Finite element analysis of tennis racquet in order to avoid tennis injuries

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Abstract - This study illustrates the finite element analysis which is also known as computer simulation to scrutiny the dynamic modal analysis of a tennis racquet made of graphite and titanium composite material. A three dimensional racquet model was generated in the Solidworks. The 3D model of the tennis ball was also created. The very tennis racquet was exported to explicit dynamics of the Ansys software. There are couple of strings used in the analysis that is nylon and polyester. The utopian agenda of the study to simulation betwixt the tennis ball and tennis racquet were done using explicit dynamics module of the Ansys software.

***Key Words*: (Tennis racquet frame, Solidworks, Explicit dynamics Ansys, dynamic analysis)**

1.INTRODUCTION

In the last four decades the game of tennis has changed drastically. The credit goes to the advanced materials and innovation in the design of the tennis racquet which proved to be lighter and stronger as comparison to the wooden tennis racquets. Today's tennis racquets have become a benchmark of high tech innovated engineering with the use of graphite composites in the frame of the racquet. These graphite composites used in the tennis racquet are among the most astonishing discoveries as they give crystal clear combinations of mechanical properties like stiffness, elastic, strength, toughness. There are couple of design aspects which are categorized as internal and external design aspects. The internal design aspect indulge material type, weight and balance while the external design aspect involves strings, beam and head size. In today's world tennis players are using latest advance engineering materials which plays a pivotal role in enhancing the performance of the tennis player. With the help of Solidworks a three dimensional tennis racquet frame and tennis ball was created. The very model was transferred to explicit dynamics module of Ansys software. The stress analysis of the racket of different materials was done at different parts on the frame at different velocities.

1.1 THREE DIMENSIONAL MODEL OF THE TENNIS RACQUET WITH STRINGS

The Solid works was used in the making of the tennis racquet frame with strings. The design is divided into couple of parts. The first part is the making of strings which indulge diameter of string that is 1.2mm and string pattern is 20/23 which means frame periphery at 23 mm distance vertically and 20mm horizontally. The linear pattern command is mainly used to multiple the strings pattern . The second part that is tennis frame is basically had elliptical section which is made with help of sweep command while the sketch is obtained by using extrude, swept, curve and sweep commands. The dimension of the tennis racquet is as follows.

1.2 Tennis ball

The tennis ball can be made using semicircle command with respect to x axis. Then by using revolve command it was revolved about the x axis and the spherical shape was got. The spline command is also used to make the lining on the ball. The outer diameter of the ball is given as per standard dimensions.

2. Stress analysis of tennis racquets of different materials and strings at different velocities

Consider five different points on the frame of the tennis racquet named as centre, centre forward, centre backward, left, right spots on which the tennis ball is strike on these spots at different velocities that is 50,75,100 m/s. Stress analysis on ansys software has been calculated.Input parameters-Frame(graphite and titanium), strings(Nylon and polyester),Velocity (50,75,100 m/s)

Table -1: Annova table

Frame	String	Velocity	Cf	c	cb	l	r
1	1	1	18.62	17.91	19.39	22.14	21.79
1	1	2	19.77	18.21	20.57	23.15	22.69
1	1	3	20.81	18.79	22.56	24.01	23.98
1	2	1	17.79	16.76	18.46	20.78	20.21
1	2	2	18.53	17.39	19.85	21.96	21.28
1	2	3	19.24	17.91	20.18	22.76	22.45
2	1	1	16.54	15.45	17.23	18.1	17.58
2	1	2	17.09	16.17	17.67	18.98	18.11
2	1	3	17.58	16.63	18.74	19.89	19.54
2	2	1	15.87	14.65	16.42	17.54	17.11
2	2	2	16.22	15.13	17.21	18.33	17.87
2	2	3	16.54	15.84	17.84	18.49	18.24

Results and Discussion

STRESS ANALYSIS OF DIFFERENT FRAMES ON DIFFERENT VELOCITIES

				Cf	c	cb	l	r
Frame	String	Velocity	Exp	1	2	3	4	5
tt	nylon	50	1	18.62	17.91	19.39	22.14	21.79
tt	poly	50	2	17.79	16.76	18.46	20.78	20.21
gr	nylon	50	3	16.54	15.45	17.23	18.1	17.58
gr	poly	50	4	15.87	14.65	16.42	17.54	17.11
tt	nylon	75	5	19.77	18.21	20.57	23.15	22.69
tt	poly	75	6	18.53	17.39	19.85	21.96	21.28
gr	nylon	75	7	17.09	16.17	17.67	18.98	18.11
gr	poly	75	8	16.22	15.13	17.21	18.33	17.87
tt	nylon	100	9	20.81	18.79	22.56	24.01	23.98
tt	poly	100	10	19.24	17.91	20.18	22.76	22.45
gr	nylon	100	11	17.58	16.63	18.74	19.89	19.54
gr	poly	100	12	16.54	15.84	17.84	18.49	18.24

TABLE FOR STRESS VALUES

tt	Titanium
gr	Graphite
cf	centre forward
c	centre
cb	centre backward
l	left
r	right

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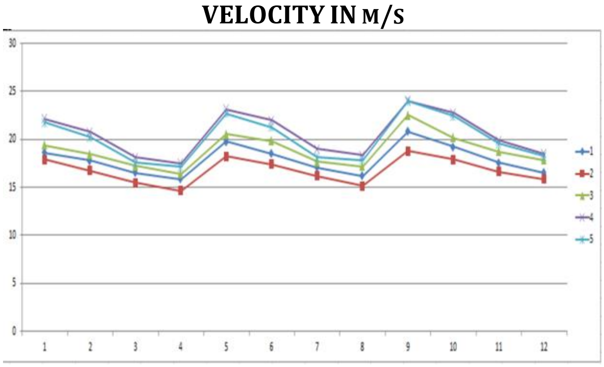
STRESS VALUES IN MPA
VELOCITY IN M/S



1-c-fwd
2- centre
3-c-bwd
4-left
5- right

No of experiments

ANNOVA TABLE

General Linear Model: Cf versus Frame, String, Velocity

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Frame	1	18.5505	18.5505	177.62	0.000
String	1	3.2240	3.2240	30.87	0.001
Velocity	2	3.5800	1.7900	17.14	0.002
Error	7	0.7311	0.1044		
Total	11	26.0857			

Regression Equation

Cf = 17.8833 + 1.2433 Frame_1 - 1.2433 Frame_2 + 0.5183 String_1 - 0.5183 String_2
- 0.678 Velocity_1 + 0.019 Velocity_2 + 0.659 Velocity_3

General Linear Model: c versus Frame, String, Velocity

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Frame	1	14.3008	14.3008	1408.29	0.000
String	1	2.5025	2.5025	246.44	0.000
Velocity	2	2.4208	1.2104	119.20	0.000
Error	7	0.0711	0.0102		
Total	11	19.2953			

Regression Equation

c = 16.7367 + 1.0917 Frame_1 - 1.0917 Frame_2 + 0.4567 String_1 - 0.4567 String_2
- 0.5442 Velocity_1 - 0.0117 Velocity_2 + 0.5558 Velocity_3

General Linear Model: cb versus Frame, String, Velocity

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Frame	1	21.068	21.0675	88.78	0.000
String	1	3.203	3.2033	13.50	0.008

Velocity	**2**	**7.646**	**3.8230**	**16.11**	**0.002**
Error	**7**	**1.661**	**0.2373**		
Total	**11**	**33.578**			

Regression Equation

cb = 18.843 + 1.325 Frame_1 - 1.325 Frame_2 + 0.517 String_1 - 0.517 String_2
- 0.968 Velocity_1 - 0.018 Velocity_2 + 0.987 Velocity_3

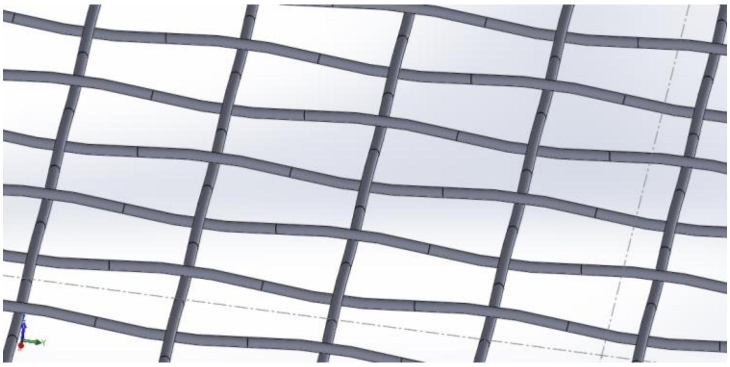


Fig 1-Cross pattern of the strings

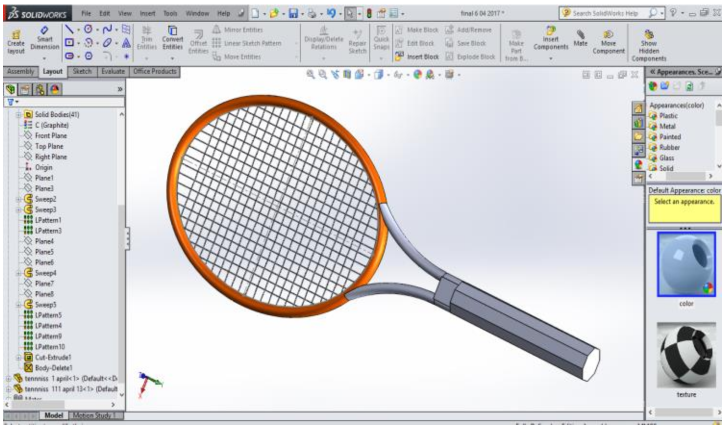


Fig 2-TENNIS RACQUET FRAME

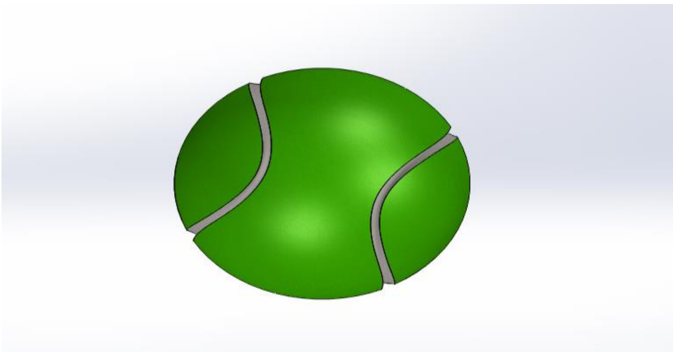
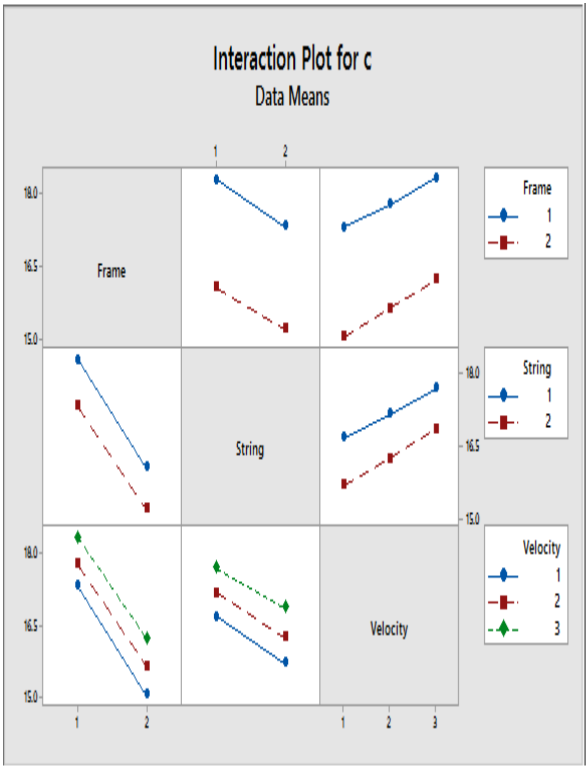
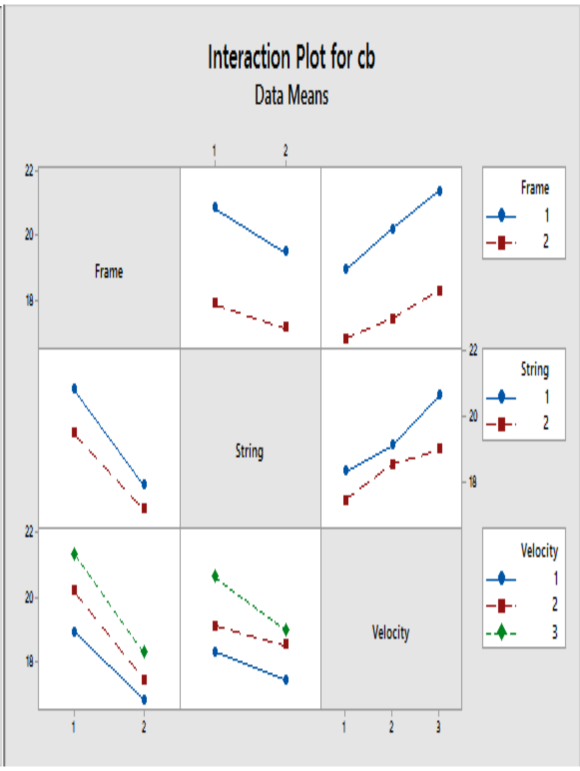


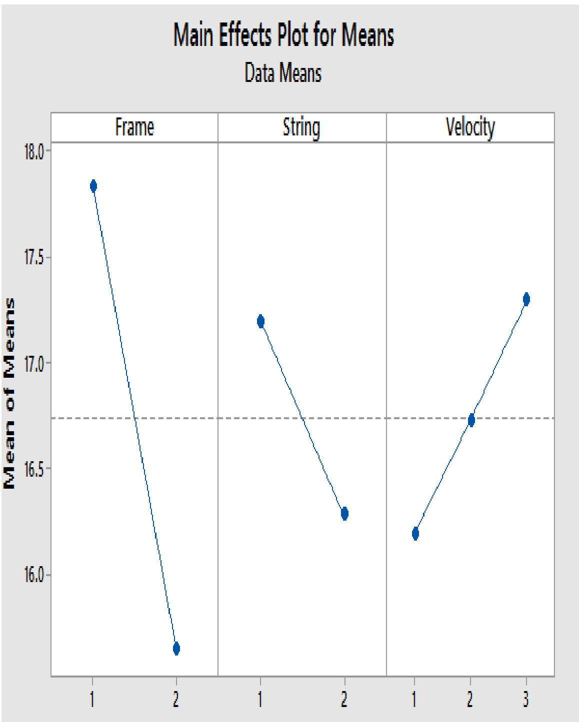
Fig- 3D model of tennis ball

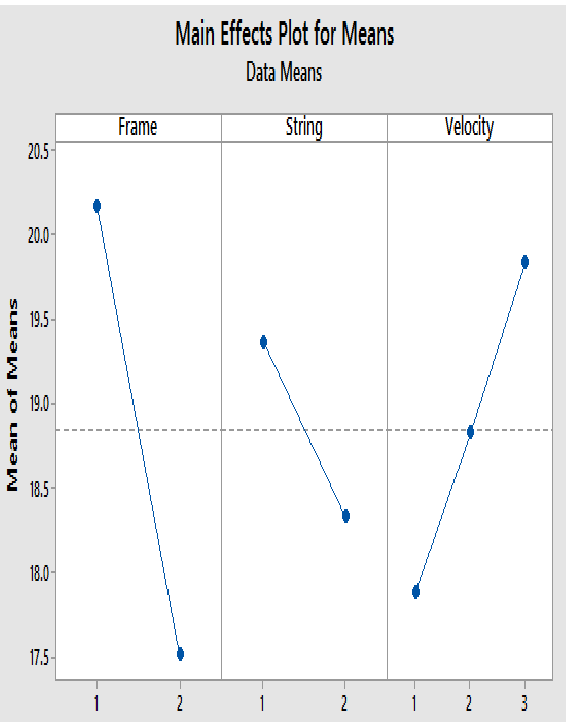


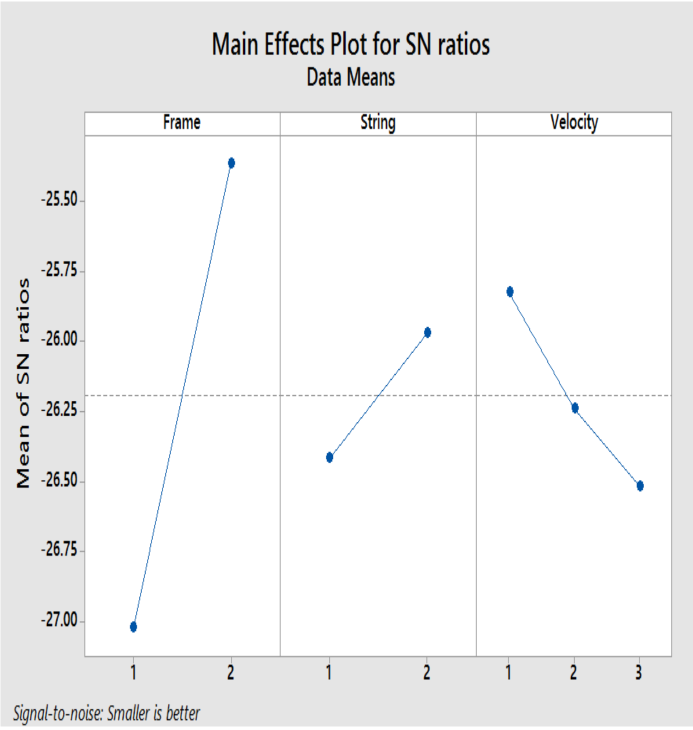


The interaction plot represents for centre spot position on the frame of the tennis racquet which reveals that the frame no 2 that is graphite undergoes less stress as comparison to the al frame when different velocities balls are imparted on the centre of the frame.

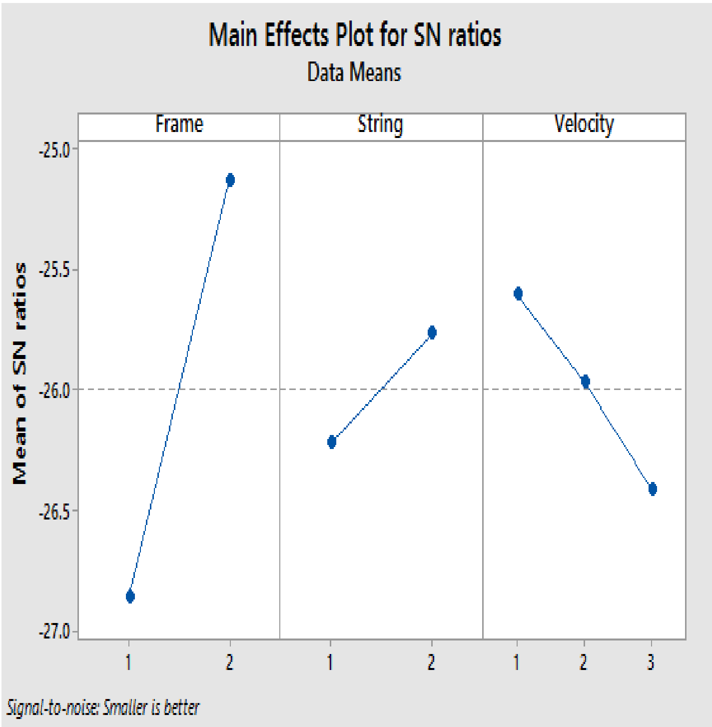
The same is the case of the strings the polyester strings undergoes less stress as comparison to the nylon strings.The interaction plot for the different velocities at centre spot of the frame reveals that 50m/s is the optimal velocity on which the value of stress is less.







SN RATIO PLOT FOR CENTRE POSITION OF TENNIS RACQUET



SN RATIO PLOT OF RIGHT POSITION

3. CONCLUSIONS

Stress analysis were done using explicit dynamics module of Ansys software for different types of tennis racquet that is graphite and titanium of different strings namely nylon and polyester at different velocities (50,75,100 m/s).After evaluating the different graphs it is vivid that the value of stress at centre is less at different velocities as comparison to the left and right spots of the tennis frame . The use of Annova table gave us accurate results. The graphite tennis racquet with polyester string undergoes less stress at different velocities which reveals that graphite tennis racquet is better option for all type of tennis players to enhance their performance which further also minimize the tennis injuries.

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