The Evolution of Material Selection of Soccer Equipment

I. The Evolution of the Soccer Ball Material

A. Background and Historical Context

Throughout history, materials have been linked to technological progress and they have had a significant impact on human development. From the “Stone Age”, when we were carving stones, to today, where we create entirely new materials such as, synthetic plastics, composites and polymers, by manipulating their chemical structure [1]. Over the years, our usage of materials has varied due to cost, mechanical properties, and various externalities (social, environmental, political). All of the industries such as automotive, aerospace and even the sports industry, have undergone significant changes in material selection. The changes in the selection of materials in the sports industry, nicely illustrates the deep relation between technological progress and materials. This paper focuses on the evolution of the materials used in soccer equipment: gloves, shin guards, jerseys and the ball. It will go through how the different equipment materials impact the players’ performance, with an emphasis on the most important piece of equipment of the game: the ball.

Football or soccer has been played since 1862, when the first standardized rules were published by the British [2]. Back then, the sport was created for pure leisure using whatever material was readily available. As a result, the first soccer balls were composed of an outer leather shell and a pig’s bladder that served as the air-containment unit [3]. Due to the fact that this method
was very rudimentary and inconsistent, in 1872, the English Football Association stated that the ball should be spherical with circumference of 27 to 28 inches, weight 13-15oz, which brought some codes of standard to the game [4]. From then, the ball became a rubber bladder covered with hand stitched leather with laces. In the 1900s the sport grew a lot in popularity, increasing the demand for better quality balls [4]. That popularity led to the famous world cups that happen every four years, starting in 1930. This gave rise to the monetization of the sport, which induced the soccer world to come up with a new ball for each World Cup.

Back in 1930, the balls were still manually inflated through laces, until the world cup of 1950, when an Argentinean company called Tossolini made a breakthrough: a ball with a hidden valve that could be pumped into shape [5]. That marked the beginning of a new era for soccer balls. These new techniques of manufacturing the soccer balls brought more consistency to the game, except in rainy regions where the leather would get waterlogged making it almost impossible to play with. For that reason, in the 1958 world cup, a Swedish company applied wax on the ball surface, which made a big difference in the water absorption [5]. The manufacturing techniques kept evolving for every world cup: from one big panel covering the rubber bladder, to 18, 25 and 32 panels in 1970, with Adidas taking over as the main ball manufacturer.

From 1862 to 1970, the changes in the materials of the soccer balls happened to improve basic playing capacity. Since 1970, the changes have been made for more sophisticated reasons. For example, in the 1970 world cup, Adidas created what became the standard soccer ball made of 20 white hexagonal and 12 black pentagonal pieces stitched together in a sphere [4]. The black pieces were added first to make the ball visible on black & white TV [5], then to allow players to learn how to curve a soccer ball and track its path [4]. Curving the ball became more of an art at that point, and more efforts were put into making sure the ball is easy to control with a trajectory
that is easy to track. To understand the flight path of the soccer ball, it is important to know the aerodynamics associated with it and how material selection and manufacturing techniques affect these aerodynamics.

B. Ball Aerodynamics and Surface Roughness

Various studies have been conducted on the aerodynamics of the ball, and it was found that the trajectory of the ball in air depends on the drag coefficient \((C_d)\), the Reynolds number \((Re)\), the side force coefficient \((C_s)\), the amount of spin put on the ball at impact, and, surprisingly, the surface roughness of the ball [6]. When kicked, a boundary layer is created around the ball, and when that layer transitions from laminar to turbulent flow, the drag coefficient decreases rapidly [7]. The lower \(C_d\) applies more side forces to the ball causing the ball to curve its trajectory more, regardless of other parameters such as wind speed and weather conditions [6]. The transition from laminar to turbulent flow occurs at a specific value for the Reynolds number \(Re_{\text{critical}}\) which is dependent on the surface roughness of the ball: the rougher the surface, the lower the \(Re_{\text{critical}}\) [8]. Since the surface roughness of the soccer ball comes from the seams of the panels covering the bladder, it opened up the door for Adidas to experiment with the materials chosen for the panels, the number of panels, and the manufacturing methods used for the balls.

C. Role of Performance and Externalities in Material Selection

From 1970 to 1994, Adidas slowly transitioned from leather to fully synthetic layers to add strength to the ball and made it waterproof and resistant to tearing by adding latex [9]. In their quest to improve performance, Adidas kept looking for new synthetic materials and invested a lot of time and money into scientific testing of the ball.
Up until 2002, panels on the ball were still hand sewn. In the 1990s, word got out that the sewing of the balls were done by children living in poverty in Pakistan or by prison inmates in China [2]. The working conditions for those workers were seen as inhumane which forced the ball manufacturers to actively change the situation. Adidas changed the working conditions for the seamsters, and for the 2006 world cup, they came up with a 14-panel ball, called the Teamgeist (Fig. 1), instead of 32. With this design, they came up with a breakthrough technology: the seams were heat sealed, where a thermoplastic composite is made airtight through heat, instead of sewn, making the ball completely waterproof [5]. From then, Adidas kept experimenting with the number of panels on the ball and the resulting surface roughness, coming up with the Jabulani in 2010.

D. The Jabulani and the Magnus Effect

The Jabulani was made out of eight panels that were thermally-bonded and twisted around the ball for extra aerodynamics [9]. The Jabulani generated a lot of controversies, which spurred some research on the ball. It turned out that, in their quest to make the balls smoother and rounder, Adidas had gone a little too far: the Jabulani was too smooth. John Bush, a professor of applied mathematics at MIT, mentioned that if the ball is too smooth, it “bends the wrong way”, which means it follows an unintended curve [10]. The curving effect is due to a phenomenon called “The Magnus Effect”; the player applies a spin to the ball during contact, creating a rotation causing the ball to curve [10]. For a ball with a rough surface, the “Magnus Effect” causes it to curve in the direction of the spin, whereas for a smooth ball like the Jabulani, the effect causes it to curve in the opposite direction, making its trajectory unpredictable [10]. That knowledge caused Adidas to move away from a smooth surface ball, thus creating the Brazuca for the 2014 world cup. The Brazuca, made out of six panels instead of eight, had seams that were 50 percent longer than the Jabulani [11], making it rougher, more predictable and more accepted (Fig. 2). The evolution of
the soccer ball is absolutely fascinating; for the changes themselves, and also for the reasons that these changes came about. Since 1862, the materials of the soccer ball has been changing with the evolution of the technology available to us to increase performance or due to the externalities that affects the industry.

II. The Evolution of Shin Guard Materials

Besides the ball, various other pieces of equipment in soccer are almost entirely made out of synthetic materials, to reduce the added weight to the players’ bodies, making it easier for the players to move fast while still fulfilling their functions. The shin guards for example, initially made out of leather and aluminum covered in cloth in 1874, are now made out of various synthetic materials to achieve properties such as weight, strength, comfort, durability and resistance to impact [12]. This shift in selected materials is due to both a quest for increased performance and to different externalities. First introduced in 1874, the shin guards increased in popularity among players due to the safety that they provided. Soon after, many players stopped wearing them due to discomfort and added weight [12]. Unfortunately, the International Football Association Board (IFAB) implemented a rule forcing every player to wear their shin guards [12], which spurred the quest for different materials that impaired the players’ movement the least, while still providing safety.

Modern shin guards consist of an outside casing made out of hard thermoplastics on the outside, and softer shock-absorbing foam-type materials on the inside (Fig. 3) [12]. These materials do not absorb a large amount of energy making the new shin guards less tough than the initial ones made out of aluminum. However, given the fact that the magnitude of the shocks encountered in soccer are reasonably small, and the fact that the polymers provide a significant
amount of weight reduction and comfort, it makes sense to move away from the metallic shin guards, in favor of synthetic materials.

### III. The Evolution of the Goal Keeper’s Gloves

In addition to the soccer ball and the shin guards, the gloves of the goal keepers are also made out of synthetic materials. First introduced in 1885, the goalkeeping gloves were initially made out of leather and cotton [13]. The gloves were meant to protect the goalies’ fingers and to help them get a better grip of the ball especially in wet conditions. However, similarly to the balls, the gloves were waterlogged, making it slippery and hard to get a hold of the ball. As a result, the design challenge here boiled down to the same challenge as the soccer balls and the shin guards: create a lightweight waterproof accessory, capable of protecting the fingers of the goalkeepers and provide good gripping ability. Inevitably, starting in the 1900’s, the soccer industry leaned towards synthetic materials.

Latex foam was introduced as the standard material for the gloves. It was durable, flexible and water resistant [13], giving the goal keepers a wide range of glove selection. They could go for a loose fit, or a tighter fit that provides them with more active contact with ball [13]. The latex foam provides damping for the ball coming at approximately 50-55 mph [11], absorbing the impact and effectively protecting the goalie’s fingers without being bulky and uncomfortable.

### IV. The Evolution of Soccer Jerseys

Finally, another piece of soccer equipment taken over by synthetic materials, is the jersey. In the same effort to increase the performance of the players, the big sports manufacturers, Adidas, Nike and Puma, have been striving for lightweight, breathable materials for the jerseys. Breathable in this case means that the material should allow perspiration to be carried out quickly. The jerseys
nowadays use a dual-layer textile to combine low friction with the skin with good moisture transport [14]. Typical dual-layer moisture-wicking fabrics have a hydrophobic layer, such as a polypropylene (PP) layer, in direct contact with the skin and a hydrophilic outer layer, which is frequently made of cotton or cotton blends [14]. The reason for that is the fact that the hydrophobic layer in contact with the skin, pushed the sweat to the outer hydrophilic layer, which in turns pull the sweat from the inner layer, facilitating evaporation to the surroundings [14]. This makes it more comfortable for the athletes to move around and, given the speed of the game of soccer, any weight reduction in any equipment amounts to enhanced player performance, especially with the development of synthetic materials in the modern era.

V. Conclusion

The history of soccer is shaped by the materials developed and used in the various pieces of equipment to increase player performance. With the game moving faster and faster, any extra weight would prevent optimal performance. Therefore, choosing the right materials for the ball, the shin guards, the gloves and even the jerseys proved to be crucial for maximizing performance. Perhaps the most fascinating equipment evolution, consist of the evolution of the soccer ball.

From first needing an actual ball, to then needing to increase performance with the available technologies, and finally due to externalities such as the working conditions of the sewers and the reactions of the frustrated players towards the Jabulani, the ball has undergone some major changes. We went from a rubber bladder enveloped by leather, to fully synthetic materials controlling the weight, the texture and even the aerodynamics of the ball in the recent years.

With the advancement of technology, the future of the sport is looking bright. For this upcoming world cup already, the goal-line technology is being introduced. This technology consist
of having the referees wear a device that notifies them when the ball crosses the goal line via sensors placed inside the ball. This technology and many more to come open the door to new opportunities to improve performance, and make the game even more exciting.

Figure 1: Picture of the Teamgeist, ball of the 2006 World Cup.
http://www.soccerballworld.com/Teamgeist.htm
Figure 2: Brazuca, the ball of the 2014 World Cup
https://www.soccercorner.com/Adidas-Brazuca-Top-Replique-Soccer-Ball-p/eb-adg73622.htm

Figure 3: Picture of outside and inside of the shin guards
https://www.hockeygear.com/bauer4.html
References