Vibrational analysis of bicycle frame

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Abstract : It is important to recognize that the design of any machine is an interdisciplinary process, involving aerodynamics, thermodynamics, fluid dynamics, stress analysis, vibration analysis, the selection of materials, and the requirements for manufacturing. The operation of any mechanical system will always produce some vibration. Our goal is to minimize the effect of these vibrations, because while it is undesirable, vibration is unavoidable. The result of excess vibration can vary from nuisance disturbance to a catastrophic failure. Bicycle frame is a major component in a system. This work involves vibration analysis to determine the key characteristics of a bicycle frame. The dynamic characteristics of bicycle chassis such as the natural frequency and mode shape will be determined. Tools used are catiaV5 for 3D modeling, Hypermesh for meshing, and Ansys for post processing.

Index Terms - Bicycle Frame, Weight Optimization, Design of Frame, Vibrational analysis, FEA, ANSYS, etc.

I. INTRODUCTION

Most modern bicycle frames have the simple form .This shape emerged in about 1895 following several decades of vigorous development and evolution and has remained basically unchanged since that time. The need for low weight coupled with high strength and stiffness has lead to continuing trail and development of high performance material for racing bicycles. Thus in trial and error method is costly and slow, and intuition does not always yield reliable result. A promising solution is to turn a proven tool of structural engineering; the Finite Element Analysis method. The method used for modelling will be described and theoretical predictions of frame stresses will be compared with F.E.A result for some simple loading cases. This design has been the industry standard for bicycle frame design for over one hundred years. The frame consists of a top tube, down tube, head tube, seat tube, seat stays, and chain stays .The main component on a bicycle is still the frame itself. Even if all the other aspects of the bicycle are of top quality, no top performance will be achieved without a frame of the highest quality. The cyclist wants his bicycle to be light, stiff, durable, strong, nice looking, weather resistant and it must also be comfortable. The developer of bicycle faces a great challenge, because designing a frame which meets all these requirements is barely impossible. For example, stiffness and comfort are each other's opposite, though a compromise between both must be found. Depending on the used material for the frame, one or other aspect can be fulfilled better. The behaviour of the frame is of big importance for the perception on comfort of the rider. Because, the better vibrations coming from the road are absorbed by the frame, the better the rider will perform. Vibrations which are not absorbed by the bicycle (frame) must be absorbed by the rider and this causes fatigue of the muscles and thus diminished performance. Research to the aspect of the dynamic behaviour eventually leads to a better frame, so one gets one step closer to the ideal bicycle frame.

II. NOMENCLATURE, SELECTION OF MATERIALS:-

A. NOMENCLATURE:-

Inner Diameter

Outer Diameter

Length of top tube

Length of head tube

Length of seat tube

Seat stay length

Chain stay length

Seat tube angle

Head tube angle

B.SELECTION OF MATERIALS FOR BICYCLE FRAME:-

Existing materials : (Mild Steel, Aluminium alloy 6061)

New materials used in our project : (Carbon fiber ,E glass Epoxy UD)

The nature and the material properties of these materials are as follows,

MILD STEEL:-

At present bicycle frame is made of mild steel material. So, first analysis is done using MS as material. Steel is the traditional material for bicycle frame .Steel is easy to get. Machinery to manipulate steel is easy to get. Steel is easy and it's also cheap. This is the main reason that 99% of the bicycle frame are made from steel. Steel is stiff but dense (heavy). Steel rates well in terms of both yield strength and ultimate strength, particularly if it's carefully alloyed and processed. Steel also resists fatigue failure well which is extremely useful - even if the flexes under load, such flexing need not lead to a critical failure. Iron and steel are used widely in the construction of roads, railways, other infrastructure, appliances, and buildings.

ALUMINIUM ALLOY 6061:-

Aluminum was first utilized in frame construction in 1895.Since then it has become the most popular of all frame materials. If the lightest bike's frame is manufactured with Aluminum , we will get better construction and higher quality tubing. The new features like new aluminum alloys, hydro forming and tubing enhancements allow the Aluminum frames to absorb shock while enjoying a pleasurable ride. There are various types of aluminum tubing in use by manufacturers. There are some ultra-light tube sets like scandium. Aluminum forks are said to be light and stiff , they could be shaped aerodynamically. They are known to provide good vibration damping in order for you to enjoy a good ride.

E Glass Epoxy UD:-

The commonly used fibers are carbon, glass, etc. The main advantage of glass fibers is low cost. It has high strength, high chemical resistance and good insulating properties. The disadvantages are low modulus of elasticity, poor adhesion to polymer, low fatigue strength and high density which increase spring weight and size. The types of glass fibers are C-glass, S-glass and E-glass. The E-glass fiber is a high quality glass, which is used as standard reinforcement fiber for all the present systems well complying with mechanical property requirements. Thus, E-glass fiber was found appropriate for this application.

CARBON FIBER:-

Carbon fiber which is also referred to as "graphite" or "carbon" or "composite" is very special because it is not a metal. Frames manufactured from carbon fiber are extremely light, durable and stiff. The greatest merits of graphite are that they can be molded into different shapes and they possess unbelievable lightness with great rigidity which aids absolute pedaling efficiency and incomparable comfort. Carbon is not affected by corrosion and it has a shining property. Carbon frames are expensive. Carbon forks are popular because of its lightness and its natural ability to absorb shocks. It is Common in automotive, aerospace, civil engineering, and sports industries. Carbon Fiber has become common in many different pieces of sports equipment. The low weight but high strength of carbon fiber allows the frames to be smaller and lighter while still extremely strong. In bicycle frames it is used for its extreme lightness. A CFRP frame weighs less than a Aluminium, titanium, or steel frame.

PROPERTIES OF THE SELECTED MATERIALS:-

SI NO	MATERIALS	YOUNGS MODULUS (Mpa)	DENSITY(Kg/m3)	POISSONS RATIO ,ν
1	Mild Steel	2.1×10^5	7850	0.28
2	Aluminium alloy	69×10^3	2700	0.33
3	E Glass Epoxy UD	73×10^3	2600	0.34
4	Carbon fiber	200×10^3	1800	0.36

DESIGN OF BICYCLE FRAME:-

DIMENSIONS OF BICYCLE FRAME

Length of head tube :120(mm)

Length of top tube : 500(mm)

Length of Seat stay :440(mm)

Length of Chain stay : 325(mm)

Head tube inner diameter : 21(mm)

Head tube outer diameter : 25(mm)

Seat tube inner diameter : 21(mm)

Seat tube outer diameter : 25(mm)

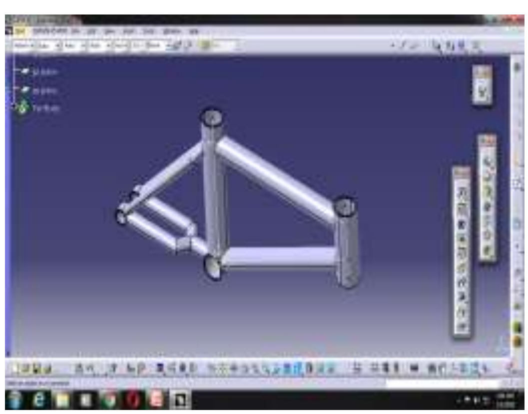
Seat stay inner diameter : 12(mm)

Seat stay outer diameter : 16(mm)

Top tube inner diameter : 21(mm)

Top tube outer diameter : 25(mm)

DESIGN MODEL:-



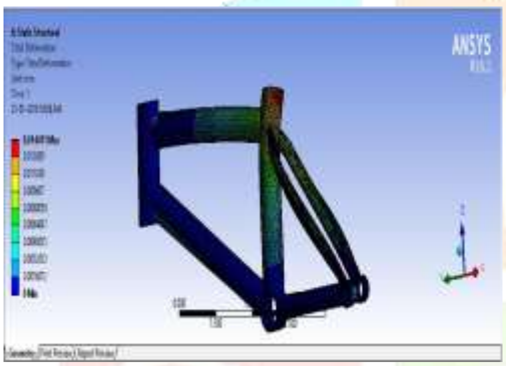
(Fig-1: CATIA Model of BICYCLE FRAME)

STATIC ANALYSIS OF BICYCLE FRAME:-

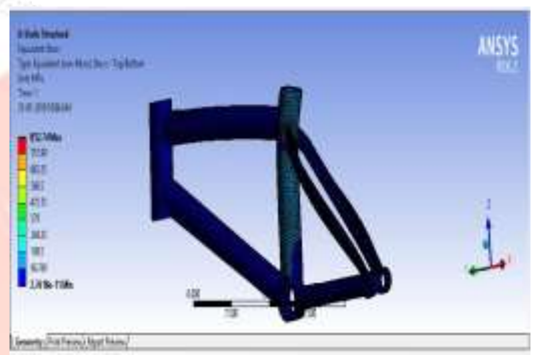
MESHING

(Fig-2: Meshed model of bicycle frame)

MILD STEEL:-

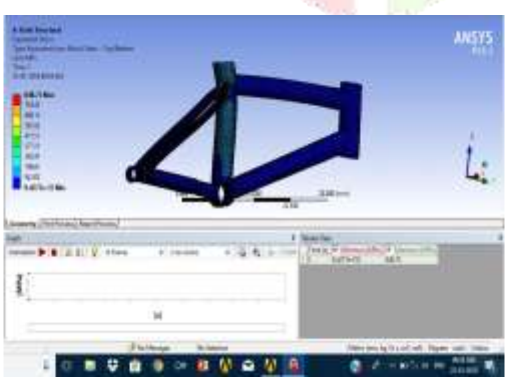


(Fig-3: Equivalent Stress)

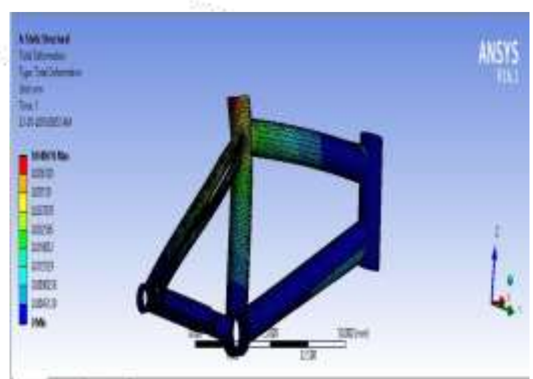


(Fig-4: Total Deformation)

ALUMINIUM ALLOY:-

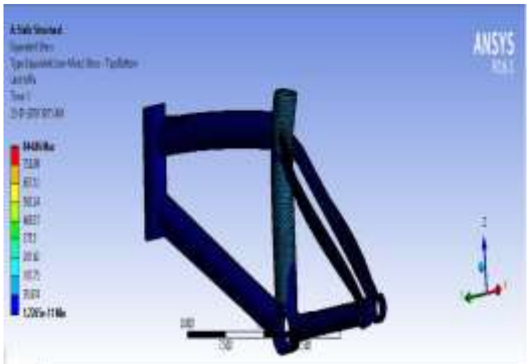


5: Equivalent Stress)

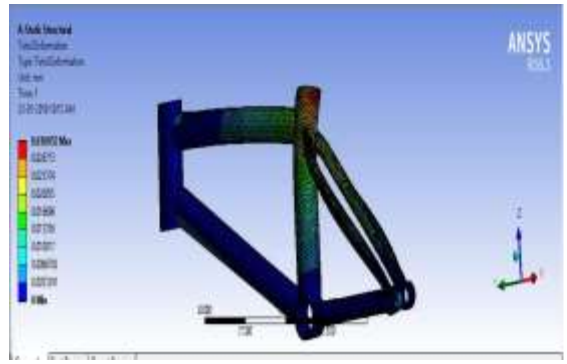


(Fig-6: Total Deformation)

CARBON FIBER:-

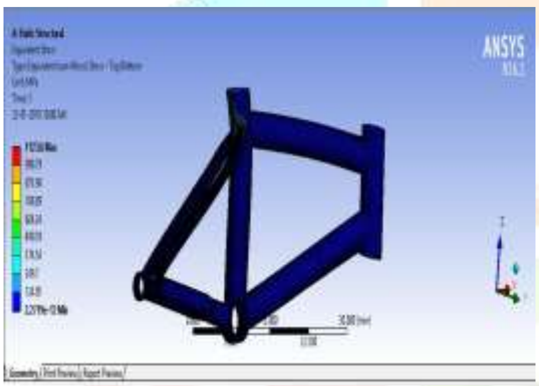


(Fig-7: Equivalent Stress)

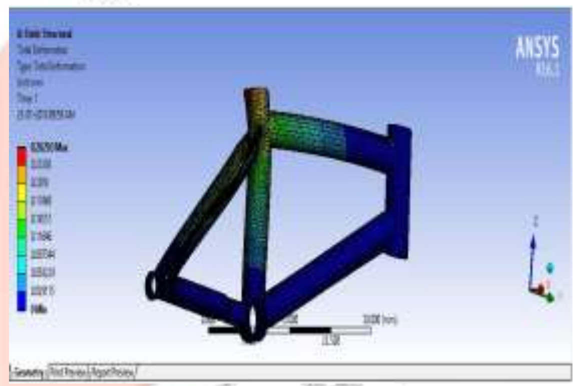


(Fig-8: Total Deformation)

E GLASS EPOXY UD:-



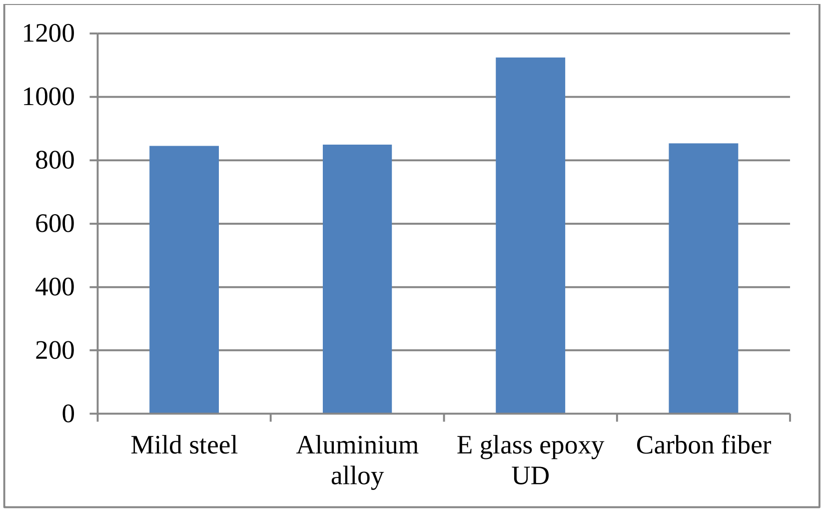
(Fig-9: Equivalent Stress)



(Fig-10: Total Deformation)

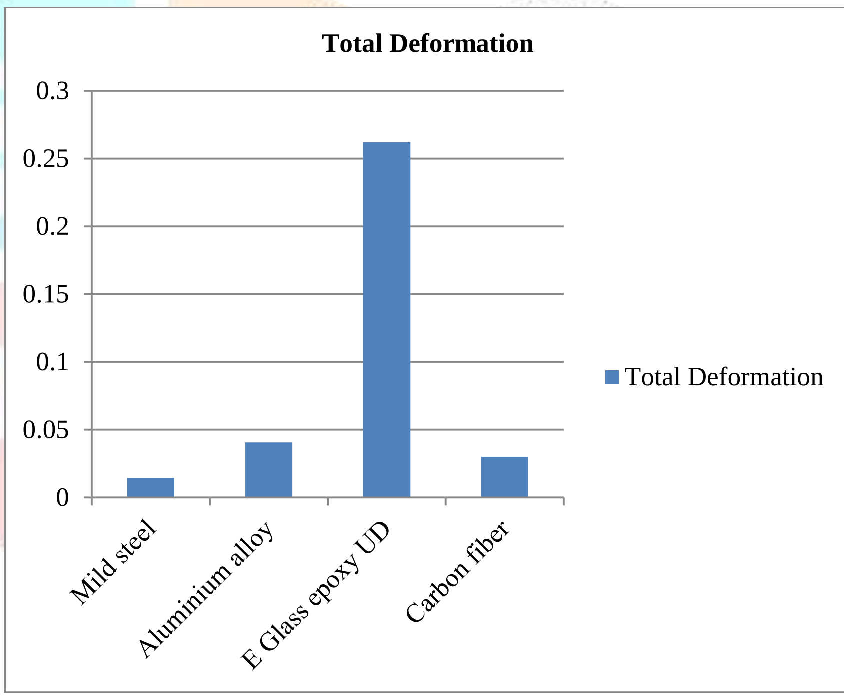
COMPARISON TABLE FOR STRESS AND TOTAL DEFORMATION:-

Materials	Equivalent Stress	Total Deformation
Mild Steel	852.74	0.014411
Aluminium Alloy	848.73	0.040616
Carbon fiber	844.86	0.030052
E Glass Epoxy UD	1123.6	0.26203



(Fig:-11: Equivalent stress of materials)

From the above table the stresses acting in the carbon fiber is comparative lesser than that of aluminium alloy and e glass epoxy and found to be effective.



(Fig-12: Total Deformation of Materials)

From the graph that has been taken from the static analysis it has been proven that there will be lesser deformation will be taking in the carbon fibre material as compared to aluminium alloy and e glass epoxy.

MODAL ANALYSIS:-(Aluminium alloy)

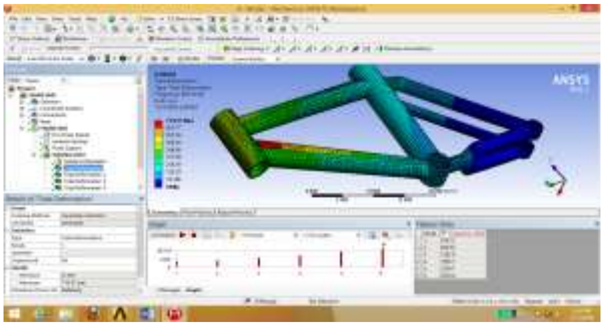


Fig:-13 1^{st} mode frequency 818.3hz.

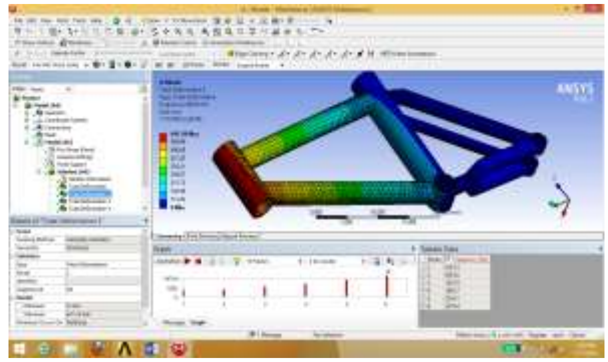


Fig:-14 2^{nd} mode frequency 929.52hz.

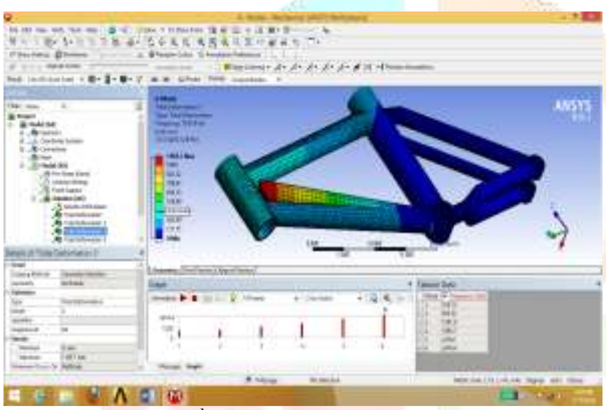


Fig:-14 3^{rd} mode frequency is 1283.9hz.

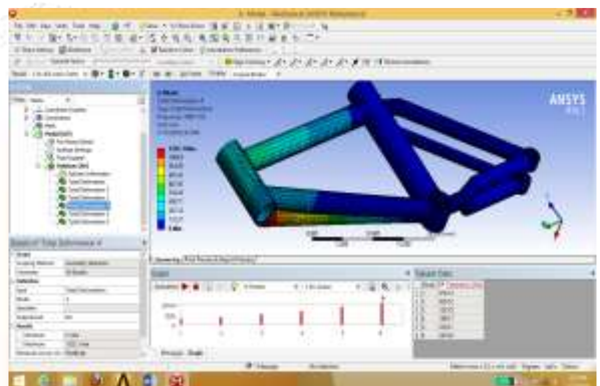


Fig:-15 4^{th} mode frequency is 1693.9hz.

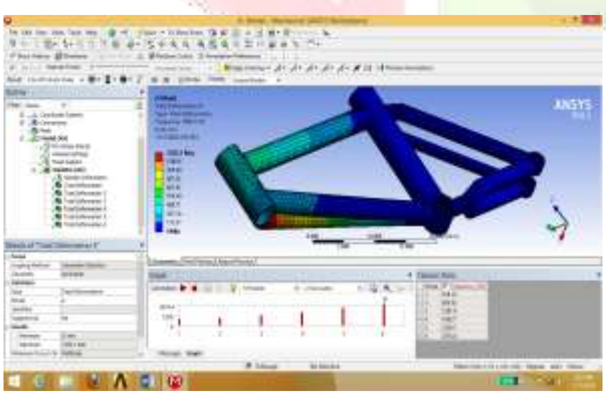


Fig:-16 5^{th} mode frequency is 2334.1hz.

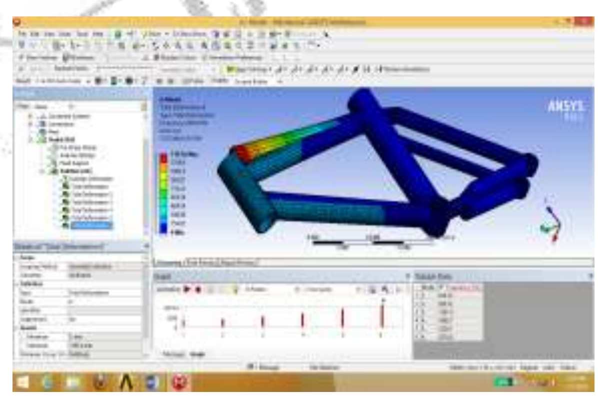


Fig:-17 6^{th} mode frequency is 2474.4hz.

Carbon Fiber:-

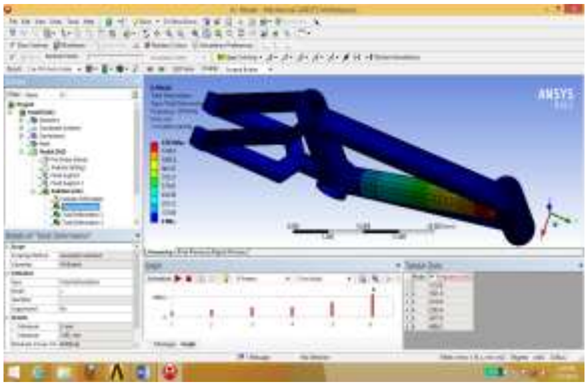


Fig:-18 1st mode frequency is 1214.6hz.

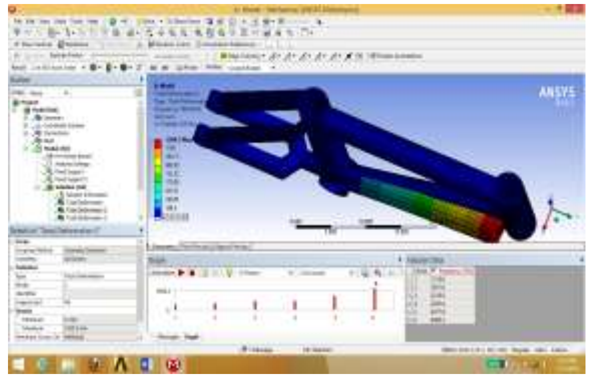


Fig:- 19 2nd mode frequency is 1623.6hz.

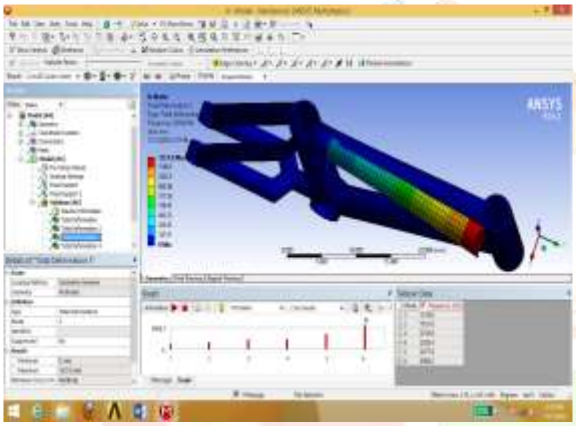


Fig:-20 3rd mode frequency is 2216.3hz.

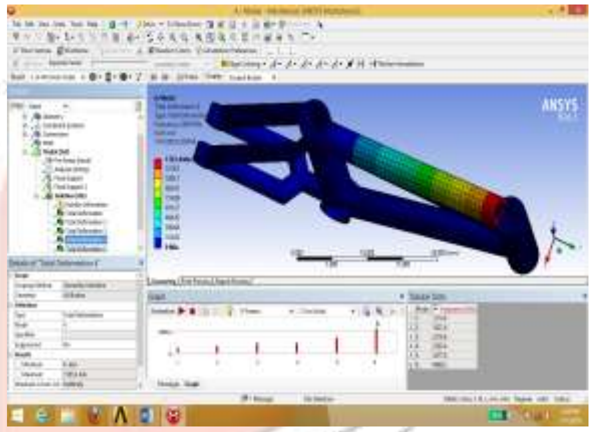


Fig:-21 4th mode frequency is 2293.4hz.

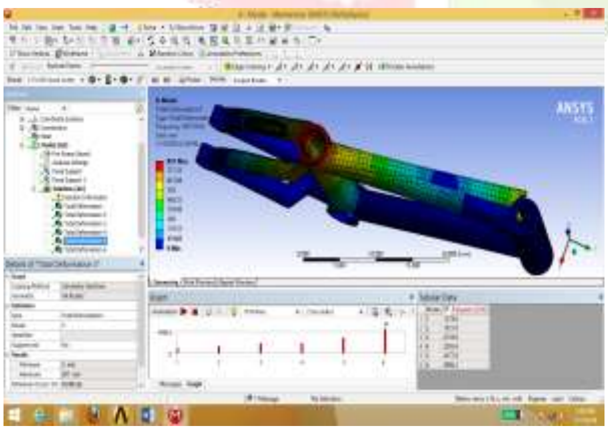


Fig:-22 5th mode frequency is 3477.3hz.

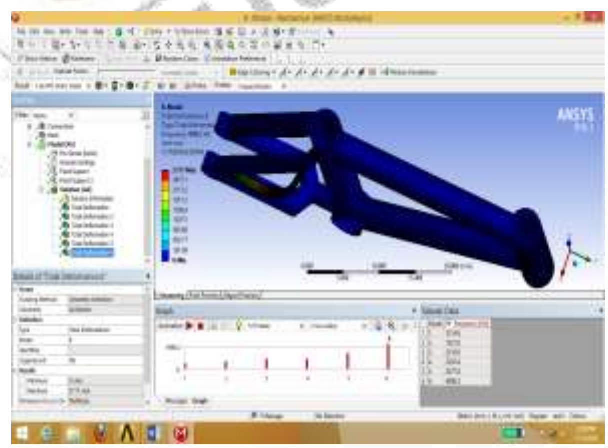


Fig:-23 6th mode frequency is 4966.2hz.

RESULT COMPARISON TABLE:-

Materials	Frequency-1	Frequency-2	Frequency-3	Frequency-4	Frequency-5	Frequency-6
Aluminium alloy	818.3hz	929.52hz	1283.9hz	1693.9hz	2334.1hz	2474.4hz
Carbon fiber	1214.6hz	1623.6hz	2216.3hz	2293.4hz	3477.3hz	4366.2hz

CONCLUSION:-

In this project we have designed the road bicycle frame the dimensions of the frame are takenfrom whippet and the design has been done in the CATIA V20 and we have analysed the frame with different materials thus through the analysis made we found that titanium alloy and carbon fiber are found to be more suitable for the purpose of reduced vibrations but titanium is found to be costlier and hence it is difficult for manufacturing in a mass and hence we suggest that carbon fiber can be used as a suitable for the manufacturing of frames in the future as it lighter in weight and as well as have good stiffness properties and also cost efficient when compared with titanium alloy.

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