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INVESTIGATIONS ON BIOMECHANICAL BEHAVIOR OF CARDIO VASCULAR STENT

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Abstract :This study aims to investigate heart disease, which is the biggest problem of our time. Cardiology is now on the path of heart diseases. Atherosclerosis, which is the narrowing of the arteries, is caused by the buildup of hard deposits called plaques on the walls of the arteries. The treatment of such problems is stent placement. A stent is a spherical medical device often used to ope n clogged arteries.Such braces are usually made of steel, cobalt chrome, platinum, titanium, etc. Many research papers have been published on the numbers and their packaging, mostly focusing on the biocompatibility of materials and the response of lies and a pkines. Mechanical wrapping must be considered when fabricating cardiovascular stents. Based on the CT scan, a coronary artery stent model was created, slices were saved as DICOM, the 3D model was transformed using 3D croaker software, and the model was imported into ANSYS for analysis. The results are for different models with different parameters based on some environment al model ((i.For example, compasses 2.25, 2.5, 2.75, 3.5,4.0) and long, for example) combination and use of biocompatible materi als

I. INTRODUCTION

Coronary artery disease is the most common heart disease. It happens when the coronary arteries, which supply the heart muscl es with oxygen.rich blood and nutrients, narrow or become blocked as they gradually "clear" well. "This shelter is made up of chole sterol, white blood cells, calcium, and other substances that build up on the walls of the arteries over time when the sacrum narrows the opening (space) of the coronary arteries. It makes the heart muscle weak for the blood it can receive, narrowing of the space ar ound the arteries and plaque, called "atherosclerosis." formation process."Decreased blood flow to the heart muscle can cause chest pain (angina), shortness of breath.

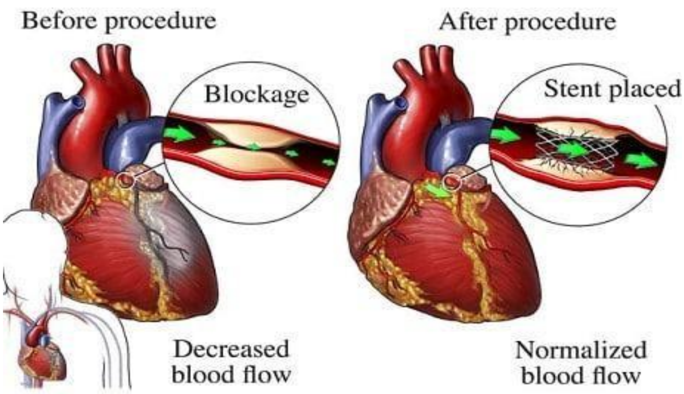


Fig 1.1: Implementation of Stent

Symptoms of coronary artery disease (CAD) may include sweating, chest pain, and pain that radiates to the arms, usually the left arm. The gradual narrowing of a blood vessel in the heart can eventually lead to a complete blockage, which can progress slowly or suddenly and lead to a heart attack, also known as a myocardial infarction. Heart attacks cause endless damage to the heart muscle. Unfortunately, coronary artery disease can sometimes be asymptomatic, and sudden death is the first sign of the disease without previous warning signs. However, advances in medical knowledge and treatment, better recognition of complaints, better testing styles, earlier judgments, and increased public awareness of heart disease symptoms and risk factors have contributed to a decline in CAD-related mortality. These joint efforts have played an important role in solving problems and saving lives.

During a stent placement procedure, the stent is initially collapsed and mounted onto a balloon catheter. The catheter is then guided to the site of the blockage within the artery. Once positioned, the balloon is inflated, causing the stent to expand and lock in place against the artery wall. This creates a stable scaffold that holds the artery open and restores proper blood flow. The stent remains in the artery permanently, providing ongoing support and maintaining the improved blood flow to the heart muscle.

The decision to use a stent is based on various factors, including the size of the artery and the location of the blockage. Stenting has become a commonly performed procedure, and the majority of angioplasty procedures now involve the use of stents. By utilizing stents, medical professionals can effectively improve blood flow to the heart muscle, alleviate symptoms such as chest pain, and promote better overall cardiac health.

The primary purpose of a stent is to provide structural support to artery walls, making inappropriate mechanical characteristics a potential cause for complications like arterial wall damage. A successful implantation hinges on a thorough comprehension of its behavior throughout its design phase. There exist two approaches for studying stent behavior: experimental techniques and numerical simulations. Stents are typically composed of materials such as stainless steel, nitinol, cobalt-chromium alloys, platinum, and tantalum. These materials encompass both bare-metal and drug-eluting balloon-expandable coronary stents, which have become a successful treatment avenue for coronary heart diseases.

In 1977, Assoc. Andreas Grüentzig used a catheter to insert a small balloon into the veins of patient Adolph Bachman. When th e balloon is inflated, it pushes plaque out of the artery wall, improving blood flow. The patient recovered after surgery and Grüentzi g marked an important milestone in the history of medicine. Then, in the 1990s, doctors began placing meshed metal in coronary ar teries during angioplasty interventions.These braided tubes provide initial support for the nerves, promote healing, restore strength and increase strength in the first few months. A new approach emerged with the introduction of drug.eluting stents from 2003. Thes e permanent wires work like bare metal stents and are coated with a substance that prevents the formation of scar tissue during the c oronary artery. The advent of fully dissolving stents marked the fourth major advance in angioplasty. Also known as dissolving ste nting, this new treatment targets coronary artery disease.Unlike previous products, the full blast is made of a material that disappear s as the nerve heals, allowing the nerve to bend and respond normally. Once the stent is completely dissolved, healing of the artery can continue without further dependence on the stent.

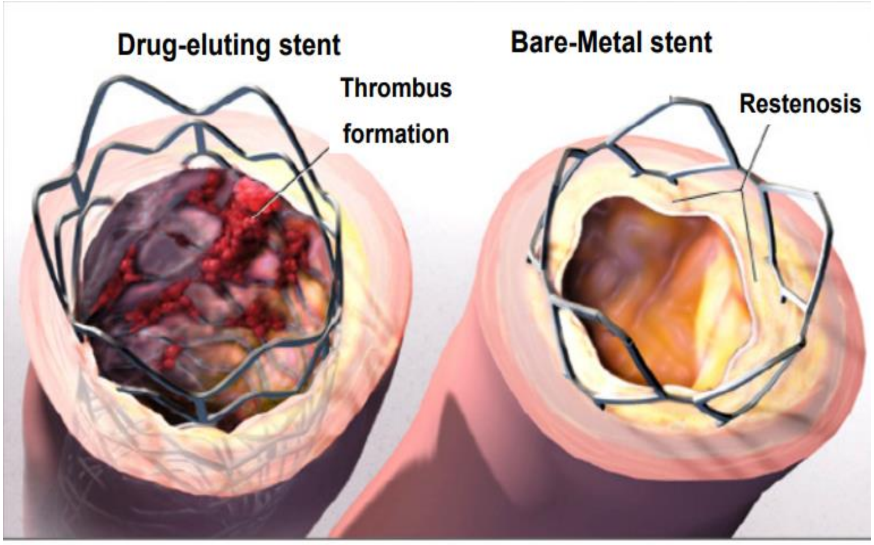


Fig 1.2: Bare metal and Drug eluting stents

II. Literature Review

Perice-vic et al. conducted an exploration of diverse techniques for revascularizing occluded arteries, encompassing Balon anjiyoplasti, stentleme, bypass phais, tiab aterektomi. Gu et al. asserted that stenting, specifically, entails no surgical procedure, entails fewer complications and pain, and offers swifter recovery compared to alternative treatments. This perspective has propelled the escalated adoption Coronary stents have been used in interventional procedures in recent years. with a staggering 1.2 million patients in the United States alone undergoing stent implantation annually.

Chua et al.'s study illuminated a correlation between restenosis rates and stress concentration within the stented vessel wall. The design of the stent profoundly impacts the stress distribution within the artery wall, emerging as a pivotal factor influencing restenosis subsequent to implantation. De Beule et al.'s investigation further underscored the impact of stent design on the occurrence of the dogbone effect in stent implantation.

In the pursuit of enhanced outcomes, Chua S.N.D et al. introduced more intricate models, such as the balloon-stent model. Meanwhile, Walke, W et al. delved into a diverse array of constitutive models for arteries and plaque, including linear isotropic formulations, that have been proposed within the existing literature.

III. Methodology

3.1 Modeling Of Stent:

Designing scaffolds is complex, and ongoing research is devoted to determining the stress distribution in these structures d uring blood flow. Human vessel geometry extracted from computed tomography (CT scans) and stored in DICOM format. Usi ng 3D DOCTOR software, CT scan images were converted into 3D models that were divided into quadrilateral and triangular elements by finite element analysis. The resulting CT scan translation (.STL) is then sent to the rapid prototyping process for f urther use.Finally, the scaffold itself is fabricated using the fused deposition modeling (FDM) technique.

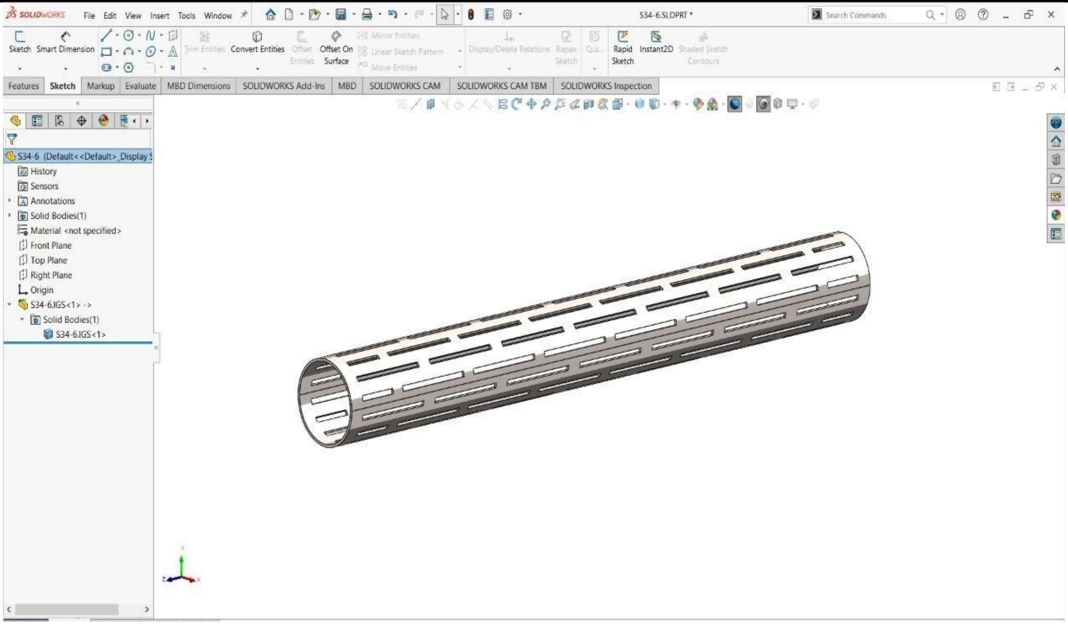


Fig.3.1: 3D model of stent design in Solid Edge

3.2 Finite Elements Model of Stent:

Figure 3.2 shows the final version of the bracket. In this model, the boundary conditions require a compressive load on the inner surface of the bracket. The size of the pressure load corresponds to a blood pressure of 1-2 MPa.

It is worth noting that the friction force during expansion is neglected. In addition, the degrees of freedom are limited to the out side of the bracket.

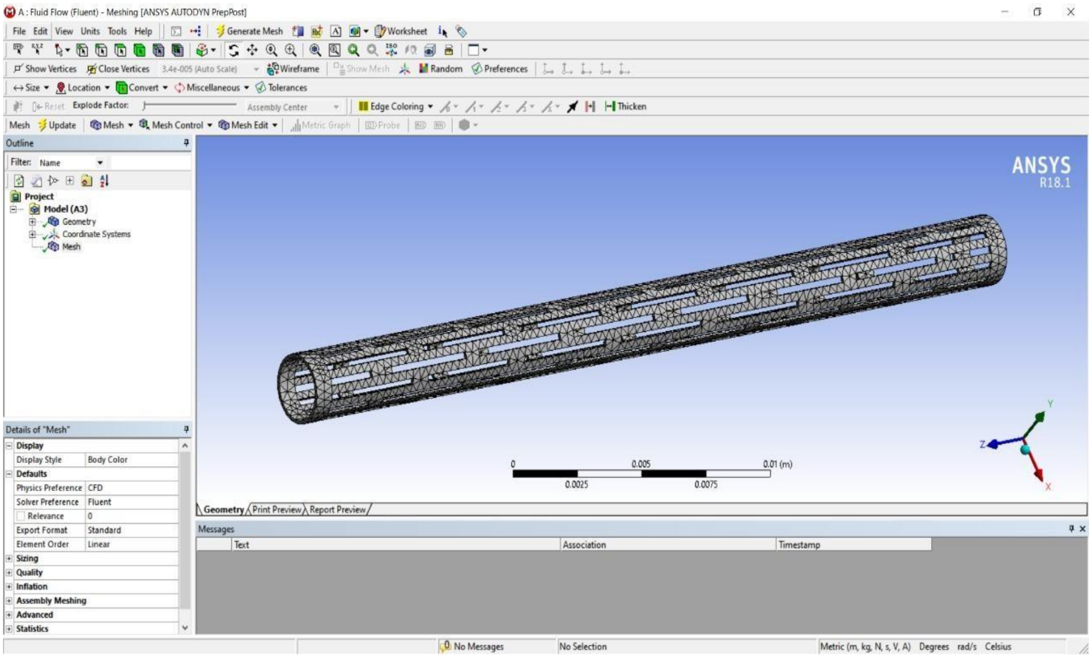


Fig 3.2: Finite element model of stent

3.2.1 Equivalent (von-misses) strain

The von Mises yield criterion, also known as the maximum strain energy criterion, indicates that plastic materials begin to yield when the second deviatoric stress invariant exceeds a critical value. This criterion is most suitable for hard materials such as metals. Before yielding, the material response can be assumed to be nonlinear elastic or linear elastic. In materials science and technology, the von Mises yield criterion can be expressed as the von Mises stress or, equivalently, the stress strain, which is a scalar value calculated from the Cauchy stress tensor. Material yielding occurs when the von Mises stress reaches a threshold value known as the yield strength. Von Mises stress is often used to predict material yield under complex loading conditions based on the results of uniaxial tensile tests. with the same strain energy have the same von Mises stress.

Fig 3.3: Equivalent(von-Mises)stress

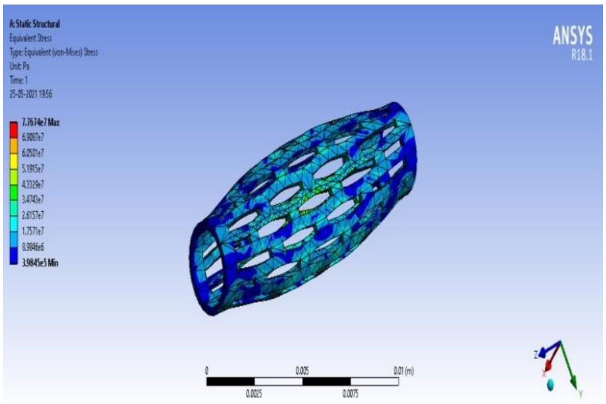
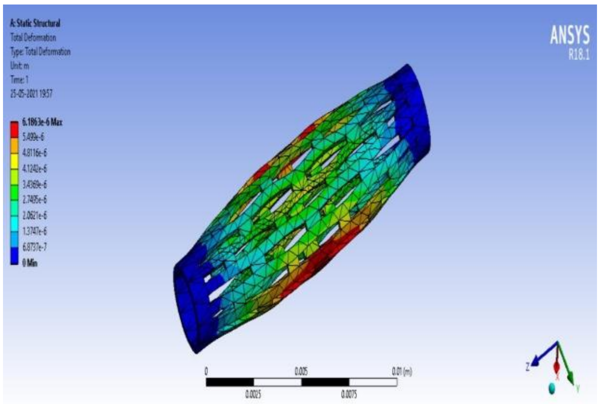


Fig 3.4: Total deformation



3.2.2 Total deformation

Strain results in ANSYS Workbench can be presented as total strains or directional strains, both of which are used to obtain strain movements. The main difference is that direction deformation calculates the deformations of a given systemin the X, Y and Z planes

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3.3 Stent Material

3.3.1 Stainless Steel

Stainless steels are iron-based alloys with key elements like Cr and Ni. Some grades incorporate Ni, Mo, Ti, Nb, and N to enhance erosion resistance, heat resistance, strength, and plasticity. Microstructure, strength, and erosion resistance primarily hinge on Ni and Cr concentrations. While stainless steels resist oxidation, they may corrode in chloride-rich environments like the human body. Categorized by phase, they are ferritic, martensitic, or austenitic. Austenitic steels are strengthened through cold work, heat treatment, and Mo addition, offering excellent erosion resistance. Austenitic 316L steel is favored for stents due to balanced strength, malleability, and erosion resistance. Its properties are refined by Mo addition, increased Ni content, and reduced carbon content, while the surface oxide transforms with molybdenum oxide exposure.

3.3.2 Ni-Ti Alloy (Nitinol)

Nitinol, an Ni-Ti alloy, boasts approximately equal amounts of Ti and Ni, showcasing exceptional traits like shape memory and superelasticity. Shape memory prompts a return to original form upon heating, while superelasticity recovers initial shape through load release. Nitinol can endure greater elastic deformation before yielding. Its transformation temperature hinges on composition, impurities, and heat treatment. After implantation, Nitinol regains shape with body temperature increase, conforming to vessel walls. Up to 8.5% strain recovery is possible after plastic deformation, endowing Nitinol with favorable mechanical properties. However, Ni release from Nitinol stents may induce tissue toxicity, and Nitinol's radiopacity is less compared to 316L stainless steel stents. Nitinol's room temperature plastic deformation allows crimping onto delivery systems. With unique attributes, Nitinol is a popular stent material, with self-expanding stents adapting from a smaller room temperature diameter to desired size at body temperature.

3.3.3 Cobalt-chromium alloy

Cobaltchromium alloy is widely used in the biomedical field. Cobalt Chrome has a density that helps improve radio trans mission and a pressure switch that limits kick. It also has very good wear compared to stainless steel.
Cast cobaltchromium alloys for biomedical applications have minor casting defects, vitamins, as well as pitting and crevice corros ion. After heat and cold treatment of cobalt chromium, it gives the same strength and durability as stainless steel

3.3.4 Platinum Alloys

Platinum blends in stents enhance strength and radiopacity. Thin yet strong designs achieved using platinum-chromium blends. Platinum-chromium stents display excellent erosion resistance, but mechanical strength is a concern. Limited research on Pt-Ir blend stents despite initial clinical promise.

3.3.5 Tantalum

TANTALUM has low magnetic efficiency and high density, making it a good material for x.rays. At the same time, it ha s excellent corrosion resistance in biological environments thanks to its stable oxide layer. However, the risk of rupture of the sten t during insertion is greater. Therefore, lower pressure is often used to place the stent, which increases the pressure. Healing rate is better for Li stents compared to 316L stainless steel stents

3.3.6 Ti6Al4V

Ti-6Al-4V also known as TC4, Ti64, or ASTM Grade 5, is an alpha-beta titanium alloy renowned for its high-specific strength and exceptional corrosion resistance. Despite these advantageous properties, the biomedical application of titanium alloys has been restricted due to their inferior shear strength and wear resistance.

Table 3.1: Properties of different material used in stent manufacturing.

Material	SS 316L	Co-Cr Alloy	Nitinol	Pt-10Ir	Ta	Ti6Al4V
Density (gr/ Cm3)	7.95	9.1	6.45	21.55	16.6	4.5
Elastic modulus (GPa)	193	243	90	150	185	107
Poisson's ratio	0.303	0.3	0.3	0.3	0.303	0.35

3.4 Computational Fluid Dynamics (CFD) of Stent

CFD involves simulating fluid engineering systems through the use of mathematical modeling and numerical methods. These methods include discretization techniques, solvers, numerical parameters, and grid generation. The overall process is illustrated in Figure 3.5

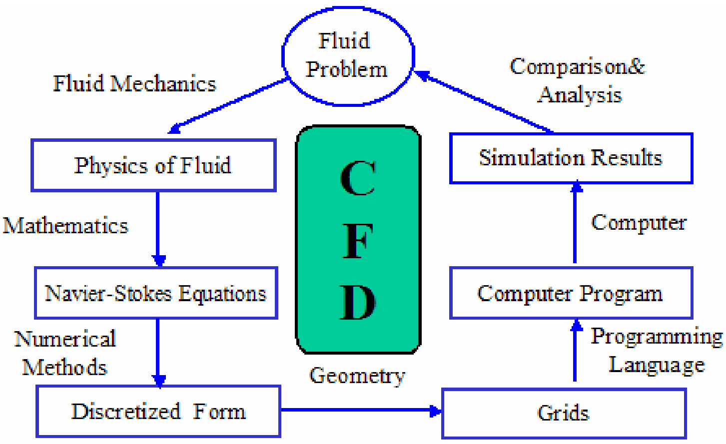


Fig 3.5: Process of Computational Fluid Dynamics

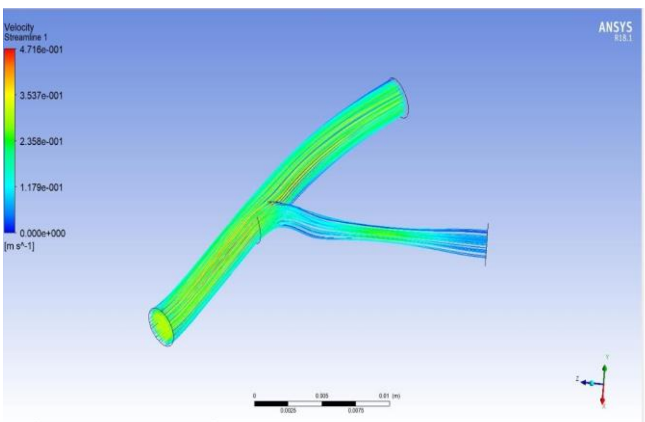
The process of CFD begins with identifying a fluid problem. To solve this problem, a thorough understanding of the fluid's physical properties using principles from Fluid Mechanics is required. Mathematical equations, specifically the Navier-Stokes Equation, are employed to describe these properties. The Navier-Stokes Equation serves as the governing equation in CFD.

Numerical discretization methods, such as Finite Difference, Finite Element, and Finite Volume methods, are used to convert the Navier. Additionally, the problem domain is divided into smaller parts to facilitate the discretization process. Programs are then developed, typically using programming languages like Fortran or C, to solve these discretized equations. These programs are executed on workstations or supercomputers.

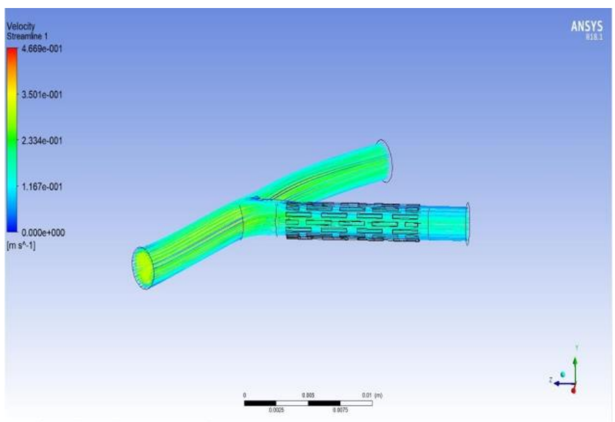
Upon completion of the simulation, the results are obtained. These results can be compared and analyzed in relation to experimental data and real-world scenarios. This iterative approach allows for refining the simulation and obtaining desired outcomes. This is the fundamental process of CFD.

IV. RESULTS AND DISCUSSION

The results are drawn for different designs with different confines grounded on some standard periphery((i.e., compasses2.25,2.5,2.75,3.5,4.0) and lengths i.e.,) combinations and with a material parcels of biocompatibility material

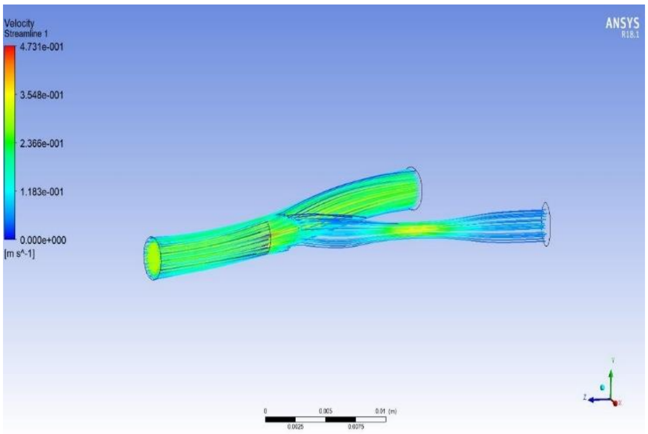


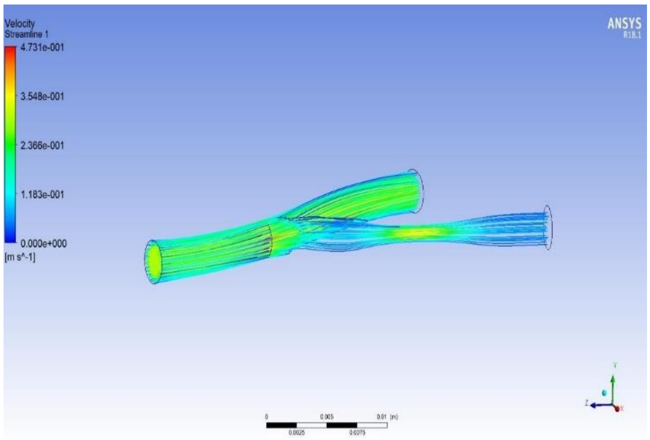
Before inserting stent



After inserting stent

Fig.4.1: 2.5 Diameter and 12 length





Before inserting stent After inserting stent

Fig.6.3: 2.5 Diameter and 18 length

4.1 Results Validation of results

Table 4.1: Comparison of velocities of stent models

Model		**Values**								
Stent models	**Diameter(mm)**	2.5	3	3.5	2.5	3	3.5	2.5	3	3.5
	Length(mm)	12			15			18		
Velocity	**(narrow nerve)**	4.52E-01	4.72E-01	4.52E-01	4.68E-01	4.66E-01	4.53E-01	4.55E-01	4.73E-01	4.53E-01
Velocity	**(stented nerve)**	4.53E-01	4.67E-01	4.57E-01	4.62E-01	4.71E-01	4.56E-01	4.63E-01	4.71E-01	4.58E-01

V. CONCLUSION

This paper presents the methodology of modelling and analysis of mechanical properties of cardio vascular stents which are used in the treatment of blood vessels are acceptable stent have following properties such as Flexibility ,Deliverability, Corrosion resistance, and wear resistance.

From analyzing these properties ,we carried out static and computational fluid dynamic analysis (CFD) ,and from analyzing of different biocompatible materials listed we know about Ti6Al4V has excellent wear and corrosive resistance. The following conclusions are made for static and CFD analysis.

- The modeling was done in solid works(3D modeling) soft ware
- The values of total deformation and equivalent stress 6.186e-6max and 876 Mpa (stress) shows that a stent of the commercial type of palmaz schatz have good flexibility
- The values of material velocity from CFD analysis for different sizes of stents of commercial type of palmaz schatz stent have shown that they have good durability
- Due to more surface area in palmaz schatz stent .it is resistant to restenosis
- Taking the results of analysis into consideration , the stent design of palmaz schatz stent type and applied material Ti6Al4V shows optimum values of flexibility and deliverability

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[2] **Gu et** al. It is stenting compared to other treatment methods, does not require surgery, provides less complications, less pa in and faster recovery. Its operating use has increased rapidly in recent years. In the United States only, 1.
Two million patients undergo stent implantation each year**.**

[3] **Chua et** al examined the relationship between restenosis rate and stress in stented vascular valves. Stent design is one of t he most important factors that can affect restenosis after stent implantation due to the effect of stent design on arterial pre ssure.

[4] **P WILES-** FEA consists of a computer model of a material or design that is stress and analyzed for specific results.

[5] **W KERN**- In case of structural failure of stent, FEA may be used to carry the design modification and optimization.

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