DESIGN ASPECTS OF A TENNIS RACKET

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Abstract: Over the last years, the racket design had many improvements. The racket heads have grown larger, on frames that have become lighter. The racket frame and strings are of great importance for the player performance. The paper proposes a racket model having the frame made by light-weight graphite and the strings made by nylon fiber. The racket shape and dimensions can be established by the designer. The racket design was performed using CATIA V5R16. The racket model can be implemented in numerical analysis software in order to study the mechanical properties of the racket, especially the impact between tennis ball and string bed of the racket.

1. INTRODUCTION

Performance in many sports is influenced to a certain extent by the equipment used. Tennis is one of those sports, and is unusual in that there are several pieces of equipment that exert such an influence. The key pieces of equipment in question are the racket, ball, surface, and shoe [6].

Modern tennis racquets are not only better than ever, they are also more sophisticated and complex than ever. Today's tennis racquets are a showcase of high tech materials and engineering [8]. These arguments allow us to consider this field as the science of tennis racket.

The science of tennis racket is a complex field in continuously development. New models are introduced and old models are improved. Tennis rackets are designed by laboratory scientists who use mathematics to calculate the effects of weight, size, and material changes. New rackets models are designed using computer-aided design (CAD) and computer-aided manufacturing (CAM) techniques, which allows precise calculation of material rigidity and center of gravity. The trend today is toward lighter, bigger rackets, and these are viable because of advanced materials engineering [6]. Today's racket designs rely heavily on the engineering and scientific fields.

For those who are interested in tennis it is important to understand the modern design aspects of tennis rackets. This knowledge can be used by a tennis player to choose the best racket for him and to improve the tennis techniques. Understanding these design aspects is also important to anyone with an interest in modern technology [5].

Matthew Vokoun described in his work The Design Aspects of Tennis Rackets the two main design aspects of tennis rackets, which are classified in external and internal design aspects. The external design aspects consist in: strings, head size, and beam size. The internal design aspects are material type, weight, and balance [1], [5]. The strings characteristics such as elongation, tension, and pattern density are of great importance in stroke production. The head size provides the desired power: a larger head provides more power (longer head) or a better control (wider head). The beam size (racket's cross section) influences the racket's stiffness and power. Most modern racket frames are made from light-weight graphite or graphite composites allowing good frame flexibility, more power or more control, depending on the shots. Other important aspect refers to how racket’s weight and its distribution affect balance and control.

The paper proposes a racket model whose shape and dimensions are established by the designer. The racket model can be imported in Finite Element Analysis software in order to simulate and analyze the mechanical characteristics of the racket, especially the impact between tennis ball and string bed of the racket.

2. DESIGN OF THE TENNIS RACKET

The International Tennis Federation limited the racket size to 29 × 12.5 inches (73.7 × 31.8cm). Racket mass has decreased from about 400g to 250g today, despite being larger [6]. This decrease in mass has the important spin off that players are able to swing the racquet faster, which generates higher impact speeds, resulting in faster ball speeds. Swing speeds are also a function of the distribution of mass. If the mass centre is close to the handle of the racket, it is easier to swing, and conversely, if the mass centre is close to the tip of the racket, it is harder to swing [6].
A racquet design tries to find an ideal balance of playing characteristics. When a tennis racket is designed, some compromises must be accepted: power vs. control, comfort vs. feel, light weight/maneuverability vs. solid shot response and stability [8].
Design of the tennis racquet was focused on many items, such as: racket size (dimensions – length, width, and thickness), size and shape of the racquet head, size and shape of the racket handle, frame and string materials, weight, centre of mass and inertial characteristics, etc.
The racket design was performed using CATIA V5R16, which is a commercial software suite multiplatform, one of the most used integrated CAD/CAM/CAE systems. CATIA offers one of the world's leading parametric solid modeling packages.
Tennis Racket designed was thought to be composed of two main components: racket frame and strings. All parts go through the same stages of design.
Design stages used usual commands. As a first result, a sketch of the racket frame was obtained (figure 1). Using the Extrude command, the shape of racket frame can be observed (figure 2).

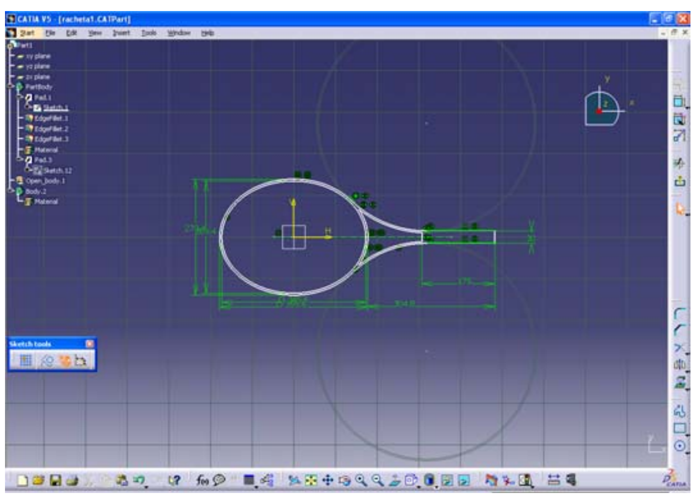

Figure 1. Sketch of the racket frame

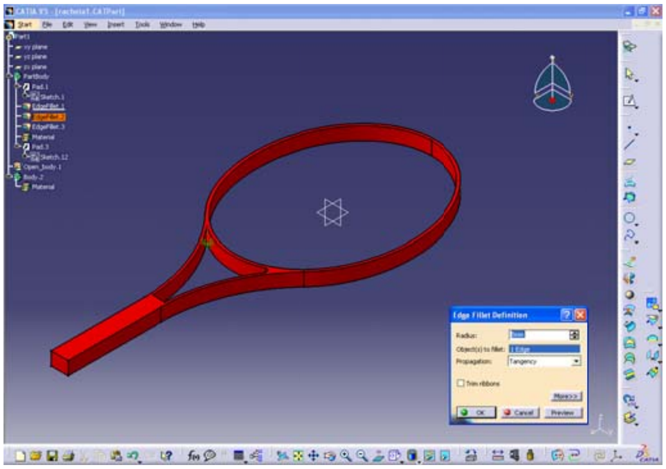

Figure 2. Shape of the racket frame

Next were realized holes into the racket frame for string placing (figure 3). There were used Hole command for the first hole and Pattern command to multiply the created hole. Pocket command was used to generate the handle.

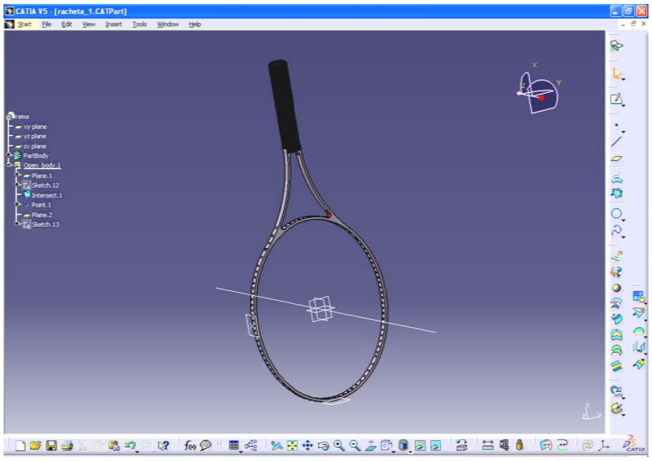

Figure 3. Making holes on racket frame

To have a high stiffness at minimum weight, the racket frame is made of carbon fiber. Carbon fibers "HM" are the most recommended materials for mechanical parts fabrication, that are highly loaded, with large longitudinal modulus of elasticity and low thermal expansion coefficient [7].
Due to their low weight and high mechanical strength, composite fibers are preferred, more and more, for making a wide range of parts for aerospace, automobile industry, and sport equipments. Using composite fibers is limited only by the high price of materials needed for their development.
The main characteristics of carbon-carbon composites as advanced tribological carbon materials are: very high heat ablation (20.000 Kcal/Kg); favorable relation strength/density, superior to conventional carbon materials; good strength at high temperatures (over 1000^{o}C ÷ 1500^{o}C); low expansion coefficient; low specific weight (~ 1,6 ÷ 1,9 Kg/dm^{3}) [3].
Racket frame has a rectangular section. The holes made in the racket frame have a diameter of 1.5mm and they are arranged on the racket frame periphery at 18 mm distance.

For string achievement, the racket frame was taken as reference, to comply as much as possible with its size. A draft plane was built perpendicular to the initial draft. Using Rib command, the string was winding. In figure 4 is presented the first string row. To obtain the braided strings there were realized two curves (figure 5).

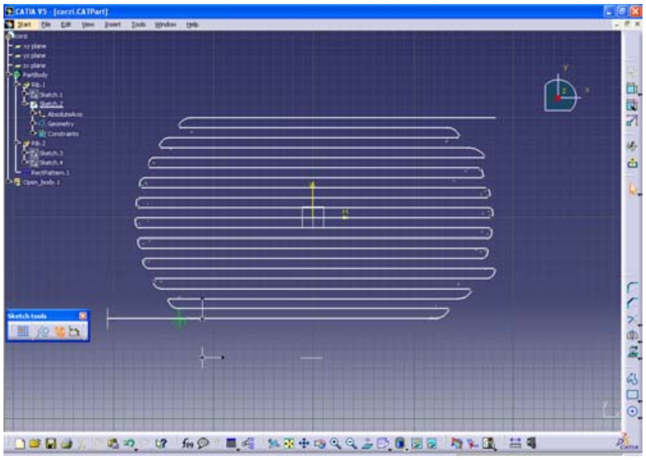

Figure 4. First string row

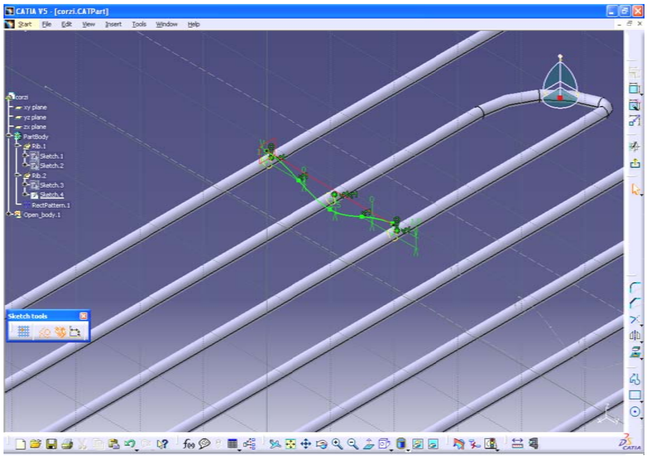

Figure 5. Sketch for braided string

String pattern density influences many aspects of a racquet's overall performance. The strings number describes the connection of the tennis racket. There are 2 variables when talking about a number of strings of tennis rackets: main strings or horizontal ones along the racket, in general their number varies from 16 to 18 and cross strings, their number ranges from 18 to 20. Depending on these parameters, when we discuss about the string pattern density, we refer to open and dense (or closed). In case of open racket, generally two main or two transversal ropes are missing. In case of dense racket, generally there are 18 main strings and 20 cross strings.
To obtain the desired length, the string was extended using Pattern command. Taking into account the string pattern density, the designed racket is of type of dense racket, having 18 main strings and 20 cross strings. The distance between two racket strings is 18mm. Using Rib and Line commands the racket strings have been twisted together (figure 6). Using the commands: Line, Spline and Circle, on the string bed it was drawn the letter W.

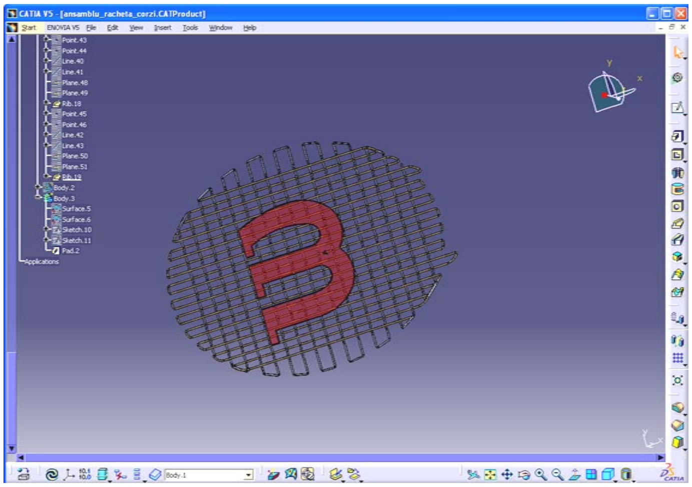

Figure 6. Final sketch of the racket strings

In terms of material, racket strings are made of natural, synthetic (monofilament and multifilament) or hybrid (main strings are made of synthetic material and the cross strings are made of natural material). The more string thickness (diameter) is greater, the more sustainability increases in expense control, elasticity and comfort default. Synthetic strings (Nylon, polyester or Kevlar) have a long life compared to natural strings, but lower flexibility, comfort and control than in natural strings. The string of the designed racket is made of nylon fiber with 1.35 mm diameter.
The tennis racket assembly was obtained using the Assembly Design command (figure 7).
The designed racket has a total mass of 360g and the following dimensions (figure 8):

- total length – 659,7 mm;
- total width of racket – 281,81mm;
- head length – 315,07 mm exterior and 310,07 mm interior;
- head width – 281,81 mm exterior and 271,81 mm interior;
- head thickness – 15 mm;
- handle length – 165 mm;
- handle thickness – 33 mm.

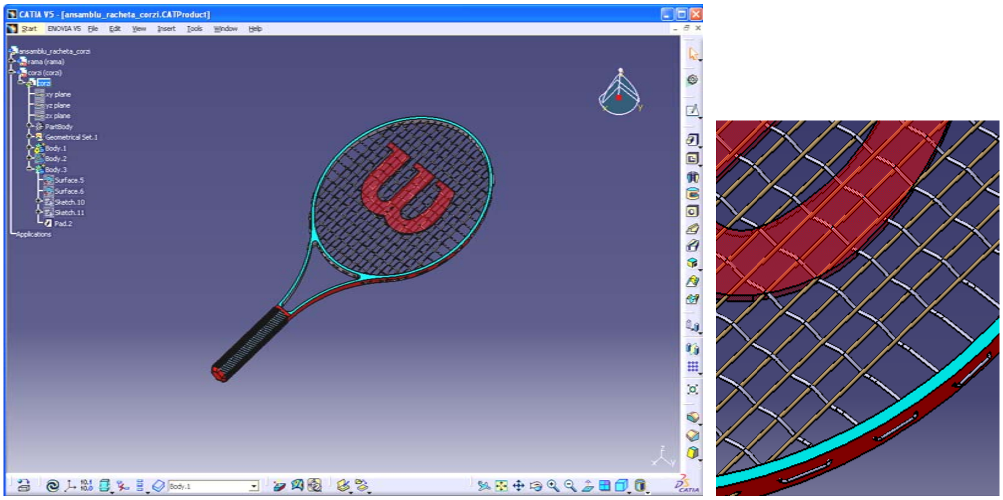

Figure 7. Racket assembly

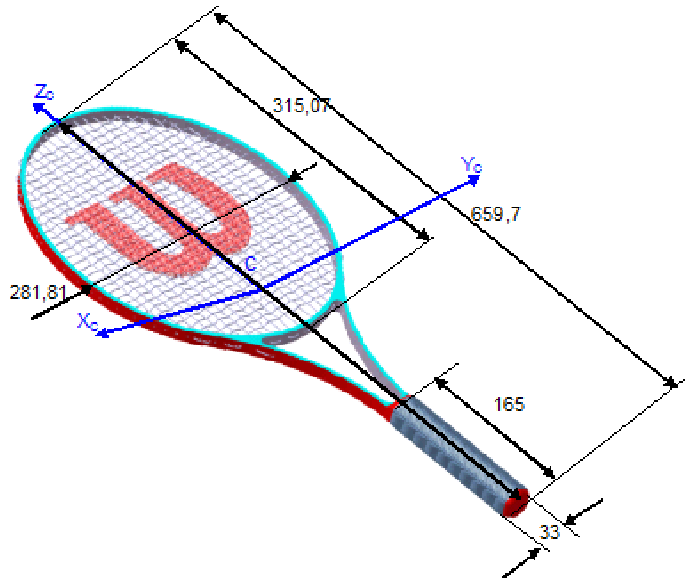

Figure 8. Racket dimensions

Using the software facilities, the mass centre was determined. The mass centre C and the reference frame attached to it, can be observed in figure 8.

3. CONCLUSIONS

Design of a tennis racket represents a part of an extensive study of tennis biomechanics. A tennis racket was designed taking into account the general characteristics of it. This model can be imported into FEA software, thus, an explicit FE model of a tennis racket string-bed will be obtained. This model will be used to simulate a range of impacts between ball and racket string-bed. Based on the results of the numerical analysis, the tennis racket model will be improved.

4. REFERENCES

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