CASE STUDY ON BLOOD FLOW OVER NFRPC BONE ATTACHED PLATE USING COMPUTATIONAL FLUID DYNAMICS

D.Chandramohan
Ph.D., Research scholar, Department of Mechanical Engineering,
Anna University of Technology Coimbatore, Coimbatore, India
Email: mail_2_cm@yahoo.com
Mobile No:+91-9994116596

K. Marimuthu
Associate Professor, Department of Mechanical Engineering,
Coimbatore Institute of Technology, Coimbatore, India
Email: kmcit@yahoo.co.uk
Mobile No:+91-9486587225

***Abstract*— In this research thermal stress analysis using Computational Fluid Dynamics [CFD] has been carried out on (Sisal (*Agave sisalana*) and Roselle (*Hibiscus sabdariffa*) hybrid plate material and the values compared with manual calculation found to be good in agreement. This invention focuses thermal properties of natural fibers that are used for bone grafting substitutes which are now becoming a great challenge for biomedical engineers. This paper proposed suggestions of using Natural fiber reinforced polymer composite [NFRPC] as a plate material which uses pure natural fibers that are rich in medicinal properties like Sisal and Roselle fiber. The most important thing that the researchers have to take into account is that these step taken now, will help the mankind to develop and to have a more pleasant life.**

Keywords- Thermal stress analysis, CFD, Agave sisalana, Hibiscus sabdariffa.

I INTRODUCTION

This project work concentrates on the biomaterials progress in the field of orthopedics. An effort to utilize the advantages offered by renewable resources for the development of biocomposite materials based on biopolymers and natural fibers, in this research work natural fiber particle reinforced materials such as (Sisal (*Agave sisalana*), Banana (*Musa sepientum*) and Roselle (*Hibiscus sabdariffa*) reinforced polymer composite plate material with bio epoxy resin Grade 3554A and Hardener 3554B were used for bone grafting substitutes.

The basic governing equations for a viscous, heat conducting fluid have been derived for NFRPC material. It is a vector equation obtained by applying Newton's Law of Motion to a fluid element and is also called the momentum equation. It is supplemented by the mass conservation equation, also called continuity equation and the energy equation. Usually, the term Navier-Stokes equations are used to refer to all of these equations.

In this research thermal stress analysis using CFD has been carried out on NFRPC plate material and the values compared with manual calculation found to be good in agreement. This invention focuses thermal properties of natural fibers that are used for bone grafting substitutes which are now becoming a great challenge for biomedical engineers. This project emphasis the enhanced property of natural fiber as bone implants. It is a challenge to the creation of better materials for the improvement of life quality. This project proposed suggestions of using Natural fiber reinforced composite as a plate material which uses pure natural fibers that are rich in medicinal properties like Sisal, Banana & Roselle (hybrid) fiber. The most important thing that the researchers have to take into account is that these step taken now, will help the mankind to develop and to have a more pleasant life.

II MATERIALS AND METHODS

TABLE I. Properties of Materials

Materials	**Young's Modulus (N/mm2)**	**Density Kg/mm3**	**Poisson ratio**
++Roselle and sisal (hybrid)	18857.075	$1.450*10^{-6}$	0.33
++Roselle and banana (hybrid)	22061.9593	$1.5*10^{-6}$	0.32
++Sisal and banana (hybrid)	25779.2532	$1.350*10^{-6}$	0.30

++Compiled from References. [2 and 3]

A. COMPUTATIONAL DETAILS OF PRESENT WORK

Manual Calculation

Assumptions Made

The following assumptions have been invoked while formulating the governing equations for the sake of simplicity:

- Buoyancy effects are negligible
- Radiation effects are negligible
- The flow is adiabatic (there is no heat transfer between the flow and the surroundings).

Plate Dimensions

Length of plate = 0.106 m
Breadth of the plate = 0.01 m
Thickness of the plate = 0.003 m
Thermal conductivity = 0.543 W/m-K
C.O.P of blood = 3594 kJ/kg-K

Domain Dimensions

Diameter of domain =0.16 m
Length of the domain =0.5 m
BOUNDARY CONDITIONS
Inlet velocity =0.5 m/s
Inlet Temperature =305 k
Outlet pressure =0 Pa

Bone Dimensions

Length of bone =0.191 m

Solution

Nusselt number

$$Nu = h\,D/k$$

$$hD/k = 0.023\times(Re)^{0.8}\times(Pr)^{1/3}$$

Where,
Nu- Nusselt number
h- Heat transfer coefficient (W/m^2-K)
D- Diameter of Domain (m)
K- Thermal conductivity (W/m-k)
Re- Reynolds number
If Re > 2300 (Flow is Turbulent)
Reynolds number

$$Re = \rho VD/\mu$$
$$= (1060\times0.5\times0.16)/0.004$$
$$= 2.12\times10^{4}$$, hence flow is turbulent

Where,
P- Density of blood (kg/m^3)
V- velocity of blood (m/s)

μ- Dynamic viscosity (kg/m-s)
Prandtl number

$$Pr = \mu Cp/k$$
$$= 0.004 \times 3594/0.543$$
$$Pr = 26.48$$

Where,
Cp-coefficient of performance (kJ/kg-K)

$$(h \times 0.16)/0.543 = 0.023 \times (2.12 \times 10^4)^{0.8} \times (26.48)^{1/3}$$
$$h = 655.27\ W/m^2\text{-}K$$

B.CFD analysis of bone attached plate material

A 3D model of bone attached flat plate is used in our analysis. CATIA v5 R18 is used for creating the model.

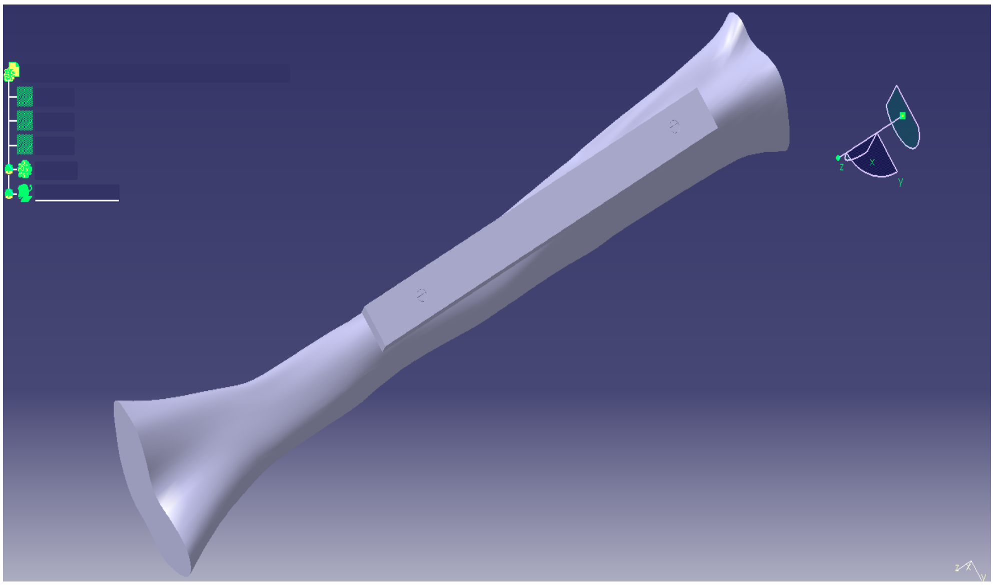

Figure 2.1 3D model of bone attached plate.

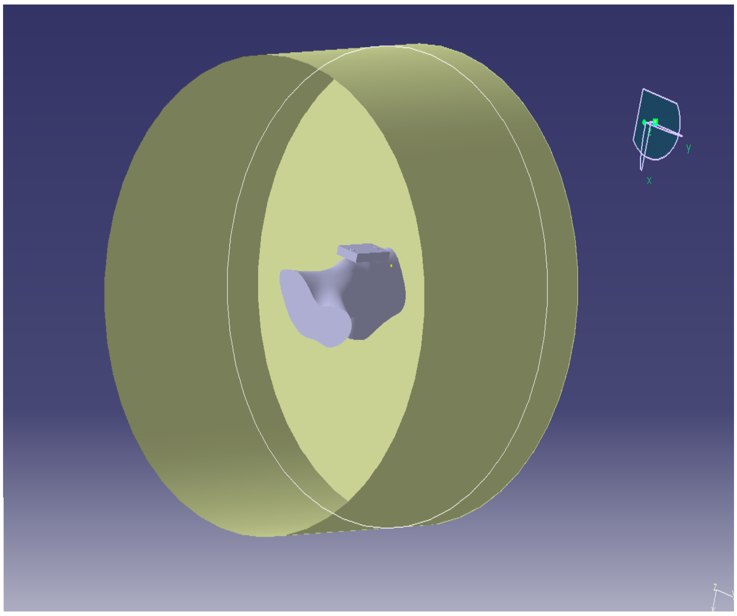

Figure 2.2 Bone with Domain

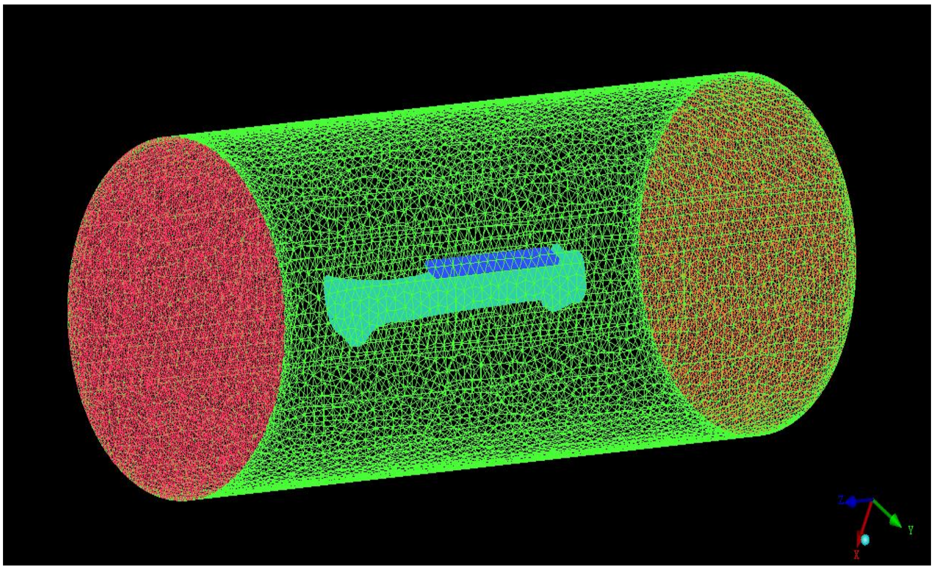

Figure 2.3 Surface Mesh Model

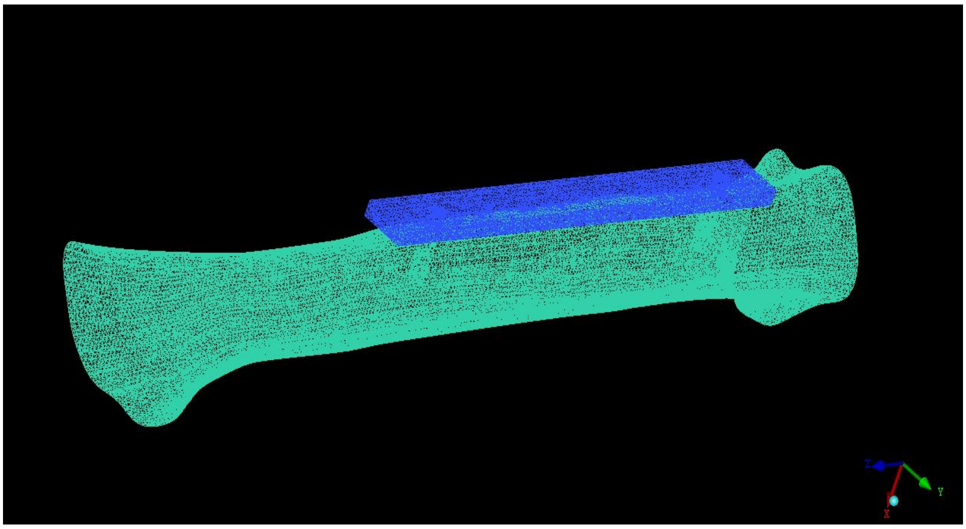

Figure 2.4 surface mesh models with bone plate

Figure 2.4 shows surface mesh of bone attached plate material. It consists of 36936 elements for bone and plate consists of 6048 elements.

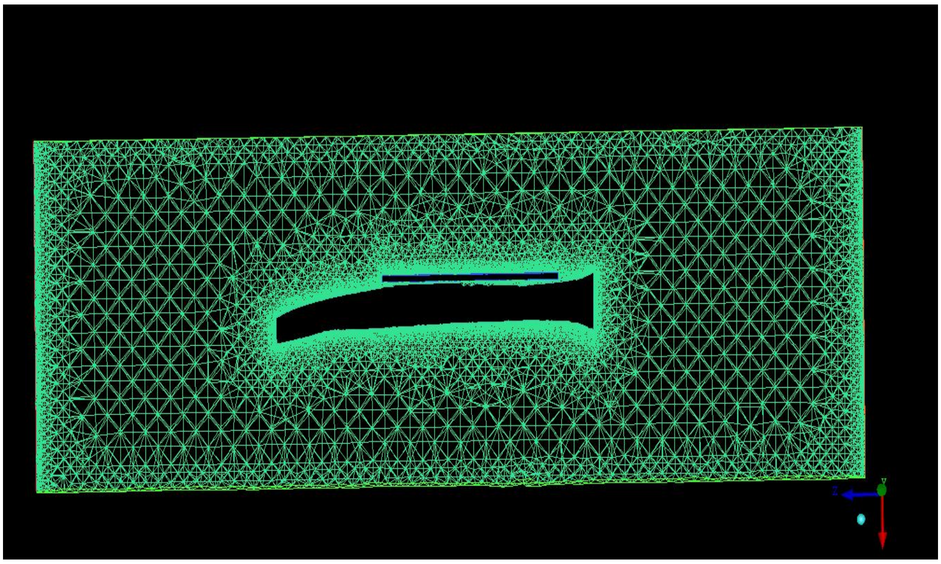

Figure 2.5 Mesh Cut plane of Bone With plate

The figure 2.5 indicates the mesh cut plane of the volume mesh of bone and plate .It consists of unstructured tetrahedral elements.

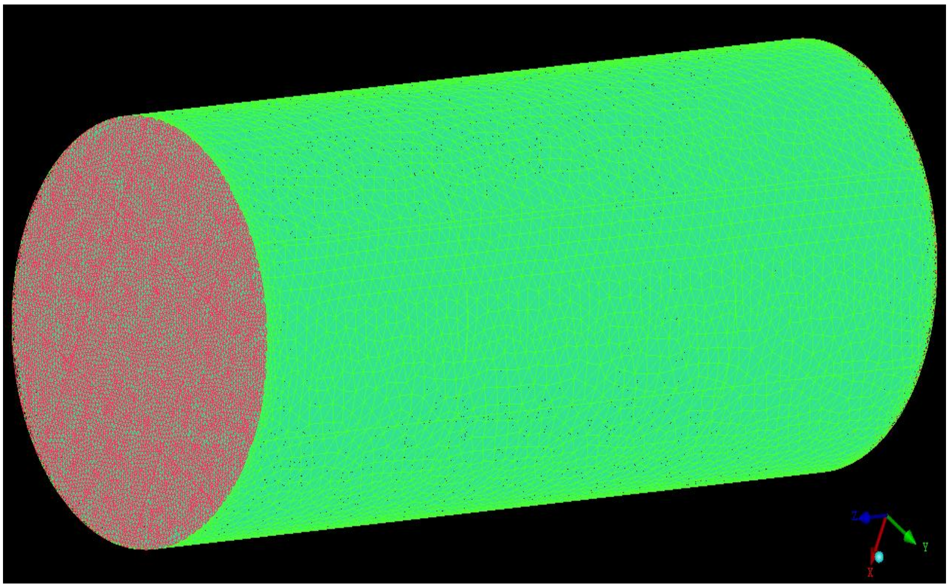

Figure 2.6 Volume Mesh Model

The figure 2.6 indicates the volume mesh of bone, plate and the domain .It consists of unstructured tetrahedral elements of 906079 and nodes of 165456.

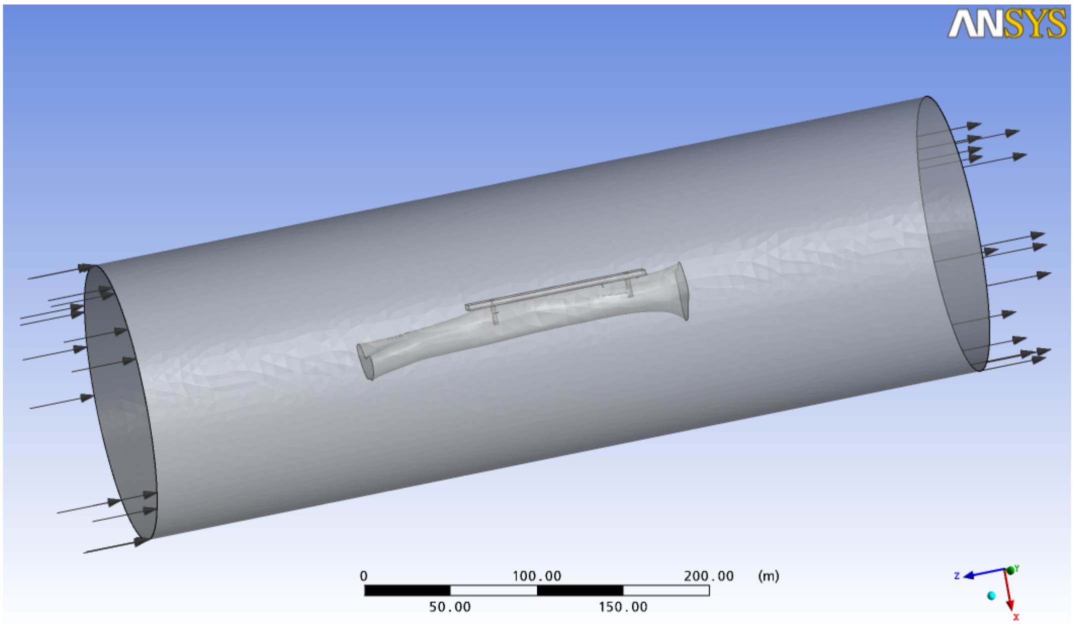

Figure 2.7 Domains in CFX

The Figure 2.7 shows the domain model of bone with plate in CFX. Domain created on the basis of the conditions inlet velocity 0.5 m/s, inlet temperature 305K, outlet pressure 0 Pa .Image indicates only the inlet and outlet directions of blood flow in the domain.

III. RESULTS AND DISCUSSIONS

A. CFD result for wall heat transfer coefficient

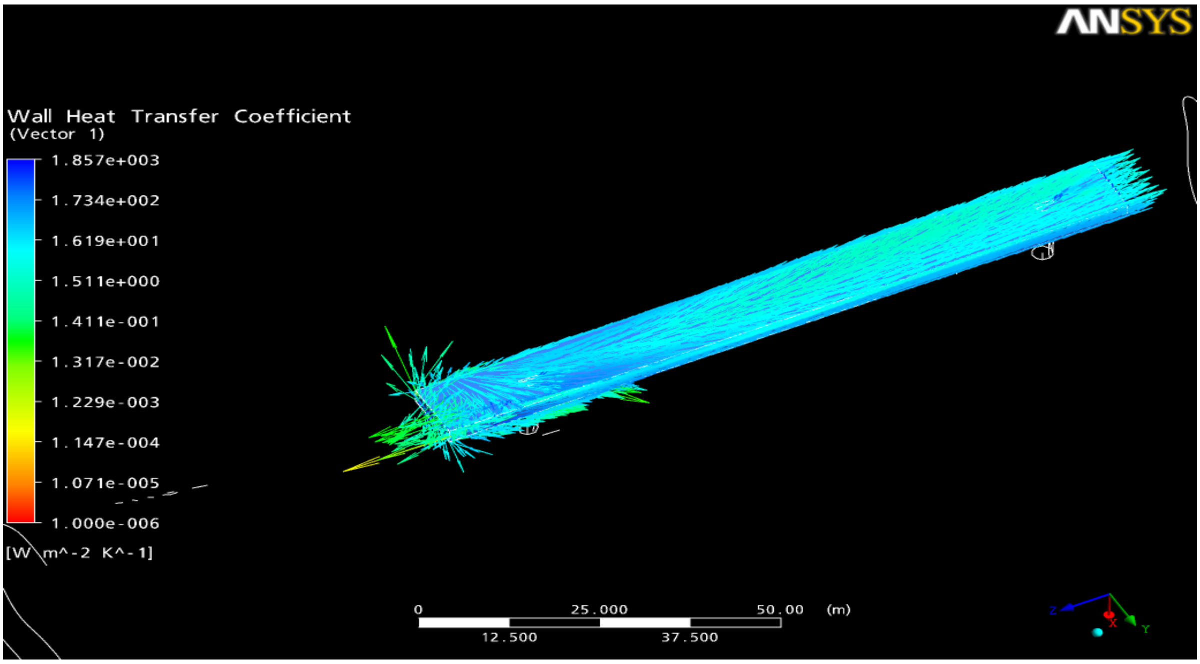

Figure 3.1 Result Image of Wall Heat Transfer Co-efficient

The figure 3.1 indicates the wall heat transfer value of bone attached plate material in which maximum and minimum values are 1857 W/m^2K, 0.000001 W/m^2K respectively.

B. Temperature contour of bone plate

The fig 3.2 indicates the temperature contour value at maximum and minimum rage. The values are 305.5K, 305 K respectively. This result indicates temperature variation is less in nature after the plate attached with bone.

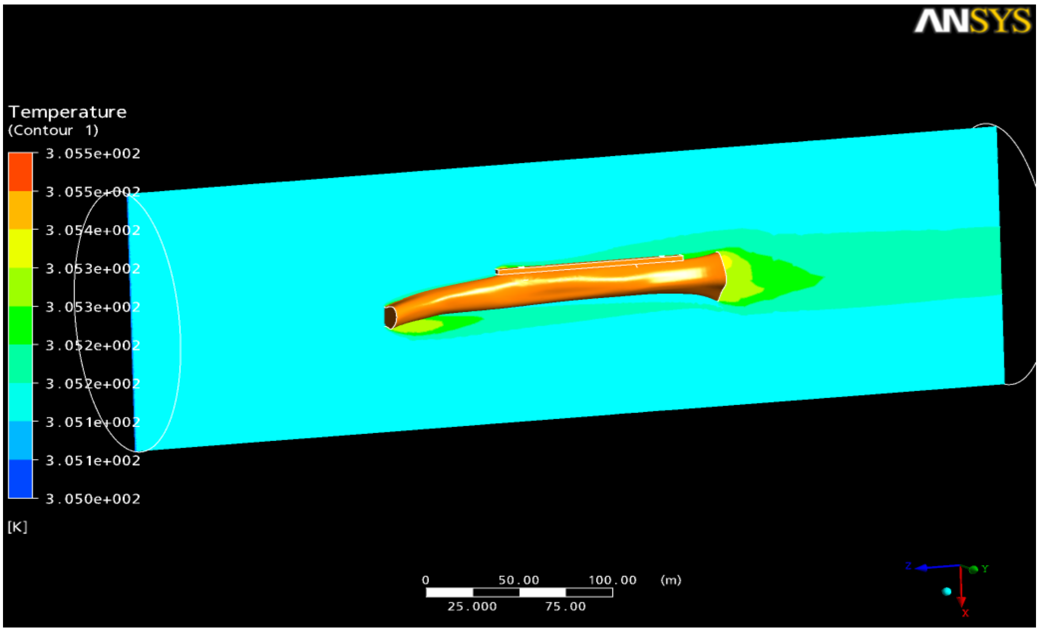

Figure 3.2 Temperature Contour of Bone Plate

C. CFD model of velocity contour

The velocity contour of the bone plate material has been shown in Figure 3.3 based on inlet velocity of 0.5m/s.

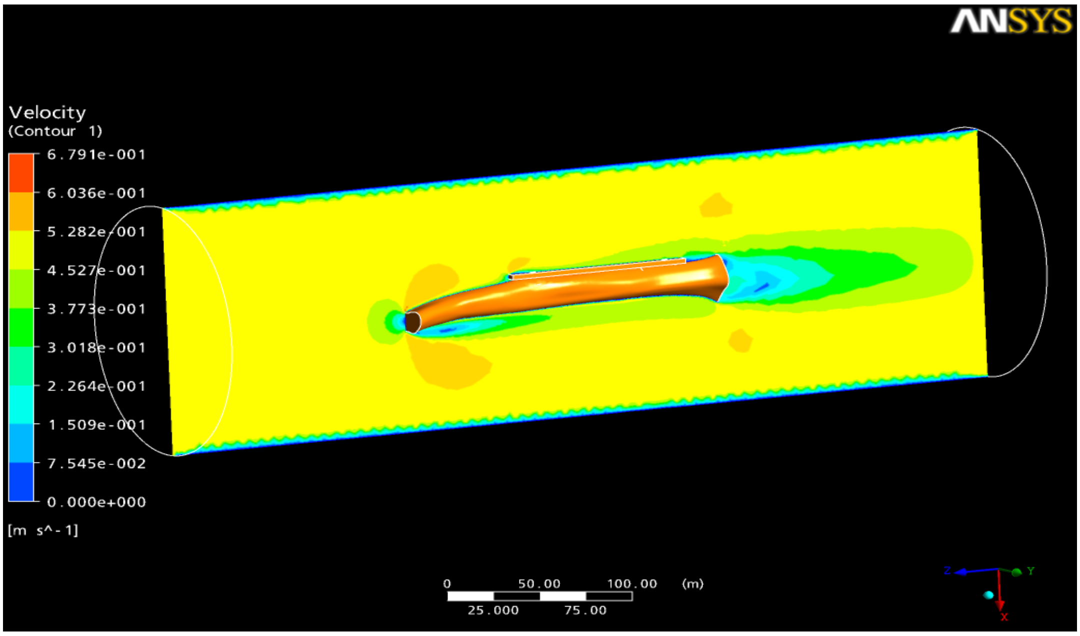

Figure 3.3 CFD model of velocity contour

C. CFD model of velocity vector

The velocity vector of the bone plate material has been shown in Figure 3.4 based on inlet velocity of 0.5m/s.

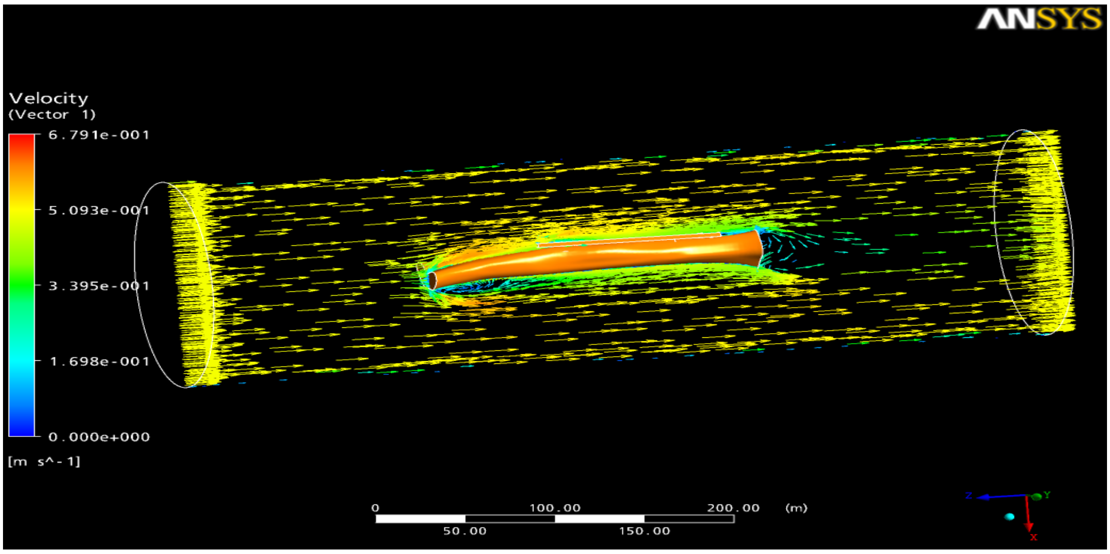

Figure 3.4 Velocity Vector

The figure 3.4 shows the velocity vector for inlet velocity of .05m/s in which maximum and minimum values 0.679m/s and 0m/s. this image shows velocity around the plate material is less and its negligible which does not affect the blood flow. Vectors show the direction of blood flow.

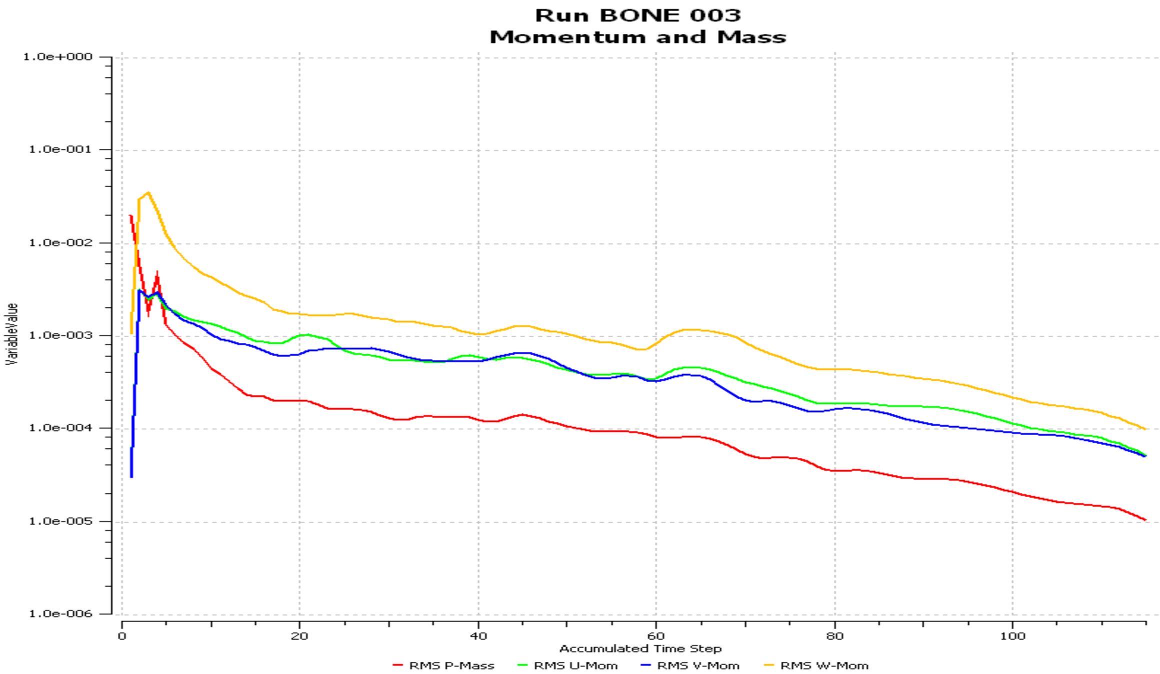

Figure 3.5 Solution convergence graph

The above Figure 3.5 indicates the convergence. Final convergence is decided based on maximum residuals of the order of 10^{-4} in mass, momentum etc. The computations were carried out on Microsoft windows XP professional 32 bit Edition using Pentium dual core processor of 4 GB Ram. Convergence is reached in about 115 iterations, which took about 3 to 4 hours for the given condition.

D. Temperature variation along axial direction of plate material

The Figure 3.6 shows the temperature Vs distance which is obtained for the inlet temperature of 305K. The starting line indicates the wall temperature value of plate material. This graphical result clearly shows temperature variation around plate material is very less.

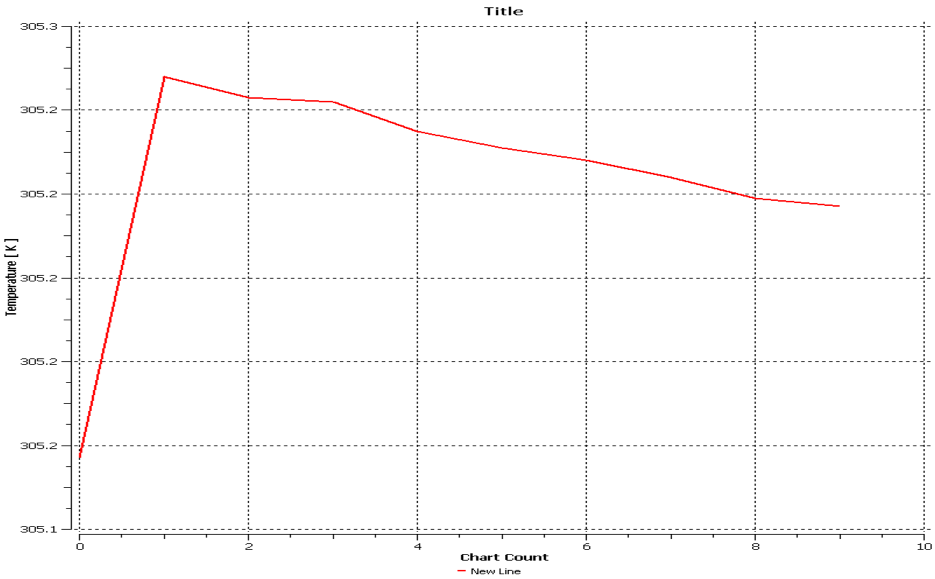

Figure 3.6 temperature variations on axial direction of plate

D. Velocity variation along axial direction of plate material

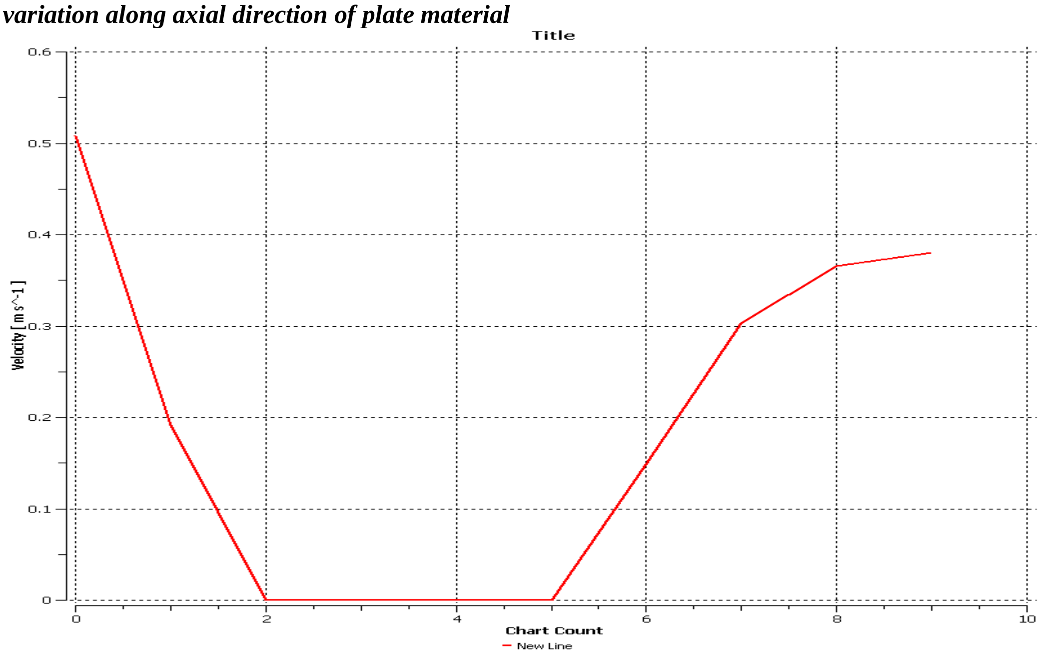

Figure 3.7 velocity variations along axial direction of plate material

The above Figure 3.7 shows the distance Vs velocity which shows velocity variation along axial direction of plate material for the input velocity of 0.5m/s. The ideal line indicates the exact position of plate material. Velocity value is at the layer of plate material is zero.

E. Wall adjacent temperature variation along axial direction of plate material

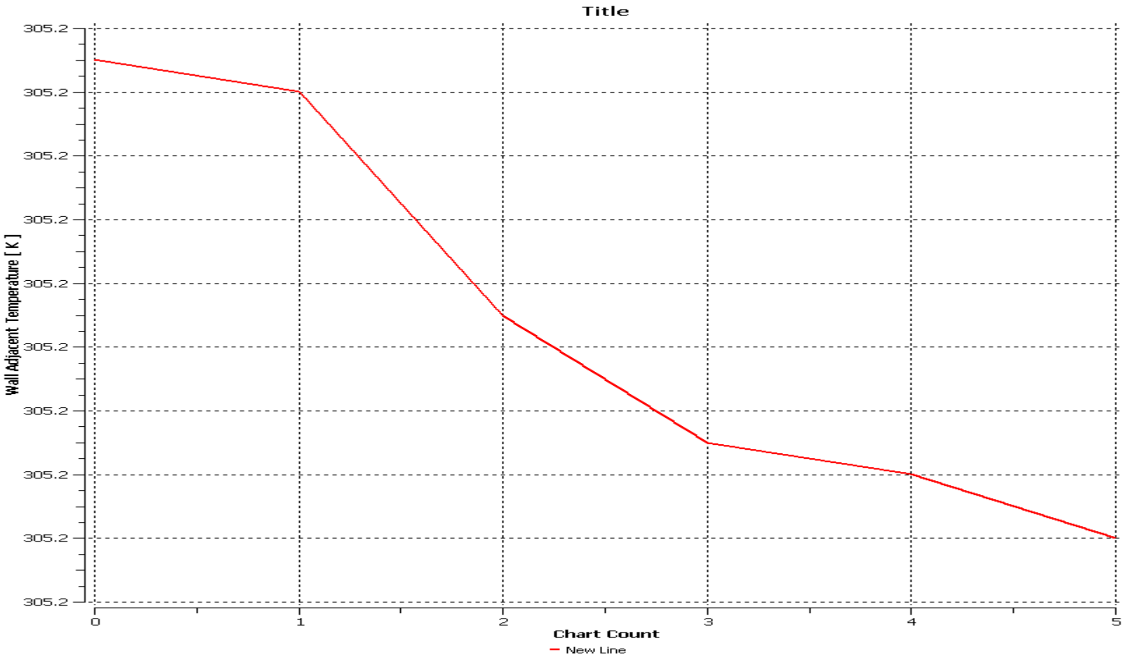

Figure 3.8 Wall adjacent temperature variation along axial direction of plate material

The above Figure 3.8 shows the distance Vs Wall adjacent temperature which shows Wall adjacent temperature variation along axial direction of plate material for the input velocity of 0.5m/s, inlet temperature of 305K The ideal line indicates the exact position of plate material. Temperature value is at the layer of plate material is 305K.

TABLE II. Comparisons of Results

MATERIAL	MANUAL Heat Transfer Co-efficient (h) w/m^2 –k	CFD Heat Transfer Co-efficient (h) w/m^2 -k
Sisal and Roselle (hybrid) Particle reinforced composite	655.27	695.75

CONCLUSION

In this research Sisal and Roselle fiber particle reinforced composite plate material's Thermal Heat transfer coefficient has been calculated manually (655.27 w/m^2 –k) and CFD (695.75 w/m^2 –k) both the results are found to be good in agreement.

ACKNOWLEDGEMENT

We express our sincere thanks to my beloved parents for their invaluable love; moral support and constant encouragement in our life. We owe immense gratitude to our principal **Prof.Dr.V.Selladurai, Ph.D.,** Coimbatore Institute of Technology, Coimbatore for his moral support during the course of my Research work. We sincere thanks to **Prof.Dr.G.Sundararaj**,**Ph.D.,** Professor, Department of Production Engineering, P.S.G.College of Technology, Coimbatore and **Prof.Dr.I.Rajendran,Ph.D.,** Professor and Head, Department of Mechanical Engineering, Dr.Mahalingam College of Engineering &Technology, Coimbatore for their valuable guidance and suggestions.

This research was sponsored by the **INSTITUTION OF ENGINEERS (INDIA), KOLKATA.** We wish to acknowledge their support.

We would like to acknowledge **THE CONTROLLER OF PATENTS & DESIGNS, The Patent office, Chennai, INDIA** for filed this research work provisional specification [**PATENT APPLICATION NO.2349/CHE//2010**].

We would like to thank the Reviewers of this editorial system for their valuable inputs and comments.

REFERENCES

Journals

[1] Chandramohan.D and Dr.K.Marimuthu, 2011. Characterization of natural fibers and its application in bone grafting substitutes. Acta of Bioengineering and Biomechanics, Vol. 13, No. 1, ,pp-77-84

[2] Chandramohan.D and Dr.K.Marimuthu, 2011. Natural fiber particle reinforced composite material for bone implant. European Journal of ScientificResearch**,**Volume54,issue3,pp-384-406

[3] Chandramohan.D and Dr.K.Marimuthu, 2011. Bio Composite Materials Based on Bio Polymers And Natural Fibers -Contribution As Bone Implant. International Journal Of Advanced Medical Sciences And Applied Research**,** Volume 1 issue 1 pp-009-012

[4] Chandramohan.D and Dr.K.Marimuthu**,** 2011**.** Natural Fiber Bone Plates-A Worldwide Patent Search Report**.** International Journal of Engineering Science and Technology**,** Volume 3 No 5,pp 3663- 3669

[5] Chandramohan.D and Dr.K.Marimuthu, 2011. Tensile and Hardness Tests on Natural Fiber Reinforced Polymer Composite Material. International Journal of Advanced Engineering Sciences and Technologies**,** Volume 6, issue 1, pp-97-104.

[6] Chandramohan.D and Dr.K.Marimuthu, 2010. Thrust Force, Torque In Drilling The Natural Fiber Reinforced Polymer Composite Materials And Evaluate Delamination Factor For Bone Graft Substitutes -A Work of Fiction Approach. International Journal of Engineering Science and Technology**,** Vol. 2(10), pp - 6437-6451.

[7] Chandramohan.D, Dr.K.Marimuthu, S.Rajesh and M.M.Ravikumar, 2010. Applications of CT/CAD/RPT in the Futurestic Development of Orthopaedics and Fabrication of Plate and Screw Material from Natural Fiber Particle Reinforced Composites for Humerus Bone Fixation – A Future Drift. Malaysian Journal of Educational Technology, Volume 10, No 2, pp 73-81.

[8] Chandramohan.D and Dr.K.Marimuthu, 2010 .Contribution of Biomaterials to Orthopaedics as Bone Implants – A Review. International Journal of Materials Science, Vol.5, No. 3, pp 445-463.

[9] Chandramohan.D, Dr.K.Marimuthu, S.Rajesh and M.M.Ravikumar, 2010. Application of Advanced Design and Development Techniques in Orthopaedics. International Journal of Applied Engineering Research, Vol.5, No. 9, pp 1653-1666.

Books

[1] Anderson, John D. 1995. Computational Fluid Dynamics: The Basics With Applications, Science/Engineering/Math, McGraw-Hill Science.

[2] Patankar, Suhas. 1980. Numerical Heat Transfer and Fluid Flow, Hemisphere Series on Computational Methods in Mechanics and Thermal Science, Taylor & Francis.

External Links

[1] **CFD Tutorial Many examples and images, with references to robotic fish.**

[2] CFD-Wiki

[3] Course*:* Introduction to CFD – Dmitri Kuzmin (Dortmund University of Technology)