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Design & Analysis of Centrifugal Pump Impeller for Optimizing Strength & Weight of Impeller

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Abstract: The pump is mechanical device which conveys liquid from one place to another place. It can be defined as hydraulic machines which converts the mechanical energy into hydraulic energy. If mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, for conveying liquid from one place to another then that pump is called centrifugal pump. It is a similar to a reversed of an inward radial flow reaction turbine. In this pump flow of liquid is in radial outward direction. The impeller increases kinetic energy of liquid which is coming from sump. Our project is industrial defined project. Shreeji diesel is the industry which gives us a project for optimizing the strength and the weight of centrifugal pump impeller. In our project, we are doing analysis on Mild Steel & Stainless steel pump impeller in order to optimize strength of centrifugal pump. Our Project gives the static & Modal analysis of Mild Steel & Stainless steel Pump Impeller to check strength of Pump & vibrations produced by pump
Index Terms - Component, formatting, style, styling, inserts.
KEYWORDS: Pump Impeller, Optimization, Strength, Weight, ANSYS Workbench

I Introduction

- A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps are classified into three major groups according to the method they use to move the fluid:
- Direct lift pumps,
- Displacement pumps &
- Gravity pumps.
- Pumps operation is by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps. Mechanical pumps are used in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering and aeration etc. Below Figure:1 Shows the working principle of the Pump.

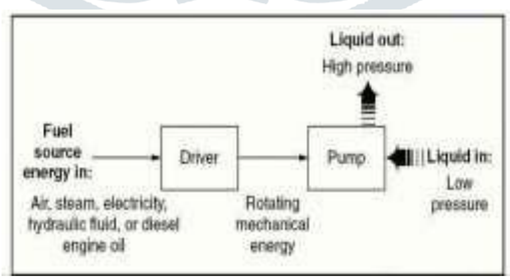

Figure: 1 -WorkingPrincipleofaPump

II Literature Survey

- Our project deals with the optimization and analysis in design of centrifugal pump so in related to these following research papers have been studied :
- **Sumit N. Gavande , Prashant D. Deshmukh ,**Swapnil **S. Kulkarni[2014]** the objective ofthestudyisin-depthanalysisofvariousmethodologies to increase the discharge of thepump. In this research paper for increasing the discharge of

the pump some methodologies were given. Some relate to change in design ofpumpwhereassomemethodologiesrelatetochangeindesignofsuctionside.

- **Pramod J.Bachche, R.M.Tayade [2013]**have analysed the shaft by using finite element analysis technique for stresses and deflections. The total work is carried out in two stages. First stage is static analysis and second stage is dynamic analysis.
- **Bin Cheng al. [2012]**have proposed a study toanalysetheflowcharacteristicsofthelateraldiversionandintakepumpingstations.Themainconclusionofthisresearchpaperisthe inlet flow pattern is more complex than singlelateral division & the flow pattern in the lateraldiversionissimilarwiththebend flow.
- **S.P.Asokal.[2011]**haveshowthe3Danalysis in prediction of pressure drop takingplaceinhelical-groovedlabyrinthseals&having a good agreement with the experimentalresults. Helical-grooved labyrinth seals bring inadditionalenergy lossesduetoflow bendingeffects.
- **HSIAO Shih-Chun al.[2011]**the main aim ofstudyistoexaminethehydrodynamicsofapumpsump.Thenumericalresultsofstreamwisevelocityprofilesandflowpatternsarediscussedandcomparedwithexperimentaldata.

III ProblemDefinition

Our Industry Shreeji Diesels is small scale Industry they are manufacturing the centrifugal pump impeller for small specific speed application. Hence, the impeller used for it not needed too robust such as impellers which are needed for high specific speed application pumps. According to the requirement of the customers they are manufacturing the impeller. Generally customer needed semi - open impeller because semi-open impeller is the most suitable for small specific speed application..Following are the reason why Shreeji diesels are using Mild Steel for Pump Impeller :

It is recyclable.
It is weldable.
It is cost - effective.
Following are the problem they are facing by using mild steel :
Mild steel is having very less tensile strength.
It has high corrosion
It has less fatigue strength
It has less stiffness

Weight of the pump is also very high. Due to this frequent customer complaints are arrived & they need problem of the solution. Here, we decide to search another material which is most appropriate to use in the pump impeller. According to research paper “Centrifugal pump design materials and specifications” published By MertinGuner& Mehmet MelihOzbsyer Following are the materials which are the most appropriate in using centrifugal pump impeller :

Mild steel ,
Cast iron ,
Stainless steel ,
Titanium-Nickel alloy ,
Super duplex stainless steel ,
Duplex stainless steel ,
316 stainless steel ,
Nickel aluminum bronze ,
Gunmetal

One of the most important thing telling us by industry is their profit margin is less so that whatever you want to improvement needed should be less costly to the industry. Now after talking with various material suppliers we finally reached to the conclusion that cost of using the material is increases as follows :

Material options	Increasing cost
Titanium	↑
Nickel alloy	
Super duplex stainless steel	
Duplex stainless steel	
316 stainless steel	
Nickel aluminium bronze	
Gunmetals	
Austenitic cast iron	
Stainless steel	
Mild Steel	

- From about table it is clear that after the mildsteelstainlesssteelissecondmostcheapestmaterialused for thepumpimpeller.

Now, we have to prove how the stainlesssteel is more good ascompared to mild steel bydoing the static and the dynamic analysismild steeland stainlesssteel pump impeller.

IV ObjectiveOf Study

Our objective of study is as follows:

To provide the best suitable material to the industry for Centrifugal pump impeller in their budget.

To inspect strength of pump impeller by static analysis using various material like Mild steel, Stainless steel.
To decrease the weight of pump impeller by keeping the same dimensions and changing the material
To determine natural frequency by modal analysis of Mild Steel, Stainless Steel.

V Methodology

I Assembly

- Therearethevariousmodelingsoftwareavailableinthemarket.Computer-AidedDesign(CAD)softwareallowsbuilding3Dmodels of parts and assemblies. CAD softwarehasadraftingcomponentthatallowsyoutocreate2Ddrawingsofyourpartsthatcanbe
- Manufactured.CADtoolsalsohavedirectintegrationintoanFEA(FiniteElementAnalysis) package so you can iterate seamlesslybetween design and analysis. Examples of 3DCAD software: SolidWorks, Unigraphics NX,CATIA, and Autodesk Inventor. Here by usingAutoCADsoftwarewearecreatingthe3Dmodel of centrifugal pump and then import totheANSYS18.1forfurtheranalysis.Itisshown infollowing figure5.1.

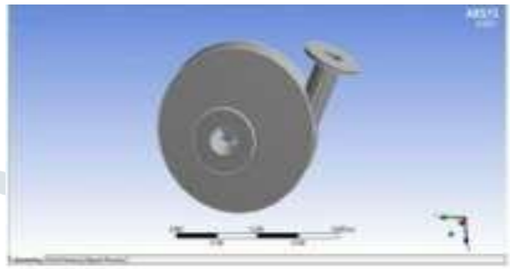

Figure: 5.1-AssemblyofCentrifugalPump

II Geometry

- A numerical description of impeller's geometryistransferred into a 3DCADsoftware.
- Below figure shows the geometry of impellerwhichistobeconsideredforforallfurtheranalysis.

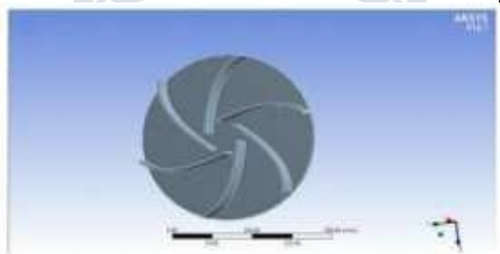

Figure: 5.2-GeometryofCentrifugalPump

-III FEAModelofCentrifugalPumpImpeller

- Structural analysis can be done with Finite Element Analysis (FEA).The Finite ElementAnalysissoftwareallowsyoutoanalysestressesanddeflectionsincomplexstructures.A structure is typically modelled in a 3D CADprogram, its geometry is built, a mesh is created to discretise the structure into elements, forcesand constraints are applied, and the model canthen be solved. From the solved model, you caninterrogatestressesanddeflectionsinthestructure.
- Examples:ANSYSandNASTRAN.
- FEAmodelofcentrifugalpumpimpellerisshown inthefollowingfigure5.3.

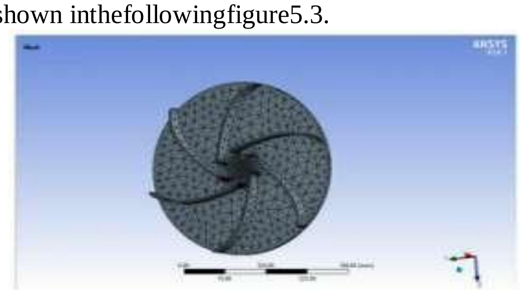

Figure: 5.3 - FEA Model of Centrifugal PumpImpeller

Statistics	
Nodes	14775
Elements	7636
Mesh Metric	None

Figure:5.4- TableofNodes&Elements

- Above Table shows the number of the nodes &elementsinmeshgeneratedforacentrifugalpump impeller. Now,for thestatic analysis ofthe Centrifugal Pump impeller it is necessary tofix the support. Generally according to the C.G.of the body place of fixed support as decidedhere also we are doing the same. According tothe C.G. of them centrifugal pump impeller wearefixing the support. It is shown in followingfigure.5.5.

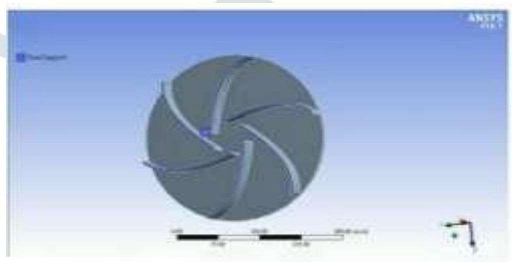

Figure:5.5- FixedSupport

VI Static Analysis ofCentrifugalPumpImpeller

I Procedure for Static Analysis in Ansys

- Following are the steps which are performed forstaticanalysisinANSYS:

1. Build the FE model as explained in previousslides,
2. Definethematerialpropertiessuchasyoung’smodulusanddensityetc.,
3. Applyboundaryconditionandpressures,
4. SolvetheproblemusingcurrentLScommandfromthe toolbar.

VII ANSYS18.1

ANSYS Work bench can be thought of as asoftware platform or framework where you performyour analysis (Finite Element Analysis) activities. Inother words, workbench allows you to organize allyour related analysis files and databases under sameframe work. Among other things, this means that youcan use the same material property set for all youranalyses. The ANSYS Workbench platform allowsuserstocreatenew,fasterprocessesandtoefficientlyinteractwithothertoolslikeCADsystems.
InthisplatformworkingonMetaphysicssimulationiseasy.
ThoseperformingastructuralsimulationuseagraphicalinterfacecalledtheANSYSWorkbenchMechanicalapplication)thatemploys a tree-like navigation structure to define allpartsoftheirsimulation:geometry,connections,mesh,loads,boundary conditionsandresults.Byusing ANSYS workbench the user can save time inmany of the tasks performed during simulation. Thebidirectional links with all major CAD systems offersaveryefficientwaytoupdateCADgeometriesalong withthe designparameters.

-VIIIStatic Analysis For Equivalent Stress (Von - Misses Stress)

- StaticanalysisofcriticalpartofcentrifugalPump i.e. static analysis of fan is done by usingFEA. Impeller is core part of centrifugal pumpandalltheperformanceofbloweristotallydepends upon impeller, so Impeller is chosencritical part of centrifugal pump for the staticanalysis.Analysis is done for thematerial MS& SS respectively, in order to check Equivalentstressesanditscorrespondingdeformationsinduced ineachmaterial.

VIV StaticAnalysisofMildSteelPumpImpeller:

(1) TOTALDEFORMATION:

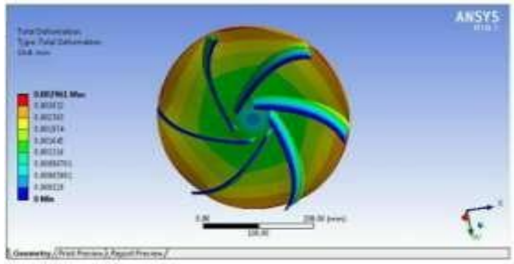

Figure: 6.1 - Total deformation in mild steelpumpimpeller

(2) EQUIVALENTSTRESS:

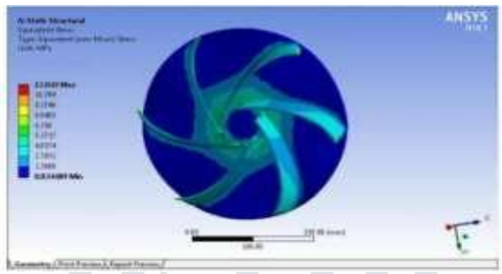

Figure : 6.2 - Equivalent stress in mild steelpumpimpeller

(3) EQUIVALENTSTRAIN:

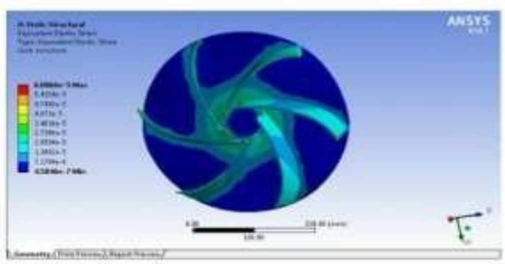

Figure : 6.3 - Equivalent strainin mild steelpumpimpeller

-STATICANALYSISOFSTAINLESSSTEELPUMP IMPELLER

(1) TOTALDEFORMATION:

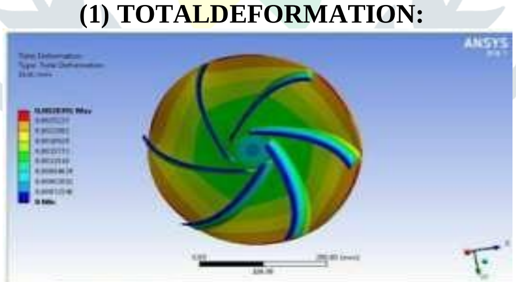

Figure:6.4-TotaldeformationinStainlesssteelpumpimpeller

(2) EQUIVALENTSTRESS :

Figure:6.5-EquivalentstressinStainless steelpumpimpeller

(3) EQUIVALENTSTRAIN:

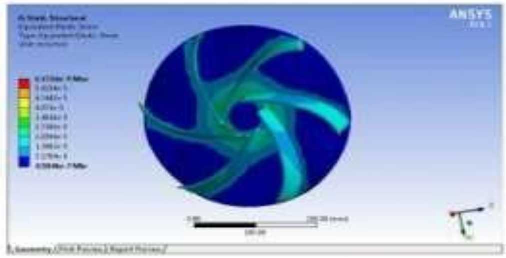

Figure:6.6- EquivalentstraininStainlesssteelpumpimpeller

I. RESULT&ANALYSIS

Sr. No.	Material	Stress (MPa)	Deformation (mm)	Weight (Kg)
1	Mild Steel	12.043	0.002961	29.202
2	Stainless Steel	11.974	0.0028391	28.83

- The maximum deflection induced in Mild SteelpumpImpelleri.e.MSmaterialis0.002961mm,whichisinsafe limits.
- Hencebasedonrigiditythedesignissafe.
- Themaximuminducedstressforthesamematerial is 12.043 Mpa which is less than theallowablestressi.eworkingstressbyconsideringfactor ofsafety(160Gpa).
- Hence,thedesignissafebased onstrength.
- Ifwecomparecorrespondingdeformationofthe material SS on above results MS material,SShavingminimumdeformationthereforethere are less chances of failure of the pumpImpeller ascompare to MSmaterials.
- Hencethestrengthofpumpgetsincreasedbecauseofthe SSmaterial.
- FromtheaboveresulttableitisclearthatweightoftheSSpump(28.83Kg)impellermaterialisminimumascomparedtoMS(29.202Kg) material, hence weight of the pumpImpeller reduced(optimized).

II. MODEL ANALYSIS OFCENTRIFUGALPUMPIMPELLER

PROCEDUREFORMODALANALYSISINANSYS

- Following are the steps which are performed forstaticanalysisinANSYS:

1. BuildtheFEmodelasexplainedinpreviousslides,
2. Definethematerialpropertiessuchasyoung'smodulusanddensityetc ,
3. Applyboundaryconditions,
4. Enter the ANSYS solution processor in whichanalysis type is taken as modal analysis, and'bytakingmodeextractionmethod',bydefiningnumberofmodestobeextracted.Solution method is chosen as Block lanczos /Directmethod.
5. Solve the problem using current LS commandfromthe toolbar.

MATERIALPROPERTIESOFPUMP

- Theanalysisisperformed on

1. MildSteelpumpImpeller
2. StainlessSteelpumpImpeller

- MaterialpropertiesofMildsteel pump:

1. Young'smodulusE=210GPa
2. Poisson'sratio=0.303
3. Massdensity=7860kg/m³
4. Dampingco-efficient=0.008

- MaterialpropertiesofStainlessSteelpump:

1. Yield stress0.2 %proofminimum- 170
2. Elastic modulus-193GPa
3. Massdensity-8000kg/m³
4. HardnessB(HRB)max-217
5. Elongation(%)-40 minimum

-MODELANALYSISFORMILDSTEELPUMPIMPELLER :

- ThefrequenciesofMSpumpimpellerfordifferentmodesareshowninfollowingtable.

Tabular Data

	Mode	Frequency [Hz]
1	1.	1938.5
2	2.	2076.
3	3.	2078.1
4	4.	2378.6
5	5.	2380.
6	6.	2495.3

TABLE:1

- DifferentmodeshapeofMSpumpimpellerisshown inthefollowingfigures:

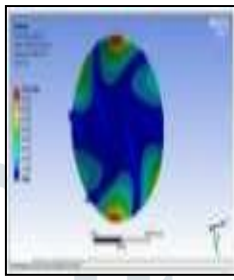
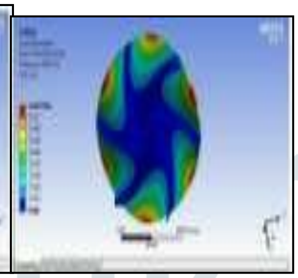

Figure :8.1-1st mode shape of MS PumpImpeller,Figure : 8.2- 2nd mode shape of MSPumpImpeller

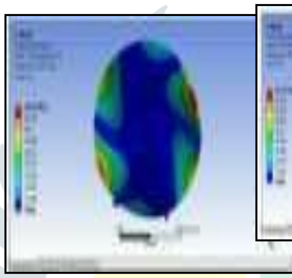
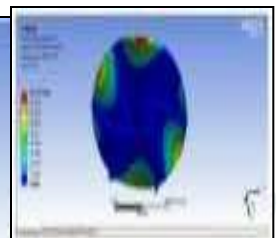

Figure:8.3-3rdmodeshapeofMSPumpImpellerFigure:8.4-4thmodeshapeofMSPumpImpeller

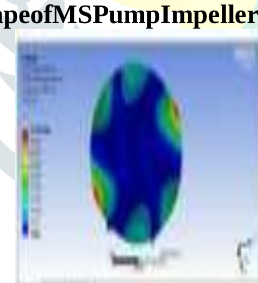
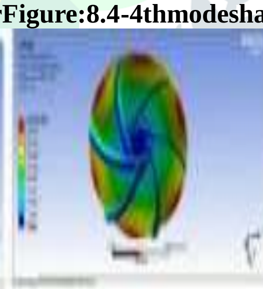

Figure:8.5-5th mode shape of MS PumpImpeller,Figure:8.6-6th modeofMSPumpImpeller

8.4-MODELANALYSISFORCENTRIFUGALSTEELPUMPIMPELLER :

- ThefrequenciesofSSpumpimpellerfordifferent modesareshownin followingtable:

Tabular Data

	Mode	Frequency [Hz]
1	1.	1959.
2	2.	2098.2
3	3.	2100.2
4	4.	2404.6
5	5.	2406.
6	6.	2526.2

TABLE:2

- DifferentmodeshapeofSSpumpimpellerisshown inthefollowingfigures:

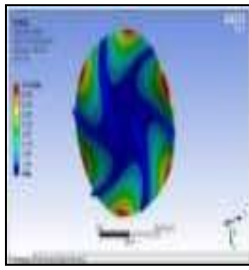
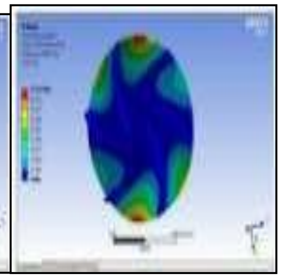

Figure:8.7-1stmodeshape ofSSPumpImpeller ,Figure: 8.8-2nd mode shapeofSSPumpImpeller

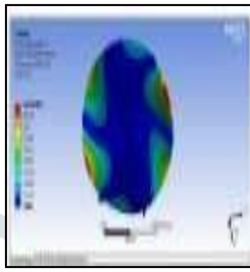
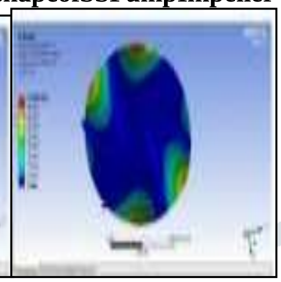

Figure :8.9 - 3rd mode shape of SS PumpImpeller ,Figure : 8.10- 4th mode shape of SSPumpImpeller

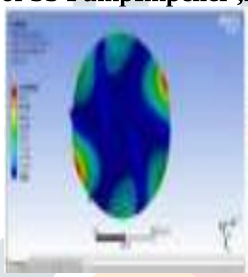
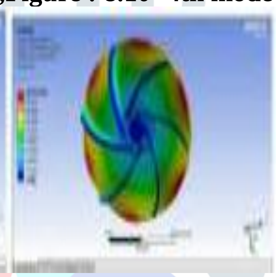

Figure :8.11 - 5th mode shape of SS PumpImpeller, Figure :8.12 -6th mode of SS PumpImpeller

I. COMPARISONOFNATURAL FREQUENCIES

Number ofModes	Naturalfrequencies of Mild Steel Pump ImpellerinHz	Naturalfrequencies of StainlessSteelPump ImpellerinHz
1	1978.5	1959.
2	2076.	2098.2
3	2078.1	2100.2
4	2378.6	2402.6
5	2380.	2406.
6	2495.3	2526.2

- Fromthistableitisclearthatnaturalfrequencies of a stainless steel pump impeller ishigher than mildsteelpumpimpeller.
- It means that we can operate at a higher speedwithoutencounteringresonancebyusingstainless steel pumpimpeller .
- In this way , for getting higher speed stainlesssteel pump impeller are better as compared tomildsteel pumpimpeller.

III. CONCLUSION

BydoingStaticandmodelanalysisofcentrifugal pump impeller it is a clear that mild steelpumpimpellerinducedmaximumdeflectionascompared to stainless steel pump . If we comparecorrespondingdeformationofthematerialSSonaboveresultsMSmaterial,SShavingminimumdeformation.Thereforetherearelesschancesoffailureofthepumpimpellerascompareto MSmaterials.Hence,thestrengthofpumpgetsincreasedbecauseofthestainlesssteelmaterial.From the table 2 , it is clear that weight ofstainless steel pump impeller (28.83 kg) is lesserthen mild steel pump impeller (29.202 kg) .In thisway , the weight of centrifugal pump impeller isminimized (Optimized) .

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