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Design and Simulation of Centrifugal Pump Using Composite Materials

K.Uday Kumar
PG Scholar,
Dept of Mechanical Engineering,
Sir Vishveshwaraiah Institute of Science and Technology,
(JNTU Anantapur), Angallu, Madanapalle, Chittoor, Andhra Pradesh.

N.Venkatramana Reddy
Assistant Professor,
Dept of Mechanical Engineering,
Sir Vishveshwaraiah Institute of Science and Technology,
(JNTU Anantapur), Angallu, Madanapalle, Chittoor, Andhra Pradesh.

M.Ramanarasimha Reddy
Associate Professor,
Dept of Mechanical Engineering,
Sir Vishveshwaraiah Institute of Science and Technology,
(JNTU Anantapur), Angallu, Madanapalle, Chittoor, Andhra Pradesh.

ABSTRACT:

Centrifugal pumps are used to transport liquids/fluids by the conversion of the rotational kinetic energy to the hydro dynamics energy of the liquid flow. The rotational energy typically comes from an engine or electric motor or turbine. In the typical simple case, the fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits. The Contemporary impellerblades in Centrifugal pumps are used in industrial applications are made up of Aluminum or Steel. It is proposed to design a centrifugal pump using Computer Aided Design (CAD) software with various metal alloys and Non-Metallic composite materials, analyze its strength and deformation using simulation software. In order to evaluate the effectiveness of Metal Alloys and Non-Metallic composites. The present work aim is to change the material and performing the different analysis like Static, Dynamic, Analysis to find the best material to decrease the weight and increase its efficiency by using the software SOLID WORKS (2014 Premium Version). This also involves the method of manufacturing process to realize the Blower using Non-Metallic composite material.

Key Words:

Centrifugal pump, Computer Aided Design (CAD), Metal Alloys, Non-Metallic Composite Materials, SOLIDWORKS, Simulation Analysis.

I. CENTRIFUGAL PUMP:

Centrifugal pumps are a sub-class of dynamic axis symmetric work absorbing turbo machinery. Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits. Common uses include water, sewage, petroleum and petrochemical pumping; a centrifugal fan is commonly used to implement a vacuum cleaner. The reverse function of the centrifugal pump is a water turbine converting potential energy of water pressure into mechanical rotational energy.

Working:

A centrifugal pump is one of the simplest pieces of equipment in any process plant. Its purpose is to convert energy of a prime mover (a electric motor or turbine) first into velocity or kinetic energy and then into pressure energy of a fluid that is being pumped. The energy changes occur by virtue of two main parts of the pump, the impeller and the volute or diffuser. The impeller is the rotating part

Generation of Centrifugal Force:

The process liquid enters the suction nozzle and then into eye (center) of a revolving device known as an

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impeller. When the impeller rotates, it spins the liquid sitting in the cavities between the vanes outward and provides centrifugal acceleration. As liquid leaves the eye of the impeller a low-pressure area is created causing more liquid to flow toward the inlet. Because the impeller blades are curved, the fluid is pushed in a tangential and radial direction by the centrifugal force. This force acting inside the pump is the same one that keeps water inside a bucket that is rotating at the end of a string. Figure below depicts a side cross-section of a centrifugal pump indicating the movement of the liquid.

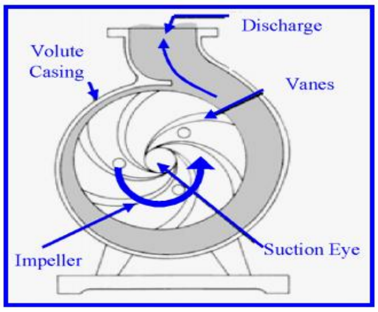

Fig. 1: Liquid Flow Path inside A Centrifugal Pump

II. GENERAL COMPONENTS OF CENTRIFUGAL PUMPS

A Centrifugal Pump Has Two Main Components:

I. A rotating component comprised of an impeller and a shaft

II. II. A stationary component comprised of a casing, casing cover, and bearings.

The general components, both stationary and rotary, are depicted in Figure 2. The main components are discussed in brief below. Figure 2 shows these parts on a photograph of a pump in the field.

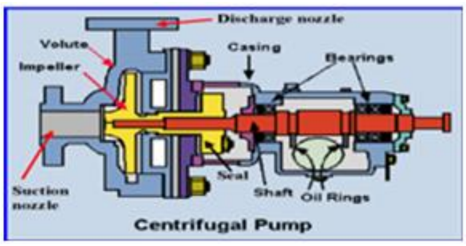

Fig. 2: Components of Centrifugal Pumps

Rotating Components:

1. Impeller

The impeller is the main rotating part that provides the centrifugal acceleration to the fluid. They are often classified in many ways.

- ➢ Based on major direction of flow in reference to the axis of rotation
- Radial flow
- Axial flow
- Mixed flow
- ➢ Based on suction type
- Single-suction: Liquid inlet on one side.
- Double-suction: Liquid inlet to the impeller symmetrically from both sides.
- ➢ Based on mechanical construction
- Closed: Shrouds or sidewall enclosing the vanes.
- Open: No shrouds or wall to enclose the vanes.
- Semi-open or vortex type.

An impeller is a rotating component of a centrifugal pump, usually made of iron, steel, bronze, brass, aluminum or plastic, which transfers energy from the motor that drives the pump to the fluid being pumped by accelerating the fluid outwards from the center of rotation. The velocity achieved by the impeller transfers into pressure when the outward movement of the fluid is confined by the pump casing. Impellers are usually short cylinders with an open inlet (called an eye) to accept incoming fluid, vanes to push the fluid radially, and asp lined, keyed, or threaded bore to accept a drive-shaft. The impeller made out of cast material in many cases may be called rotor, also. It is cheaper to cast the radial impeller right in the support it is fitted on, which is put in motion by the gearbox from an electric motor, combustion engine or by steam driven turbine. The rotor usually names both the spindle and the impeller when they are mounted by bolts.

Types of Impeller:

The efficiency of a centrifugal pump is determined by the impeller.

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Vanes are designed to meet a given range of flow conditions fig illustrates the basic types of impellers.

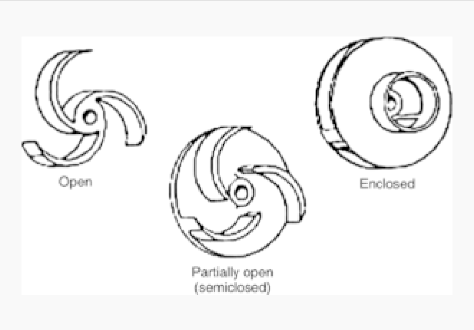

Fig. 3: Basic types of impellers.

Open Impellers:

Vanes are attached to the central hub, without any form, sidewall, or shroud, and are mounted directly onto a shaft. Open impellers are structurally weak and require higher NPSHR values. They are typically used in small-diameter, inexpensive pumps and pumps handling suspended solids. They are more sensitive to wear than closed impellers, thus their efficiency deteriorates rapidly in erosive service.

Partially Open Or Semiclosed Impellers:

This type of impeller incorporates a back wall (shroud) that serves to stiffen the vanes and adds mechanical strength. They are used in medium-diameter pumps and with liquids containing small amounts of suspended solids. They offer higher efficiencies and lower NPSHR than open impellers. It is important that a small clearance or gap exists between the impeller vanes and the housing. If the clearance is too large, slippage and recirculation will occur, which in turn results in reduced efficiency and positive heat buildup.

Closed Impellers:

The closed impeller has both a back and front wall for maximum strength. They are used in large pumps with high efficiencies and low NPSHR. They can operate in suspended-solids service without clogging but will exhibit high wear rates. The closed-impeller type is the most widely used type of impeller for centrifugal pumps handling clear liquids.

They rely on close-clearance wear rings on the impeller and on the pump housing. The wear rings separate the inlet pressure from the pressure within the pump, reduce axial loads, and help maintain pump efficiency.

Number of Impellers:

Single Stage Pumps:

The single-stage centrifugal pump, consisting of one impeller, is the most widely used in production operations. They are used in pumping services of low-to-moderate TDHs. The TDH (total dynamic head) is a function of the impeller’s top speed, normally not higher than 700 ft/min. Single-stage pumps can be either single or double suction. The single-stage pump design is widely accepted and has proved to be highly reliable. However, they have higher unbalanced thrust and radial forces at off-design flow rates than multistage designs and have limited TDH capabilities.

Multistage Pumps:

The multistage centrifugal pump consists of two or more impellers. They are used in pumping services of moderate-to-high TDHs. Each stage is essentially a separate pump. All the stages are within the same housing and installed on the same shaft. Eight or more stages can be installed on a single horizontal shaft. There is no limit to the number of stages that can be installed on a vertical shaft. Each stage increases the head by approximately the same amount. Multistage pumps can be either single or double suction on the first impeller.

III. SCOPE AND OBJECTIVE OF PRESENT WORK

The Contemporary blades in Centrifugal pump used in industrial applications are made up of Aluminum or Steel. The objective of present work is to design a Impeller of a Centrifugal pump with TWO materials, which are:

(a) Aluminum Alloy 1060
(b) E-glass/Epoxy

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Static and dynamic analysis on centrifugal pump impeller balde is carried out to evaluate performance at different load conditions:

(a) Static Analysis.
(b) Dynamic Analysis.

The modeling of the impeller and the above mentioned analyses will be done by Solid works software. In addition to that a method to fabricate the Impeller with E-glass/Epoxy is studied for realization of product.

IV. Literature Review:

G. Kalyan, K.L.N. Murty. "Design and Optimization of Centrifugal Pump Guide Vanes" In this paper an impeller of a centrifugal pump is designed and modeled in 3D modeling software Pro/Engineer.. Materials used are steel and aluminum. The optimization of the impeller design is done by observing the results obtained from the analysis performed. The results considered are stress frequency velocity pressure flow rates. Analysis is done in ANSYS. By observing the structural analysis result the stresses by increasing number of blades and increasing the angle of blade. When Aluminum material is used the stresses are less than that of steel. By observing modal analysis results the frequencies are reducing by increasing the number of blade.

IV. THEORITICAL CALCULATION:

Attempts are made to address this issue through considering the input values as below.

TABLE 1: Values For Theoretical Calculations:

Sl. No.	Parameters	Values
1	θ	40^o
2	ϕ	50^o
3	N	1300 rpm
4	b_1	53.4 mm
5	b_2	58.4 mm
6	r_1	16.25 mm
7	r_2	295 mm
8	R	381 mm
9	Bladecurve	Parabolic

$u_1 = r_1 \times \omega$
$u_2 = r_2 \times \omega$
$\tan\theta = v_1/u_1,\ v_1 = v_{f1}$
$Q = 2\pi r_1 b_1 v_1$
$V_{f2} = Q/2\pi r_2 b_2$

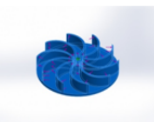
By using the above mention edequations and input values, the following values were calculated:

Angular velocity ω = 136.13 rad/sec
Vane velocity at inlet u_1 = 2.212 m/s
Vane velocity at outlet u_2 = 29.4 m/s
Velocity of flow at inlet $v_{f1} = v_1$ =292 m/s
Velocity of flow at outlet v_{f2} = 26.17 m/s
Discharge Q = 1.592 m/s
Whirl velocity at outlet V_{w2}= 12.47

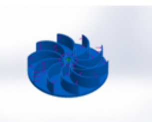
V. ANALYSIS & DATA COLLECTION

MATERIAL PROPERTIES:

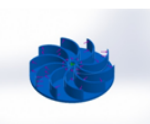
Al Alloy 1060:

Model Reference	Properties	Components
	Name: Al Alloy1060 Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 2.75742e+007 N/m^2 Tensile strength: 6.89356e+007 N/m^2 Elastic modulus: 6.9e+010 N/m^2 Poisson's ratio: 0.33 Mass density: 2700 kg/m^3 Shear modulus: 2.7e+010 N/m^2 Thermal expansion: 2.4e-005 /Kelvin	Solid Body 1(Combine1)(fan (2))

Graphite:

Model Reference	Properties	Components
	Name: Graphite Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 1.20594e+008 N/m^2 Tensile strength: 1.00826e+008 N/m^2 Elastic modulus: 4.8e+009 N/m^2 Poisson's ratio: 0.28 Mass density: 2240 kg/m^3 Thermal expansion: 1.3e-005 /Kelvin	SolidBody 1(Combine1)(fan (2))

Titanium:

Model Reference	Properties	Components
	Name: Titanium Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 3.7e+008 N/m^2 Tensile strength: 3.44e+008 N/m^2 Elastic modulus: 1.05e+011 N/m^2 Poisson's ratio: 0.37 Mass density: 4510 kg/m^3 Shear modulus: 4.5e+010 N/m^2 Thermal expansion: 9e-006 /Kelvin	SolidBody 1(Combine1)(fan (2))

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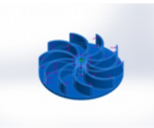
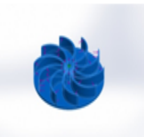
E-glass/Epoxy Material:

Model Reference	Properties	Components
	Name: EPOXY Model type: Linear Elastic Isotropic Default failure criterion: Max von Mises Stress Yield strength: 1.1551e+008 N/m^2 Tensile strength: 4e+008 N/m^2 Compressive strength: 3.5e+008 N/m^2 Elastic modulus: 4.46e+010 N/m^2 Poisson's ratio: 0.13 Mass density: 1750 kg/m^3 Shear modulus: 7.2e+009 N/m^2 Thermal expansion: 10 /Kelvin	Solid Body 1(Combine1)(fan (2))

VI. MODELLING AND SIMULATION

STATIC ANALYSIS ON IMPELLER OF AL ALLOY 1060

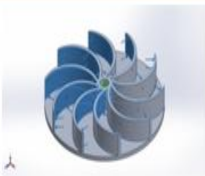
Model with volumetric properties of AA1060

Solid Bodies			
<L_MdInf_SldBd_Nm />	Treated As	Volumetric Properties	Document Path/Date Modified
Combine1 	Solid Body	Mass:8.16993 kg Volume:0.0030259 m^3 Density:2700 kg/m^3 Weight:80.0653 N	---

Applying Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 1 face(s) Type: Fixed Geometry

Applying Loads and Fixtures on impeller of AA1060

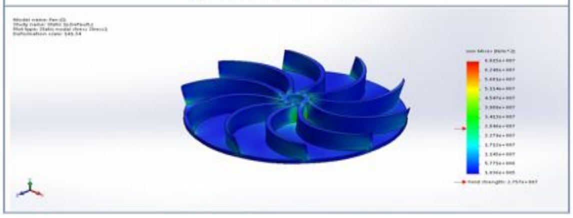
Load name	Load Image	Load Details
Force-1		Entities: 10 face(s) Type: Apply normal force Value: 1500 N

STATIC STRESS, STRAIN AND TOTAL DEFORMATION VALUES OF AA1060

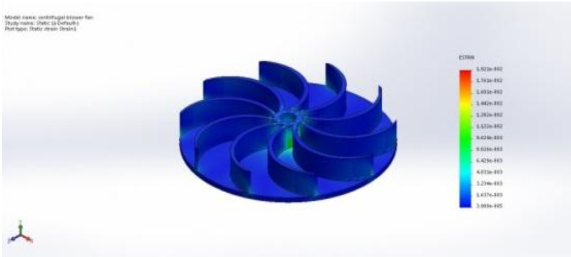
Static stress result table of AA1060

Name	Type	Min	Max
Stress1	VON: von Mises Stress	103614 N/m^2 Node: 6549	6.81544e+007 N/m^2 Node: 2813

Impeller AA1060-Static 1-Stress-Stress1

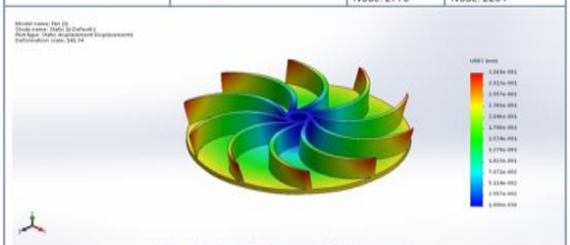


Strain result of AA 1060



Total deformation table of AA1060

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 2776	0.306852 mm Node: 2204

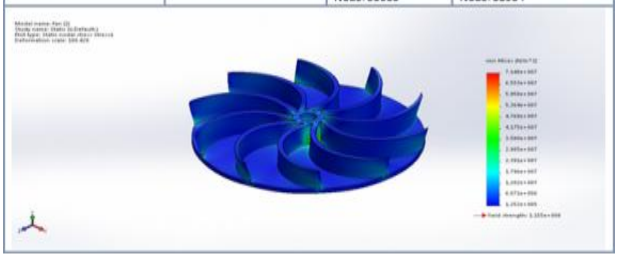


fan (2)-Static 1-Displacement-Displacement1

STATIC ANALYSIS ON IMPELLER OF E-GLASS/EPOXY MATERIAL-STATIC STRESS, STRAIN AND TOTAL DEFORMATION VALUES

Static stress result table of E-glass/Epoxy Material

Name	Type	Min	Max
Stress1	VON: von Mises Stress	125239 N/m^2 Node: 53063	7.14759e+007 N/m^2 Node: 38934



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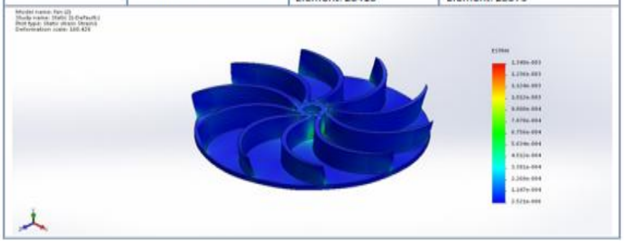
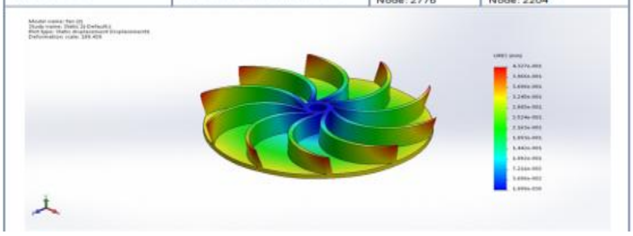
Strain result of E-glass/Epoxy Material

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.52068e-006 Element: 26410	0.00134867 Element: 25579



Total Deformation Table of E-Glass/Epoxy Material.

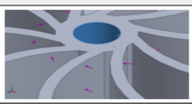
Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 2776	0.432677 mm Node: 2204



DYNAMIC ANALYSIS

DYNAMIC ANALYSIS ON IMPELLER OF AL ALLOY 1060

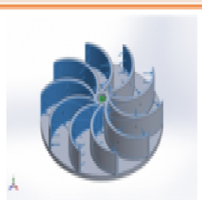
Applying Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 1 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.00553608	3.54707	-0.0149179	3.54711
Reaction Moment(N.m)	0	0	0	0

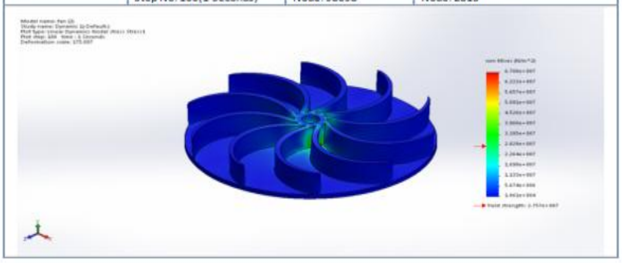
Applying Loads and Fixtures on impeller of Al Alloy 1060

Load name	Load Image	Load Details
Force-1		Entities: 10 face(s) Type: Apply normal force Value: 1500 N

DYNAMIC STRESS, TOTAL DEFORMATION

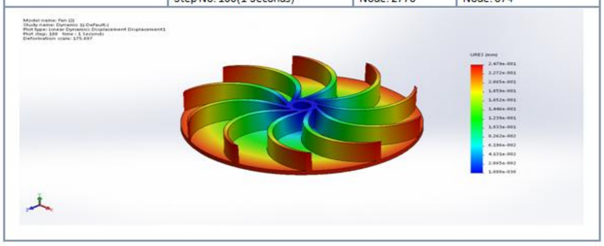
Dynamic stress result table of Al Alloy 1060

Name	Type	Min	Max
Stress1	VON: von Mises Stress at Step No: 100(1 Seconds)	18607.6 N/m^2 Node: 98698	6.78785e+007 N/m^2 Node: 2813



Total deformation table of Al Alloy 1060

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement at Step No: 100(1 Seconds)	0 mm Node: 2776	0.24785 mm Node: 674

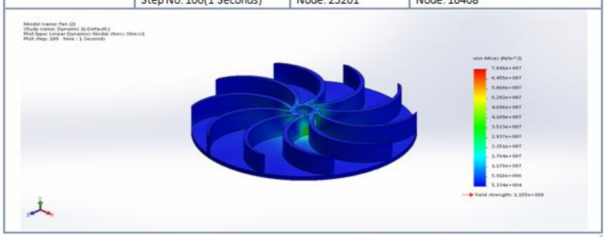


DYNAMIC ANALYSIS ON IMPELLER OF E-GLASS/EPOXY MATERIAL.

DYNAMIC STRESS, TOTAL DEFORMATION

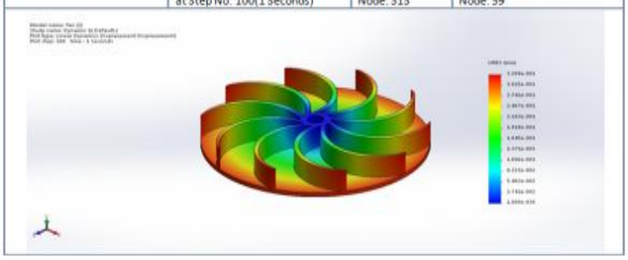
Dynamic stress result table ofE-glass/Epoxy Material

Name	Type	Min	Max
Stress1	VON: von Mises Stress at Step No: 100(1 Seconds)	53336.9 N/m^2 Node: 23201	7.04098e+007 N/m^2 Node: 16408



Total deformation table ofE-glass/Epoxy Material

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement at Step No: 100(1 Seconds)	0 mm Node: 313	0.328937 mm Node: 59



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SIMULATION RESULTS

STATIC STRESS ANALYSIS RESULTS

Load applied on each material was 1500N

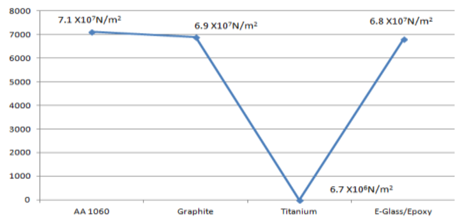

Fig.4: Maximum stress (N/M^2) Vs. Material

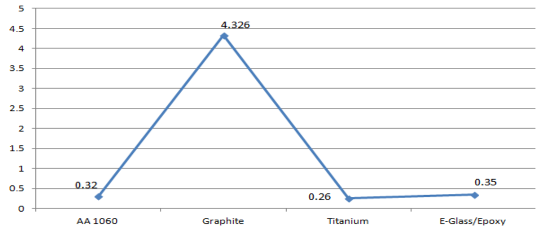

Fig.5: Deformation (Mm) Vs. Material

DYNAMIC ANALYSIS RESULTS

Load applied on each material was 1500N

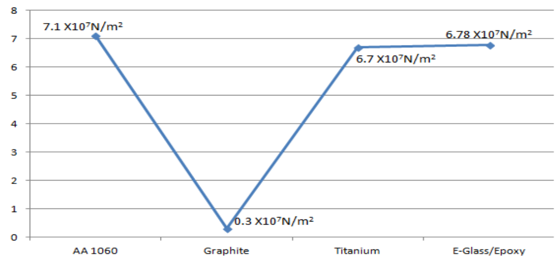

Fig.6: Maximum stress (N/M^2) Vs. Material

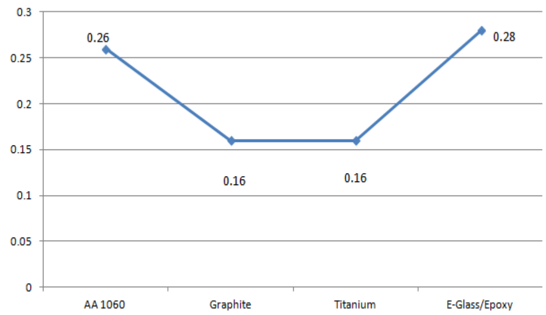

Fig.7: Deformation (Mm) Vs. Material

CONCLUSION:

- Modeling and simulation of centrifugal pump impeller has done using Solid Works software.
- After observing the static and dynamic analysis values we can conclude that e-epoxy has the better stress bearing capacity compared with the other materials except titanium deformation values by showing its better strength values to the applied loads.
- E-glass/Epoxy material is non metallic component so, the chattering noise will be low compared to other materials during the functioning process.
- For manufacturing the centrifugal pump impeller we can proceed with Epoxy/E-glass material because it has high stress bearing capacity and reasonable manufacturing cost.

FUTURE SCOPE:

The composition of e-epoxy can be changed with optimum composition of the resin and hardeners, So that the maximum stress acting on the material may reduce which proportionally decreases the deformation.

REFERENCES:

[1]S.Rajendran and Dr.K.Purushothaman, “Analysis of a centrifugal pump impeller using ANSYS-CFX,” International Journal of Engineering Research & Technology, Vol. 1, Issue 3, 2012.

[2]S R Shah, S V Jain and V J Lakhera, “CFD based flow analysis of centrifugal pump,” Proceedings of the 37th National & 4th International Conference on Fluid Mechanics and Fluid Power, IIT Madras, Chennai, 2010.

[3]P.UshaShriansC.Syamsundar, “computational analysis on performance of a centrifugal pump impeller,” Proceedings of the 37th National & 4th International Conference on Fluid Mechanics and Fluid Power, IIT Madras, Chennai, 2010.

[4]E.C. Bacharoudis, A.E. Filios, M.D. Mentzos and D.P. Margaris, “Parametric Study of a Centrifugal Pump Impeller by Varying the Outlet Blade Angle,” The Open Mechanical Engineering Journal, no 2, 75-83, 2008.

[5]Marco Antonio Rodrigues Cunh and Helcio Francisco Villa Nova, “Cavitation modelling of a

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

centrifugal pump impeller," 22nd International Congress of Mechanical Engineering, Ribeirao Petro, Sao Paulo, Brazil, 2013.

[6]Mohammed Khudhair Abbas, "cavitation in centrifugal pumps," Diyala Journal of Engineering Sciences, pp. 170-180, 2010.

[7]AbdulkadirAman, SileshiKore and Edessa Dribssa, "Flow simulation and performance prediction of centrifugal pumps using cfd-tool," Journal of EEA, Vol. 28, 2011.

[8]Erik Dick, Jan Vierendeels, Sven Serbruyns and John VandeVoorde, "Performance prediction of centrifugal pumps with cfd-tools," Task Quarterly 5, no 4, 579–594, 2001.

[9]S. C. Chaudhari, C. O. Yadav and A. B. Damo, "A comparative study of mix flow pump impeller cfd analysis and experimental data of submersible pump," International Journal of Research in Engineering & Technology, Vol. 1, Issue 3, 57-64, 2013.

[10]D. Somashekar and Dr. H. R. Purushothama, "Numerical Simulation of Cavitation Inception on Radial Flow Pump," IOSR Journal of Mechanical and Civil Engineering, Vol. 1, Issue 5, pp. 21-26, 2012.