ABSTRACT

We review technical developments in the artificial turf industry with a special focus on yarn technology. Polyolefin resins have become the primary choice for manufacturing of artificial grass. Polyethylene (PE) and to a lesser extent polypropylene (PP) are used in yarn production while backing fabrics are predominantly made of PP. We discuss the performance requirements, material science and yarn extrusion technology for producing high end artificial grass yarn from PE. With focus on yarns, significant developments have enabled the production of soft, player friendly yarn that is however resilient and very durable, satisfying more and more the complex end-user performance requirements in a dynamic and competitive market.

Key Words: ARTIFICIAL GRASS YARN, DURABILITY, RESILIENCY, MATERIALS, POLYOLEFINS

1. INTRODUCTION

The global artificial turf yarn market consumes annually about 70,000 MT of PE, 25,000 MT of PP and 7,000 MT of polyamide (PA) [1]. As shown in Figure 1, PA has been one of the first polymers used in the production of artificial grass yarn. Although having excellent toughness and durability, PA’s abrasiveness on skin contact led to the development of more player friendly yarn based on PP. The PP based pitches with short piles were and are still very successful in Hockey, becoming the standard playing ground on all levels of the sport and improving the game significantly. Subsequently, PE based yarn improved upon skin abrasion and offered superior player friendliness in sliding and tackles, in combination with changes in the construction of the pitch: in the latest installations, longer piles with an elastic infill and a shock absorbent system are used to provide optimal player safety and comfort.

Figure 1. Evolution of artificial turf.
Medical studies have compared the injury risk on artificial versus natural turf and concluded that there is no significant difference in the injury severity or a greater risk on either of the surfaces [2].

Latest generation artificial turf constructions based on PE have by now made significant inroad into American Football, Soccer, Rugby and other mayor sports historically played on natural turf. Benefits of artificial turf systems include reduced maintenance and water (fertilizer) requirements, higher utilization (more playing hours), rendering the transition to artificial turf also economically interesting. The reduced water consumption makes artificial turf very attractive for landscaping, leisure and private use, especially in warm climates where water is short or available at premium charges.

The technology and PE materials used in the production of artificial grass yarn are the focus of this paper. We will start with the performance requirements of artificial grass yarn and its implications on material (polymer) science and discuss technology for producing high end artificial yarn.

2. END-USER AND APPLICATION PERFORMANCE REQUIREMENTS

The Dow Chemical Company is constantly working with artificial grass yarn and turf producers to optimize PE materials in meeting the challenging performance requirements of this application. An overview of the complex interplay between the various artificial turf market needs and detailed performance requirements on the yarn is given in Figure 2.

The major performance requirements of artificial grass yarn can be summarized as

- Softness (player friendliness)
- Resiliency (repeated elastic recovery of yarn after bending)
- Durability (wear, split and degradation resistance)

These requirements are first evaluated from a material science perspective and secondly from a yarn production technology perspective.

Figure 2. Market needs and performance requirements.
3. MATERIAL SCIENCE

Linear PE, ranging from Ziegler-Natta catalyzed HDPE, MDPE and LLDPE to metalloocene catalyzed mLLDPE, is preferred over branched LDPE, produced in high pressure reactors, due to superior mechanical properties. Linear PE can be classified as shown in Figure 3 [3].

![Polyethylene – The Artificial Grass Yarn Material](image)

**Figure 3.** Structural model and related mechanical properties for linear PE [3].

For artificial grass yarn, we consider the properties of monoaxially oriented (stretched) polyethylene. Properties like elastic modulus, temperature resistance and tensile strength of oriented yarn increase with increasing density, which is linearly related to the polymers crystallinity (PE is semicrystalline). Apparent softness (a subjective property), elastic recovery and shrinkage of yarn increase with decreasing density. Tear resistance (related to durability) of the linear PE shows an optimum between densities of 0.905 and 0.925 g/cc [4]. The elastic modulus is related to the bending stiffness of the yarn, which is important to maintain ball roll on the pitch within certain prescribed limits [5,6]. Tensile strength is relevant in the production process for artificial turf carpets and ensuring the mechanical strength and integrity of the yarn. Temperature resistance of the yarn during turf carpet production and in the ultimate field installation, where temperatures can rise above 50°C, is related to the melting and softening point of polyethylene of given crystallinity. Softness of yarn, experienced as player friendliness, is a function of density and crystallinity as shown in Figure 4. It is not related to the comonomer type of the LLDPE used [3,4,7]. Repeated elastic recovery after bending of the yarn, often called resiliency, can be related to density as well. Two resiliency tests are summarized in Figure 5, showing the clear dependence of elastic recovery on density. The first (Fig.5a) is a one time 90° bending test recording the recovery angle as % of full recovery. The second (Fig.5b) is a repeated bending test recording the force, applied by a cantilever, which is required for bending the yarn (Test developed by Ghent University). It is recorded as the % of the force after 300 cycles over the initial force. Excellent elastic recovery of yarn is key to ensure consistent visual appearance of the artificial grass and prevent unrecoverable layflat. Additionally, recovery to vertical standing of yarn is
necessary to maintain consistent ball roll and other performance related attributes of the field during its lifetime.

**Figure 4.** Secant modulus vs density for LLDPE (DOWLEX™ Polyethylene resins [8]), inversely related to softness and directly to bending stiffness.

**Figure 5.** Elastic recovery or resiliency as a function of density for LLDPE (DOWLEX™ Polyethylene resins [8]). (a) Dow test, recovery after one time bending; (b) Ghent University test method of force recovery after 300cycles.

**Figure 6.** Tear resistance as function of density (a) Comparing Octene- and butene-comonomer based LLDPE [4]. (b) Tear for oriented tapes of LLDPE (DOWLEX™ Polyethylene resins [8]), stretching ratio of 5x.

High tear resistance, relevant to prevent splitting of yarn along the axis of orientation and to maintain yarn dimensional integrity, increases the mechanical durability of the yarn. Figure 6(a) shows the superior tear resistance as function of density for LLDPE with octene as copolymer compared to butene. Figure 6(b) demonstrates the dependence of tear on density for oriented tapes made of DOWLEX™ LLDPE [8].
Shrinkage causing curling or inhomogeneous performance of yarn is undesired in the process of grass carpet production and backing as well as in the installed field. Stretched tapes have a high degree of polymer orientation. The distributed crystal phase is connected by stretched polymer chains, the tie chains. Thermally activated, these out-of-equilibrium polymer chains start to retract towards an equilibrium, random state. If lower polymer densities are chosen for high performance in other properties, highly optimized processing is needed to minimize or control shrinkage.

The aforementioned influence of density on yarn properties demonstrates the need to find the right balance of optimized properties as maximizing all properties simultaneously is not feasible. Based on a careful selection of key properties based on the most important performance requirements, optimization will result in the best possible artificial grass yarn. In addition to the right material choice, the processing equipment plays an important part as well, as seen in the next section.

4. ARTIFICIAL GRASS YARN TECHNOLOGY AND PRODUCTION

The two main artificial grass yarn production technologies are fibrillated tape (or slit monotape) and monofilament yarn extrusion. Fibrillated tape technology is based on cast film extrusion, cutting the film into ~10cm wide tapes, stretching them and cutting long slits (fibrillating) into the tape giving it the dimensions of grass blades. Monofilaments are directly extruded into individual yarns with desired cross section followed by orientation and relaxation steps in hot ovens. The existing and new monofilament lines differ depending on the machine manufacturer and customer specifications. Nowadays, monofilament is the dominating technology because of better visual appearance and durability. The choice of a LLDPE resin for artificial grass has to reflect the specific line hardware and the selected, most important yarn performance requirements. In Figure 7(a) optimization of yarn properties for a durable and resilient Octene-comonomer based LLDPE resin is shown. To reduce shrinkage to minimal values, a 3-oven line-setup is providing the best results. The optimization is specific to the particular high-quality resin used and will not generally apply to any resin. In Figure 7(b) theoretical calculations of heat transfer are shown to support the selection of most suitable process conditions for shrinkage minimization. It is clearly important to understand that both the material science of LLDPE, the material of choice for artificial grass yarn, and the processing technology enable the tailored production of high quality artificial grass yarn.

![Figure 7](image-url)
5. YARN PERFORMANCE – LISPORT TEST

The industrially most relevant test for durability and resiliency of artificial grass yarn is the Lisport test [6]. Two rotating studded rollers are moved back and forth over an artificial grass carpet filled with infill (as installed). After several thousands of cycles the remaining quality of the turf yarn is evaluated: has the yarn split, is the yarn laying flat, has it shown significant wear? The better durability of octene-cocomonomer based LLDPE over one based on butene-cocomonomer at the same density is shown in Figure 8(a) to demonstrate the significant differences between LLDPE resins. Figure 8(b) shows the influence of processing conditions on final performance in the Lisport test. The Dow Chemical Company has worked extensively on finding the optimal synergies of material science and processing to support the artificial grass industry.

![Lisport Test](image)

**Figure 8.** (a) Lisport test carried out for different yarns, made with LLDPE based on octene or butene copolymer at the same density. Splitting starts earlier for the butene-copolymer LLDPE. (b) Lisport test results for two different resins produced with four different processing conditions.

6. REFERENCES

6. FIFA, FIFA quality concept – artificial turf football surfaces; February 2005 ([www.fifa.com](http://www.fifa.com)).
8. ®Trademark of The Dow Chemical Company (“Dow”) or an affiliated company of Dow