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CENTRIFUGAL IMPELLER MODELING AND STATIC ANALYSIS WITH DIFFERENT MATERIALS

RAHUL D. SHELKE [1], MOHAMMED SHOEB SHAKEEL AHMED[2]

HOD, Associate Professor, Department of Manufacturing Engineering, EESGOI, Aurangabad [1]
ME Student, Department of Manufacturing Engineering, EESGOI, Aurangabad [2]

Abstract: ***Centrifugal pump is a fluid energy-producing mechanism. This energy may make a fluid flow or increase to a greater level. Centrifugal pump is a very simple machine composed of two fundamental parts: the rotating element or impeller and the stationary element or case. Centrifugal pumps are widely utilized worldwide, because the pump is durable, efficient and cost-effective. A centrifugal pump is a red dynamic pump which employs a spinning pump to boost the fluid's pressure. Centrifugal pumps are utilized for transportation of liquids via a tube system. The fluid enters the pump impeller along or near the turning path and is propelled by the impeller, which flows outward radially into a diffuser or volute chamber (case), from which it joins the downstream pipe system. It is intended to transform the energy of a primary mover (electric motor or turbine) into speed or kinetic energy and subsequently into pressurized energy of the pumped liquid. Centrifugal pumps are utilized through smaller heads for greater discharges. Centric-fugal pumps transform mechanical energy from the engine into a moving fluid's energy; some energies go into kinetic energy of fluid movement, and others into potential energy, which is represented by a fluid pressure or by raising a fluid upwards. The transmission of energy from the mechanical rotation of the impeller to fluid motion and pressure, in particular in earlier literature published before the contemporary notion of centrifugal force as fictitious force, is adequately defined in a rotating referential frame. In fact, the idea of centrifugal force is not needed to describe the centrifuge pump's function. The CFRP, GFRP, INCONEL, STAINLESS STEEL, AL-6061 Pump Impeller is being analysed for the purpose of increasing centrifugal pump resistance. The aim is to build an impeller using computer aided design software (CAD) using different metal alloys and composite materials, with Ansys software, to analyse static analyses and to detect stress, stress and deformation. To assess the efficiency of the appropriate impeller material.***

Keywords: *Computer Aided Design (CAD), Computational Fluid Dynamics (CFD), Carbon Fiber Reinforced Polymer (CFRP), Graphite Fiber Reinforced Polymer (GFRP).*

I INTRODUCTION

Many research applications now focus on decreasing losses, power consumption and efficiency of certain devices such as pumps in hydraulics and fluid dynamics. Centrifugal pump is an essential kind that transfers mechanical energy to kinetic energy by producing force that imparts fluid to the pillar blades. Rotation vans in a centrifugal pump that is within the pump box are used to transmit the kinetic energy and transfer it via centrifugal force to the fluid, and the fluid is pushed to flow through the vapors by pressure. Design elements such as number of blades have a strong impact on pump efficiency. The number of blades also has some impact on the overall pump properties like as efficiency and head. As the number of the blade increases, the flow rate will increase as the area is crowded, and this flow will decrease if the blades of the impeller are few owing to increased diffusion loss. At the moment, the revolution in computer technology and the fast development in various analytics software such as (ANSYS) make numerical simulation and fluid dynamics (CFD) one of the best alternatives as a tool for investigating and estimating optimal pump characteristics. Simulation of this type is highly beneficial for forecasting and estimating various pump performance parameters and provides numerous solutions before further stages. The physical condition of the pump includes the most performance elements that can be anticipated and the actual values may be seen and observed by a computer technique. Simulation analysis (CFD) is a strong design and toll estimate that reduces time, costs and outcomes. It can decrease the inaccuracy and provide a broad variety of alternatives by making tests many times with different settings possible. Optimization processes require a high level of talent and design abilities, but the combination of these talents (CAD) with the system speeds up design process generation and provides appropriate solutions for many parameters of design. Research has shown that any compound between short and long blades in the pumping impeller would enhance the pump efficiency because the uniform distribution near the intake suction is a powerful prevention to any growth that it calls (wake flow). The composite of short and long blades in a single rotor case is beneficial for the efficiency of the pump owing to variations in the position. By correct numerical and simulation method, the major features and performance of the pump may be anticipated. Many simulation results have validated that the flow rate efficiency of the pump will rise when the blade angle increases.

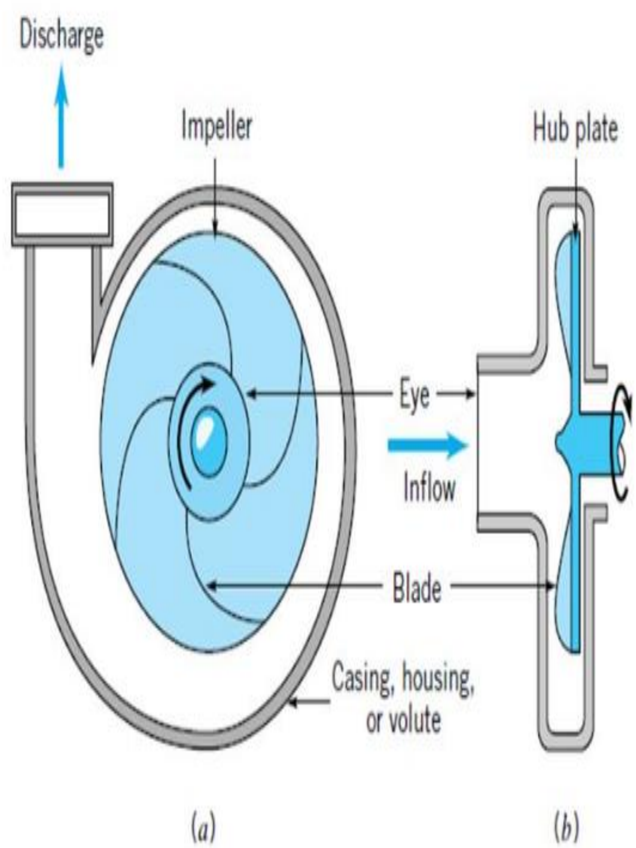

Figure No 1.1: Centrifugal pump basic working.

II LITERATURE SURVEY

The authors Malik N. Hawas, Akeel Abbas Mohammed & Audai Hussein Al-Abbas, flow mechanics and dynamic performance of centrifugal pumps are usually altered by alteration of blade form and configuration. In order to have a better understanding of the ideal shape of the impeller and the adequate number of blades with a fitting angle. Numerical simulation is now the primary verification approach utilised in the examination of these properties. Commercial code Fluent (CFD) under ANSYS software has been utilised for research of pump impeller operating characteristics under two different geometrical models under different circumstances. Two distinct impellers with a variable number of blades in 3D configuration are built with the single arc curved blades and are submitted for analysis and simulation in the comparison approach to identify the optimum features. Conventional impeller case utilised to record any change in each individual case as a basis for comparative reasons, such as heads, flow rates, and efficiency. The dynamic analysis solution allows the impeller construction to resist and survive various varying loads and turbulent situations. Results confirmed that static pressure, total head and efficiency are related to the numbers of the blades and shape of the blades. Moreover, certain essential characteristics have an influence on the performance of the centrifugal pump, such as inlet diameter and padding angle. From this work, it can be concluded that appropriate anticipated outcomes are calculated and those findings may be used and accepted for such centrifugal pumps [1].

Gang-Hyeon Jang,Ji-Hun Ahn,Byung-Ok Kim,Dong-Hyun Lee,Jae-Sung Bang and Jang-Young Choi Authors design guideline for a 110 hp, 12 500 r/min centrifugal pump for a high velocity permanent magnet synchronous motor (PMSM), taking account of the mechanical and electromagnetic features. The size of the rotor was determined based on the torque per unit volume approach. The study of rotor stress was conducted using the analytical technique and the finite element method. Based on these results, suitable sleeve thickness and material were chosen based on mechanical stability and electrical efficiency. The PMSM design was carried out utilising a mechanically stable rotating body. The iron loss analysis and the eddy current loss analysis were based on the finite-element technique, which chose the model with good electromagnetic performance. Furthermore, a critical speed study of the finally constructed PMSM model proved the stability of the high-speed operation. The high-speed PMSM checks the performance during production and tests, which have shown that the real centrifugal pump systems have no difficulty [2].

Kaviarasan .R,Nagarajan. S & Prasanth. E authors design optimization of a rearward curved blade centrifugal pump must be implemented using three dimensional modelling and CFD analysis to enhance the hydraulic performance of the pump. This research examines the analysis of complicated internal flows in centrifugal pump impellers, using CFD software that facilitates pump design. The pump specifications to be examined are discharge and speed. The specifications for a comparative analysis of various pump impellers are different. To improve the performance of the centrifugal pump by modifying the impeller design. The impeller is modelled in Pro engineering software and a fluid flow simulation tool is used to do CFD analysis. CFD study can forecast the pump performance and comparison analysis is carried out with changing meshing for the full control volume. The correct results in terms of velocity distribution and pressure distribution need to be predicted and the hydraulic efficiency of the centrifugal pump has to be increased. For the parameterization of the impeller a number of geometric variables are added. Geometry also allows easy changes to the design. The calculations for the continuous flow field are displayed in a specific impeller and the results are examined using 3-dimensional diagrams [3].

In recent times the author Venkatratnam dirisala of complicated interne flows via the impeller have received a great deal of interest in this field. The pumps' rotational speed, blade number and flow rate are essential design factors that have a significant influence on the pump's properties. The study now mainly focuses on the performance characteristics (h, η) of the pump. The analysis has been done for five distinct flow rates at various rotating speeds, with various pale numbers maintaining the impeller size, the diameter of the eye, the width of the blade and the thickness of the blade [4].

The author Mane Pranav Rajanand, A centrifugal pump is a red dynamic pump that employs a spinning pump to boost the fluid's pressure. Centrifugal pumps are usually used to transport liquids via a pipe system. The liquid enters the pump impeller along or near the rotational axis and flows radically to an air diffuser (casing) and out into the downstream piping system through the impeller. The goal is to transfer energy from the prime mover first into speed or kinetic energy and subsequently into the pressure energy of the pumped fluid. For big discharges through smaller heads are utilized centrifugal pumps. Centrifugal pumps transfer mechanical energy from the engine to the mobile fluid energy; some energy goes into kinetic energy of the fluids, and some into potential energy, which is either fluid pressure or raising the fluid to a higher level against gravity. The transfer of energy from the mechanical rotation of the impeller to the velocity and pressure of the fluid is normally characterized as centrifugal force, especially in earlier literature, published prior to the current notion of centrifugal force in a rotating reference frame. The idea of centrifugal force does not actually explain the centrifugal pump's function. This study analyses the MS & SS pump impeller for optimizing the strength of the centrifugal pump. This article offers the MS & SS Pump Impeller static & model analysis to verify the strength of pump and pump production vibrations [6].

The authors Karthik Matta, Kode Srividya & Inturi Prakash , One pushbutton is a revolving component of a centrifugal pump, generally constructed of iron, steel, bronze, brass, aluminium or plastic, which transmits motor power to pump the fluid from the centre of rotation. The impeller speed translates to pressure when the external movement of the fluid is limited within the pump box. In general, the impellers are small cylinders with an open intake (called the eye) that accept inbound fluid, vanes that radially press the fluid, and the splintered, keyed or threaded hole to accept a driving shaft. The impeller was modelled using the CATIA V5 R18, solid modelling programme. It is proposed that a blower using composite material be designed, its strength and deformation analysed using FEM software. To assess the efficiency of metal blower and impeller composites with FEA packaging (ANSYS). Modal analysis is carried out for the first 5 natural frequencies on both aluminium and composite centrifugal blower impels [8].

Authors A Syam Prasad, BVVV Lakshmipathi Rao, A Babji, Dr P Kumar Babu , many technical applications, alloys play a key role. They offer excellent mechanical characteristics, design flexibility and manufacturing simplicity. Further advantages include light weight and resistance to corrosion, impact resistance and good fatigue strength. In such varied applications as cars, aeroplanes, space vehicles, offshore constructions, containers and pipelines, sports items, electronics and appliances nowadays alloys are commonly utilised. In this article the static and dynamic analysis of a centrifugal pump impeller composed of three distinct alloy materials (i.e. Inconel alloy 740, Incaroy alloy 803 and Warpaloy) is examined in order to evaluate its performance. The research was carried out utilising software CATIA and ANSYS13.0. CATIA is utilised for impeller modelling and ANSYS is used for analysis. ANSYS is a devoted finite element software used to determine stress, strain and deformation variations throughout the rotor profile. HYPER MESH 9.0 is also utilised to achieve good and optimal roller mesh for precise outcomes. Structural study for the stress, stresses and displacements of the impeller and modal analysis for frequency and deflection of the impeller were carried out. It is also tried to propose the optimum alloy for a centrifugal pump impeller by comparing the findings for three distinct alloys [10].

The authors Gundale V.A. & Joshi G.R.,offer a simpler vane profile design process of the radial kind. This article gives a thorough image of the method for designing the radial type vane profiles based on a basic comprehension of published procedures. There is a limited number of published vane profile design processes, which typically lack the clarification and thorough procedure for designers to systematically design and develop the radial-type vane profile, forcing designers to reverse engineer the vane profiles that are common on the market. There is a major difficulty in the case of published processes when following them, as some of them are inconsistent. The overall dimensions of an existing impeller were not altered in this research when developing the vane profile. To generate a 3D model, commercial 3D CAD software is utilised. This method will push designers to improve the performance of both existing and future pump types [13].

The authors Pramod J. Bachche1 & R.M.Tayade study Centrifugal pump is one of the oldest pumping currencies in the world. The current work examines the centrifugal pump shaft for static and dynamic analysis. As we know, rotodynamic machines are highly designed, as load and speed fluctuations are widespread. The shaft is evaluated using a technique for finite element analysis for stress and deflections. The overall work is performed in the first two phases of static analysis. In this phase pump shaft, stress and deflection are analysed and the same findings are checked using the graphical integration technique. Secondly, for dynamic analysis, static analysis is utilised to compute dynamic forces entering the pump shaft at this phase. Again, the shaft is examined and the findings are confirmed using the graphical technique for integration. HYPERMESH is the software used for finite-element meshing and RADIOSS is the solver utilised. For deflection and stress the results obtained are compared in both situations. The results of the visual technique and the FEA are almost comparable and are within acceptable limits [14].

The writers Khin Cho Thin, Mya Mya Khaing and Khin Maung Aye, deal with the centrifugal pump design and performance analysis. This article analyses the centrifugal pump utilising a single-stage centrifuge suction pump. The impeller and the case are two key components of a centrifugal pump. The rotary component is the impeller while the box is a stationary component. Water enters the centrifugal pump axially through the impeller's eyes and water radially departs. The pump case should direct the liquid into the impeller, transform the high-speed kinetic energy of the flow from the impeller discharge into pressure and remove the liquid from the fluid's energy. A centrifugal pump design is performed and studied to get the greatest possible performance. The centrifugal pump is designed and performed because it is the most beneficial mechanical rotodynamic machine for fluid processes that is extensively utilised in the household, irritional, industrial, large-scale plant and river pumping systems. Centrifugal pumps are also manufactured in Myanmar via industrial methods. The pump is operated by a horse power motor and design is based on the Berman method in this study. This pump has a head speed and flow rate of 10 m and 0,179 m3/s and an engine speed of 2900 rpm. The low speed is picked as the value of the specified speed is 100. The number of blades is 9. The number of blades. After the design of the centrifugal pump dimensions, the performance analysis is performed. Shock losses, impeller friction losses, flawless friction losses, disc friction losses and centrifugal pump recirculation losses are also included for centric fugal pump performance study [15].

III. EXPERIMENTAL INVESTIGATION

3.1 CFPR Material

Carbon fibre-reinforced thermoplastic (CRP, CRP, CFRTP or frequently just carbon fibre, or even carbon), is a very strong and lightweight fiber-reinforced plastic containing carbon fibres. The term 'fibre' is popular in the United Kingdom.CFRPs can be costly but usually employed when there is a need for a high strength-to-weight ratio and stiffness, for example aerospace, automotive engineering, civil engineering, sports goods and a growing variety of further consumer and technical applications.

Binding polymers are generally a thermoset resin like epoxy, but sometimes other thermoset or thermoplastic polymers, such as polyester, vinyl ester and nylon, are employed. (UHMWPE) or fibreglass, and fibreglass. The characteristics of the final CFRP product may also be influenced by the additive type included in the binding matrix (the resin). The most common addition is silica, however other additives can be utilised, such as rubber and carbon nanotubes. The material is known as graphite-reinforced polymer (GFRP is less prevalent as GFP conflicts with glass-(fiber)-reinforced polymer). It is frequently referred to simply as graphite fibre for short in product marketing.

3.2 GFRC Material Composition

Reinforced or GFRC glass fibre concrete is a form of reinforced concrete. The substance is also known in

British English as glass fibre reinforced concrete or GRC. Glass fibre concrete is utilised primarily as an architectural precast concrete in outside construction façade panels. Fiber cement siding and cement boards are somewhat comparable materials. Glass fiber-reinforced concrete comprises of alkaline-resistant high resistance fibre-glass incorporated in a concrete matrix. This means that both the fibres and the matrix retain their physical and chemical identity and offer a synergistic mix of characteristics that cannot be produced with each component operating alone. In general, fibres are the main carriers, while the surrounding matrix maintains them in the required positions and orientation and acts as a means of load transmission between the fibres. The fibres support the matrix and other important functions in fiber-reinforced composites. Glass fibres can be added in continuous or discontinuous lengths into a matrix. The durability of the first type of glass fibres was low as cement alkalinity interacts with silica. Alkaline-resistant glass fibres were marketed in the 1970s. Resistance to alkalis is accomplished by the addition of zirconia to the glass. The higher the zirconia, the greater the resistance against alkaline assault. The best fibres have 19 percent or higher zirconia content.

3.3 Stain Less Steel

In metallurgy, stainless steel also known as French stainless steel or stainless steel (inoxidizable) is a steel alloy with a minimum mass concentration of 10.5% chromium. Stainless steel is remarkable for its corrosion resistance and, amongst many other applications, is used frequently for food handling and cutlery. As regular steel, steel does not corrode, rust or discolour quickly with water. However, under low oxygen, high salt or poor air circulation conditions, it is not totally stain-resistant. The grades and surface finishes of stainless steel are different for the environment that the alloy must withstand. In stainless steel, both the characteristics of stainless steel and the resistance to corrosion are needed. The quantity of chromium contained differs from carbon steel. Carbon steel is easily rusted when exposed to air and humidity. This iron oxide coating (the rust) is active and corrosion accelerates by facilitating the formation of additional iron oxide. Since iron oxide is less dense than steel, the film stretches and falls. By comparison, stainless steels contain enough chromium to passive effects, creating an inert chromium oxide layer on the surface. This layer inhibits further corrosion by preventing the passage of oxygen on the steel surface and prevents corrosion from spreading to the metal bulk. Passivation happens only if the chromium percentage is sufficiently high and oxygen is present.

IV EXPERIMENTAL RESULTS

The built impeller in catia is examined using ANSYS 14. The findings are presented below.

4.1. MATERIAL CFRP:

Here the pressures, stresses and deformations occur when the impeller is analyzed using cfrp material, as illustrated in the following figures.4.1. Von-mises stress of CFRP material

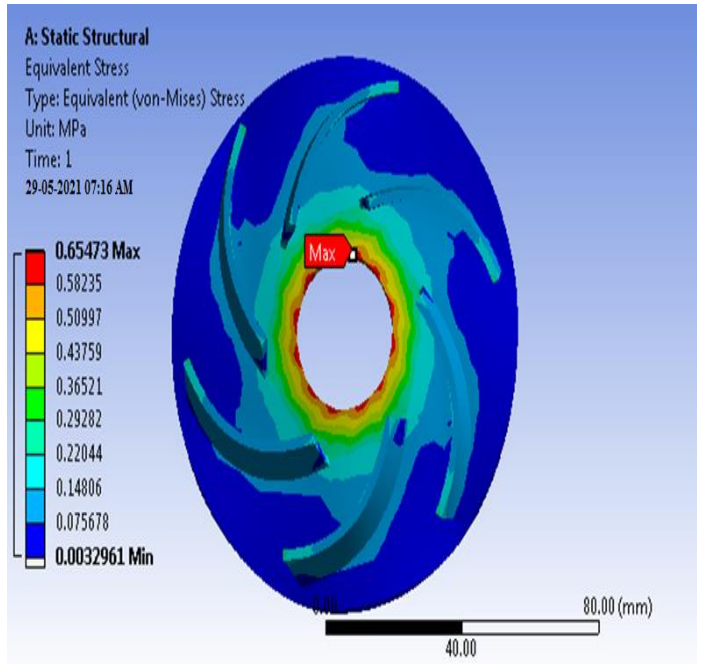

Figure No 4.1: Von-mises stress of CFRP material

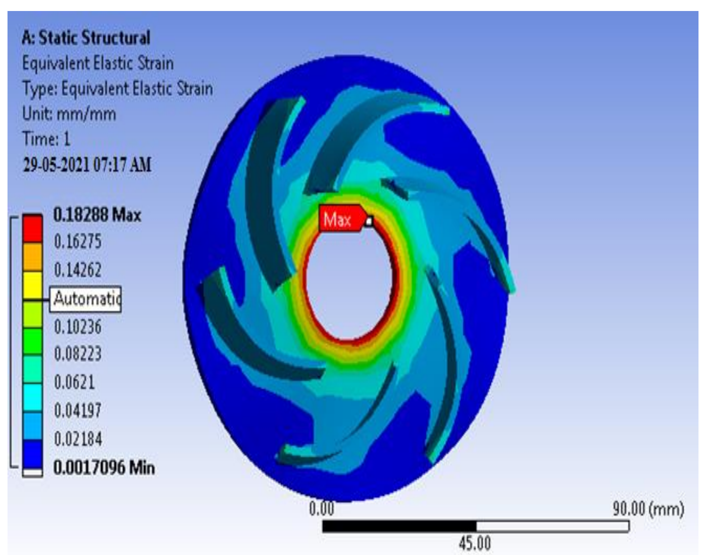

Figure No 4.2: Strain of CFRP material

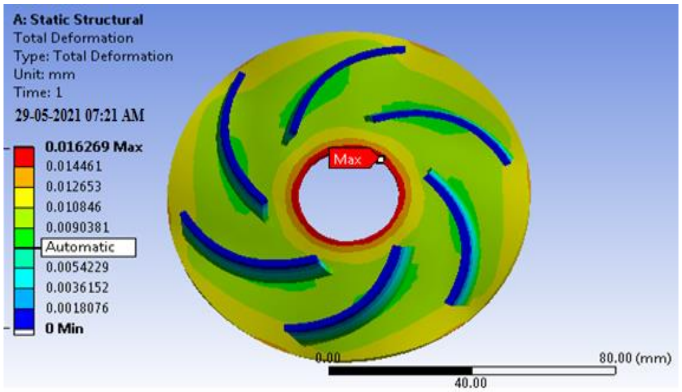

Figure No 4.3: Total deformation of CFRP material

Table No 4.1: Results

Materials	Von-Mises Stress(Mpa)	Strain	Total Deformation(Mm)
GFRP	0.595	0.179	0.0156
CFRP	0.654	0.182	0.0162
AL-6061	0.744	0.191	0.0195
INCONEL	0.684	0.185	0.0169
STAINLESS STEEL	0.726	0.188	0.0185

4.2 GFRP MATERIAL:

In this case, stresses, strains, deformations are achieved by the impeller analysis utilizing GFRP material, as illustrated below fig. 4.4.

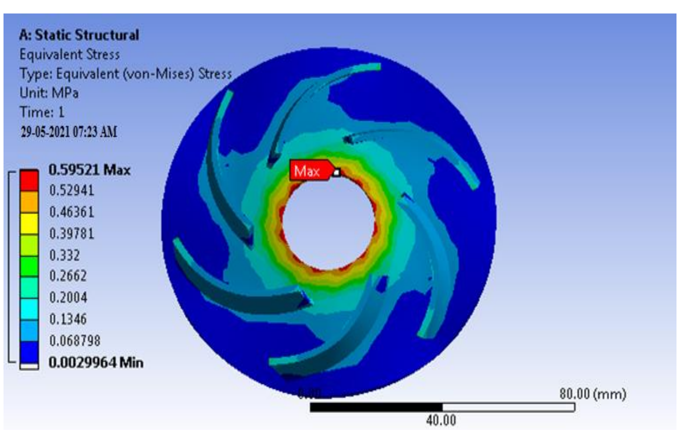

Figure No 4.4: Von-mises stress of GFRP material

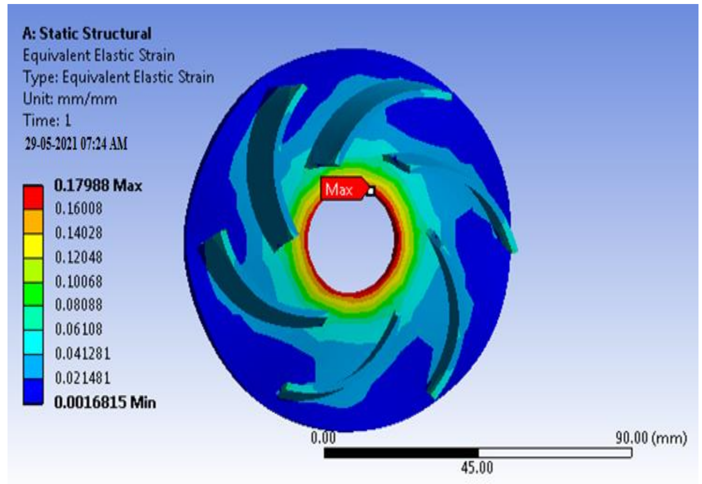

Figure No 4.5: Strain of GFRP material

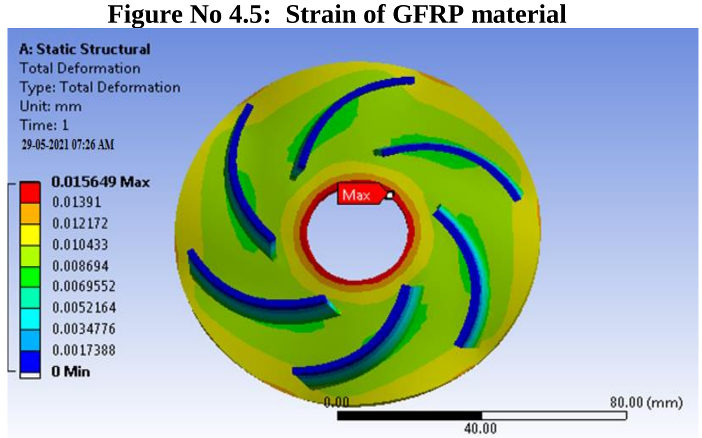

Figure No 4.6: Total deformation of GFRP material

V CONCLUSION

The centrifugal blower fan was modelled and simulated using catia software. Following the observation of the static analytical values we can infer that GFP, CFRP are more able than the other materials to support stress and have superior strength values when applying loads. When the pump impeller is statically analysed it is evident that, in Stainless Steel, Al-6061, the highest stresses, strains and deformation is generated compared to other materials (composites). Compared with stress, GFRP and CFRP are eventually concluded to be the appropriate material if corresponding deformations of the composites (GFRP,CFRP) over outcome are compared For centrifuge impeller and centrifugal impeller production, we may use GFRP,CFRP materials because of its excellent load-bearing capability and economical production costs.

REFERENCES

1. Malik N. Hawas, Akeel Abbas Mohammed & Audai Hussein Al-Abbas,"Improving the Efficiency and Performance of Centrifugal Pump through Model Development and Numerical Analysis for the Pump

Impeller",International Journal of Mechanical Engineering and Robotics Research Vol. 9, No. 1, January 2020.

2. Gang-Hyeon Jang,Ji-Hun Ahn,Byung-Ok Kim,Dong-Hyun Lee,Jae-Sung Bang and Jang-Young Choi,"Design and Characteristic Analysis of a High-Speed Permanent Magnet Synchronous Motor Considering the Mechanical Structure for High-Speed and High-Head Centrifugal Pumps",IEEE Transactions on Magnetics,May 30,2018.

3. Kaviarasan .R,Nagarajan. S & Prasanth. E,"Design and Analysis of Centrifugal Pump Impeller using CFD Analysis",International Journal of Engineering Research & Technology (IJERT),Volume 5, Issue 07,2017.

4. Venkatratnam dirisala,"Performance Analysis of Centrifugal Pump by Using CFD",International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 10,pp. 474–483,October 2017.

5. Vijayanandh R.,Raj Kumar G.,Senthil Kumar M.,Karthick M. & Ramganesh T.,"Fatigue life estimation of Aircraft engine compressor with suitable material selection",IEEE,2016.

6. Mane Pranav Rajanand,"Design & Analysis of Centrifugal Pump Impeller by FEA",International Research Journal of Engineering and Technology (IRJET),Volume: 03,Issue: 01,Jan-2016.

7. Kamonwan Mondee, Nutchanant Foojinphan, Praemai Wannawat and Phornphop Naiyanetr,"The Effect of Shear Stress on The Impeller Design of Centrifugal Blood Pump",The 2016 Biomedical Engineering International Conference,IEEE Explorer,2016.

8. Karthik Matta, Kode Srividya, Inturi Prakash , "Static and Dynamic Response of an Impeller at Varying Effects" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 1 Ver. III pp 101-106 (Jan. 2014),

9. Ashish Bowade & Charu Parashar,"A Review of Different Blade Design Methods for Radial Flow Centrifugal Pump",International Journal of Scientific Engineering and Research (IJSER),Volume 3 Issue 7,July 2015.

10. A Syam Prasad, BVVV Lakshmipathi Rao, A Babji, Dr P Kumar Babu , "Static and Dynamic Analysis of a Centrifugal Pump Impeller" International Journal of Scientific & Engineering Research,Volume 4,Issue 10,pp966-971,October-2013.

11. Ling Zhou,Weidong Shi and Suqing Wu,"Performance Optimization in a Centrifugal Pump Impeller by Orthogonal Experiment and Numerical Simulation",Hindawi Publishing Corporation Advances in Mechanical Engineering,Volume 2013.

12. S R Shah,S V Jain,R N Patelb & V J Lakhera,"CFD for centrifugal pumps: a review of the state of the art",elsevier,Procedia Engineering 51,715–720,2013.

13. Gundale V.A. & Joshi G.R.,"A Simplified 3d Model Approach in Constructing the Plain Vane Profile of A Radial Type Submersible Pump Impeller",Research Journal of Engineering Sciences,Vol.2(7),33-37,July 2013.

14. Pramod J. Bachche1, R.M.Tayade " Finite Element Analysis of Shaft of Centrifugal Pump" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 7, Issue 3 (Jul. - Aug. 2013), pp 37-42

15. Khin Cho Thin, Mya Mya Khaing and Khin Maung Aye,"Design and Performance Analysis of Centrifugal Pump",World Academy of Science, Engineering and Technology, 22 2008.