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Design Optimization of Internal Axial Flow Ventricle Assist Device (VAD) using CFD Model.

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Abstract: ***Every year everywhere throughout the world, Millions of patients from new-born children to grown-ups are determined to have heart disappointment. Aless number of contributor hearts accessible for the patients brings about a gigantic interest of mechanical type circulatory system, as a ventricular assist device (VAD). As of now mechanical help is generally encouraging option in contrast to heart transplantation. Ventricle Assist Device (VAD) were initially used to give mechanical help in patients anticipating arranged heart transplantation.***
VAD is a mechanical circulatory device that is used to partially replace function of heart failure i.e., to direct blood away from failing ventricle and guide flow to the circulation. VAD is analogous to pump (Blood Pump), so the performance characteristics of the pump is very important like pump curves (H-Q curves). The H-Q curve shows the head the pump pump can perform at a given stream.
Plan strategy adopted for this object is computational fluiddynamics (CFD). CFD based structure to decide the response of the pressure rise, flow rate for optimization purpose.

Keywords: heart failure, heart transplantation, ventricular assist device (VAD), computational fluid dynamics (CFD).

I.INTRODUCTION

Coronary illness keeps on being the main source of death over the globe. Coronary illness is a type of disorder in the ordinary working of the heart. Even though coronary illness might be available from childhood, regularly maturing procedure prompts higher-weight and decrease in the general flexibility of the blood vessels, makes the heart incapable to produce satisfactory cardiovascular yield for fringe and heart course. Alongside Coronary Artery Disease event of other circulatory illness gives off an impression of being rising, predominantly for men in more established age gathering. In spite of noteworthy advancement made throughout the most recent years in the medicinal sector and a reduction in death rate from all cardio sickness by 45% in INDIA, every year a large number of individuals experience the ill effects of interminable coronary illness and myocardial dead tissue (MI) that is usually referred to as a heart attack. Congestive Heart Failure (CHF), is a condition wherein the heart can't siphon required amount of blood to address the issue of different parts of body.

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India has seen a disturbing ascent in the event of stroke, coronary illness,diabetes and malignant growths in previous years, a progression of new investigations distributed in The Lancet and its associated journals have revealed.
Definite assessments of diabetes, cardiovascular illnesses, cancer, chronic respiratory diseases and suicide show that their commonness has increased in each Indian state somewhere in the range of 1990 to 2016, yet there is huge variety among different states.
The predominance of stroke and coronary illnesshas expanded by half from 1990 to 2016 in different states of India, with an expansion saw in each Indian state.

A. Need of Mechanical Circulatory Support (MCS)

Improved coordination between donor, recovery and transplantation has prompted a 10-fold increment in heart transplantations in India since 2016.
There have been almost 300 heart transplantations crosswise over India in two years, as indicated by information given by the National Organ and Tissue Transplantation Organization (NOTTO), the national planning office for cadaveric organ donation, compared to around 350 somewhere in the range of 2015 and 1994, when the first heart transplantation was done in India.
However, if we look at the need, this is only a drop. Each inside in India that does heart transplant has a holding up rundown of 10 or 20 at some random time. An expected 50,000 hearts are required for transplants.
A restricting element for cardiovascular transplantation is a huge deficiency of contributor hearts.
A normal holding up period before heart transplant is around three to a half year. Numerous patients become ineligible for cardiovascular transplant because of irreversible disappointment of indispensable organs during their holding up period.
Extreme lack of contributors has developed thought for advancement of pumping devices artificial as an answer for current issue. Artificial heart otherwise called total artificial heart (TAH) that is VAD.
Other purpose behind the necessity of TAHs and MCSs is money related, which is related to the expense of consideration for patients enduring cardio sickness. Coronary illness is one of the top reasons for hospitalization that require longer time of remain at medical clinics, just as it expands the significant segment of the general spending on wellbeing by government. MCSs can be useful in diminishing the quantity of days for hospitalization, diminishing the measure of assets expended alongside the improvement in personal satisfaction for the patients with end state heart failure.

II.OBJECTIVES

- Design an axial flow pump that can satisfy the hydraulic requirement of VAD.

- CFD based statistical design of experiment, investigation of the design parameters to determine the response of the pressure rise, flow rate for the range of the rotating speed of VAD impeller
- Optimization of the design parameters using CFD.

A. Hydraulic Requirements

- The pump should generate 60 to 120mm Hg rise in pressure.
- The flow rate volume of 6-12L/min
- Speed range: 5000 -10000rpm

III.COMPUTER AIDED DESIGN (CAD) OF AN AXIAL FLOW PUMP

Computer aided design (CAD) is useful in picturing determined geometry utilizing old style hypothesis. With the end goal of this proposition and study, monetarily accessible CAD device SOLID GEOMETRY has been utilized to create 3D geometry of different parts of VAD. An ability of skilful Geometry creation is required to produce surfaces for complex impeller geometry.

A. Size Requirements

- Hub diameter of impeller: ≤ 18mm.
- Blade Tip diameter of impeller: ≤20mm.
- Clearance between the inner wall and blade top: 2-4mm.
- Number of blades: 4.
- Blade thickness: 0.5mm.

IV.CONVERTING CAD GEOMETRY FOR CFD ANALYSIS

Procuring a tasteful plan of design of a pump is an iterative procedure. The decided estimations of plan parameters need an examination to help the structure speculation and structure hypothesis. A test at each period of the structure strategy can be unrestrained and time-taking activity. Numerical apparatuses like computational liquid elements (CFD) can be used to start with times of the arrangement method just as in later periods of improvement. Close by included favourable circumstances of the detail stream portrayal and target arranged improvement codes, CFD is an amazingly significant device for lessening the quantity of assessments required for the plan of the blood pump.

An axial pump impeller is a rigid object that creates the pressure variance over the pump by rotating in the fluid region. For the investigation of the stream conduct over the impeller, this liquid locale ought to be made utilizing the strong work geometry of an impeller. With the ultimate objective of this project and concentrate economically accessible ―ANSYS programming has been used. Ansys stage underpins the smooth progression of information among different sections using numerical tools and meshing.

V.CFD ANALYSIS OF AXIAL FLOW PUMP

The Axial flow design of VAD is a repetitive technique that requires investigating different geometries and shapes of an impeller; in addition, it includes the confirmation of impeller shapes for their reasonableness to be utilized as VAD. CFD displays simulations results with the end goal of the proposal. This section is restricted to the specific structure that was chosen for mock trial assessment of VAD.

In these sections, it gives simulation results of a VAD working as a blood flow pump that integrates the results based on CFD using every parametric investigation. This was done to analyse the effect of working speed on the characteristic structure parameters. The Pump performance as a continuous flow blood pump is computed by using the results of optimization. Results of the CFD simulations for pressure at steady-state are discussed to picture the inward flow details.

The CFD based Design study has been done to examine the reaction of the needy parameters primarily the mass flow rate, pressure rise for the scope of the independent parameter that is a rotating speed of VAD. The structure grid is created for the scope of VAD rotating speed-shifting from 5000 to 10,000 RPM, flow rate differing from 3L/min - 9L/min, and pressure rise of 5mmHg to 120mmHg.

A. Blood Properties

At a large scale, various models exist with different degree of precision in catching the elastic behaviour of the blood. In CFD investigation of blood stream moves inside VADs blood pump is generally considered as a Newtonian liquid, in spite of the fact that it is known to show non-Newtonian properties.

Blood is not a pure Newtonian fluid, if we use this non-Newtonian fluid for simulation, it will make the simulation procedure into a very complicated one. But, in few cut strains, blood is viewed as Newton fluid; numerous scientists and international researchers likewise treat it like this.

- Blood viscosity is considered normally 3 ~ 4 (10-3) Pa. But here we take 0.0035 Pa . s.
- Normal adult blood flow rate of heart is 6L/min (0.106kg/s),
- Normal blood pressure is 80 ~ 120mmHg.
- Blood density is 1060kg/m3.
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Mass flow rate is considered as the inlet boundary condition which is 0.106kg/s. Set Pressure at outlet as an exit boundary condition as 100mmHg (13332Pa). Consider a steady-state condition, by using standard turbulence model ε−k, to use wall condition as solid wall without any slip.

ChoosingPower Law-Three Coefficient method,

Blood viscosity = 0.0035 Pa . s,

Temperature reference = 273.16 K,

n = 0.6,

Blood Conductivity - 0.52 W/m. K, Blood Specific Heat - 3617 J/kg .K.

Name	Parameter
Number of blades	4
Chord Length	54.97mm
Import Angle	13°
Export Angle	76°
Airfoil Angle	38°
Diameter of Hub	14.8mm
Blade outer Diameter	18.5mm

Optimized Values

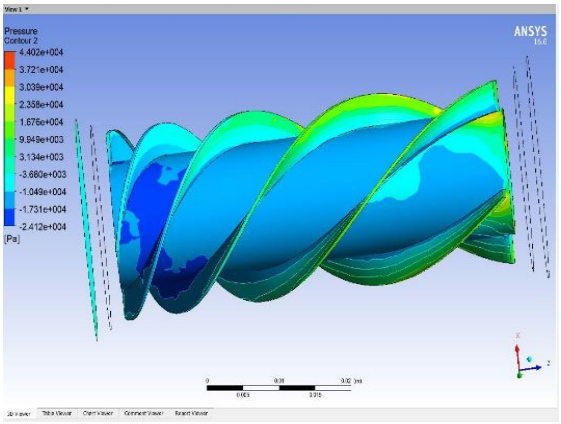

Fig.1. Pressure contour of optimized design

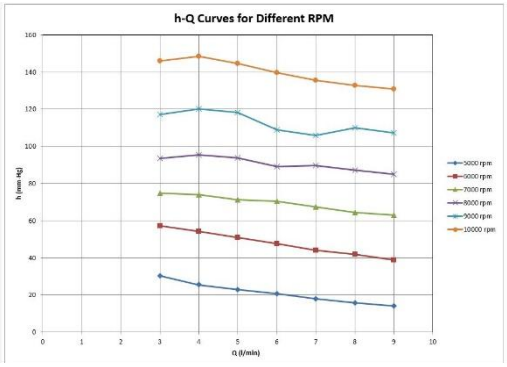

Fig.2. H-Q curve obtained for the design

VI.CONCLUSION

This postulation shows the plan and advancement of aaxial flow ventricular assist device (VAD). The evaluation assessment utilizing CFD of a VAD indicates a satisfactory design to expand upon and optimized VAD. The CFD consequences of VAD as anaxial pump have demonstrated the best approach to build up a controlled flow that can fulfil the hydraulic prerequisite. The scope of working condition picked for this examination is expected to cover the scope of condition that the VAD will involvement during clinical use when working with the native heart. VAD can support the scope of pressure and flow rate prerequisite with levels by working it at varying limit speed. Henceforth, the old-style structure hypothesis of an axial flow pump can be utilized to design axial flow pump that can produce a controlled stream. As an underlying structure step, working parameters were improved for consistent pressure riseand flow, the VAD can help patients as a nonstop flow pump.

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