeller and the casing. So impeller plays a very important role in obtaining the efficiency of centrifugal pump. In this project, we will deal with selection of suitable material for impeller. For tempcore process, combination of centrifugal pumps is used. Hence, we will also deal with the selection of best suitable combination of centrifugal pumps.

1.1. LIGHT AND MEDIUM MERCHANT MILL

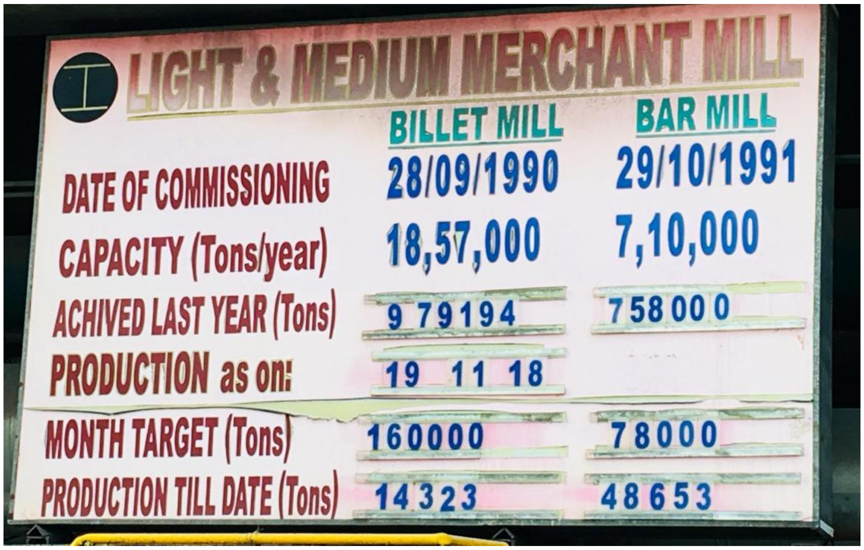
Visakhapatnam Steel Plant (VSP), the first coast based Steel Plant of India is located, 16km southwest of City of Destiny i.e., Visakhapatnam. The plant is located amidst nature’s bounty, in the city fast emerging as the face of the future and also with the pictures of Ghats on one side and the mighty Bay of Bengal on the other. Bestowed with modern technologies, VSP has an installed capacity of 3 million tons per annum of liquid steel and 2.656 million tons of saleable steel. At VSP there is an emphasis on total automation, seamless integration and efficient up gradation, which result in wide range of long and structural products to meet stringent demands of discerning customers within India and abroad. VSP products meet exalting International Quality Standards such as JIS, DIN, BIS, BS, etc.

VSP has become the first integrated steel plant in the country to be certified to all the three international standards for quality (ISO-9001), for environment management (ISO-14001) and for occupational health & safety (OHSAS-18001).The certificate covers quality systems of all operational, maintenance, service units besides purchase systems. Training and Marketing functions spreading over 4 Regional Marketing Offices, 20 branch offices and 22 stock yards located all over the country .

VSP occupies 25,780 acres of land comprising of 6400 acres of production facilities, 6620 acres for township and 12760 acres for other facilities.VSP successfully installed and are operating efficiently Rs 460 crores worth of pollution control and environment control equipments and converting the barren landscape by planting more than 3 million plants has made the steel plant, steel township and surrounding areas into a heaven of lush greenery. This made steel township greener, cleaner and cooler place which can boast of 3 to 4 C lesser temperature even in the peak summer compared to Visakhapatnam city.

VSP exports quality pig iron and steel products to Sri Lanka, was awards "star trading house" status during 1997-2000. Having a total manpower of about 16,613 VSP has envisaged a labor productivity of 265 tons per man year of liquid steel which is the best in the country and comparable with the international levels**.**

The Light and Medium Merchant Mill (LMMM) of VSP has been envisaged to produce:



LIGHT & MEDIUM MERCHANT MILL

	BILLET MILL	BAR MILL
DATE OF COMMISSIONING	28/09/1990	29/10/1991
CAPACITY (Tons/year)	18,57,000	7,10,000
ACHIVED LAST YEAR (Tons)	9 79194	758000
PRODUCTION as on:	19 11 18	
MONTH TARGET (Tons)	160000	78000
PRODUCTION TILL DATE (Tons)	14323	48653

Figure 1.1: Statistics of LMMM

1.2. PROCESS TECHNOLOGY IN LMMM

Blooms for LMMM are placed on charging grids (3 no's) of 150 tons per hour capacity each by 16 tons claw cranes (2 no's). The blooms are then delivered to the furnace approach roller table (+5.8mts) by an inclined elevator from bloom storage roller table (+0.8mts)

The approach roller table is provided with a weighing scale, a tilter and disappearing stops. The blooms are positioned in front of the furnaces and then pushed by hydraulic pushers on to the charging skids of the furnaces. There are two nos. of walking beam type furnaces of 200 T/hr capacity with double row charging. The blooms also can be discharged from the charging side of the furnaces in case of emergency. Heated blooms are placed piece by piece by discharging devices on to the furnace delivery roller table. The blooms are decaled by high pressure de-scalar. The continuous Break-Down group (non-reversing) consists of 7 stand -2 Horizontal (850x1200mm) and 5 alternating vertical and horizontal (730X1000mm and 630X1000mm).

There are 7 stands (4 horizontal and 3 vertical) in the break down mill. In 5 box passes the bloom is reduced from 320mmx250mm to 125mm square of 33mts length (referred to nominal bloom length of 6.3mts) with a finishing temperature of 1100c-1200c. The draw –in speed of bloom varies from 0.256m/sec to 0.315m/sec depending up on the discharge bloom temperature. The stand arrangement is as shown below:

Table 1.1: Arrangement of Rollers in LMMM

Stand 1	Stand 2	Stand 3	Stand 4	Stand 5	Stand 6	Stand 7
Horizontal	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical

In 5 Box passes and one each of diamond and square passes, the blooms are reduced to 125 mm square in the 7 stands. The finishing speed will be 1.3 to 1.6 mts/sec. A four crank shear installed behind the mill stands is designed to crop both ends and to cut billet lengths as per requirement of WRM & Sales as per requirement to achieve optimum yield in cutting. Billets feeding the LMMM are cropped at the front and back ends. Normally one Bloom is rolled for LMMM and the next one for the WRM alternately, Billets are also sold.

The billets for WRM and for sale are cooled on 2 turn over - type cooling beds to a maximum discharge temperature of 4000 C. These billets are picked up by magnet cranes of 16Tcapacity in the intermediate billet storage and transferred to the transfer grids in the shipping area or dispatched for sale.

Billets after cropping by the 4-crank shear and having a length of about 32 mts are transported to the inline 2 strand roller hearth furnace of 200 T/h Capacity. Billets normally arrive at the furnace with a surface temperature of 11000C. Billets are heated and soaked to discharging temperature of 11500 C to 11300C.

The continuous multi-line mill comprises 8 stand double strand roughing train, 2 Nos, 4 Stand Single strand finishing trains.

The billet head now approaches the first groove at a predetermined speed. If, however, entry does not take place (rolls are no roll of the pinch roll (Hem-4-1) which is located between inline roller hearth furnished and first stand will be shifted over the billet and lowered down on to the billet and bottom pinch roll is made to rotate at about 0.6m/sec.

The entering process is assisted due to frictional engagement between pinch rolls and billet. The billet, entering the Bar Mill, normally needs no head end crop cut by pendulum shear because the four Crank shear in Billet Mill has already performed the job.

Table 1.2: INTERMIDIATE TRAIN-1

STAND 9	**STAND 10**	**STAND 11**	**STAND 12**	**STAND 13**
Horizontal	Horizontal	Vertical	Horizontal	Horizontal

Table 1.3: INTERMIDIATE TRAIN-2

STAND 14	**STAND 1**	**STAND 16**	**STAND 17**	**STAND18**
Horizontal	Horizontal	vertical	Horizontal	Horizontal

Table 1.4: FINISHING TRAIN-1

STAND 19/1	**STAND 20/1**	**STAND 21/1**	**STAND 22/1**
Vertical	Horizontal	Vertical	Horizontal

Table 1.5: FINISHING TRAIN-2

STAND 19/2	**STAND 20/2**	**STAND 21/2**	**STAND 22/2**
Vertical	Horizontal	Vertical	Horizontal

Shears for cropping and emergency cutting are arranged ahead of the first of roughing mill stand and upstream of intermediate mills. Snap shears for emergency cuts only are ahead of finishing mill. The rotating shears after the finishing mills crop the materials leaving at rolling speed. and cut into multiples of specified sales lengths.

The finished bar now enters the cooling stretches. There are two cooling stretches each installed just downstream the last stand of the finishing mill. The purpose of the cooling stretches is to cool down the rebars to such an extent so as to produce desired mechanical properties. It also serves to control the scale formation.

The bar leaving the last stand of the finishing mill passes through a cooling stretch. The cooling efficiency of this installation is such that a surface layer of the bar is quenched into martensite, the core remaining austenite. The quenching treatment is stopped when a determined thickness of martensite has been formed under the skin when the rebar leaves the cooling stretch, a temperature gradient is established in the cross-sections of the bar causing heat to flow from center to the surface, which results in self-tempering of the martensite Finally during slow cooling of the rebar on the cooling bed, the austenitic core transforms into ferrite and pearlite. To achieve the required mechanical properties, it is sufficient to maintain the tempering temperature within a predetermined range. The obvious control variables are the length of the quenching line and the cooling water flow late at suitable number of cooling pipes whose diameter, are chosen as a function of product diameter.

Air Strippers are fitted at the end of cooling pipes to make sure that the material leaves the stretch in dry condition. The pinch roll units; downstream the cooling stretch guarantees the correct bar speed during the cooling process. These pinch rolls are speed synchronized with the exit stands of finishing mill 1 & II so that bar speed remains same when the bar tail has left exit stand of finishing mill. They also serve to enter the material into the rotary shear. A total cooling bed of 130 mts X 12 mts has been provided for cooling down the rolled section at about 80∞C maximum for straightening.

In the downstream of the cooling beds there are multi strand straightening machines (maximum 8 straightening strands) The number of straightening rolls are 8 (top 4 and bottom 4). The bar groups from the strengtheners are collected in layers for the downstream cold shear by cross transfers. The 2 cold shears have cutting pressure of 500 MPa each. Desired finished lengths normally 12 mts are set by girder type gauge carriages. Tail lengths less than 6 mts are discharged into cradles near the cold shears. Downstream file cold shears, rounds, and rebars are transported to bar bundling facility. There are two bundling facilities. The bar bundling facilities have provision for counting the bars, and strapping the collected bars into bundles of 4500 Kgs and 10000 Kgs. Strapping of bar bundles and packs is by means of wire and straps.

The finished section packs/bundles are finally transported to the weighers and the loading grid permits the bundles to be picked up by magnetic cranes in the finished product storage area having lifting magnets of 20 Tones capacity.

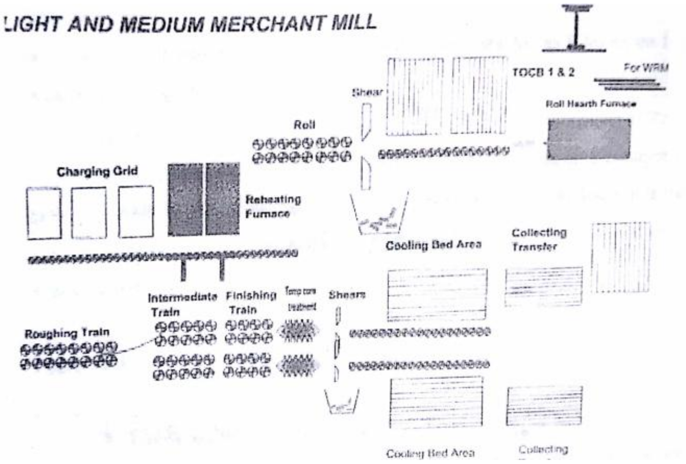


Figure 1.2: Process Mechanism in LMMM

1.3. PRODUCTS MANUFACTURED IN LMMM DEPARTMENT

In LMMM Department various type of rebars and plain bars are produced. The major difference in rebar and plain bar is tempcore process is not performed for plain bars. Tempcore process is performed only for rebars only. Rebars are used for constructions and plain bars are used for production of nuts, bolts etc.

Various sizes of rebars like 16RE, 18RE, 20RE, 22RE, 25RE, 28RE, 32RE, 36RE are produced. Plain bars like16P, 18P, 20P, 20.64P, 22P, 25P, 28P, 32P are produced.

Figure 1.3: Various Types of Products Produced In LMMM Department

CHAPTER 2

LITERATURE REVIEW

Ghnanasyam G.Iratkar investigates about the Efficiency of a centrifugal pump (ηo) = Mechanical efficiency (ηm) × Volumetric efficiency (ηv). Most of the study has been done in the improvement of Hydraulic efficiency but overall efficiency depends on both factors Hydraulic and Mechanical. Mechanical components. The modelling of the impeller will be done by using solid modelling software, CATIA. The meshing and boundary condition application will be carried using Hyper mesh, it is also used to produce good and optimal meshing of the impeller to obtain accurate results and analysis has been done by using ANSYS. A static analysis on 3HP pump impeller has been carried out to examine the stresses and displacements of the centrifugal impeller. Conventional MS material is replaced with glass fibre composite material.

Saeid Farokhzad tells about ANSYS software package was used to develop a three dimensional, fully turbulent model of the compressible flow across a complex geometry of impeller, such as those found in centrifugal pump. The present paper describes the simulation of the flow in the impeller of a centrifugal pump. The analysis of centrifugal pump impeller design is carried out using ANSYS-CFX. The complex internal flows in Centrifugal pump impellers can be well predicted through ANSYS-CFX. The numerical solution of the discredited three-dimensional, incompressible Navier-Stokes equations over an unstructured grid is accomplished with an ANSYS-CFX. The flow pattern, pressure distribution in the blade passage, blade loading and pressure plots are discussed in this paper.

Shyam Karanth observed that this work deals with design of an Impeller type Centrifugal pump and do analysis using ANSYS WORK BENCH. The variation of von-mosses stress, von-mosses strain, deformation factor, natural frequencies, mode shapes for different materials can be taken into consideration. ANSYS DESIGN MODELER is used for modelling the parts and analysis is done in ANSYS WORKBENCH. ANSYS is dedicated finite element package used for determining the variation of stresses, strains and deformation across profile of the impeller. A structural analysis has been carried out to investigate the stresses, strains and displacements of the impeller.

D. S. Khedekar has done centrifugal pump analysis on MS & SS pump impeller is done in order to optimize strength of centrifugal pump. This paper gives the static & Modal analysis of MS & SS Pump Impeller to check strength of Pump & vibrations produced by pump.

S.Venkatesh investigates the study of complex internal flows in centrifugal pump impellers with the aid of Computational Fluid Dynamics software thus facilitating the design of pumps. The impeller was modelled in Pro Engineering and the blade to blade plane of the impellers was taken for the detailed study purpose because the flow occurs through this passage only.

N.Karthikeyan tells about the enhancement the performance of the centrifugal pump through design modification of impeller. Vane profile of the impeller is generated using point by point method. The impeller is modelled in SolidWorks 2012 software and CFD analysis is done using fluid flow simulation package. CFD analysis enables to predict the performance of the pump and a comparative analysis is made for the entire control volume by varying meshing. Pump impeller models have been developed for critical design parameters of the pump. CFD analysis is done in the models to predict the pump performance virtually.

Prof.Pranav R Mane observes that Computational Fluid Dynamics (CFD) approach was suggested to investigate the flow in the centrifugal pump impeller using the Ansys Fluent. Impeller is designed for the head (H) 70 m; discharge (Q) 80 L/sec; and speed (N) 1400 rpm. Impeller vane profile was generated by circular arc method and point by point method and CFD analysis was performed for the impeller vane profile. Further the impeller was analysed for both forward and backward curved vane.

A.Syam Prasad tells about static and modal analysis of a centrifugal pump impeller which is made of three different alloy materials. (viz., Inconel alloy 740, Incoloy alloy 803, Warpaloy) The best material for design of impeller is Inconel 740. Specific modulus of Inconel 740 obtained in static analysis is 10 % higher than other material. The natural frequency in modal analysis is 6% higher than other material. The deformation of Inconel 740 in static analysis is reduce by 12%.

Karthik Matta tells about the modeling of the impeller was done by using solid modeling software, CATIA V5 R18. It is proposed to design a blower with composite material, analyze its strength and deformation using FEM software. In order to evaluate the effectiveness of composites and metal blower and impeller using FEA packaged (ANSYS). Modal analysis is performed on both Aluminum and composite centrifugal blower impeller to find out first 5 natural frequencies. If number of blade and outer diameter increases stresses and deformation also increases all are allowable limit.

CHAPTER 3

DEFINITION OF PROBLEM

In a LMMM Department of a Steel Manufacturing Industry Tempcore Process plays a very important role. Tempcore Process is required for production of reinforced bars (rebars). For Tempcore Process, cooling equipment is required for cooling hot rolled bars to be transformed into reinforced bars.

For cooling of hot rolled bars Centrifugal Pumps are used as the cooling equipment. Centrifugal pumps are used in combination in order to maintain the correct amount of flow in Tempcore Boxes where Tempcore Process takes place.

In this project we will find the best combination of pumps by performing Energy Audit on pumps. Centrifugal Pumps consists of impeller as its main part. So, by performing Modal Analysis on Centrifugal Pump Impeller and by comparing their respective parameters, the most suitable material for Centrifugal Pump Impeller is determined.

3.1. HEAT TREATMENT OF STEEL

A communication of heating of cooling operation , find and applied to a metal as alloy in the solid state in a way that will production directed properties " All basic trailing processes for steel involve the transformation of as decomposition of austenite. Heat treatment of steel involves a combination of heating, holding and cooling at controlled rates to produce the desired conditions. The following heat treatment process are generally applied to steel for obtaining the desired conditions.

(1) Annealing - to soften the steel.

(2) Normalizing -to refine the structure.

(3) Hardening -to increase the hardness.

(4) Tempering -to eliminate brittleness in hardened steel.

3.1.1 ANNEALING:

Annealing is a widely used heat treatment process which involves heating the material to mainly soften the steel at the austenitic temperature, and subsequently cooling it very slowly in a way similar to that of the cooling line A. Such cooling rate is achieved by living the steel inside the heating furnace itself without any further heat input. Because of the extremely slow cooling rate, final structure of the steam would be very coarse pearlite. This structure would eliminate all internal stress, reduce hardness, increase ductility enhance machinability, refine grain size and also effect some changes in electrical & magnetic properties. The major limitation of the process that it is suitable only for small components for heavy components the structure obtain is not uniform.

3.1.2 NORMALIZING:

Normalizing is the process of heating the steel to above the upper critical temperature (810c-910c) followed by cooling in still air. In normalizing, somewhat faster cooling rate is used. This may be achieved by cooling the heated specimen in still air. Because of the faster cooling rate, pearlite structure obtained would be of uniformly of the grain size. In the final structure there is better dispersion of cementite. This would result in higher tensile strength and hardness then what is possible by annealing. The mechanical properties achieved through normalizing depend to a great extent on the thickness of this section. In case of thicker objects or sections, the outer surface may be normalized, but the core would be annealed.

3.1.3 HARDENING:

Hardening may be defined as the process of heating steel to austenite phase following by rapid cooling in a liquid bath such as water or oil. The purpose of hardening is to develop high hardness ware resistance and ability to cut the other materials. To improve the strength and toughness.

3.1.4 TEMPERING:

It is a process of heating hardened steel to a temperature below lower critical temperature followed by cooling tempering renders the steel tough &ductile . As mentioned earlier, the hardening increases strength and hardness in steel, but decreases ductility and toughness i.e. imparts brittleness.

3.1.4.1 LOW-TEMPERATURE TEMPERING:

The purposes of low temperature tempering are.

1. To relive internal stresses, and
2. To increases ductility without changing the structure.

The process is done in the temperature interval from (150-125c) the tempered components cannot carry dynamic loads for this reason, the process is applied to cutting tools, measuring tools and that have been carburized and surface hardened .

3.1.4.2 MEDIUM-TEMPERATURE TEMPERING:

In this case the hardened steel is heated between the temperature range 350c-450c the object of heating up to this temperature is to change the martensite structure in to troosite. Medium temperature tempering is commonly employed for coils and laminated springs.

3.1.4.3 HIGH-TEMPERATURE TEMPERING:

It consists of heating the steel to the temperature interval of 500c-650c. at this temperature marten site is transformed to sorbet. In this process the internal stresses is improved. Scorbutic steels are softer and more ductile than troositic steels and troosite are usually known as tempered martensite high temperature-tempering is applied to gear wheels, axles shafts and connecting rods.

3.2. BACKGROUND OF TEMPCORE PROCESS

During the last few years the civil engineering sector has increased its demand for low-cost reinforcing steel bars with guaranteed minimum yield point characteristics of 500 MPa. This need arose since these steel grades are covered by the relevant standard specifications of all developed industrial countries. The use of such Grade500 high strength rebars reduces civil construction cost because of

· Saving in reinforcement

· Reduced labor costs

· Easy processing due to high weldability

Steel bars with a minimum yield point of 500 MPa is close to the upper limit for normal rebars used in reinforced concrete.

The tempcore process has been developed in the early seventies by C.R.M., Belgium in order to manufacture high yield strength wieldable concrete reinforcing bars from mild steel, without V or Nb additions. Cooling stretches used in bar mill of Light and medium Merchant mill of VSP is in line with this. This processes limit scale formation to a minimum, due to the quenching effect of these systems. A fine layer rich in Wustite, (FeO) is formed.

Cold twisted deformed (CTD) rebars were developed about 30 years ago to obtain high strength rebars as a cheap alternative to the use of costly alloying elements such as Cr, Ni, V, Nb, Ti. But the CTD rebars sacrificed the two essential properties of weldability and elongation and hence are not used in developed countries - whereas they became popular in India and the neighboring countries.

The Indian Region, where CTD rebars had a stronghold for the past 2 - 3 decades, is today waking up to the benefits of the Tempcore rebars primarily on account of

a) Superior product with consistent properties

b) High strength combined with high ductility

c) Better corrosion resistance

d) Better resistance to high temperatures, as in the case of fires

e) Easy manufacture of different strengths of rebars from nearly the same steel grades

f) Saving of 10-20% in steel consumption when using Tempcore 500 in place of CTD rebars

g) Better fatigue resistance

h) Better weldability

i) Easy and less construction time

j) Lastly, an ideal choice for seismic zones due to excellent ductility properties. This is of great importance for India because nearly 60% of the country falls in the high Seismic hazard category.

3.3. TEMPCORE PROCESS METHODLOGY:

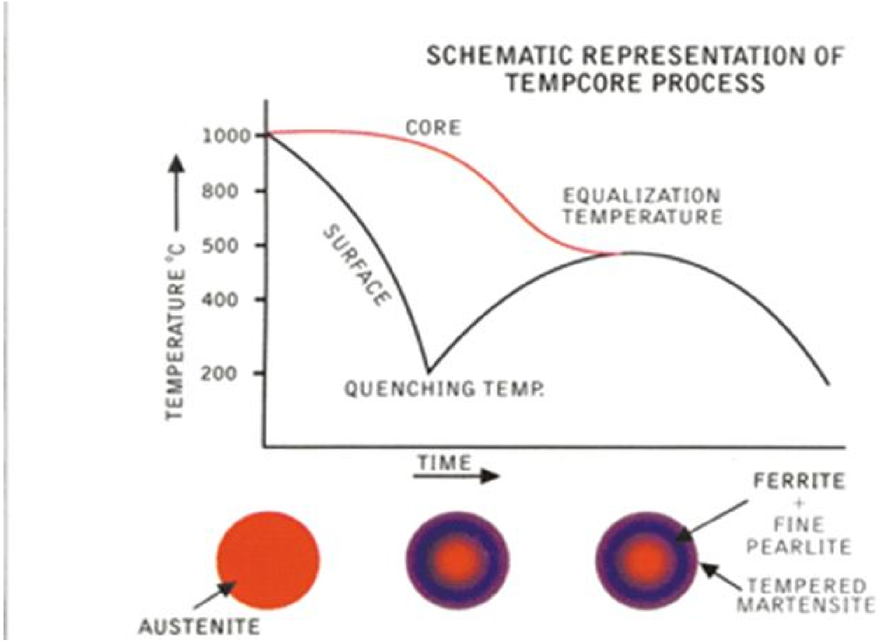


Figure 3.1: Schematic Representation of Tempcore Process

Traditionally, the rebars are produced through conventional hot rolling process in which the heated billets of required chemical composition pass through a series of forming operations where the billet cross section is gradually reduced till the required shape and dimensions are achieved. After final forming stage, the hot bars are air cooled to ambient temperatures. The properties are achieved through the addition of alloying elements mainly carbon and manganese. For high strength application other alloying elements like Ti, V, Nb may also be used in smaller quantities, the air cooling produces a layer of mill scale on the rebar surface, the thickness of which depends on temperature and cooling duration. The final structure of the rebars is also influenced by these parameters. The air cooling results in ferritic pearlitic structure, typical of a medium carbon steel.

The quenched bars are also produced through hot rolling; however they are rapidly water cooled after the last forming operation. The rapid water cooling, called quenching, inflicts micro structural changes in the bar in such a way that at the end, the rebar's micro structure is composed of an outer rim of tempered martensite, a hard constituent, with a ductile core of ferrite and pearlite as shown in Fig. Combination of these two structures imparts the needed strength and ductility to the rebars. The quenching reduces the surface temperature of the bars to a much lower degree as compared to the conventional hot rolled materials before they are air cooled to ambient temperature. Lower temperature air cooling of the rebars does not allow the mill scale to grow and the bars have a smooth shiny surface with a very thin layer of mill scale.

In the case of hot rolled rods of plain steel or low alloyed steel grades these goals are:

1. The improvement of the mechanical properties of the finished products with the specific chemical composition.
2. Important savings due to the fact that subsequent thermal processes of the hot rolled product are no longer necessary.
3. Better mechanical properties without the use of expensive micro alloying elements.
4. The improvement of the weldability obtained by the use of low carbon and manganese steel grades (lower equivalent carbon).

The technological processes applicable in this case, generally assume a high reduction in the last stand of the finishing block after which the rolled rod is intensively cooled using water sprays, followed by temperature equalization between the surface and core which will take place during the time necessary for the rod to reach the coiler. With such a technology one can obtain a ferrite-pearlitic microstructure, with fine grains in the core and tempered martensite near surface zone.

In the case of the wire rod rolled steel grades the main manufacturer’s goal refers to obtain characteristics more suitable for subsequent drawings. Wire rod coiled in the regular manner after hot rolling normally has a fairly coarse structure with pearlite due to the slow cooling rate after the coiling. To improve the wire drawing properties, it is therefore most cases necessary to subject the wire to a patenting treatment sometimes during the drawing process.

A proper choice of the technological parameters and of the structure of the cooling equipment is based, no matter what technological process one use, on a better modeling of the heat transfer during cooling.

It consists in subjecting the hot rolled steel to an in-line heat treatment in 3 successive stages:

STAGE 1:

As soon as it leaves the final mill stand, the product is rapidly surface hardening (martensite layer). The efficiency of this water cooling stretch is such that the cooling rate up to a certain depth below the skin of the bar is higher than the critical rate of cooling for martensitic quenching.

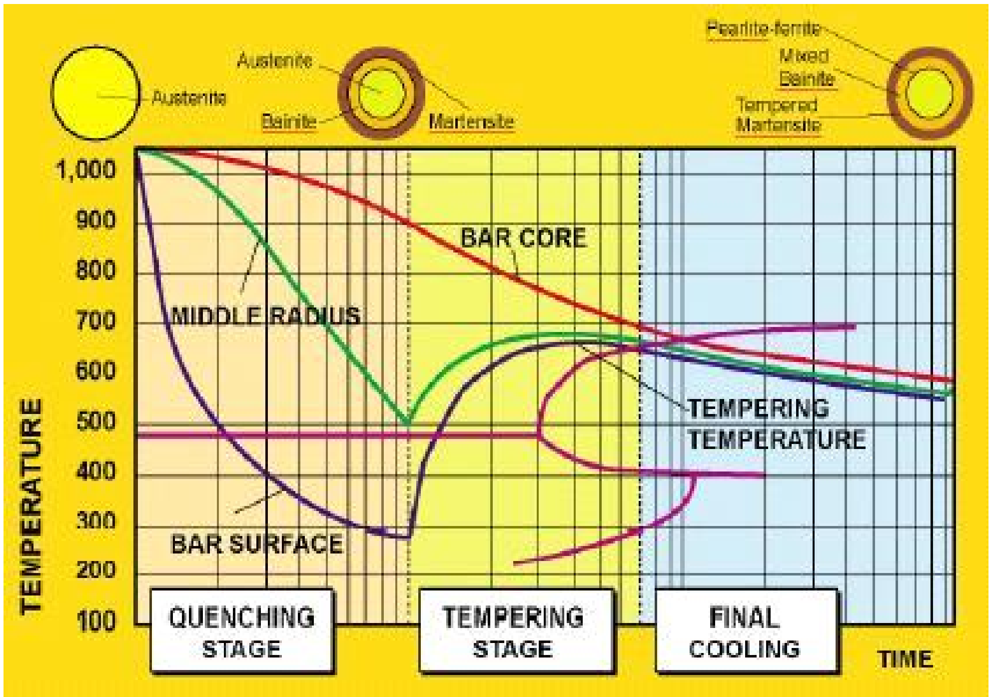


Figure 3.2: TTT Diagram of Tempcore Process

During this stage a martensitic surface layer is formed. Below this depth, a mixture of austenite and martensite and with an austenitic core is formed. The length of cooling stretch, water flow and pressure is manipulated to get the desired thickness of martensitic layer for a given speed of rolling (last stand speed).

STAGE 2:

As soon as this quenching operation is stopped, and the bar leaves the cooling stretch remaining heat in the core dissipates to the surface and due to the sharp temperature gradient the surface is rapidly heated and temperature of core is lowered to an equilibrium temperature suitable for tempering. Thus the surface layer is Tempered, by using the residual heat left in the CORE of the bar (self-tempering of the martensite layer); hence the name **TEMPCORE**. This self-tempering ensures adequate ductility while maintaining high yield strength. During this stage, the untransformed austenite in the surface layer transforms to bainite while the core remains austenitic.

STAGE 3:

The third stage takes place while the product lies on the cooling bed where the bar is subjected to normal cooling down to ambient temperature. During this stage, isothermal transformation of the residual austenite in the core to ferrite and pearlite takes place. The extent of transformation depends on steel composition, bar diameter, finish rolling temperature and the cooling conditions during the first stage. Tempcore type process is the best process for the production of High Quality rebars. In this the costly alloying elements (Vanadium, Niobium) are replaced by low-cost ... water, in order to obtain from low C-Mn steel, concrete reinforcing bars with high mechanical properties (Fe500, Fe 550 ...) , excellent weldability , excellent ductility and bendability. This replaces extra operation of cold working and problem of non-uniform elongation of CTD bars.

3.4. TEMPCORE PROCESS IN LMMM AT VSP:

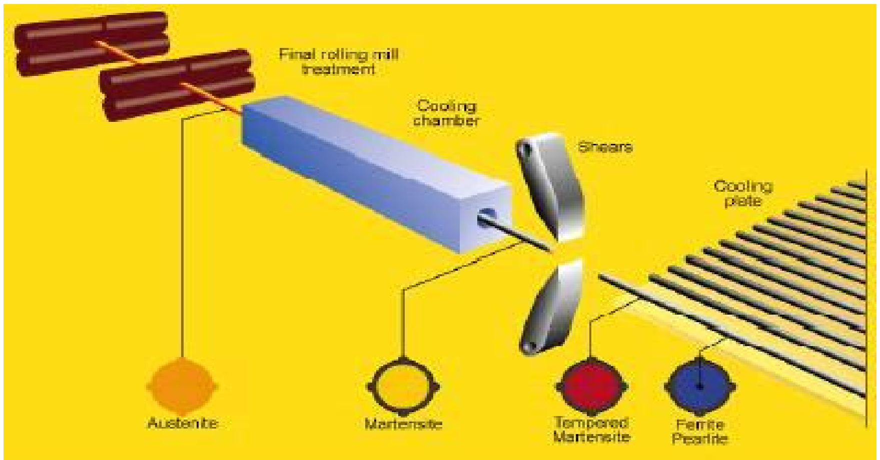


Figure 3.3: Micro Structure Of Rebar At Various Stages Of Tempcore Process

The two cooling stretches of about 20 m length are arranged close to the last stand of finishing train I and finishing train II on the downstream side. The high pressure water needed for the tempcore cooling process is generated in a separate pressure booster station. The quantity of water per cooling unit is regulated manually.

Cooling and/or guide pipes are selected as function of the diameter of round being rolled. At the end of each cooling stretch a stripper and a dryer is fixed to ensure that the material clears the cooling stretch in dry condition. All cooling and/or guide pipes are jacket cooled to ensure that pipes will not distort even when operated under hot conditions (plain rolling).

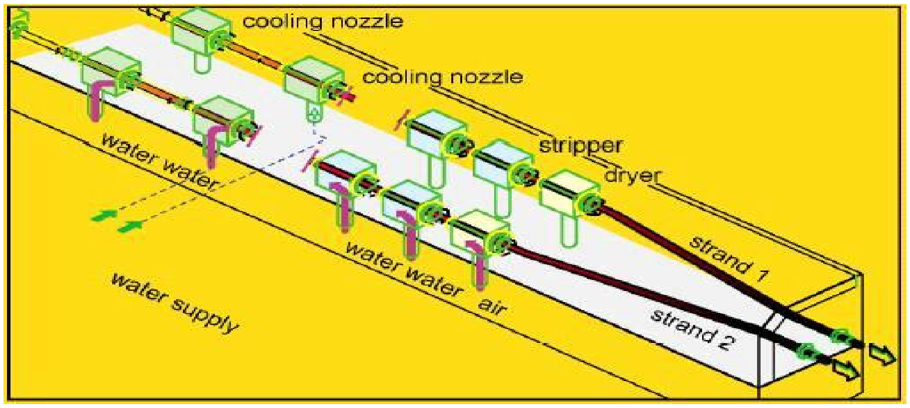


Figure 3.4: SCHEMATIC DIAGRAM OF TEMPCORE PROCESS AT VSP

The width of the ring gap nozzles depend on the specific type of cooling process and the rolled bar diameter. The width of each ring nozzle can be varied by adding or removing spacer discs as required which causes the bush with tapered outer member to take a different axial position relative to the bush with tapered inner element. The width of spacer required for a given ring gap.

Intermediate ring width = (Ring gap width) / Sin 15^0

A stripper unit consists of three cooling heads with ring gap nozzles arranged to discharge water against rolling direction

At the end a dryer unit comprising of 8 nozzles blowing air on the rolled stock is fixed so that bar leaves the cooling stretch in dry condition

3.5. PROCESS TECHNOLOGY OF TEMPCORE PROCESS

The input material for TMT rebars is billet of varying sizes depending upon the final diameters of the rebars. The billets are reheated at a temperature of about 1200C followed by rolling through roughing, intermediate and finishing stands. After the finish rolling, the thermo-mechanical treatment is done in two stages: primary cooling and secondary cooling. Primary cooling involves intensive cooling of hot rolled rebars through water quenching and is provided immediately after last finish rolling stand. The secondary cooling involves normal cooling on the cooling bed (in Merchant Mill) or on the loop conveyor (in wire Rod Mill). Primary cooling ensures martensitic transformation at and near the surface of rebar, while the core steel remains in the austenitic temperature is below MS (Martensite-start temperature).

The depth of the martensite rim can be controlled by intensity of cooling (the temperature below MS) and residence time in the cooling pipe. The heat flux entrapped at the core diffuses out during secondary cooling and tempers the outer martensite ring, resulting in composite microstructure-tempered martensite at the outer ring with the core of ferrite-pearlite structure. This cooling process with some degree of variance with respect to cooling arrangement has been patented under different commercial names like Temprimer and Tempcore. Temprimer process. This involves multiple sequential quenching and tempering cycles. Micro alloying is necessary for rebars having a diameter greater or equal to 22 mm and production rate greater than 140t/hr. Tempcore process it involves a single quench and temper cycle. No micro alloying is required diameter also. Tempcore process has been the most popular so far. This process is being marketed under different brand names to suit specific product requirement.

The two such processes are:

3.5.1. Thermax process:

It involves rapid water quenching of hot rebars immediately after finish rolling through a series water jackets. Intricacy of this technology lies with the control of entry and equalization temperatures of the bar and it is translated into design parameters by way of controlling water volume (flow rate) and pressure in the jacket.

3.5.2. Thermo-coil process:-

This process is employed for the production of 8 and 10 mm diameter TMT rebar/coils. Intensive cooling is introduced immediately after the last finishing stand, followed by further cooling of hot coil over the moving conveyor belt using air suction

3.6. FACTORS INFLUENCING THE PROPERTIES OF REBARS

There are so many factors that influence on the properties of the reinforcement bars. They are as follows:

1. Duration of at first stage
2. Type of cooling equipment
3. Steel composition
4. Finishing temperature of hot rolling sequence

3.6.1. Duration of first stage:

The increase in the yield strength as a function of duration of first stage. The duration of the first stage i.e., Quenching Time acts on the yield trends in three ways

a) The volume of quenched surface layer increases with increase in the duration of the first stage.

b) The tempering temperature decreases with increase in duration of first stage, causing the yield strength of the Martensite to increase.

c) The transformation starts temperature of unquenched zone decreases with increase in duration of first stage.

The thermal analysis showed that the microstructure obtained for steel of a given composition depends essentially on the temperature of the bar after quenching. As this temperature decreases, the microstructure change from ferrite-pearlite to ferrite-pearlite-bainite and finally to bainite.

3.6.2. Type of cooling equipment:

The yield strength vs cooling time for three cooling devices. For a given cooling time, the gains in yield strength are seen to vary significantly, demonstrating the importance of selecting the right type of cooling equipment. The best cooling devices is that which optimizes between thermal efficiency, simplicity of design, and operating costs.

The technological problems such as wear, bat guidance and slowing effect of the cooling water were solved during the industrial trails

3.6.3. Steel Composition

The following value determine the steel composition.

- Desired minimum yield strength
- Maximum acceptable value of the yield strength / tensile strength ratio
- Desired ductility
- Maximum carbon content as related to weldability
- Maximum achievable duration of the first stage as related to design speed of rolling mill
- Available flow rate and pressure of water

The effect of carbon on the properties of the Tempcore bar is that with the increase in carbon content, the starting temperature of the martensitic transformation decreases sharply resulting in decreases in volume percentage of quenched surface layer of the given cooling sequence. This means that all other things being equal, the increase in yield strength will be more in low carbon steels than in medium or high carbon steels, also with increasing carbon content also modified the position of the TTT curves and cause acicular structures within the unquenched portion. In case when core consists of ferrite-pearlite, carbon percentage increases the yield strength by interstitial solid solution strengthening of ferrite and by increasing the volume fraction and fineness of pearlite.

3.6.4. Finishing temperature of rolling sequence

Higher finish rolling temperature causes the growth of austenitic grains and Hence have adverse affect on its properties. Another drawback of finishing rolling temperature is that the amount of heat to be removed during the first stage in order to reach a given temperature at the end of the second stage increases. This corresponds to a similar percentage increases in this length of the cooling device and off the water composition.

3.7. CENTRIFUGAL PUMPS

Centrifugal pump is a roto-dynamic machine that imparts energy to fluid by rotating impeller to increase the pressure of a fluid. These pumps are commonly used to move liquids through a piping system. When the fluid enters the pump impeller along or near to the rotating axis it is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits into the downstream piping system. Centrifugal pumps are used for large discharge through smaller heads.

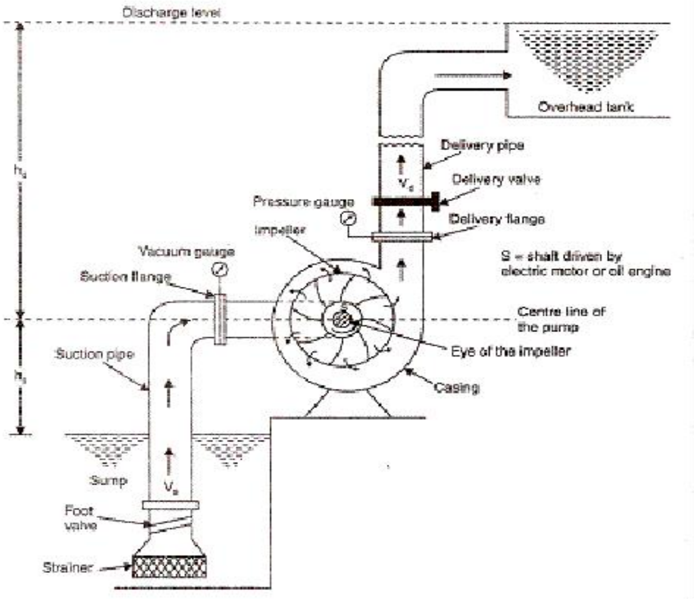


Figure 3.5: Layout of Centrifugal Pumps

The fluid enters the inlet of the centrifugal pump under atmospheric pressure, and flows into the eye of the impeller. The Centrifugal force exerted on the liquid by the rotating impeller, moves the liquid away from the impeller eye and out along the impeller vanes to their extreme tip where the liquid is then forced against the inside walls of the volute and out through the discharge of the pump.

Due to the reduction of pressure occurring at pump inlet and impeller eye, liquid is drawn into the pump in continuous flow as it moves through the pump. The shape of the volute is wider at discharge point which permits the liquid to expand, and slows down the motion of the liquid. When the water from the impeller strikes the side of the volute, the velocity is increased. This accelerated motion is called "Kinetic Energy", which is the energy in motion. As soon as the liquid slows down inside the volute, Kinetic Energy is transformed into pressure. This pressure then forces the liquid out of the pump discharge nozzle into the outlet pipe lines.

3.8. IMPELLER

The impeller is of cast manufacture and open type; i.e. the impeller vanes are open in front. This type allows visual inspection of the vanes and the area between them. A semi-open impeller is also available which is easy

The impeller has two or multiple vanes depending on the type of centrifugal pump. The impeller diameter and width will vary dependent upon the duty requirements.

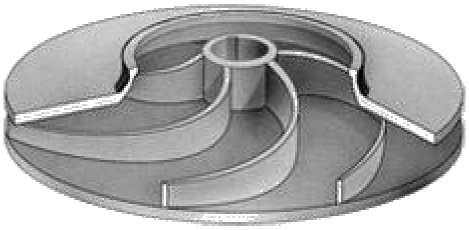


Figure 3.6: Impeller of Centrifugal Pump

There are three types of impellers, based on the number of shrouds.

- **Open Impeller**: The vanes are cast free on both sides.
- **Semi-Open Impeller**: The vanes are free on one side and enclosed on the other.
- **Closed Impeller:** The vanes are located between the two discs, all in a single casting.

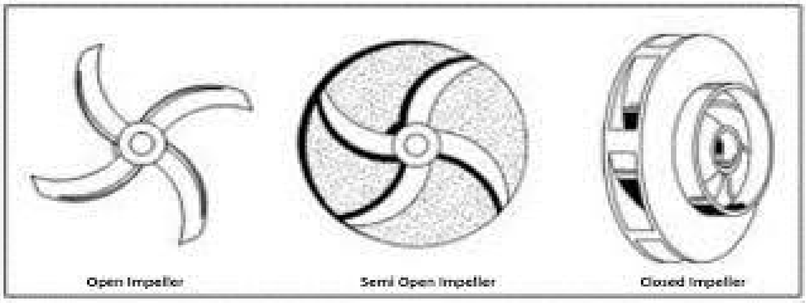


Figure 3.7: Various Types of Impellers

3.9. CENTRIFUGAL PUMP WORKING PRINCIPLE

A Pump is generally used to induce flow or raise the pressure of a liquid. Centrifugal pumps are a category of Dynamic pumps. The **working principle** of **centrifugal pumps** involves imparting energy to the liquid by means of a centrifugal force developed by the rotation of an impeller that has several blades or vanes. The basic **centrifugal pump theory** of working comprises of the following working stages.

- Liquid enters the pump casing at the impeller eye.

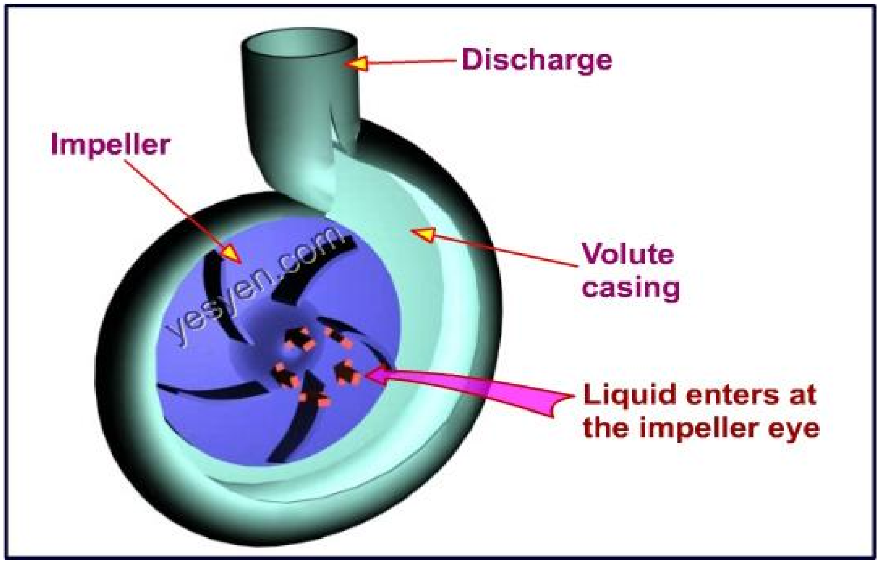


Figure 3.8: Working Principle of Centrifugal Pump

Velocity energy is imparted to the liquid by means of the centrifugal force produced by rotation of the impeller and the liquid is radially pushed out towards the impeller periphery.

The velocity energy of liquid is converted to pressure energy by directing it to an expanding volute design casing in a volute type centrifugal pump or diffusers in a turbine pump.

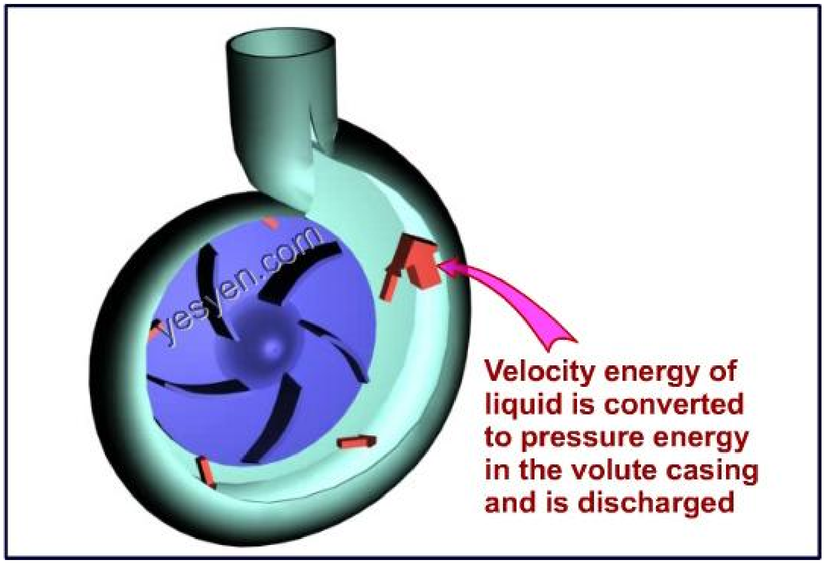


Figure 3.9: Energy Conversion in Centrifugal Pump

Pumps are primarily classified as dynamic pumps and positive displacement pumps. As explained in theory above, dynamic pumps operate by developing a high liquid velocity. Positive displacement pumps operate by forcing a fixed volume of liquid. The dynamic action in the centrifugal pump working principle makes it comparatively lesser efficient than positive displacement pumps. However they operate at relatively higher speeds thus permitting a high liquid flow rate in relation to the physical size of the pump. They also usually require lesser installation and maintenance cost. Because of these advantages centrifugal pumps are the most commonly used pumps in industries.

Centrifugal pumps have various application in agriculture, infrastructure, industries, aerodynamics. Centrifugal pumps are used to deliver fuel for high capacity engines in ships and rockets

3.10. TYPES OF CENTRIFUGAL PUMPS

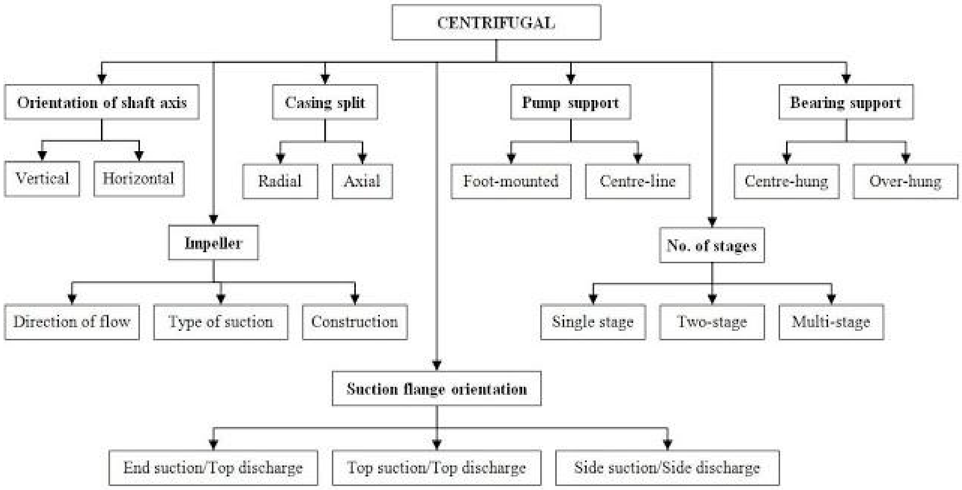


Figure 3.10: Different Types of Centrifugal Pumps

Centrifugal pumps generate flow by using one of three actions:

- axial flow.
- radial flow
- mixed flow.

3.10.1. AXIAL FLOW IMPELLER

Axial flow pumps are characterized by high flow and low pressure. They lift liquid in a direction parallel to the impeller shaft, operating essentially the same as a boat propeller. Pressure is developed wholly by the propelling action of the impeller vanes.

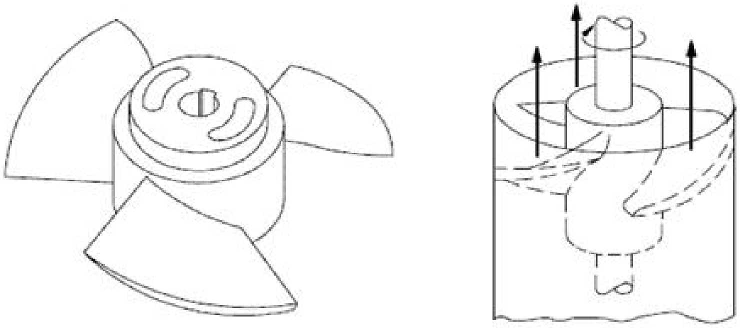


Figure 3.11: Axial Flow Impeller

3.10.2. RADIAL IMPELLER

Radial flow pumps are characterized by high pressure and low flow. They accelerate liquid through the center of the impeller and out along the impeller blades at right angles (radially) to the pump shaft. Pressure is developed wholly by centrifugal force.

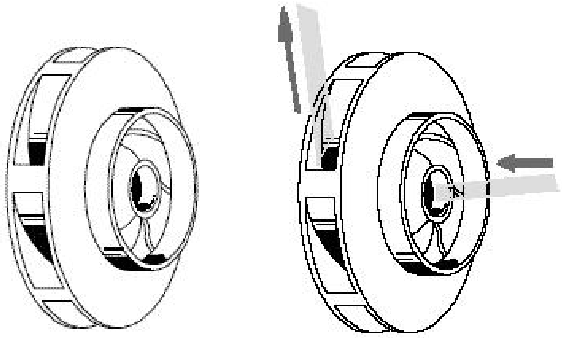


Figure 3.12: Radial Flow Impeller

3.10.3. MIXED FLOW IMPELLER

Mixed flow pumps incorporate characteristics from both axial and radial flow pumps, with typically medium flow and medium pressure. They push liquid out away from the pump shaft at an angle greater than 90°. Pressure is developed partly by centrifugal force and partly by the lifting action of the impeller.

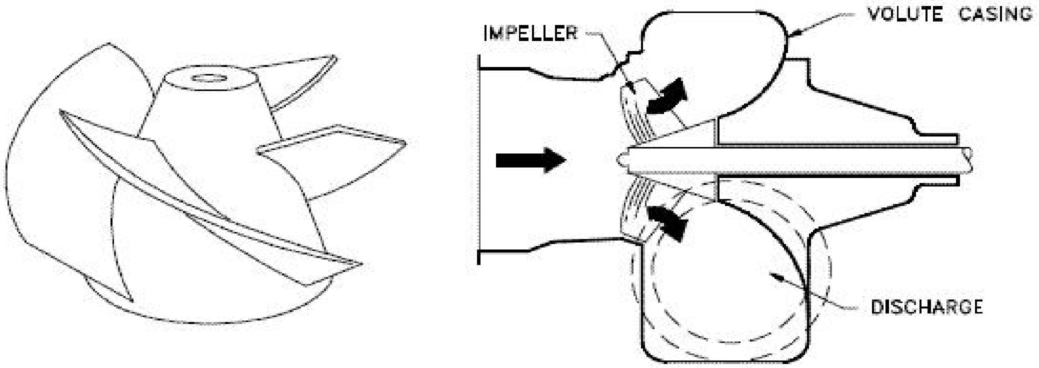


Figure 3.13: Mixed Flow Impeller

3.11. ENERGY AUDIT OF CENTRIFUGAL PUMPS IN LIGHT AND MEDIUM MERCHANT MILL

In Light and medium merchant mill of a steel manufacturing industry production of reinforced bars (rebars) takes place. Rebars are produced with tempcore process. Tempcore process is cooling of hot rolled bars is specially designed equipment called tempcore boxes. Tempcore Boxes require water input for cooling which is supplied by centrifugal pumps.

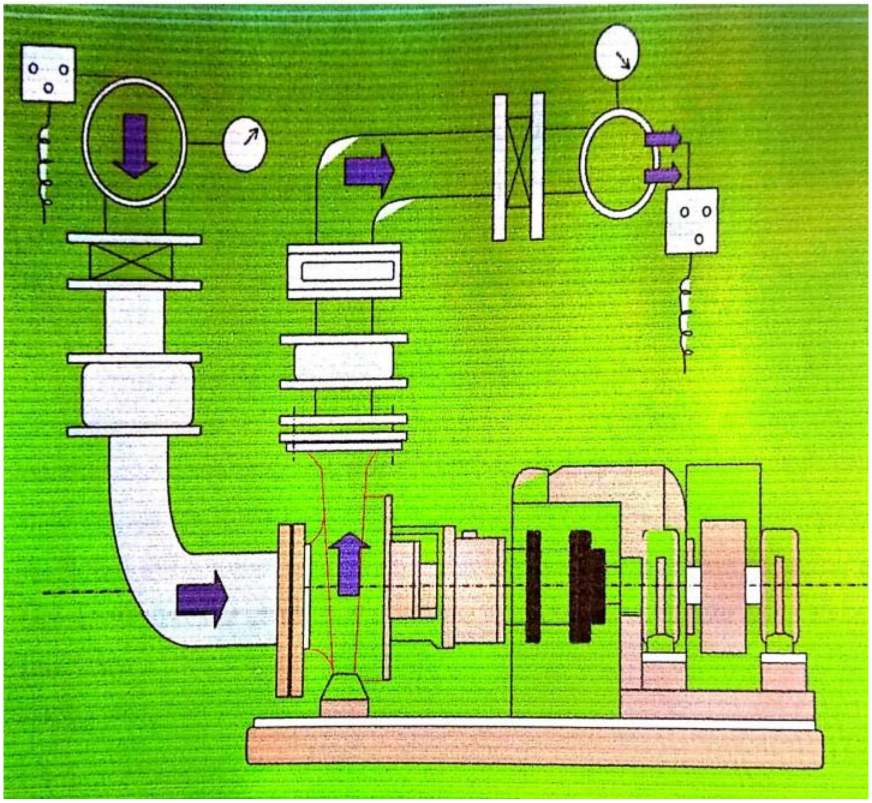


Figure 3.14: Layout of Centrifugal Pump in LMMM Department

Tempcore boxes requires water input according to the microstructure of reinforced bars. So multiple pumps are connected to tempcore box. These pumps works according to the water input required for tempcore boxes. Different microstructures of reinforced bars require different water input. The microstructure of reinforced bars consists of tempered martensite, bainaite, ferrite. Themartensite formation will purely depends on the amount of cooling given to hot rolled bars. The amount of cooling will purely depends on the water input to the tempcore box. So, for the required amount of water input centrifugal pumps must work in combination. Combination of centrifugal pumps are used for tempcore process.

In the Light and Medium Merchant Mill of Vizag Steel Plant there were six pumps connected to tempcore box. Out of six only two were used while operating. Out of six three pumps are previously installed centrifugal pumps i.e. old pumps and three pumps are newly installed pumps i.e. new pumps.

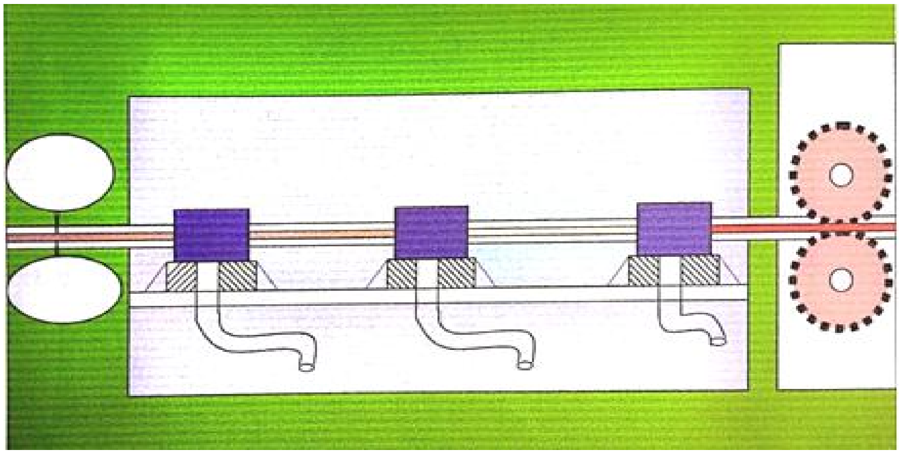


Figure 3.15: Side View of Tempcore Box Arrangement in LMMM Department

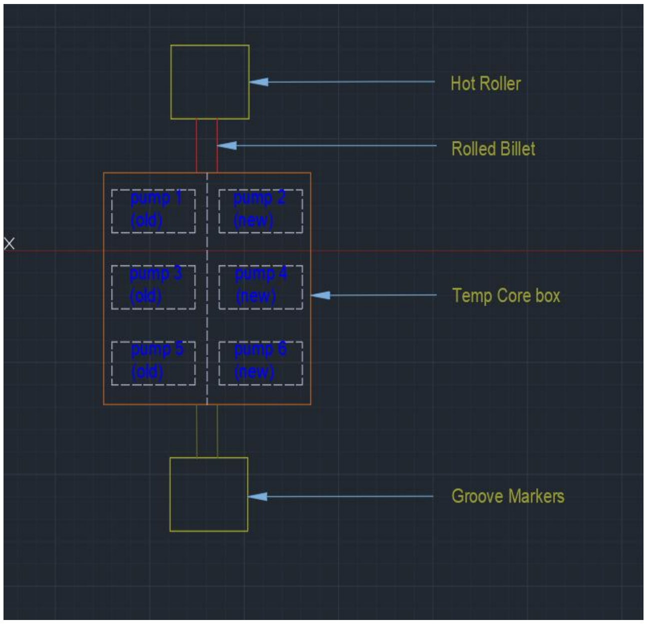


Figure 3.16: Top View of Tempcore Box Arrangement in LMMM Department

3.11.1. NECESSARY CONDITIONS FOR COMBINATION OF PUMPS

There are some necessary conditions required for combination of centrifugal pumps

- Only two centrifugal pumps can form combination of pumps.
- There should be at least one or more than one old centrifugal pump in the combination.
- The selected combination of pumps could not have more than one new pump.

In LMMM department of Vizag steel plant, tempcore box is connected to six centrifugal pumps, out of six centrifugal pumps three pumps are old pumps and remaining three are new pumps. By following the necessary conditions there are a total of twelve (12) combination of centrifugal pumps are possible. By conducting energy audit for these twelve (12) combination of pump we can find out the best combination of pumps used for tempcore process.

3.11.2. ENERGY AUDIT METHODOLOGY

Energy Audit is conducted on centrifugal pumps used for tempcore process. The energy audit methodology for centrifugal pumps consists of following steps.

STEP 1: Calculating the basic data of centrifugal pumps like head, shaft power, hydraulic power efficiency with the help of pump inputs like inlet and outlet pressures, flow rate, current consumed etc.

STEP 2: Finding the combination of pumps with the help of necessary conditions.

STEP 3: Finding the overall efficiency of combination of centrifugal pumps at a maximum loading condition.

STEP 4: Select the combination of centrifugal pumps which have maximum efficiency at maximum load.

3.12. FORMULAS USED FOR ENERGY AUDIT

- Head(h) = $(P_2-P_1)/\rho g$ (m) (eqn 1)

- Hydraulic power = $\rho Qgh/3600$ (W) (eqn 2)
- Shaft power = $\sqrt{3}VI\cos\varphi\ \eta_{motor}$ (W) (eqn 3)
- Efficiency(η) = Hydraulic power / Shaft power (eqn 4)

3.13. ENERGY AUDIT FOR CENTRIFUGAL PUMPS USED FOR PRODUCTION OF 28 REBAR

Table 3.1: Energy Audit for Pump 1 for 28 Rebar (Old Pump)

S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	65	5.1	10.3	253	313	53.00	45.205	152.715	29.60
2)	72	4.85	9.8	260	422	50.45	58.014	156.941	36.90
3)	80	4.6	9.5	265	504	49.94	68.58	159.95	42.87
4)	88	4.3	8.9	275	630	46.84	80.41	165.99	48.44
5)	100	4.0	7.9	288	793	39.75	85.89	183.84	46.71

MODEL CALCULATIONS FOR ENERGY AUDIT

Consider the model calculations for pump 1 at 28 rebar

Let,

P_1 = Inlet pressure to the centrifugal pump= 4.0 bar

P_2 = Outlet pressure to the centrifugal pump= 7.9 bar

I = Current supplied to the motor= 288 amps

V = Voltage supplied to the motor= 210 V

Q = Flow rate of fluid to pump= 793 m^3/hr

ρ = Density of fluid (water) = 1000 kg/m^3

g = Acceleration due to gravity = 9.81 m/sec^2

η_{motor} = Motor efficiency = 0.68(for old pump)

= 0.81(for new pump)

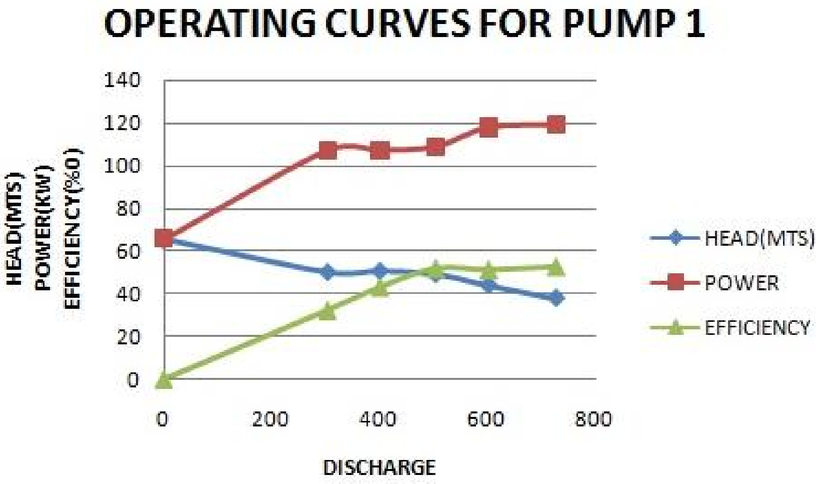
Cosφ = Power factor of motor = 1

Head (h) = $(P_2-P_1)/\rho g$ = 39.75 m (From eqn 1)

Hydraulic power = $\rho Qgh/3600$ = 85.89 KW (From eqn 2)

Shaft power = $\sqrt{3}VI\cos\varphi\ \eta_{motor}$ = 183.84 KW (From eqn 3)

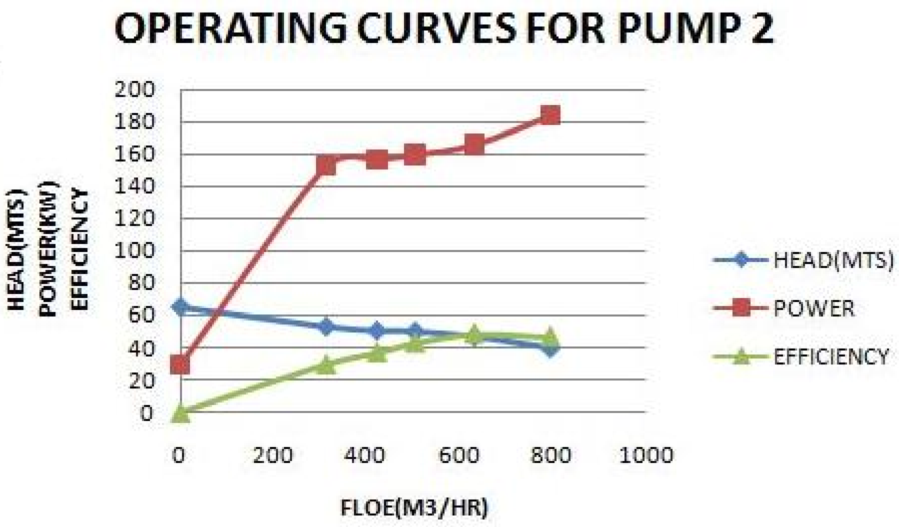
Efficiency(η) = Hydraulic power/Shaft power = 46.71 % (From eqn 4)



Graph 3.1 Operating Curves for Pump1 For 28 Rebar

Table 3.2: Energy Audit for Pump 2 For 28 Rebar (New Pump)

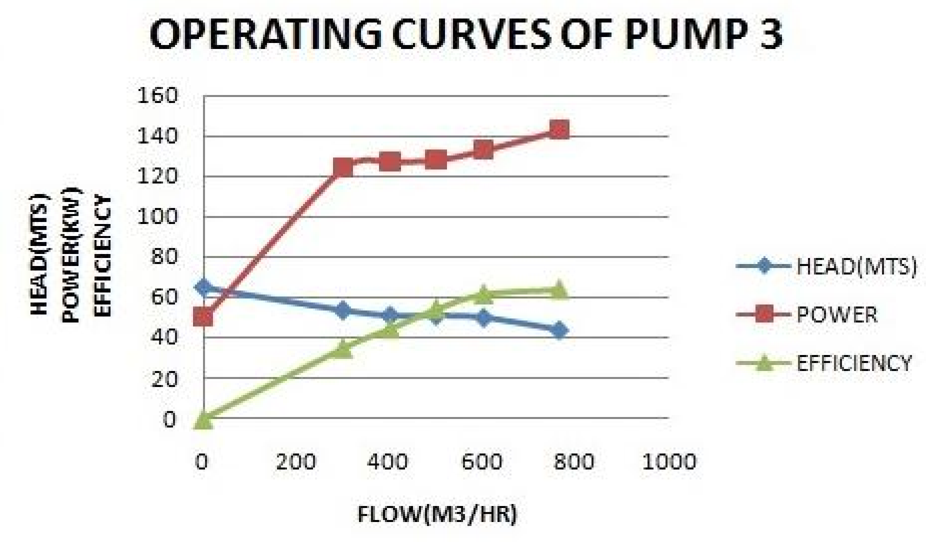
S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	65	5.1	10.3	253	313	53.00	45.205	152.715	29.60
2)	72	4.85	9.8	260	422	50.45	58.014	156.941	36.90
3)	80	4.6	9.5	265	504	49.94	68.58	159.95	42.87
4)	88	4.3	8.9	275	630	46.84	80.41	165.99	48.44
5)	100	4.0	7.9	288	793	39.75	85.89	183.84	46.719



Graph 3.2: Operating Curves for Pump 2 For 28 Rebar

Table 3.3: Energy Audit for Pump 3 For 28 Rebar (Old Pump)

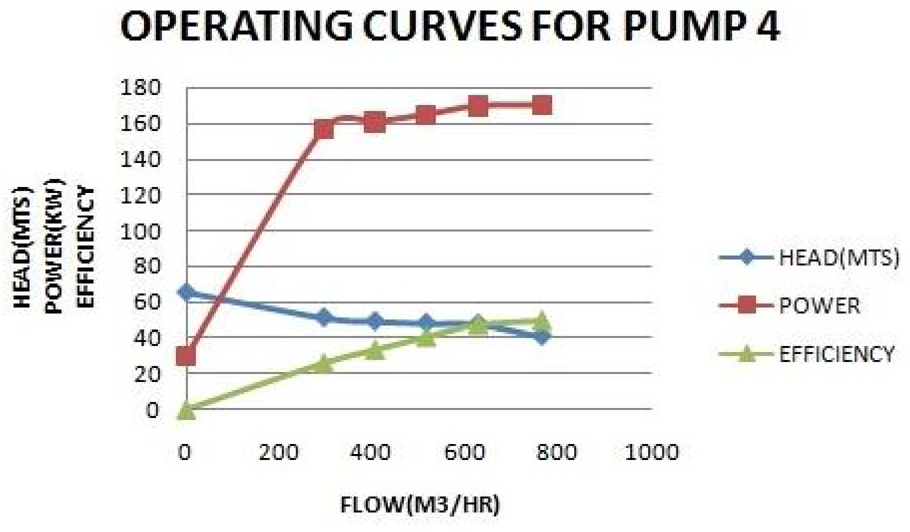
S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	65	4.6	9.8	2532	300	53.64	43.36	123.89	35
2)	72	4.6	9.6	258	402	51	55.86	126..84	44.69
3)	82	4.6	9.6	260	501	51	69.62	127.82	54.47
4)	88	4.6	9.5	270	602	49.98	81.98	132.74	61.77
5)	100	4.2	8.5	290	765	43.86	91.43	142.57	64.13



Graph 3.3: Operating Curves for Pump 3 For 28 Rebar

Table 3.4: Energy Audit for Pump 4 For 28 Rebar (New Pump)

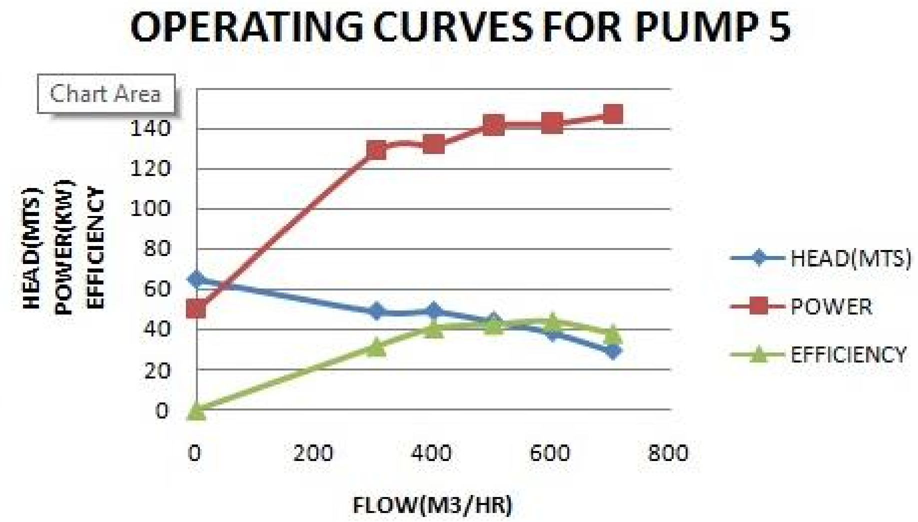
S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	65	5.2	10.2	260	295	50.96	40.96	156.94	26.09
2)	75	5.0	9.8	266	405	48.92	53.98	160.56	33.61
3)	80	4.6	9.3	273	515	47.91	67.23	163.78	40.80
4)	88	4.25	8.9	281	625	47.40	80.72	169.61	47.59
5)	100	3.9	7.9	292	762	40.77	84.65	170.03	49.78



Graph 3.4: Operating Curves for Pump 4 For 28 Rebar

Table 3.5: Energy Audit for Pump 5 For 28 Rebar (Old Pump)

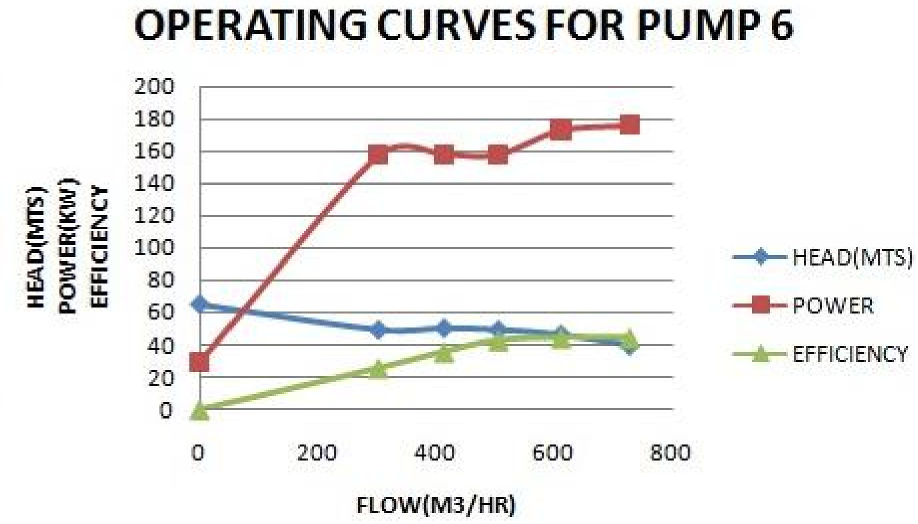
S.NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
1)	70	4.8	9.6	262	304	48.96	40.55	128.81	31.49
2)	5	4.8	9.6	268	400	48.96	53.36	131.76	40.50
3)	82	4.7	9.0	288	501	43.86	59.87	141.59	42.29
4)	92	4.6	8.35	290	600	38.25	62.53	142.57	43.86
5)	100	4.4	7.25	299	702	29.07	55.58	147.00	37.81



Graph 3.5: Operating Curves for Pump 5 For 28 Rebar

Table 3.6: Energy Audit for Pump 6 For 28 Rebar (New Pump)

S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	68	4.8	9.6	261	301	48.92	40.125	157.54	25.46
2)	75	4.65	9.55	262	412	49.94	56.06	158.14	35.44
3)	82	4.55	9.35	262	504	48.93	67.108	158.14	42.47
4)	90	4.4	8.9	287	610	45.92	76.24	173.23	44.008
5)	100	4.2	8.05	292	726	39.24	77.695	176.25	44.08



Graph 3.6: Operating Curves for Pump 6 For 28 Rebar

3.13.1. COMBINATION OF PUMPS FOR 28 REBAR

3.13.1.1. COMBINATION OF OLD PUMP AND NEW PUMP FOR 28 REBAR

Table 3.7: Combination of Pump 1 And Pump 2 for 28 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1	100	4.2	7.9	290	726	37.74	74.66	142.57	
2	100	4.0	7.9	288	793	34.75	85.89	183.842	
					1519	77.49	160.55	326.412	49.186

Table 3.8: Combination of Pump 1 And Pump 4 for 28 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1	100	4.2	7.9	290	726	37.74	74.66	142.57	
4	100	3.9	7.9	292	762	40.77	84.65	170.03	
					1488	78.11	159.31	312.6	50.96

Table 3.9: Combination of Pump 1 And Pump 6 For 28 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1	100	4.2	7.9	290	726	37.74	74.66	142.57	
6	100	4.2	8.05	292	726	39.24	77.695	176.256	
					1452	76.98	152.35	318.82	47.78

Table 3.10: Combination of Pump 3 And Pump 2 for 28 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
3	100	4.2	8.5	290	765	43.86	91.43	142.57	
2	100	4.0	7.9	288	793	34.75	85.89	183.842	
					1558	83.61	177.32	326.412	54.37

Table 3.11: Combination of Pump 3 And Pump 4 for 28 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
3	100	4.2	8.5	290	765	43.86	91.43	142.57	
4	100	3.9	7.9	292	762	40.77	84.05	170.25	
					1527	84.63	176.08	312.6	56.32

Table 3.12: Combination of Pump 3 And Pump 6 For 28 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
3	100	4.2	8.5	290	765	43.86	91.43	142.57	
6	100	4.2	8.05	292	726	39.24	77.69	176.25	
					1491	83.1	169.125	318.82	53.04

Table 3.13: Combination of Pump 5 And Pump 2 For 28 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
5	100	4.9	7.25	299	702	29.07	55.58	147	
2	100	4.0	7.9	288	793	34.75	85.89	183.842	
					1495	68.82	141.47	330.84	42.76

Table 3.14: Combination of Pump 5 And Pump 4 For 28 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
5	100	4.9	7.25	299	702	29.07	55.58	147	
4	100	3.9	7.9	292	762	40.77	84.65	170.03	
					1469	69.89	140.23	317.03	44.23

Table 3.15: Combination of Pump 5 And Pump 6 For 28 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
5	100	4.9	7.25	299	702	29.07	55.58	147	
6	100	4.2	8.05	292	726	39.24	77.69	176.25	
					1428	68.31	133.27	309.52	43.05

3.13.1.2. COMBINATION OF TWO OLD PUMPS FOR 28 REBAR

Table 3.16: Combination of Pump 1 And Pump 3 For 28 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
1	100	4.2	7.9	290	726	37.74	74.66	142.57	
3	100	4.2	8.5	290	765	43.86	91.43	142.57	
					1491	81.6	166.09	285.14	58.24

Table 3.17: Combination of Pump 1 And Pump 5 For 28 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
1	100	4.2	7.9	290	726	37.74	74.66	142.57	
5	100	4.9	7.25	299	702	29.07	55.58	147	
					1428	66.81	130.24	289.57	45.06

Table 3.18: Combination of Pump 3 And Pump 5 For 28 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
3	100	4.2	8.5	290	765	43.86	91.43	142.57	
5	100	4.9	7.25	299	702	29.07	55.58	147	
					1467	73.53	147.61	290.27	50.64

By performing energy audit the combination of pumps which have highest efficiency is used.

By performing Energy audit on combination of pumps the following conditions are proposed

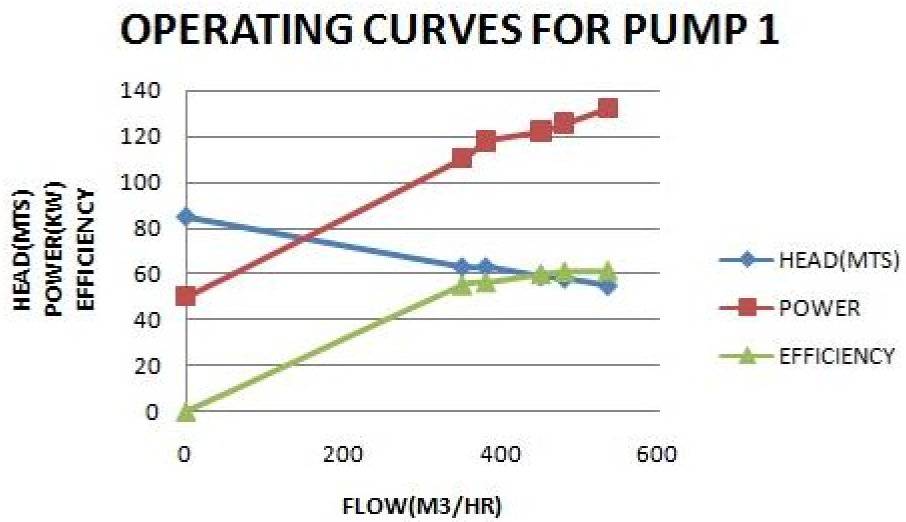
- If we have to use two old pumps then combination of pump 1 and pump 3 is used
- If we have to use one old pump and one new pump then combination of pump 3 and pump 4 is used

3.14. ENERGY AUDIT FOR CENTRIFUGAL PUMPS USED FOR PRODUCTION OF 16 REBAR

Table 3.19: Energy Audit for Pump 1 For 16 Rebar (Old Pump)

S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	72.5	4.5	10.7	224	350	63.24	60.31	110.12	54.77
2)	76.6	4.5	10.7	238	380	63.24	65.48	117.61	55.96
3)	82	4.5	10.3	248	450	59.16	72.54	121.92	59.50
4)	90	4.5	10.2	255	480	58.14	76.04	125.36	60.66
5)	100	4.5	9.9	268	535	55,08	80.29	131.76	60.94

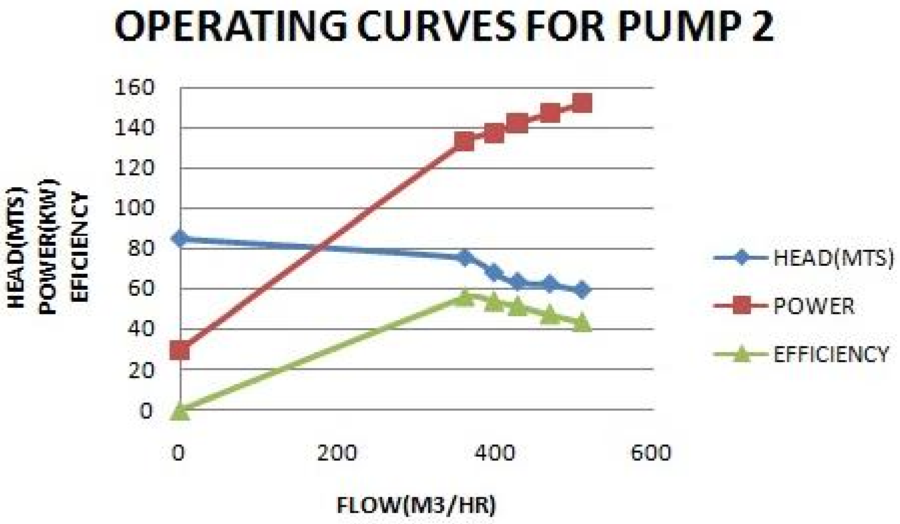
Similar calculations are done for 16 rebar



Graph 3.7: Operating Curves for Pump 1 For 16 Rebar

Table 3.20: Energy Audit for Pump 2 For 16 Rebar (New Pump)

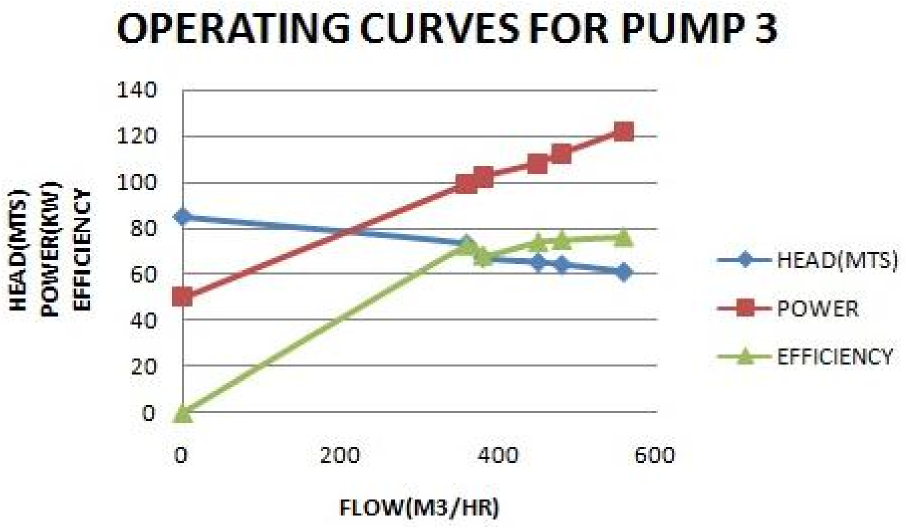
S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	70	4.7	12.1	220	361	75.43	74.20	132.79	55.87
2)	76	4.6	11.25	227	398	67.78	73.51	137.02	53.64
3)	83	4.6	10.8	235	428	63.20	73.20	141.85	51.60
4)	90	4.5	10.6	243	469	62.18	69.46	146.67	47.35
5)	100	4.4	10.2	251	510	59.123	66.16	151.50	43.66



Graph 3.8: Operating Curves for Pump 2 For 16 Rebar

Table 3.21: Energy Audit for Pump 3 For 16 Rebar (Old Pump)

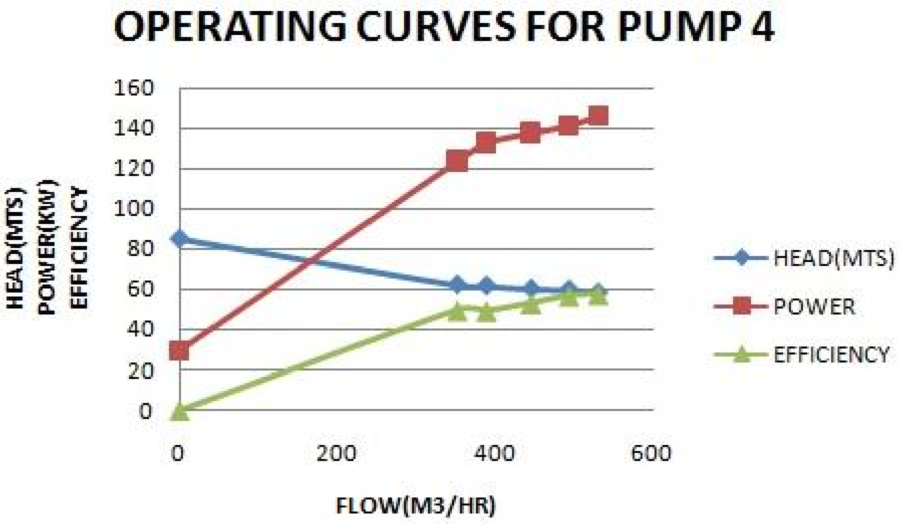
S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	70	4.5	11.7	202	359	73.39	71.79	98.97	72.53
2)	74	4.5	11.1	208	380	67.32	69.70	102.26	68.17
3)	81	4.5	10.9	220	450	65.28	80.04	108.16	74.01
4)	86	4.5	10.8	228	480	64.26	84.05	112.09	74.98
5)	100	4.4	10.6	248	558	61.2	93.05	121.92	76.32



Graph 3.9: Operating Curves For Pump 3 For 16 Rebar

Table 3.22: Energy Audit for Pump 4 For 16 Rebar (New Pump)

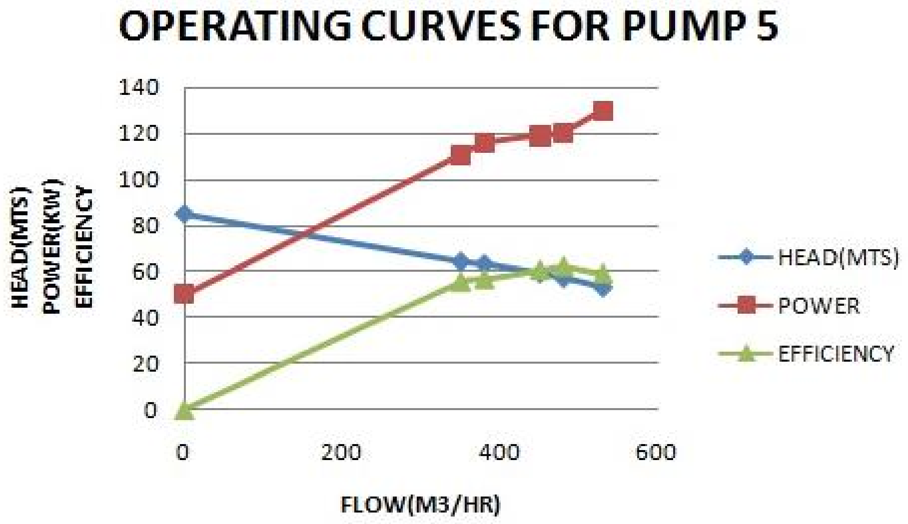
S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	68	4.8	10.9	205	351	62.18	61.16	123.74	49.42
2)	72	4.75	10.8	220	388	61.67	65.20	132.79	49.10
3)	79	4.7	10.6	228	444	60.14	72.76	137.62	52.87
4)	85	4.4	10.25	235	492	59.63	79.99	141.5	56.53
5)	100	4.1	9.8	242	529	58.10	83.75	146.07	57.33



Graph 3.10: Operating Curves for Pump 4 For 16 Rebar

Table 3.23: Energy Audit for Pump 5 For 16 Rebar (Old Pump)

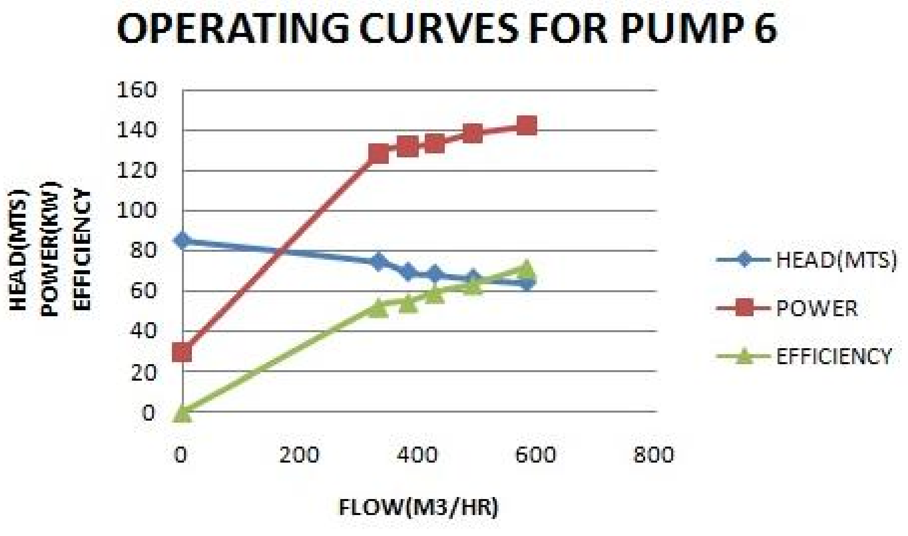
S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	71	4.5	10.8	225	350	64.26	61.28	110.62	55.40
2)	74	4.5	10.7	225	380	63.24	65.48	115.53	56.68
3)	83	4.5	10.3	242	450	59.16	72.54	118.97	60.47
4)	90	4.5	10.1	245	480	57.12	74.71	120.45	62.03
5)	100	4.5	9.7	264	530	53.04	76.60	129.79	59.02



Graph 3.11: Operating Curves for Pump 5 For 16 Rebar

Table 3.24: Energy Audit for Pump 6 For 16 Rebar (New Pump)

S.NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1)	65	4.9	12.2	212	330	74.41	66.913	127.96	52.29
2)	72	4.8	11.6	218	380	69.39	71.77	131.58	54.54
3)	80	4.4	11.1	221	425	68.29	79.08	133.39	59.286
4)	88	4.1	10.6	229	490	66.25	88.40	138.22	63.39
5)	100	3.6	9.9	235	580	64.20	101.46	141.85	71.52



Graph 3.12: Operating Curves for Pump 6 For 16 Rebar

3.14.1. COMBINATION OF PUMPS FOR 16 REBAR

3.14.1.1. COMBINATION OF OLD PUMP AND NEW PUMP FOR 16 REBAR

Table 3.25: Combination of Pump 1 And Pump 2 For 16 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
1	100	4.5	9.4	268	535	55.08	80.29	131.70	
2	100	4.4	10.2	251	516	59.12	66.16	151.50	
					1051	121.24	146.45	283.2	51.71

Table 3.26: Combination of Pump 1 And Pump 4 For 16 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
1	100	4.5	9.4	268	535	55.08	80.29	131.70	
4	100	4.1	9.8	242	529	58.10	83.75	146.07	
					1064	113.18	164.04	277.7	59.05

Table 3.27: Combination of Pump 1 And Pump 6 For 16 Rebar

PUMP NO	**% OPENING**	**INLET PRESSURE (bar)**	**OUTLET PRESSURE (bar)**	**MOTOR CURRENT (amps)**	**FLOW (m^3/hr)**	**HEAD (m)**	**HYDRAULIC POWER (kw)**	**SHAFT POWER (kw)**	**EFFICIENCY %**
1	100	4.5	9.4	268	535	55.08	80.29	131.70	
6	100	3.6	9.9	235	580	64.20	101.46	141.85	
					1115	119.28	181.75	275.55	65.95

Table 3.28: Combination of Pump 3 And Pump 2 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
3	100	4.9	10.6	248	558	61.2	93.05	121.92	
2	100	4.4	10.2	251	516	59.12	66.16	151.50	
					1074	120.323	159.21	273.42	58.22

Table 3.29: Combination of Pump 3 And Pump 4 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
3	100	4.9	10.6	248	558	61.2	93.05	121.92	
4	100	4.1	9.8	242	529	58.10	83.75	146.07	
					1087	119.3	176.8	267.99	65.97

Table 3.30: Combination of Pump 3 And Pump 6 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
3	100	4.9	10.6	248	558	61.2	93.05	121.92	
6	100	3.6	9.9	235	580	64.20	101.46	141.85	
					1138	125.4	194.51	263.77	73.74

Table 3.31: Combination of Pump 5 And Pump 2 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
5	100	4.5	9.7	269	530	53.04	76.60	129.79	
2	100	4.4	10.2	251	516	59.12	66.16	151.50	
					1046	112.163	142.76	281.29	50.75

Table 3.32: Combination of Pump 5 And Pump 4 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
5	100	4.5	9.7	269	530	53.04	76.60	129.79	
4	100	4.1	9.8	242	529	58.10	83.75	146.07	
					1059	111.19	160.353	275.46	58.21

Table 3.33: Combination of Pump 5 And Pump 6 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
5	100	4.5	9.7	269	530	53.04	76.60	129.79	
6	100	3.6	9.9	235	580	64.20	101.46	141.85	
					1110	117.29	178	271.64	65.52

3.14.1.2. COMBINATION OF TWO OLD PUMPS FOR 16 REBAR

Table 3.34: Combination of Pump 1 And Pump 3 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1	100	4.5	9.4	268	535	55.08	80.29	131.70	
3	100	4.9	10.6	248	558	61.2	93.05	121.92	
					1093	116.28	173.34	253.68	68.33

Table 3.35: Combination of Pump 1 And Pump 5 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
1	100	4.5	9.4	268	535	55.08	80.29	131.70	
5	100	4.5	9.7	269	530	53.04	76.60	129.79	
					1065	108.12	156.4	261.52	59.97

Table 3.36: Combination of Pump 3 And Pump 5 For 16 Rebar

PUMP NO	% OPENING	INLET PRESSURE (bar)	OUTLET PRESSURE (bar)	MOTOR CURRENT (amps)	FLOW (m^3/hr)	HEAD (m)	HYDRAULIC POWER (kw)	SHAFT POWER (kw)	EFFICIENCY %
3	100	4.9	10.6	248	558	61.2	93.05	121.92	
5	100	4.5	9.7	269	530	53.04	76.60	129.79	
					1088	114.11	169.653	251.74	67.40

By performing energy audit the combination of pumps which have highest efficiency is used.

By performing Energy audit on combination of pumps the following conditions are proposed

- If we have to use two old pumps then combination of pump 1 and pump 3 is used
- If we have to use one old pump and one new pump then combination of pump 3 and pump 6 is used

CHAPTER 4

MODELLING AND ANALYSIS

Centrifugal pump impellor is used for the supply of coolant(water) in the tempcore boxes in LMMM department of Visakhapatnam steel plant. Centrifugal Pump consists of two main parts namely impellor and casing. So as impeller is the main part of the centrifugal pump, we are going to design Impeller which is used for tempcore process in SolidWorks software and Modal Analysis for the same impeller is done in ANSYS Workbench.

So, by designing the impeller in SOLIDWORKS and performing model analysis using ANSYS we get the deformation of centrifugal impellor. so, to design the impellor in solid works we have taken the dimensions of an impellor from fig.4.1. and have made an impellor. To perform

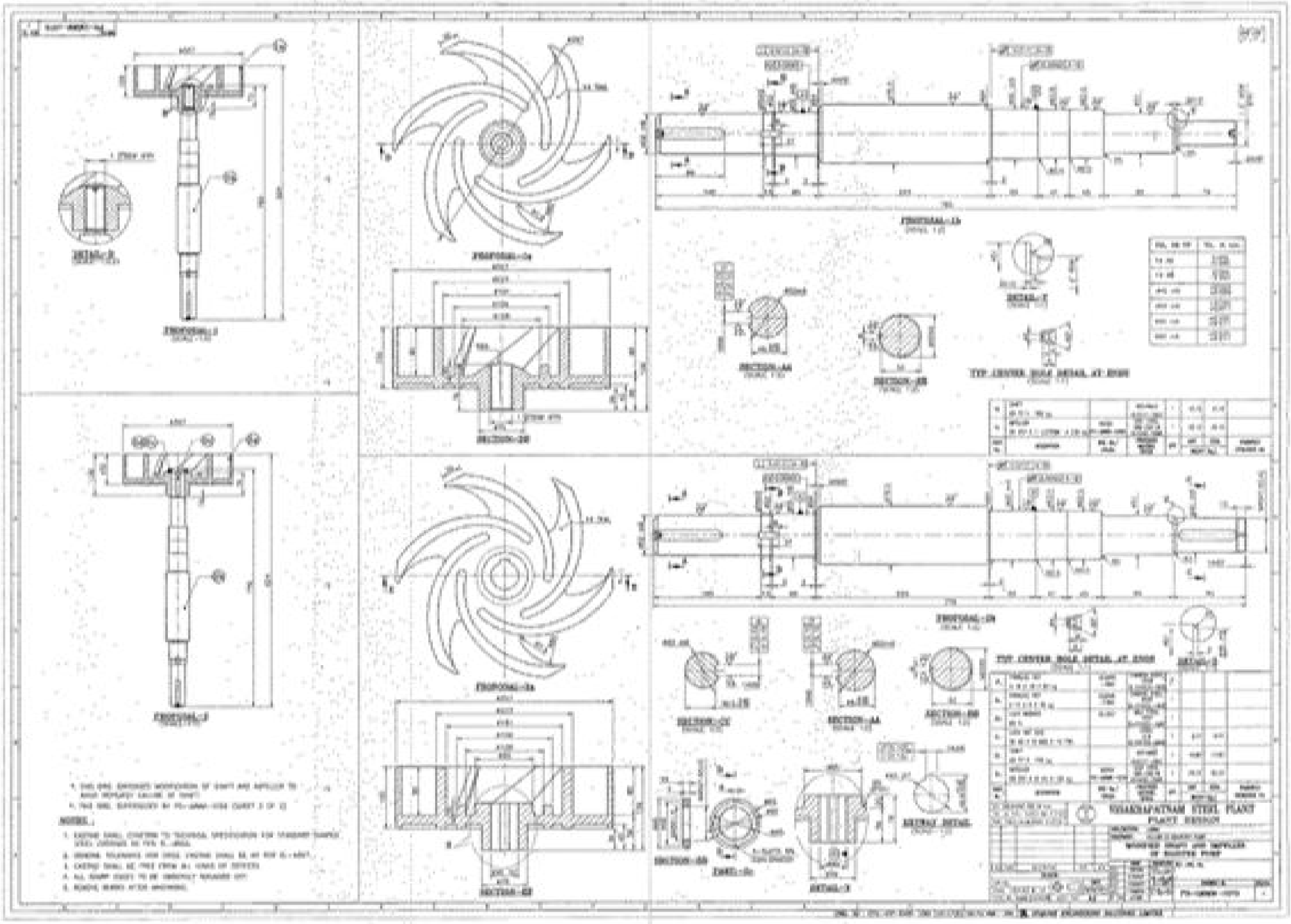
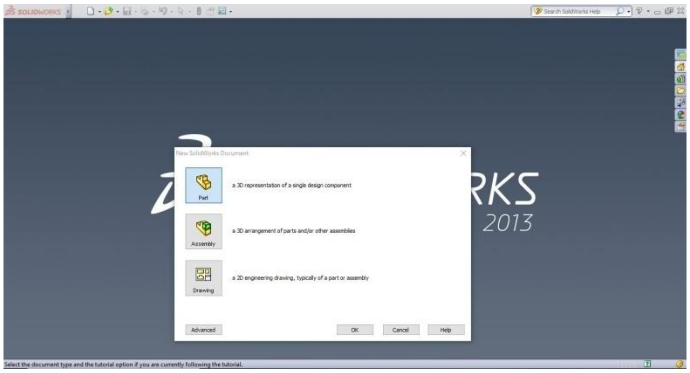


Figure 4.1: Dimensions of Impeller

4.1 PROCEDURE OF MODELLING IN SOLID WORKS:

Step 1: Open the SOLIDWORKS application and select the part geometry from of design of centrifugal pump impeller.



a 3D representation of a single design component

a 3D arrangement of parts and/or other assemblies

a 2D engineering drawing, typically of a part or assembly

Select the document type and the tutorial option if you are currently following the tutorial.

Figure 4.2: SolidWorks Interface.

Step 2: Select the top plane in part geometry

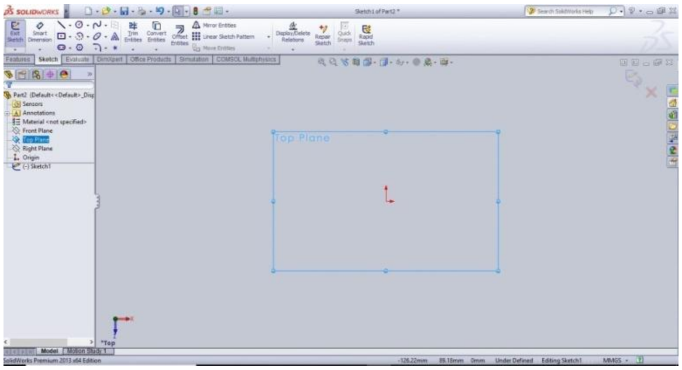
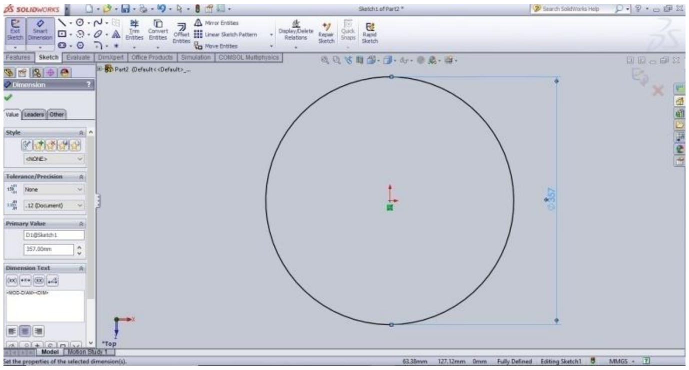


Figure 4.3: Selection of Top Plane

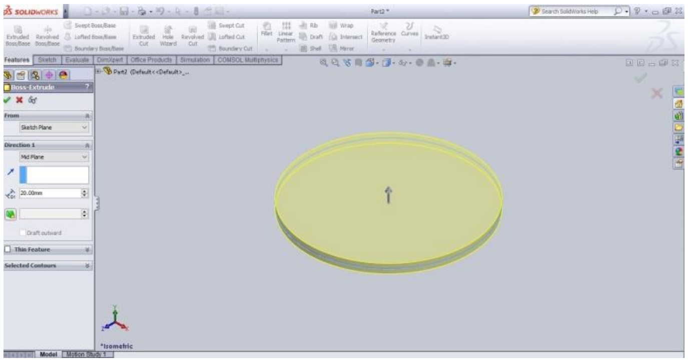
Step 3: Select the circle command and draw a circle



<NONE>
None
.12 (Document)
Primary Value
D1@Sketch1
357.00mm
<MOD-DIAM><DIM>
Set the properties of the selected dimension(s).

Figure 4.4: Sketch of a circle.

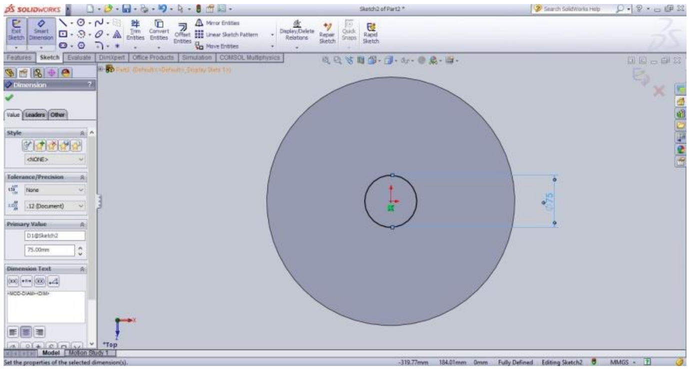
Step 4: Extrude the circle about mid plane



From
Sketch Plane
Direction 1
Mid Plane
20.00mm
☐ Draft outward

Figure 4.5: Extrusion of Circle.

Step 5 : Draw another circle on extruded cylinder



<NONE>
None
.12 (Document)
Primary Value
D1@Sketch2
75.00mm
<MOD-DIAM><DIM>
Set the properties of the selected dimension(s).

Figure 4.6: Sketch of circle on extruded cylinder

Step 6 : Draw the line command and by using linear sketch pattern divide the line into six parts

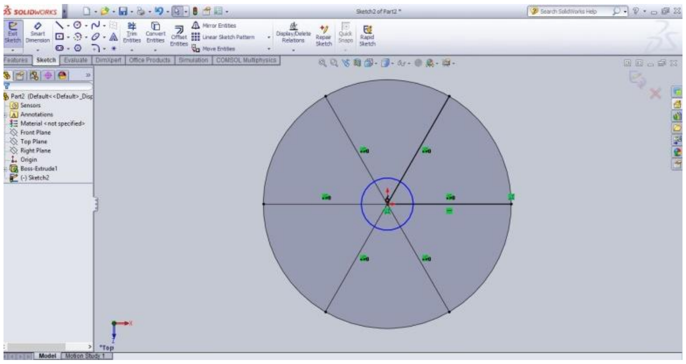


Figure 4.7: Sketch of dividing line with linear sketch pattern

Step 7: Trim four lines and leave two lines

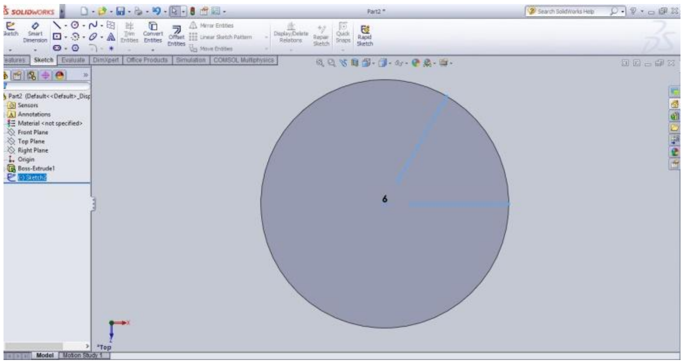
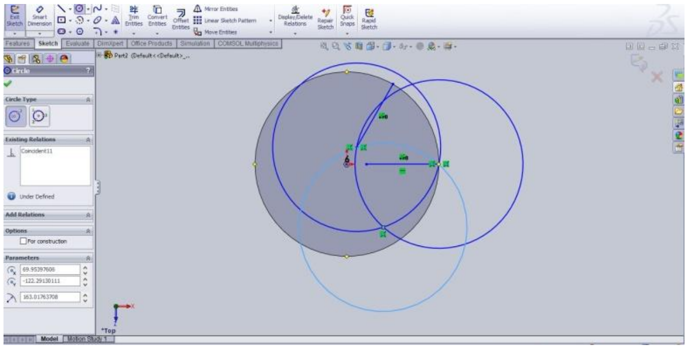


Figure 4.8: Trimming of unwanted lines.

Step 8 : Draw the circles by using conjugate circle method



Coincident11

Under Defined

☐ For construction

69.95397606

-122.29130111

163.01763708

Figure 4.9: Sketch of circles by conjugate circle method

Step 9 : Trim the unnecessary circles and leave the vane line

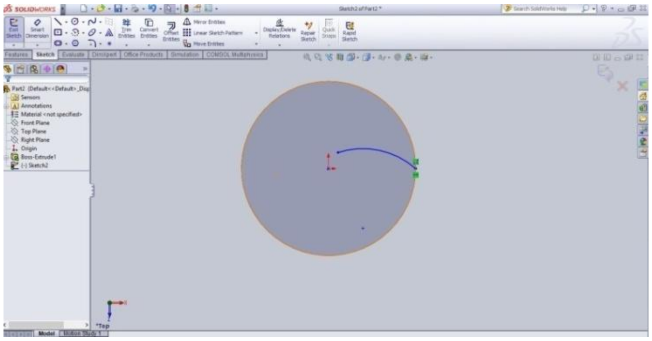


Figure 4.10: Trimming of unwanted circles.

Step 10: By using offset command give offset to vane line and the edges by using lines .Now by using linear sketch pattern divide the vane into six vanes

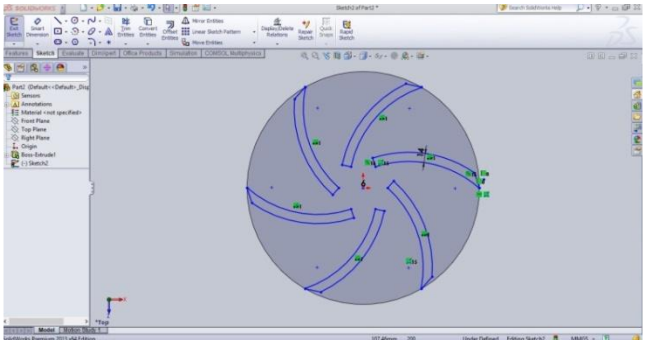


Figure 4.11: Linear Pattern Operation on vanes.

Step 11: Extrude the vane above the cylindrical surface

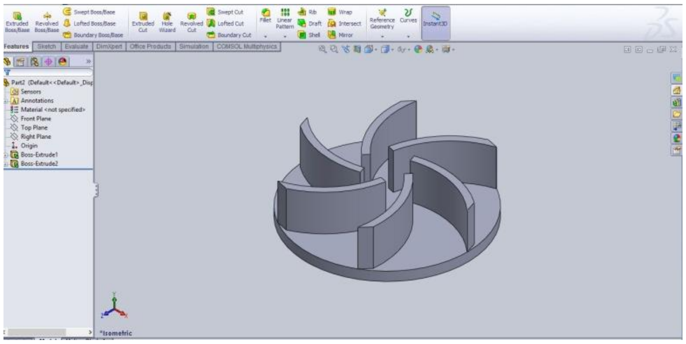
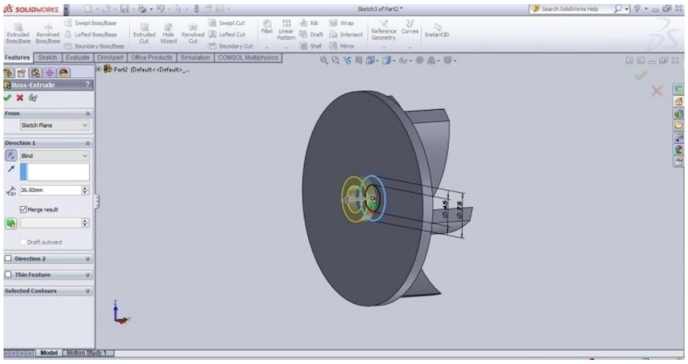


Figure 4.12: Extrusion of vanes

Step 12: Select the other side of the impeller and draw two circles and extrude them to form a groove for impeller shaft



Boss-Extrude

From
Sketch Plane

Direction 1
Blind
36.00mm
☑ Merge result
☐ Draft outward

☐ Direction 2
☐ Thin Feature
Selected Contours

Figure 4.13: Extrusion of groove.

Step 13 : By doing trimming of unwanted edges the final impeller is designed

Figure 4.14: Centrifugal Pump Impeller

4.2. PROCEDURE OF ANALYSIS IN ANSYS :

Step 1: Initially save the assembly of the impeller in “IGES” file and then open a new project in Ansys workbench

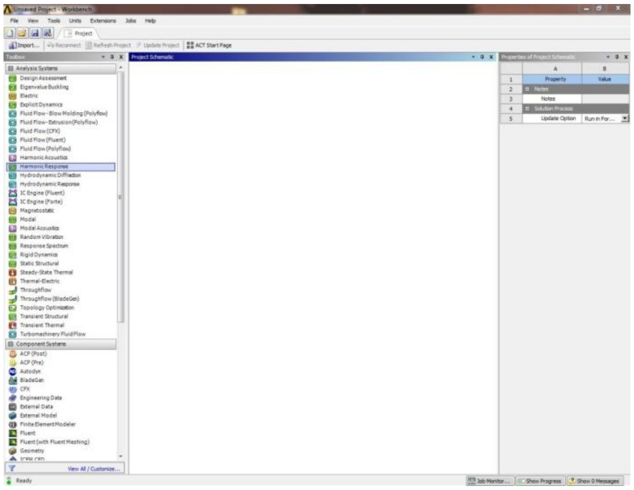


Figure 4.15: ANSYS Workbench

Step 2: Now double click on the “Engineering Data**”** and click on Edit.

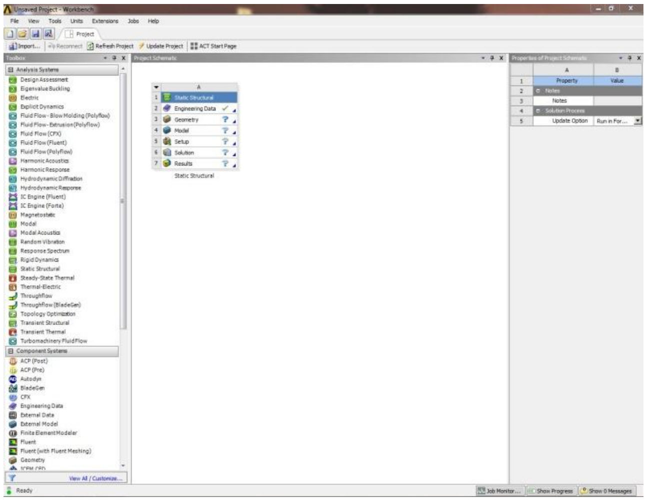
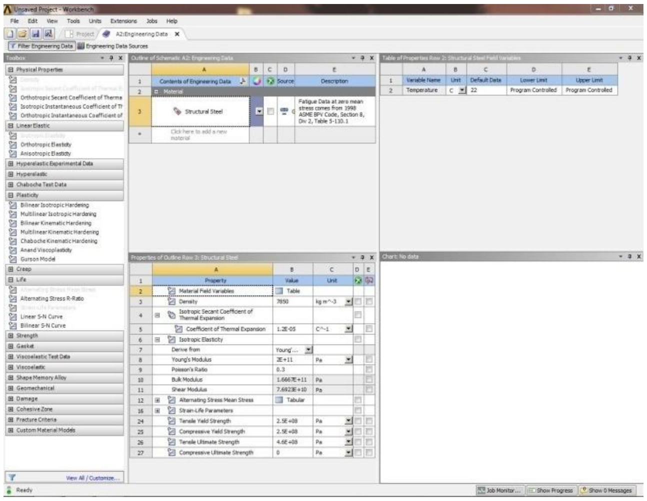


Figure 4.16: Importing Geometry

Step 3: Now type the name of the material as “Mild Steel” and apply properties of it.



Outline of Schematic A2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Structural Steel		☐		Fatigue Data at zero mean stress comes from 1998 ASME BPV Code, Section 8, Div 2, Table 5-110.1
*	Click here to add a new material				

Table of Properties Row 2: Structural Steel Field Variables

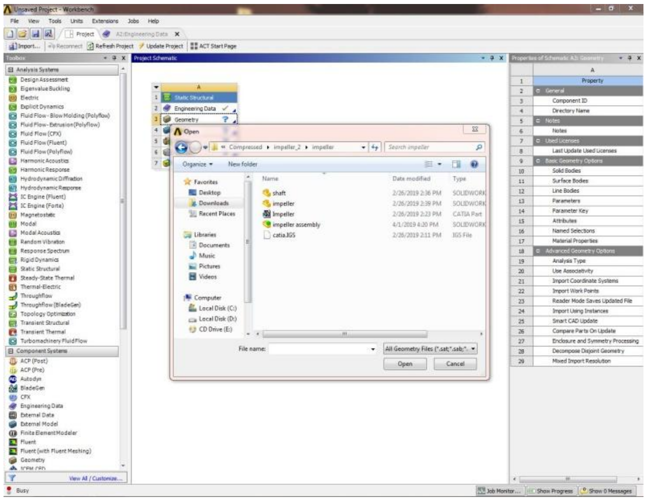
	A	B	C	D	E
1	Variable Name	Unit	Default Data	Lower Limit	Upper Limit
2	Temperature	C	22	Program Controlled	Program Controlled

Properties of Outline Row 3: Structural Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3	☐	☐
4	Isotropic Secant Coefficient of Thermal Expansion			☐	
5	Coefficient of Thermal Expansion	1.2E-05	C^-1		☐
6	Isotropic Elasticity			☐	
7	Derive from	Young'...			
8	Young's Modulus	2E+11	Pa		☐
9	Poisson's Ratio	0.3			☐
10	Bulk Modulus	1.6667E+11	Pa		☐
11	Shear Modulus	7.6923E+10	Pa		☐
12	Alternating Stress Mean Stress	Tabular		☐	
16	Strain-Life Parameters			☐	
24	Tensile Yield Strength	2.5E+08	Pa	☐	☐
25	Compressive Yield Strength	2.5E+08	Pa	☐	☐
26	Tensile Ultimate Strength	4.6E+08	Pa	☐	☐
27	Compressive Ultimate Strength	0	Pa	☐	☐

Figure 4.17: Selection of material

Step 4: Go back to modal window and right click on the geometry import geometry and browse the “IGES” file of centrifugal pump impeller.



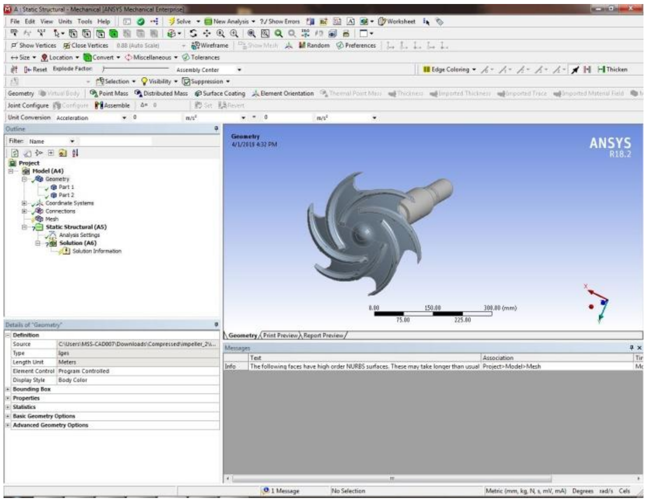
Name	Date modified	Type
shaft	2/26/2019 2:36 PM	SOLIDWORK
impeller	2/26/2019 2:39 PM	SOLIDWORK
Impeller	2/26/2019 2:23 PM	CATIA Part
impeller assembly	4/1/2019 4:20 PM	SOLIDWORK
catia.IGS	2/26/2019 2:11 PM	IGS File

File name:

All Geometry Files (*.sat;*.sab;*.

Figure 4.18: Importing Geometry

Step 5: Again go back to the modal window and double click on the “Model”, a new window along with solid model of impeller appears on the screen and change the material of impeller as “Mild Steel”.



Details of "Geometry"

Definition	
Source	C:\Users\MSS-CAD007\Downloads\Compressed\impeller_2\...
Type	Iges
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Properties	
Statistics	
Basic Geometry Options	
Advanced Geometry Options	

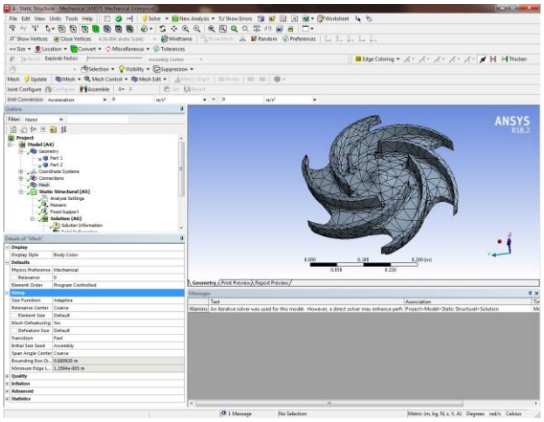
Messages

	Text	Association
Info	The following faces have high order NURBS surfaces. These may take longer than usual	Project>Model>Mesh

1 Message No Selection Metric (mm, kg, N, s, mV, mA) Degrees rad/s Cels

Figure 4.19: Centrifugal Pump Impeller along with Shaft

Step 6: Now click on "Mesh" and change the sizing from "Coarse" to "Fine".Riight click on the "Mesh" and click on "Generate Mesh"



Messages

	Text	Association
Warning	An iterative solver was used for this model. However, a direct solver may enhance perf.	Project>Model>Static Structural>Solution

1 Message No Selection Metric (m, kg, N, s, V, A) Degrees rad/s Celsius

Figure 4.20: Generating Mesh

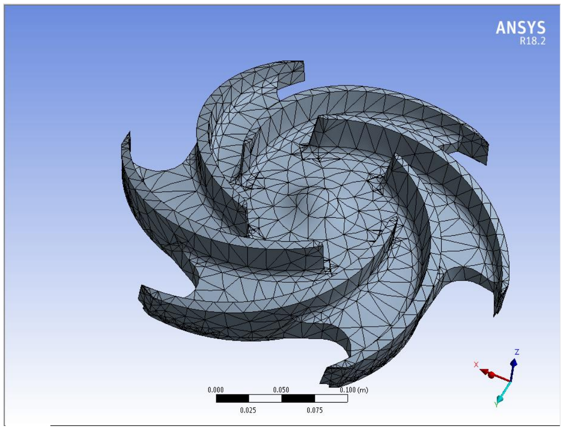
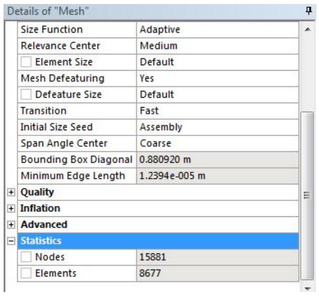


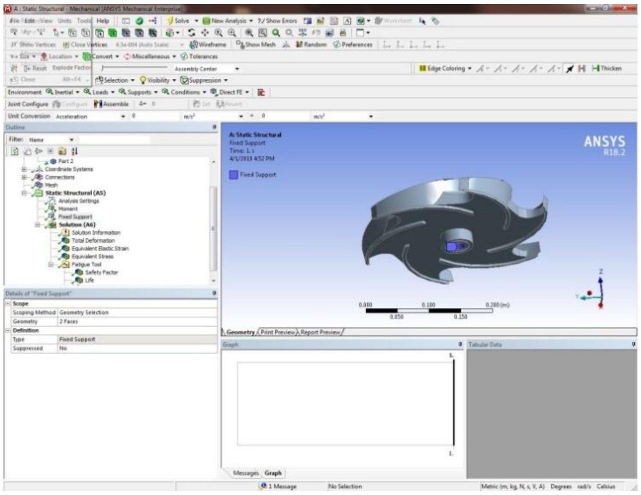
Figure 4.21: After Meshing



Details of "Mesh"

Size Function	Adaptive
Relevance Center	Medium
☐ Element Size	Default
Mesh Defeaturing	Yes
☐ Defeature Size	Default
Transition	Fast
Initial Size Seed	Assembly
Span Angle Center	Coarse
Bounding Box Diagonal	0.880920 m
Minimum Edge Length	1.2394e-005 m
Quality	
Inflation	
Advanced	
Statistics	
☐ Nodes	15881
☐ Elements	8677

Step 7: Inorder to resist the motion of the "Impeller", go to "modal" →Insert →Fixed Support.



Details of "Fixed Support"

Scope	
Scoping Method	Geometry Selection
Geometry	2 Faces
Definition	
Type	Fixed Support
Suppressed	No

Figure 4.22: Applying Fixed Support to Impeller

Step 8: Now apply Modal Analysis on Centrifugal Pump Impeller by taking suitable no of modes. Modal →analysis settings →maximum no of nodes to find→5

Step 9: To find the first natural frequency of mild steel impeller by clicking modal→solution→total deformation 1

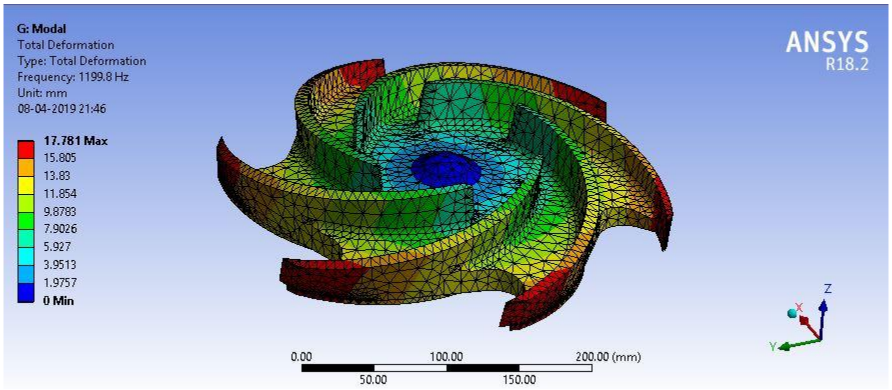


Figure. 4.23. First Mode Shape of MS Pump Impeller

Step 10: To find the second natural frequency of mild steel impeller by clicking modal→solution→total deformation

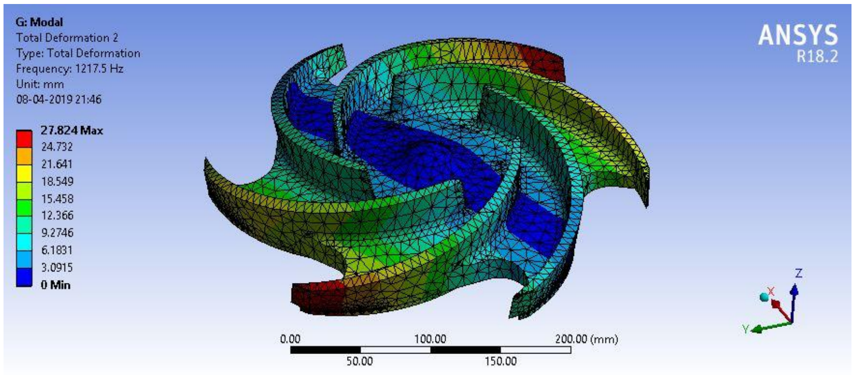


Figure. 4.24. Second Mode Shape of MS Pump Impeller

Step 11: To find the third natural frequency of mild steel impeller by clicking modal→solution→total deformation 3

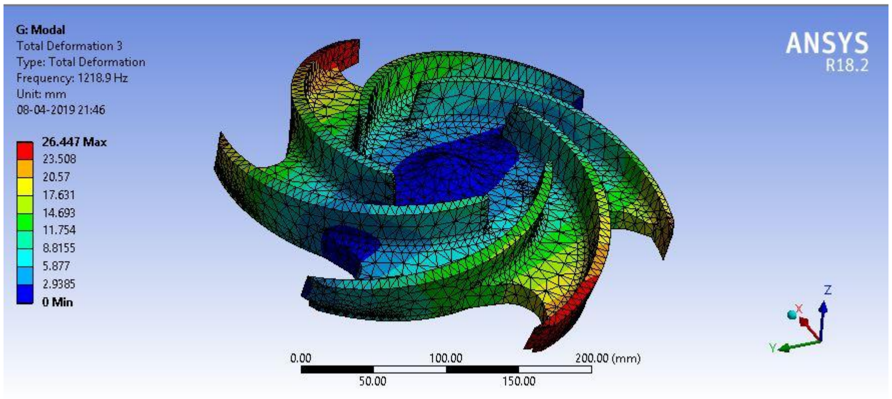


Figure. 4.25. Third Mode Shape of MS Pump Impeller

Step 12: To find the fourth natural frequency of mild steel impeller by clicking modal→solution→total deformation 4

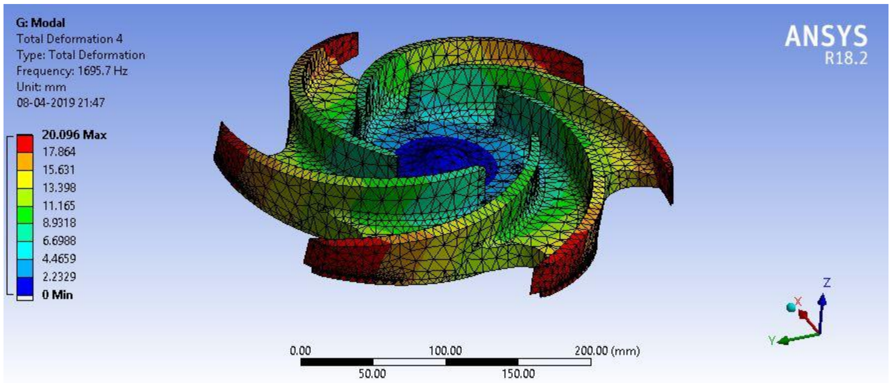


Figure. 4.26. Fourth Mode Shape of MS Pump Impeller

Step 13: To find the fifth natural frequency of mild steel impeller by clicking modal→solution→total deformation 5

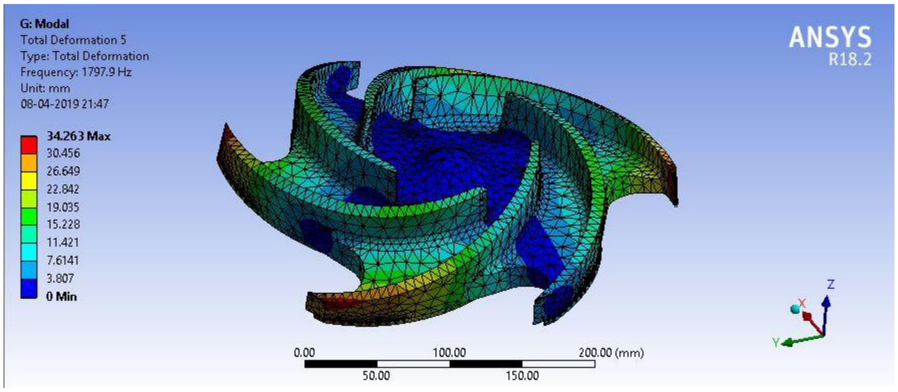


Figure. 4.27. Fifth Mode Shape of MS Pump Impeller

Step 14: Similarly, the same procedure is applied for aluminium alloy from step 1 to step 8

Step 15: To find the first natural frequency of aluminium alloy impeller by clicking modal→solution→total deformation 1

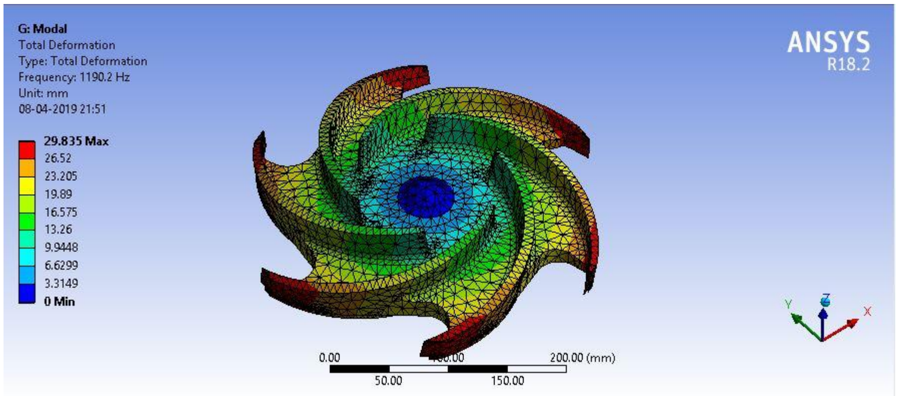


Figure. 4.28. First Mode Shape of Aluminum alloy Pump Impeller

Step 16: To find the second natural frequency of aluminium alloy impeller by clicking modal→solution→total deformation 2

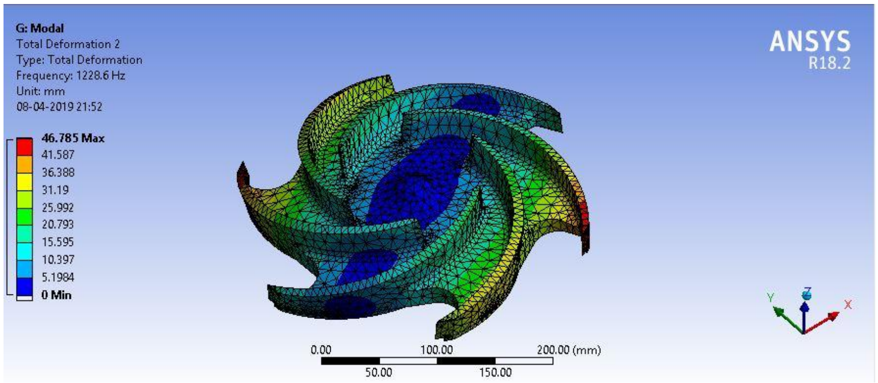


Figure. 4.29. Second Mode Shape of Aluminum alloy Pump Impeller

Step 17: To find the third natural frequency of aluminium alloy impeller by clicking modal→solution→total deformation 3

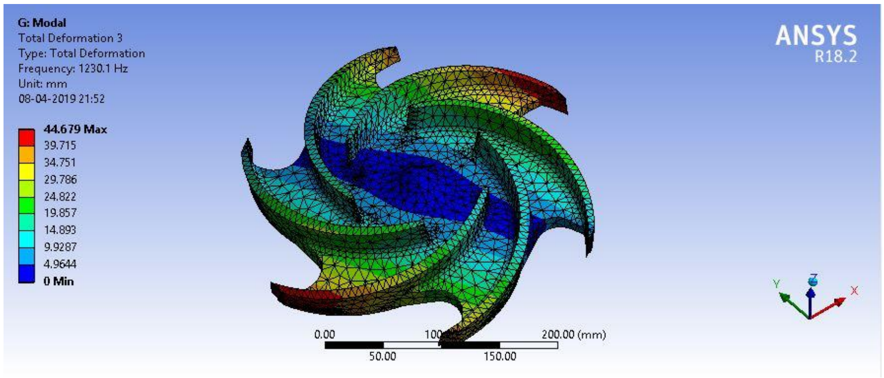


Figure. 4.30. Third Mode Shape of Aluminum alloy Pump Impeller

Step 18: To find the fourth natural frequency of aluminium alloy impeller by clicking modal→solution→total deformation 4

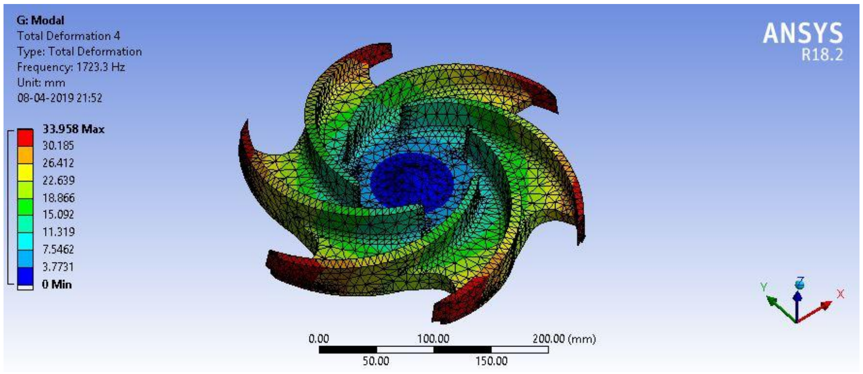


Figure. 4.31. Fourth Mode Shape of Aluminum alloy Pump Impeller

Step 19: To find the fifth natural frequency of aluminium alloy impeller by clicking modal→solution→total deformation 5

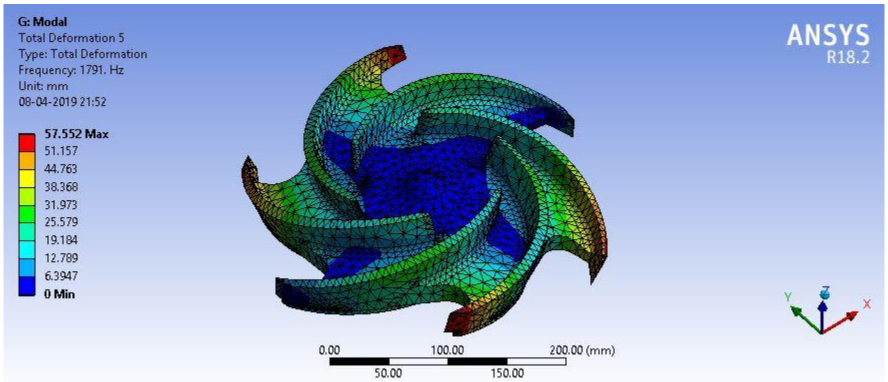


Figure. 4.32. Fifth Mode Shape of Aluminum alloy Pump Impeller

Step 20: Similarly, the same procedure is applied for epoxy glass fiber from step 1 to step 8

Step 21: To find the first natural frequency of epoxy glass fiber impeller by clicking modal→solution→total deformation 1

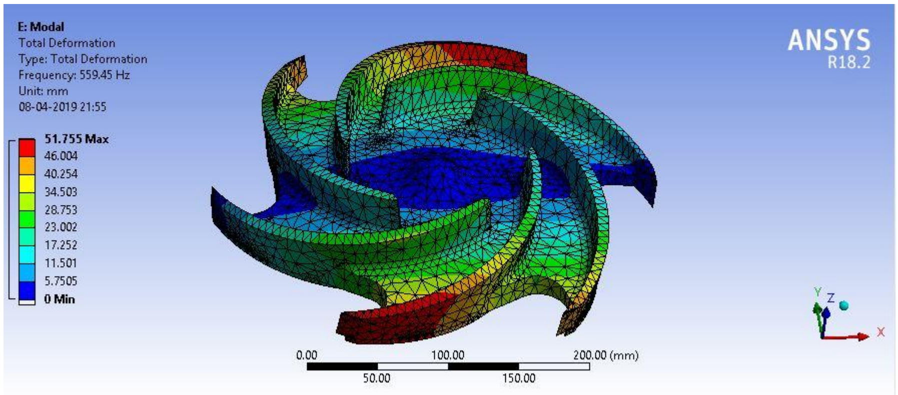


Figure. 4.33 First Mode Shape of Epoxy Glass Fiber Pump Impeller

Step 22: To find the second natural frequency of epoxy glass fiber impeller by clicking modal→solution→total deformation 2

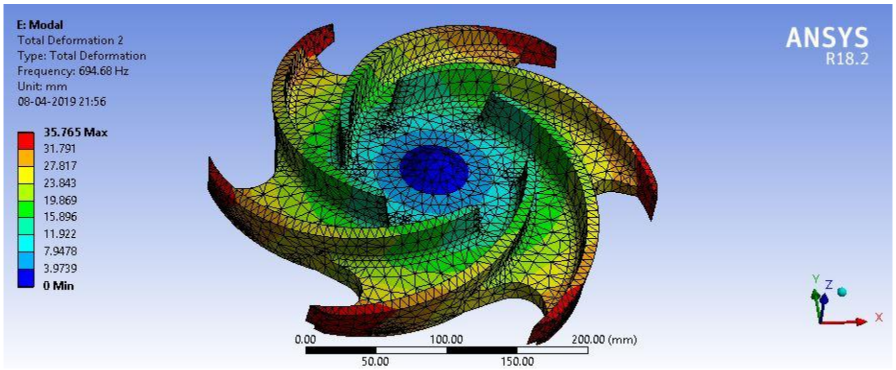


Figure. 4.34 Second Mode Shape of Epoxy Glass Fiber Pump Impeller

Step 23: To find the third natural frequency of epoxy glass fiber impeller by clicking modal→solution→total deformation 3

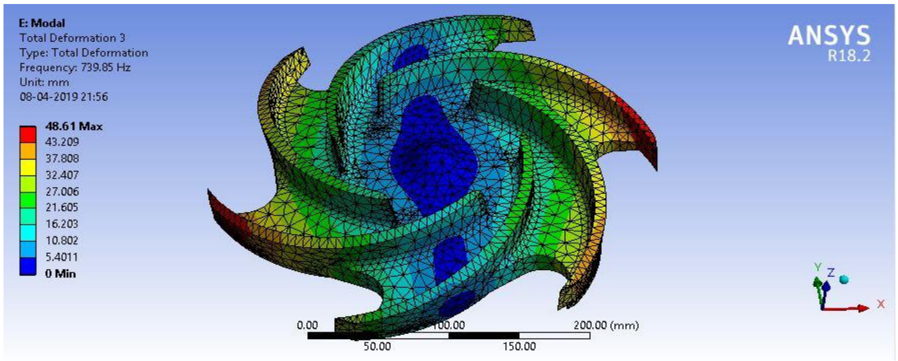


Figure. 4.35. Third Mode Shape of Epoxy Glass Fiber Pump Impeller

Step 24: To find the fourth natural frequency of epoxy glass fiber impeller by clicking modal→solution→total deformation 4

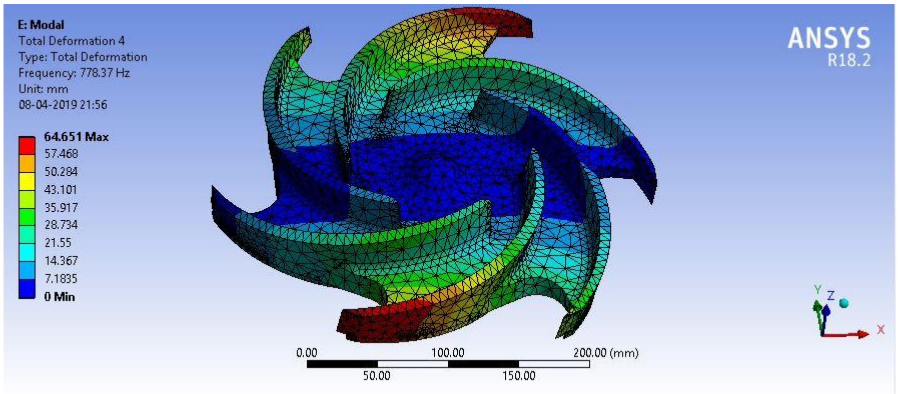


Figure. 4.36 Fourth Mode Shape of Epoxy Glass Fiber Pump Impeller

Step 25: To find the fifth natural frequency of epoxy glass fiber impeller by clicking modal→solution→total deformation 5

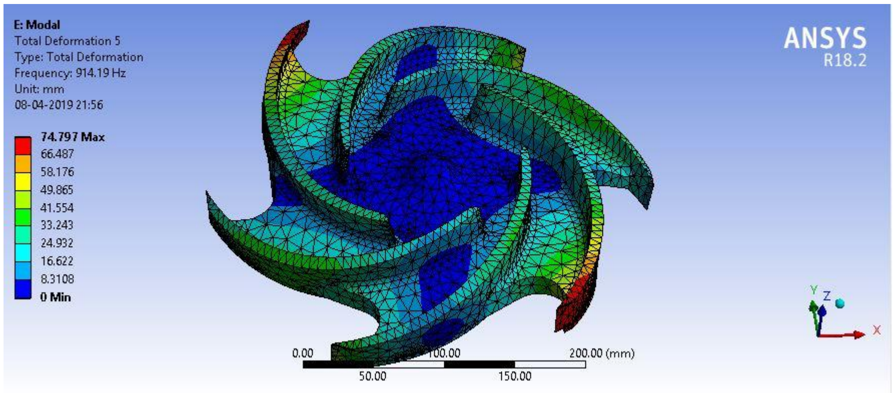


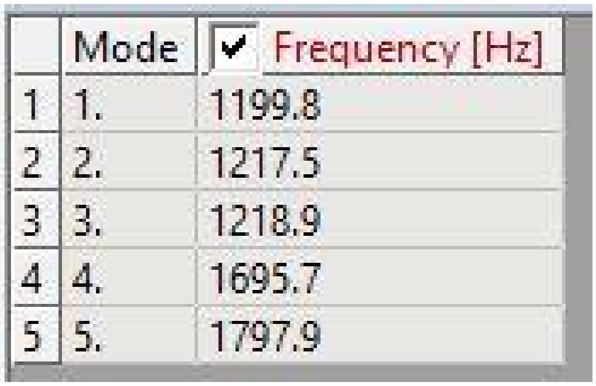
Figure. 4.37. Fifth Mode Shape of Epoxy Glass Fiber Pump Impeller

CHAPTER 5

RESULTS AND DISCUSSION

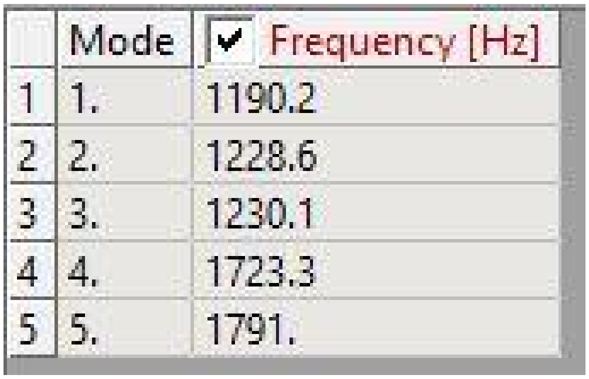
Modal Analysis of centrifugal pump impeller is done to propose the manufacturing material for centrifugal pump impeller used in tempcore boxes of LMMM. The Analysis of centrifugal pump impellor is done by applying different manufacturing materials like mild steel, aluminum alloy and epoxy glass fibre is applied in ANSYS Workbench. Output parameters like natural frequencies are determined and are used to find out the manufacturing material for centrifugal pump impeller where resonance frequency and natural frequency has maximum difference.

5.1. RESULTS FOR MODAL ANALYSIS:



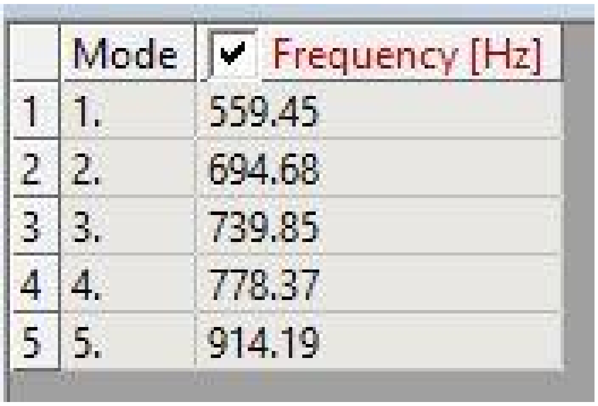
	Mode	☑ Frequency [Hz]
1	1.	1199.8
2	2.	1217.5
3	3.	1218.9
4	4.	1695.7
5	5.	1797.9

Figure. 5.1 Maximum Frequencies of MS Pump Impeller at Different Mode Shapes



	Mode	☑ Frequency [Hz]
1	1.	1190.2
2	2.	1228.6
3	3.	1230.1
4	4.	1723.3
5	5.	1791.

Figure5.2 Maximum Frequencies of Aluminum Alloy Pump Impeller at Different Mode Shapes



	Mode	☑ Frequency [Hz]
1	1.	559.45
2	2.	694.68
3	3.	739.85
4	4.	778.37
5	5.	914.19

Figure. 5.3 Maximum Frequencies of Epoxy Glass Fiber Pump Impeller at Different Mode Shapes

CALCULATION OF WORKING FREQUENCY

when impeller is rotating with 2000 rpm the angular velocity is calculated by using the formula

$$\omega = \frac{2\pi N}{60} = \frac{2\pi * 2000}{60} = 209.43 \text{ rad/sec}$$

the working frequency of the impeller is calculated by using formula

$$f = \frac{\omega}{2\pi} = \frac{209.43}{6.28} = 33.24 \text{ Hz}$$

Table 5.1: Result table for modal analysis

S.NO	Material	Working Frequency (Hz)	Minimum Natural Frequency (Hz)
1	Mild Steel	33.24	1199.8
2	Aluminium alloy	33.24	1190.2
3	Epoxy Glass Fiber	33.24	559.45

CHAPTER 6

CONCLUSIONS AND FUTURE SCOPE

6.1. CONCLUSIONS

By performing Energy audit on combination of pumps at 28 rebar section the following conditions are proposed

- If we have to use two old pumps then combination of pump 1 and pump 3 is used
- If we have to use one old pump and one new pump then combination of pump 3 and pump 4 is used

By performing Energy audit on combination of pumps at 16 rebar section the following conditions are proposed

- If we have to use two old pumps then combination of pump 1 and pump 3 is used
- If we have to use one old pump and one new pump then combination of pump 3 and pump 6 is used

For sake of convince and to get optimum result we have taken five modes for Modal Analysis, each mode wise natural frequency is shown. From the mode shapes diagrams the mode shapes represent the bending mode in the blade of impeller and deformation of impeller. It is clear that the blade of impeller stiffness needs to be increase. On the other hand, to avoid the resonance at the operating speed, the difference between first natural frequency and operating frequency must be high.

The working frequency of centrifugal pump impeller is 33.24 Hz and by doing analysis on ANSYS Workbench the minimum natural frequencies of different materials like mild steel, aluminium alloy, epoxy glass fiber are 1199.8 Hz,1190.2 Hz, 559.45 Hz so resonance will not occur for centrifugal pump impeller because working frequency is very much less than natural frequency. The difference between natural frequency and working frequency is higher for mild steel, so mild steel is proposed for fabrication of centrifugal pump impeller.

6.2. FUTURE SCOPE

- The project can be extended to do the dynamic structural load analysis for the centrifugal pump impeller and analyze different parameters acting on centrifugal pump impeller.
- CFD Analysis can also applied on centrifugal pump impeller and geometrical variation on centrifugal pump impeller can be done.

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2) Modal Analysis of a Semi-Closed Impeller of Centrifugal Water Pump Saeid Farokhzad, Asade Modarres Motlagh, Payam Farhadi, Vols 537-538 (2007) pp 533-540 Online: 2007-02-15Tr ans Tech Publications, Switzerland

3) "Design, Modeling & Analysis of a Submersible Pump and to improve the Pump Efficiency" by Shyam Karanth, V. K. Havanur , Journal of Mechanical Engineering Vol SI 5(2), 36-53, 2018

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