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CRICKET BAT: AN ANALYTICAL ASSESMENT OF SWEETSPOT & PERFORMANCE

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CERTIFICATE OF RESEARCH

The thesis title "CRICKET BAT: AN ANALYTICAL ASSESMENT OF SWEETSPOT & PERFORMANCE" submitted by A. A. MAHMUD HASAN (121418) and SHARIAR ALAM (121413), has been accepted as satisfactory in partial fulfillment of the requirement for the Degree of Bachelor of Science in Mechanical and Chemical Engineering on December, 2016.

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DECLARATION

THIS IS TO CERTIFY THAT THE WORK PRESENTED IN THIS THESIS IS AN OUTCOME OF THE ANALYSIS, SIMULATION AND RESEARCH CARRIED OUT BY THE AUTHOR THEMSELVES UNDER THE WATCHFUL SUPERVISION OF PROF. DR. MD. ZAHID HOSSAIN.

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ABSTRACT

In the game of cricket importance of using the right type of bat is very crucial. Boundaries of laws set by the MCC does not permit massive alteration of traditional bat design, materials and its manufacturing process. Yet the performance of the cricket bat can be boosted using FEA method within the limitations of laws. The purpose of this study was to show the presence of sweet spot in cricket bat and its location using modal analysis. The results that were found from the computer simulation showed the natural frequencies and their corresponding mode shapes. From these results verdict can be made about the performance of the cricket bat and how to enhance it. Computer aided modified design was further analyzed which showed improved results in terms of performance.

CHAPTER 1 : INTRODUCTION

Cricket as a sport has gained much popularity in half of the world. People enjoys the game by playing it and watching it. The charm of the game is kept by governing the game with some codes of law for over 250 years. Alterations and additions to these codes have been made by the recommendations of the governing authorities of the time. The Marylebone Cricket Club (MCC), since 1787 has been recognized as the sole authority for drawing up the Code.

According to the described law by MCC the specification of the cricket bat are fixed. The dimension and materials of the cricket bat are guided by some rules. The blade of the bat can't be made other than wood. Within these boundaries if some wise modifications are made than the performance of the cricket bat can be improved.

Especially when the player is playing different type of match the goal of the game is different. So to achieve this different goals the player should be provided with appropriate type of bats (1). Test match, one day and T20 requires different types of scoring rate. To score more runs in a match there is no alternative of scoring boundaries, and it requires perfect impact on the ball. The efficiency of the impact on the ball by the bat depends upon where the ball gets the hit from the bat (2; 3). If the ball hits the sweet spot of the bat it will get the maximum energy from the bat (2). This energy can be maximized by increasing momentum of the bat. The momentum can be increased by repositioning the center of mass of the bat. There are high possibilities of scoring boundaries with a low positioned sweet spot. It is best for pull shot. The momentum can further be increased by addition of mass on the blade. This can be done by increasing the thickness of the blade (4). This will also lower/increase the natural frequency of the bat. Which will lead to a better shock absorption from the ball impact

1.1. LAWS THAT GOVERN THE BAT (QUOTATION)

LAW 6 THE BAT

1. The bat

The bat consists of two parts, a handle and a blade.

2. Measurements

All provisions in sections 3 to 6 below are subject to the measurements and restrictions stated in Appendix E.

3. The handle

(a) One end of the handle is inserted into a recess in the blade as a means of joining the handle and the blade. The part of the handle that is then wholly outside the blade is defined to be the upper portion of the handle. It is a straight shaft for holding the bat.

The remainder of the handle is its lower portion used purely for joining the blade and the handle together. It is not part of the blade but, solely in interpreting 5 and 6 below, references to the blade shall be considered to extend also to the lower portion of the handle where relevant.

(b) The handle is to be made principally of cane and/or wood, glued where necessary and bound with twine along the upper portion.

(c) Providing 7 below is not contravened, the upper portion may be covered with materials solely to provide a surface suitable for gripping. Such covering is an addition and is not part of the bat. Note, however, 8 below.

(d) Notwithstanding 4(c) and 5 below, both the twine binding and the covering grip may extend beyond the junction of the upper and lower portions, to cover part of the shoulders as defined in Appendix E.

4. The blade

(a) The blade comprises the whole of the bat apart from the handle as defined above. The blade has a face, a back, a toe, sides and shoulders. See Appendix E.

(b) The blade shall consist solely of wood.

(c) No material may be placed on or inserted into either the blade or the lower portion of the handle other than as permitted in 3(d) above and 5 and 6 below, together with the minimal adhesives or adhesive tape used solely for fixing these items, or for fixing the handle to the blade.p.13

5. Covering the blade

All bats may have commercial identifications on the blade. Type A and Type B bats may have no other covering on the blade except as permitted in 6 below. Type C bats may have a cloth covering on the blade. This may be treated as specified in 6 below.

Such covering is additional to the blade and is not part of the bat. Note, however, 8 below.

6. Protection and repair

Providing neither 4 above nor 7 below is contravened,

(a) solely for the purposes of either (i) protection from surface damage to the face, sides and shoulders of the blade or (ii) repair to the blade after damage material that is not rigid, either at the time of its application to the blade or subsequently, may be placed on these surfaces. Any such material shall not extend over any part of the back of the blade except in the case of (ii) above and then only when it is applied as a continuous wrapping covering the damaged area.

(b) solid material may be inserted into the blade for repair after damage other than surface damage. Additionally, for protection from damage, for Types B and C, material may be inserted at the toe and/or along the sides, parallel to the face of the blade.

The only material permitted for any insertion is wood with minimal essential adhesives.

(c) to prevent damage to the toe, material may be placed on that part of the blade but shall not extend over any part of the face, back or sides of the blade.

(d) the surface of the blade may be treated with non-solid materials to improve resistance to moisture penetration and/or mask natural blemishes in the appearance of the wood. Save for the purpose of giving a homogeneous appearance by masking natural blemishes, such treatment must not materially alter the color of the blade.

Any materials referred to in (a), (b), (c) or (d) above are additional to the blade and not part of the bat. Note, however, 8 below.

7. Damage to the ball

(a) For any part of the bat, covered or uncovered, the hardness of the constituent materials and the surface texture thereof shall not be such that either or both could cause unacceptable damage to the ball.

(b) Any material placed on any part of the bat, for whatever purpose, shall similarly not be such that it could cause unacceptable damage to the ball.

(c) For the purposes of this Law, unacceptable damage is deterioration greater than normal wear and tear caused by the ball striking the uncovered wooden surface of the blade.

8. Contact with the ball

In these Laws,

(a) reference to the bat shall imply that the bat is held in the batsman's hand or a glove worn on his hand, unless stated otherwise.

(b) contact between the ball and either (i) the bat itself or (ii) the batsman's hand holding the bat or (iii) any part of a glove worn on the batsman's hand holding the bat or (iv) any additional materials permitted under 3, 5 or 6 abovep.14 shall be regarded as the ball striking or touching the bat or being struck by the bat.

APPENDIX E – THE BAT: LAW 6

All Law references are to sections of Law 6

Categories of bat – Types A, B and C are bats conforming to Law 6, sections1 to 8 inclusive.

Bats which do not qualify for any of the three categories are not recognized in the Laws. Type A bats may be used at any level. Bats of Type B or Type C and any other bats may be used only at or below levels determined by the Governing Body for cricket in the country concerned.

The blade – The face of the blade is its main striking surface. The back is the opposite surface.

The shoulders, sides and toe are the remaining surfaces, separating the face and the back. The shoulders, one on each side of the handle, are along that portion of the blade between the first entry point of the handle and the point at which the blade first reaches its full width.

The toe is the surface opposite to the shoulders taken as a pair.p.63

The sides, one each side of the blade, are along the rest of the blade, between the toe and the shoulders.

Adhesives – Throughout, adhesives are permitted only where essential and only in minimal quantity.

Materials in handle – As a proportion of the total volume of the handle, materials other than cane, wood or twine are restricted to one-tenth for Types A and B and one-fifth for Type C. Such materials must not project more than 3.25in/8.26cm into the lower portion of the handle.

Binding and covering of handle – The permitted continuation beyond the junction of the upper and lower portions of the handle is restricted to a maximum, measured along the length of the handle, of

2.5in/6.35cm for the twine binding

2.75in/6.99cm for the covering grip.

Length and width

(a) The overall length of the bat, when the lower portion of the handle is inserted, shall not be more than 38in/96.5cm.

(b) The width of the bat shall not exceed 4.25in/10.8cm at its widest part.

(c) Permitted coverings, repair material and toe guards, not exceeding their specified thicknesses, may be additional to the dimensions above.

Length of handle – Except for bats of size 6 and less, the handle shall not exceed 52% of the overall length of the bat.

Covering of blade – The cloth covering permitted for Type C bats shall be of thickness not exceeding 0.012in/0.3mm before treatment as in 6.6(d).

Protection and repair of blade – The material permitted in 6.6(a) shall not exceed

0.04in/1mm in thickness. In 6.6(a) (ii), the repair material shall not extend along the length of the blade more than 0.79in/2cm in each direction beyond the limits of the damaged area. Where used as a continuous binding, any overlapping shall not breach the maximum of 0.04in/1mm in total thickness.

In 6.6(d), the use of non-solid material which when dry forms a hard layer more than

0.004in/0.1mm in thickness is not permitted.

Toe and side inserts – The wood used must not be more than 0.3in/0.89cm in thickness.

The toe insert shall not extend from the toe more than 2.5in/6.35cm up the blade at any point.

Neither side insert may extend from the edge more than 1in/2.54cm across the blade at any point.

Toe protection – The maximum permitted thickness of protective material placed on the toe of the blade is 0.12in/3mm.

Commercial identifications – These identifications may not exceed 0.008in/0.2mm in thickness.

On the back of the blade they must occupy no more than 50% of the surface. On the face of the blade, they must be confined within the top 9in/22.86cm, measured from the bottom of the grip.

1.2. SWEET SPOT

Sweet spot of a cricket bat is the zone where if the ball strikes gets the maximum impact force and minimal vibration is transmitted to the hand of the player (2). The main part of a cricket bat and the most important thing is the sweet spot of a cricket bat. Sweet spots means the position in the cricket blade where due to impact of cricket ball, the force transferred to the handle of the bat is minimal and also the co- efficient of restitution is maximum. Impact of cricket ball in the sweet spot causes minimum deflection in the handle and minimum deformation in the cricket bat.

Sweet spot fully depends upon the design of the cricket bat (1; 4). Mostly the position of the maximum curve thickness causes the positioning of the sweet spots. Different batsmen choose different bats according to their choice and situations of the game (3).

There are three different types of sweet spots.

- High position sweet spot
- Medium position sweet spot
- Medium/low position sweet spot

HIGH POSITIONED SWEET SPOT:

In the high position sweet spots tend to remain in 250mm above the toe of the bat. These bats are for a pacey and bouncy pitch. These types of bats are suitable for the batsmen who prefer to play the hooks and pulls. In the fig we can see that the curve blade maximum thickness is a bit upward and it is nearly at the 250mm height from the bottom of the bat.

MEDIUM POSITIONED SWEET SPOT:

Medium position sweet spot means that the sweet spot is not at the high position nor at the bottom. The pitches where there is nothing like bounce but only pace, batmen use these type of bats. Batsmen who tend to play in the offside prefers these type of bats. In the test matches and county cricket batsmen tend to use these type of bats. Medium sweet spot is placed at 225mm from the bottom of the bat.

LOW POSITIONED SWEET SPOT:

In the medium/low sweet spot area this area is located above 210mm from toe area of bat. Medium/Low sweet spot area helps the player in low bounce pitch where players get easily connect the ball in sweet spot area. Batsman with classic drives and shots prefers this type of bat. Mostly the opening batsmen tend to use this type of bats who prefers drive shots.

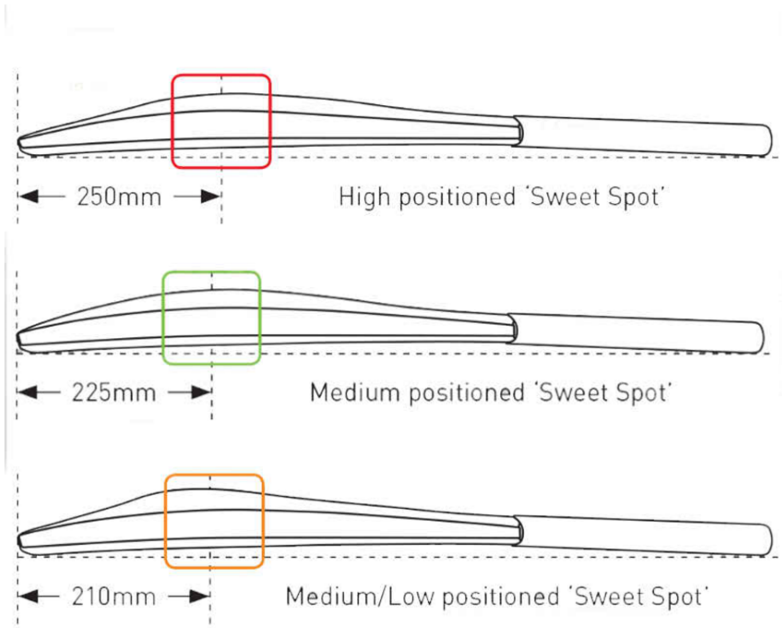


Figure 1Types of sweet spot

1.3. VARIETIES IN CRICKET BATS

From the very beginning there was a lot of varieties in the design of the cricket bat. Within the limitations of the law these designs shows a wide variety (3; 4).

Name Of Cricket Bats	Overall standing height (mm)	Length (mm)	Width (mm)	Maximum Thickness (mm)	Maximum Edge thickness (mm)
1905 'Ranjit'	854.00	549.00	109.25	45.00	14.36
1980 Powerspot	852.00	554.00	108.48	55.00	18.48
2009 Predator	853.00	547.00	107.76	59.00	29.25
2013 Scooped	857.00	558.00	109.34	47.10	34.20
2013 Nemesis	860.00	557.00	109.40	69.00	41.01

CHAPTER 2 : METHODS

The 3D design of the cricket bats were prepared using SolidWorks 2013. Finite element analysis is often applied to further our understanding of the mechanics of sports equipment. Finite element methods have been used by many researchers to aid the process of development of safety equipment and ergonomic sportswear (4). For the purpose of simplifying the analysis the handle and the blade of the cricket bat was considered a single unit made of same material. This drawing was than imported to ANSYS work bench. Using modal analysis the natural frequencies and corresponding mode shapes was found (1; 6). The point of interest of this study was the first two bending mode.

2.1. MODAL ANALYSIS

Modal analysis is the study of the dynamic properties of structures under vibrational excitation.

Modal analysis is the field of measuring and analyzing the dynamic response of structures and or fluids during excitation

The purpose of a modal analysis is to find the shapes and frequencies at which the structure will amplify the effect of a load. Modes are inherent properties of a structure, and are determined by the material properties (mass, damping, and stiffness), and boundary conditions of the structure. Each mode is defined by a natural (modal or resonant) frequency, modal damping, and a mode shape (i.e. the so-called “modal parameters”). If either the material properties or the boundary conditions of a structure change, its modes will change. For instance, if mass is added to a structure, it will vibrate differently.

2.2. DESIGN OF THE CRICKET BAT

The cricket bat was designed in the SolidWorks. The blade and handle of the bat are of same part. This was done to simplify the calculations. The bat was a single unit. Three different bat was modeled with identical dimensions except the thickness. These bats were designed reflecting the history of the revolution of cricket bats (3).

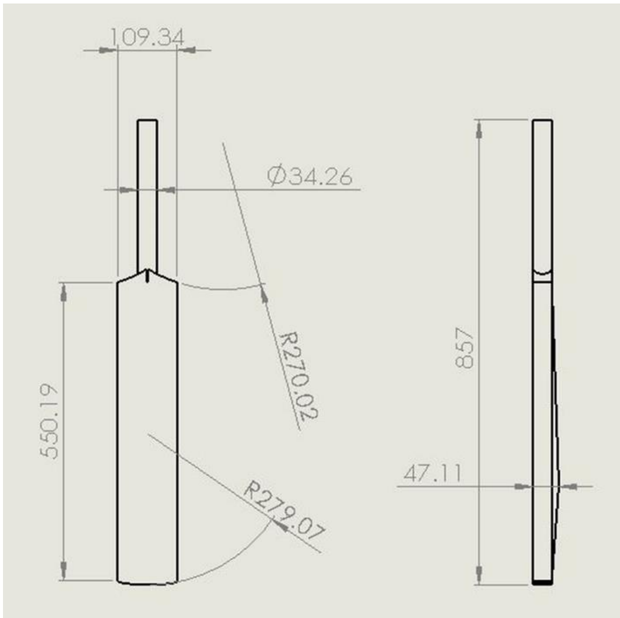


Figure 2Dimension of the cricket bat

2.3. MATERIAL PROPERTIES:

In the engineering data section a new user defined material was created using the properties of an English Willow (7). The material properties of the bat we analyzed was defined with this material data. The properties were as follows:

Density (kg/m3)	Young's Modulus(GPa)			Poisson's Ratios(GPa)			Shear Modulus(GPa)		
P	Ex	Ey	Ez	Vxy	Vyz	Vxz	Gxy	Gyz	Gxz
650	13.3	.883	7.06	.015	.35	.16	1.33	.133	1.33

WHY ENGLISH WILLOW? (8)

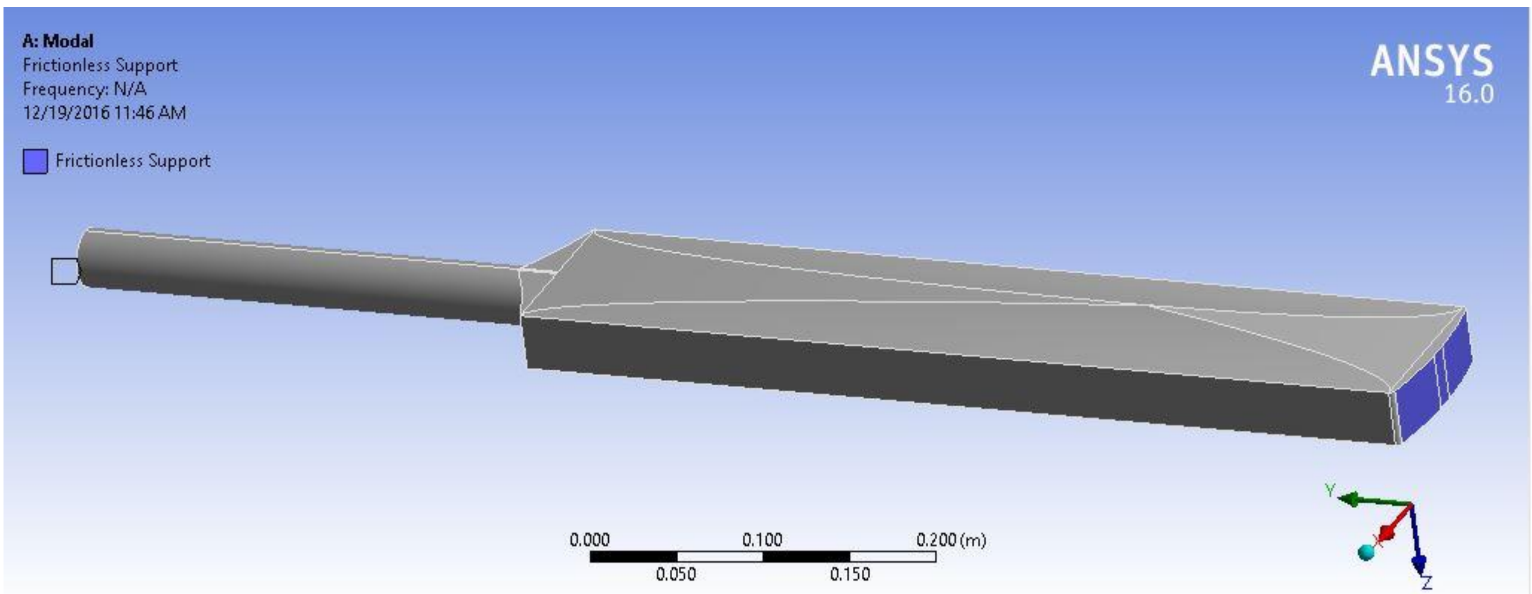
- Very tough and shock-resistant.
- Not being significantly dented nor splintering on the impact of a cricket ball at high speed
- Light weight.
- Soft fibrous wood, with a "honeycomb" type cell structure.
- Natural moisture and its ability to be pressed in the manufacturing process to give great ball striking qualities.
- Lower priced Kashmir Willow, this is harder and therefore more resilient but generally gives less ball striking satisfaction.

2.4. MESHING:

Unit cell size of a mesh is very important. The accuracy of the result of the experiment depends on the element size of the mesh. Finer element size enhances the precision of the result, but this requires higher computing power and consumes more time. As the total number of nodes increases with the increase of total number of element size, the simulation requires to solve all those points. Keeping the computing power of the computer used, the element size was taken as 10mm. This provides an acceptable accuracy of result consuming a moderate computational time.

2.5. BOUNDARY CONDITIONS:

At the both ends of the cricket bat (end of the handle and end of the blade) frictionless support was given (7). Frictionless supports place a normal constraint on an entire surface. Translational displacement is allowed in all directions except into and out of the supported plane. Since we would expect frictional forces to at contact areas this is a conservative approach (5).



CHAPTER 3 : RESULTS

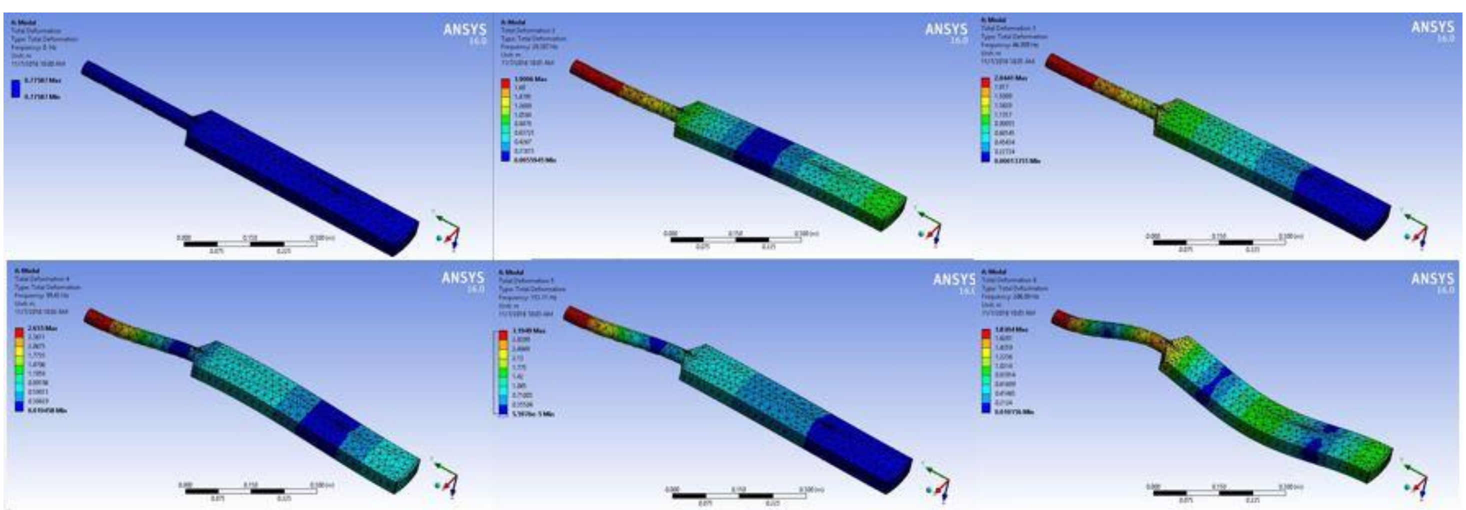
We analyzed 3 different models of cricket bat. All three models had the same cross sectional area in the xy plane, but had different thicknesses. These three cricket bat was analyzed for mode shapes and natural frequencies in ANSYS workbench with the same boundary conditions.

3.1. PROPERTIES OF THE ANALYZED CRICKET-BAT DESIGN:

Serial No.	Volume (cc)	Center of mass (mm)		
		x	y	z
A	2556	54.67	327.2	-18.49
B	2629	54.67	314.5	-19.71
C	2928	54.67	318.25	-21.73

3.2. NATURAL FREQUENCY AND THE MODE SHAPES OF THE CRICKET BATS:

While running the simulation, we set in the analysis settings to find out 6natural frequencies and their corresponding mode shapes. From this six modes we considered only the first two bending modes.



First two bending mode was point of interest of this study. First two bending mode shape was overlapped using image processing, which gave us a common intersection of nodes in the sweet spot.

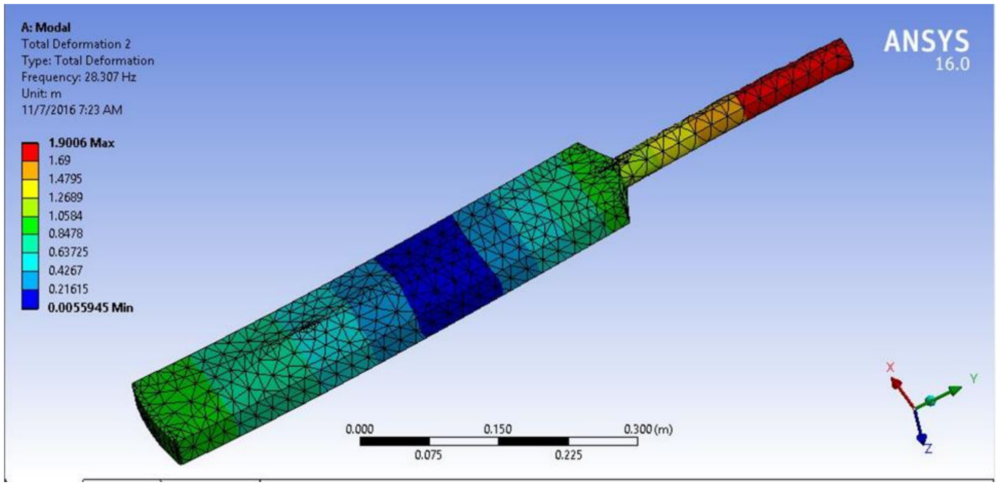


Figure 3First bending mode of bat 'A'

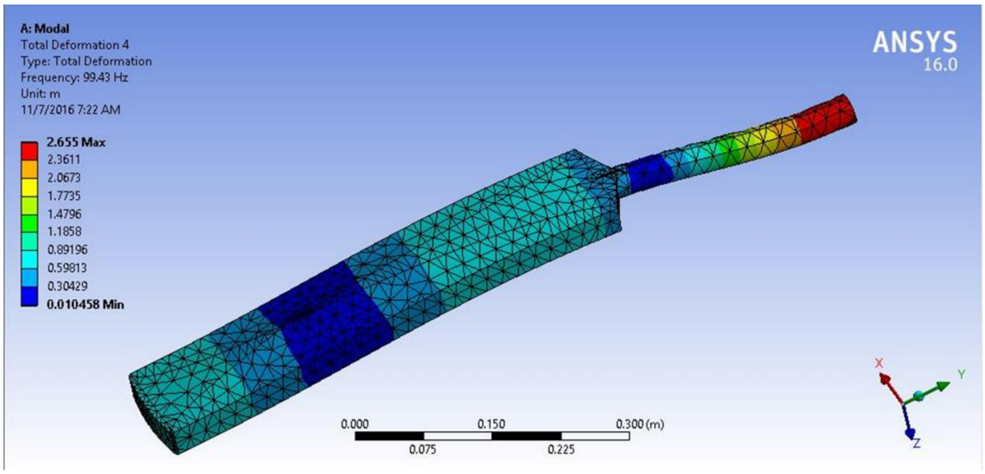


Figure 4Second bending mode of bat 'A'

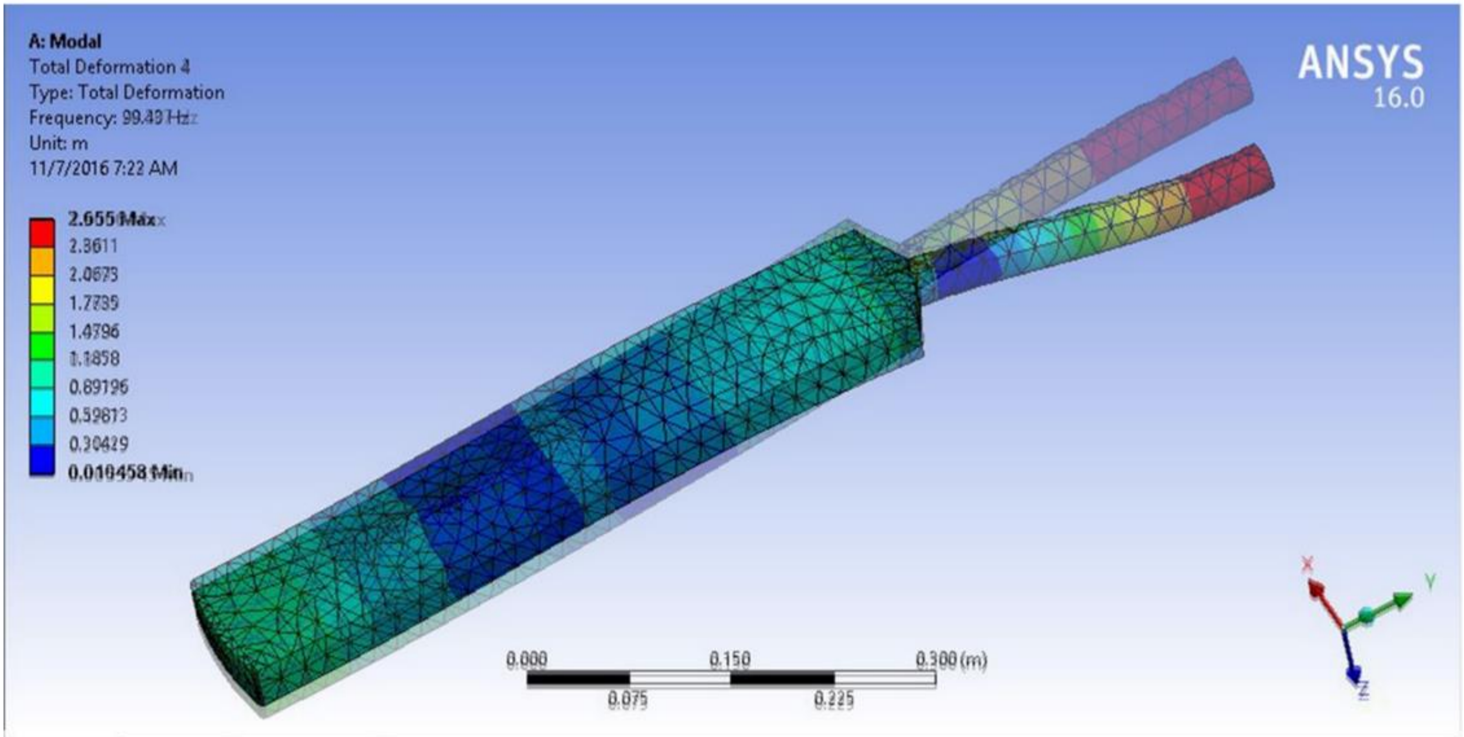


Figure 5Overlapped image of first two bending modes of bat A

3.3. NATURAL FREQUENCY OF THE CRICKET BATS:

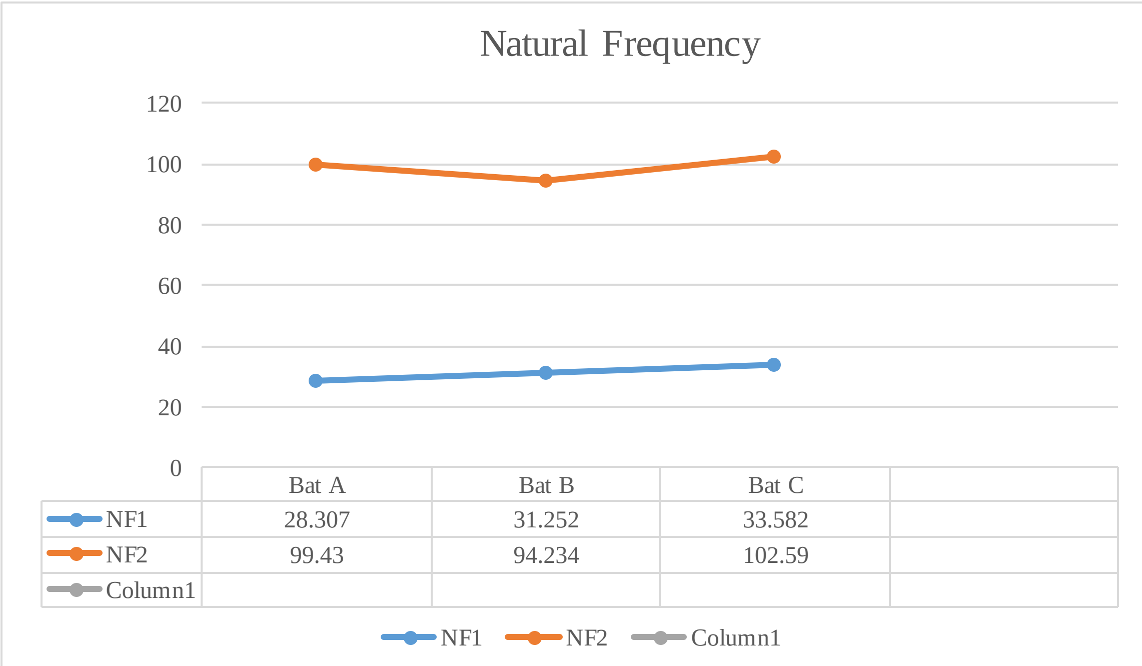
Cricket bat	NF of first bending mode	NF of second bending mode
A	28.307	99.43
B	31.252	94.234
C	33.582	102.59

CHAPTER 4 : DISCUSSION

From the analysis of the mode shapes we can find that the sweet spot lies in the intersection of the first two bending modes' node point. That means the sweet spot will subject to minimum deflection even when the bat will resonate at its natural frequencies. So, the batsman will experience minimum amount of force in his hand, if he can strike the ball with the sweet spot of the bat. This will additionally ensure the maximum impact force delivered to the ball. As the center of mass also lies in the sweet spot.

The thickness of the bat is also very important. We can see that with the increase of the thickness both of the natural frequencies also increases by a significant amount. Which means bat with low positioned sweet spot and thicker blade cross section will perform better for hitting the ball. Though the player will need more energy for longer play time, but it will also deliver less vibration to the hand of the batsman. The bat with higher thickness will have higher apparent coefficient of restitution (6).

Further study and experimentation will establish the findings of this experiment.


Natural Frequency
120
100
80
60
40
20
0
Bat A
Bat B
Bat C
NF1
28.307
31.252
33.582
NF2
99.43
94.234
102.59
Column1
NF1
NF2
Column1

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