Good essay on shaping the soccer ball

Science, Mathematics

1. 0 Introduction

Many sports played across the world that involves throwing, hitting and kicking are done so using a ball. However, many parameters such as humidity, materials of manufacture of the ball, size of the ball, etc. control the movement of the ball in air. Research on golf balls and tennis balls reveal their aerodynamic properties and the various parameters affecting their flight. The effect of seams on a baseball on the flight has been evaluated along with the relationship between rotation and lateral forces (Watts & Sawyer 1987). Similar studies have also been conducted on cricket balls, rugby balls, volleyballs etc. An important parameter that affects the physical and aerodynamic properties of a ball is the materials used in its fabrication. In this paper, the science behind choosing particular materials for manufacturing a soccer ball will be discussed with respect to how these materials affect different physical and aerodynamic parameters.

2. 0 Description

There are numerous ways in which a soccer ball can be assembled. However, there one such design which is unique and stands out from among the rest. In this design, 32 polygons are stitched together, 12 of them five-sided and 20 of them six-sided, joined in a way that every pentagon is surrounded by hexagons. Traditional balls had the pentagons painted black and hexagons painted white. Many questions arise relating to the shape and design of the ball and this paper primarily focuses on answering a few of these questions.

2. 1 Putting the Ball Together

Designing the soccer ball is a complex mathematical procedure. There is a certain symmetry that needs to be understood and maintained before assembling the different pieces together. Generally, soccer balls have a geodesic design. What is the significance of a geodesic design? How is this shape defined mathematically? What are the fundamental mathematical principles behind giving the ball its shape? Answering these questions gives basic geometrical insights into the engineering of the soccer ball, particularly in shape and design. 2. 2 The Individual Components

Mathematically understanding the design and shape of the soccer ball has been a challenge to many researchers for almost a century. However, using basic principles of graph theory, number theory and mathematical topology a clear picture on the intricate design of the ball has been drawn out. These components of the design is discussed in the following sections

2. 2. 1 The Geodesic Design

The geometry of a soccer ball can be easily understood by looking into some of the primary features of the ball. According to the Federation Internationale de Football Association (FIFA) a soccer ball must be spherical with a circumference between 68 and 70 cm, with a maximum deviation of 1. 5% from its sphericity. Mathematicians define the soccer ball as a spherical polyhedron. The vertices and edges of the polygons trace a map on a surface called a graph. From the Graph Theory’s perspective, a soccer ball is a polyhedron that is comprised of 1) twelve pentagons and twenty hexagons, 2) each pentagon shares its sides with only hexagons, and 3) alternate sides of each hexagon are a pentagon and hexagon.

2. 2. 2 Soccer Ball Topology

This definition categorizes the geometry of the ball into graph theory and topology. Topology is a branch of mathematics that deals with objects that remain the same even after they are subject to continuous deformations, just like an inflated soccer ball. From topological perspectives, the length of each edge, a round polyhedron, or even a shape with flat sides, is irrelevant. An interesting question that is often asked is to figure out the number of polygons a soccer ball contains based on the points 1 to 3 discussed earlier. A similar problem arose in chemistry when the C60 molecule or the Buckminsterfullerene was discovered. The spatial distribution of the carbon atoms in the Bucky ball is similar to the shape of a soccer ball consisting of 12 pentagons and 20 hexagons, with all 60 carbon atoms occupying the vertices of each polygon and the edges representing chemical bonds. This class of molecules called fullerenes satisfy assumption 1 and have what is known as a geodesic design.

2. 2. 3 Soccer Ball Mathematics

Understanding the geometry of fullerenes and soccer balls needs a deeper knowledge on the properties of polyhedra. One of the first ways of doing so is understanding the Euler formula, an essential tool in graph theory and topology. According to the equation, $v-e+f= 2$, where v is the number of vertices, e the number of edges, and f the number of faces. Applying the formula to a polyhedron comprising of x black pentagons and y white hexagons, we get the total number of faces present as $x+y$. Overall, the pentagon will have 5b edges and all the hexagons consist of 6y edges. Thus, the total number of edges is $e= 12(5x+6y)$. This equation can be taken further to solve the problem on the number of edges and to calculate the weighting side. However, solutions to the above equation show that there is no limit to the number of vertices in the polyhedron (Yakobson & Smalley

1997). It can be shown that there are infinite possibilities for fullerene shaped polyhedra and the number of such polyhedra corresponding to existing molecules is subject to research. Soccer balls have a well-defined relationship between the pentagons and hexagons that build up its basic structure. Here, the minimum values for x and y are satisfied due to assumptions 2 and 3.

3. Going Beyond Conventional Designs

There are different variations to modern day soccer balls that go beyond pentagons and hexagons. Thus, it is necessary to generalize the shape of a soccer ball that fits most of the shapes. To do so, assume the different faces of the ball are painted black and white where the black faces have k edges and white faces have l edges. Conventionally, k = 5 and l = 6 and the edges of black faces only meet the edges of white faces while the edges of white faces alternatively meet the edges of both black and white faces. We can further assign an nth edge of a white face meets a black face, and all the other edges meet white faces. This makes l to be a multiple of n, which means l= n ×m for some integer m. This design can be termed a " generalized soccer ball" which is defined by three integers (k, m, n) (Kotschick 2006).

4. Alternate Soccer Ball Layouts

How do we understand soccer balls that have more than three faces meeting at a vertex? Interestingly, there are infinite sequences through which soccer balls can be designed through a topological branching method known as branched covering. This complex patterning involves a method of distorting the ball by stretching in such a way that all the zigzag points lie on a straight line connecting the topmost and bottom most points of the ball and then slicing the ball in half. Similar steps are repeated along different directions until a two-fold branched covering design of the ball with the poles of the ball as the branch points is obtained. This new ball looks the same as the earlier one. However, the geometry is completely changed with six faces meeting at two vertices as compared to the earlier three. This shape has 116 vertices with three faces meeting at each of them. Similar to this model, multiple fold branch coverings can be designed to suit different conditions. It is possible to design all these models with all the pieces fit together in perfect seams. Multi-faced polygons have been a topic of research and discussion since the times of Plato and Aristotle. One such polygon is the Platonic solid. Platonic solids are polygons the largest degree of symmetry. All the faces are equilateral with the same number of sides and faces meeting at every vertex. Designing a soccer ball on any of the Platonic solids is difficult since many of the actual shapes of these solids do not particularly suit the soccer ball layout. However, generalizing the soccer ball is a more adept way of looking into giving the soccer ball its shape.

5. Conclusions

Soccer balls give intricate insights into relationships that exist between graphs on surfaces and branched coverings. The solutions to the different shapes and the potential shapes soccer balls can possess lie in a combination of algebraic geometry and number theory. Besides the geodesic design conventional soccer balls possess, different physical and aerodynamic properties depend on a number of other factors such as materials used in manufacture, air pressure, compressibility, etc. The trick lies in optimizing the shape of the ball with all these parameters to obtain a ball that is suitable for a World Cup game!

References

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