Serena Shanaia Selvam
Supervisor: ***Dr Michael Okereke***
UNIVERSITY of GREENWICH

COMPUTATIONAL FRAME VIBRATION ANALYSIS OF TENNIS RACKETS FOR PERFORMANCE METRICS

Introduction/Motivation

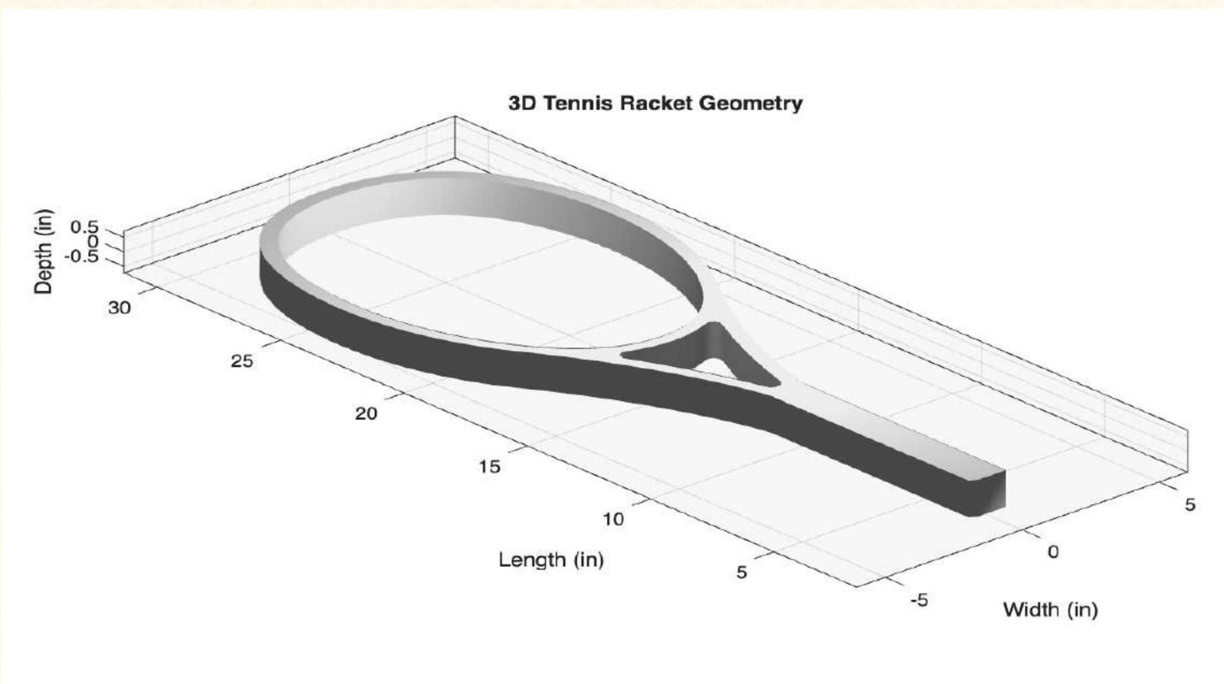
Tennis rackets have evolved from wood to carbon fibre reinforced polymer (CFRP), with geometry and material properties collectively governing structural performance under impact. Most finite element studies rely on fixed, simplified racket geometries, preventing systematic investigation of how individual design parameters influence structural response. No open parametric racket geometry framework exists in published literature.

Aims/Objectives

This project aims to develop a MATLAB parametric geometry framework integrated with ANSYS to investigate how geometric design parameters influence structural deformation, stress, and natural frequency. Objectives: generate STL racket geometries from adjustable inputs; vary six parameters; establish a repeatable STL-to-ANSYS pipeline; conduct a 13-configuration one-factor-at-a-time study; validate against published FEA and experimental literature.

Design

MATLAB Geometry → Material → Mesh → Boundary Conditions

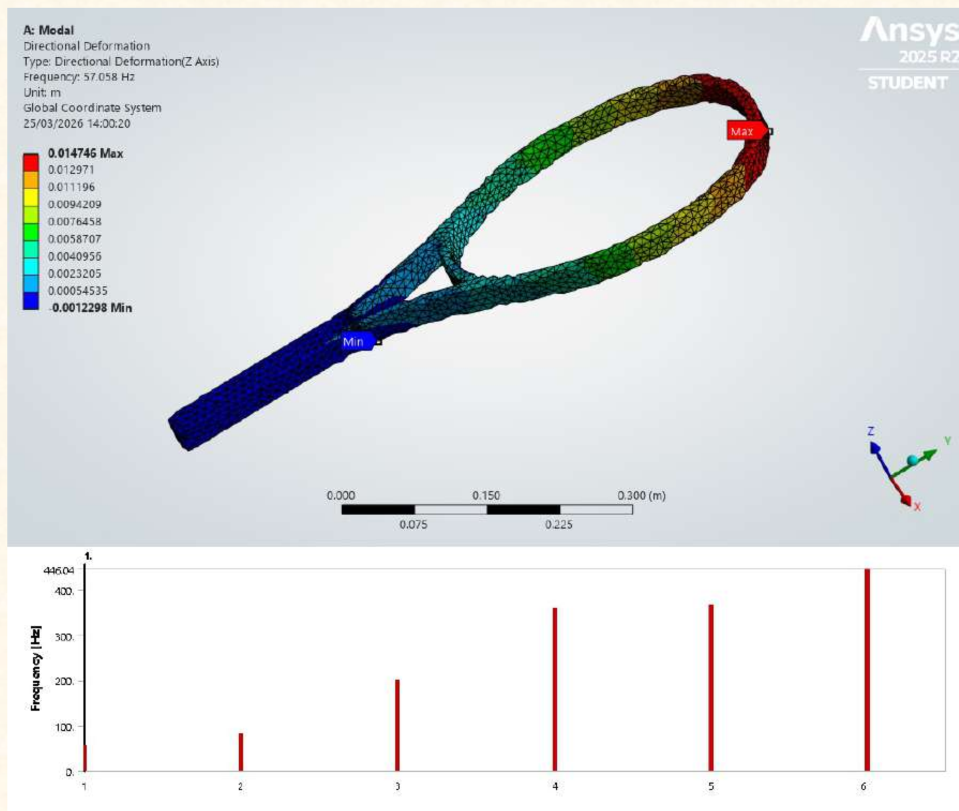


Parameter	Values Tested		
	Smaller Than BV	Baseline Value (BV)	Larger than BV
Head Size (in²)	85	100	115
Beam Height (mm)	20	26	32
Beam Width (mm)	18	23	28
Wall Thickness (mm)	1.5	2.5	3.5
Aspect Ratio	1.2	1.35	1.55
Total Length (in)	26	27	28

Outputs per configuration:

- Maximum total deformation
- Directional Z-deformation
- Regional von Mises stress (throat, hoop, shaft, handle)
- 6 natural frequencies (Modes I-VI)

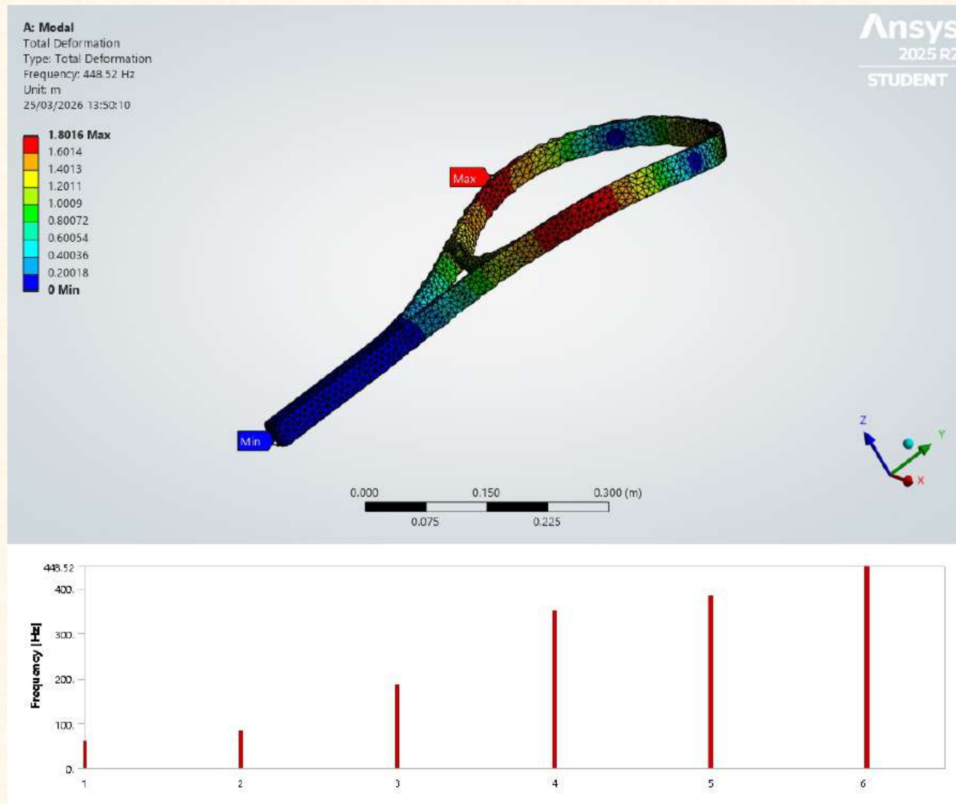
Implementation and Results



Modal Analysis and Validation

Mode III:

- Baseline value = 185.4 Hz
- Within published values of 100-200 Hz fundamental bending range (Banwell et al., 2014)



Mode V:

- Baseline value = 383.6 Hz
- Russell (2014) experimental torsional mode = 382 Hz
- < 0.5% discrepancy

Longer rackets lower torsional frequency, moving towards 80-200 Hz forearm loading band – linked to overuse injury *(Hennig, 2007)*

Static Structural Analysis

Throat Junction: Peak stress zone in all configurations (baseline value is 41180 Pa, matching Kotze et al. (2000))
Head Size: Small head (+1,084% Z-deformation) — torsional stiffness collapse; oversize head — marginal torsional stiffening
Frame Length: +137% Z-deformation for extended frame (L^3 scaling); shorter frame redistributes stress throat → shaft
Beam Height: 32 mm records highest throat stress — 44,703 Pa

Conclusions / Scope for Further Work

The MATLAB-to-ANSYS parametric framework was successfully developed and validated against published literature. Frame length was found to govern deformation magnitude and modal frequency, while head size governs torsional deformation character. Beam cross-section is the primary determinant of throat stress magnitude, and the throat junction was confirmed as a geometry-independent critical failure zone across all configurations. Future work should address explicit string-bed modelling via LINK180 elements, dynamic transient FEA to capture ball-impact inertial effects over a 4–6 ms window, experimental validation via DIC and accelerometry, and optimisation coupling to minimise throat stress for a target frame mass.

References

Kotze, J. et al. (2000). Journal of Sports Sciences. · Russell, D.A. (2014). Acoustics Today. · Banwell, G.H. et al. (2014). Procedia Engineering. · Hennig, E.M. (2007). Journal of Sports Science & Medicine. · Allen, T. et al. (2015). Sports Engineering. · Grant, R. et al. (2024). Sports Engineering.