

# MONOFILAMENTS FOR ARTIFICIAL TURF APPLICATIONS

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## ABSTRACT

Lack of resilience and fibrillation are the major problems encountered in the applications of monofilaments. The aim of this study was therefore to develop a bending test to assess the resilience of a monofilament and to correlate this with the results obtained with a newly developed apparatus: a 12m Lisport.

The measurements of the ball roll distance with the 12m-Lisport are representative of the resilience and fibrillation resistance of the yarns in artificial turf applications. The density of the polymer, the drawing conditions and the geometry of the monofilaments are important parameters for the resulting resilience and fibrillation behaviour.

**Key Words:** monofilament, resilience, orientation, polyethylene

## 1. INTRODUCTION

The use of artificial turf for sport surfaces has known an enormous increase in the last years. The reasons for this are various: climate and weather independent, better wear and tear behaviour compared to natural turf, less maintenance, more even and uniform playing surface. Recently, it is been used more and more for soccer applications, especially with the development of the so-called “third generation” artificial turf. This “third generation” artificial turf – also called “football turf” – gets full support by official soccer organisations like FIFA and UEFA [1], in their striving to standardise the soccer game. Despite this support, there is still quite some resistance among players and clubs. In general, players tend to perceive that the ball speed is higher and sometimes is considered too high. Joosten [2] found that 77% of the players experienced the ball speed and ball roll capacity as high. Most players want a field with a normal ball speed when it comes to official games.

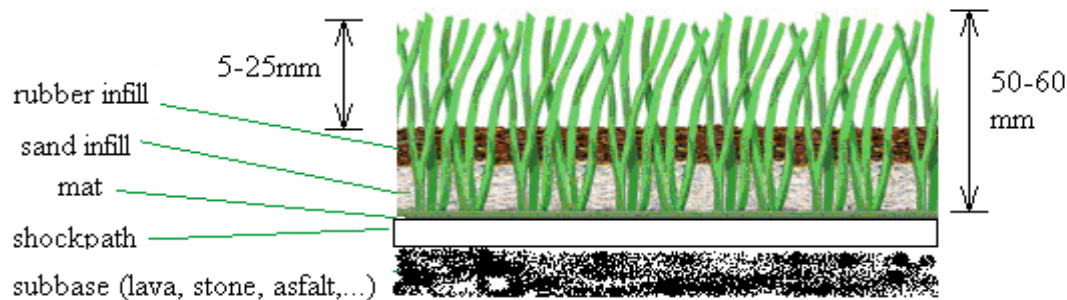
It is known from experience that these ball roll problems on artificial turf start already a few months after installation. Whereas the ball roll behaviour on a newly installed artificial pitch is comparable to the one on natural turf, this is no longer the case for an artificial field that has been played on for some months. This is often indicated as a lack of “resilience” of the field.

## 2. KEY REQUIREMENTS OF SPORT SURFACES

The key requirements of artificial sports surfaces are related to the characteristics of natural turf structures and are described in the FIFA 2 star and IRB regulations [3]. These standards reproduce the characteristics of the best quality natural turf football or rugby pitches.

The most important or key requirements for the used textiles or fibres are the mechanical properties as function of time and outdoor weathering, temperature, the friction coefficient of the fibres, the resilience and fibrillation resistance of the yarns. The complete artificial turf structure and the fibres must withstand temperatures from -30°C up to 70°C. From the

different key requirements, the ball roll distance will be discussed in more detail as this is related to the resilience and fibrillation resistance of the fibres and the requirement for a “two star sport surface” is a ball roll distance under standardised conditions between 4 and 8m.



**Figure 1:** General structure of the third generation artificial turf

The third generation artificial turf comprises artificial fibres tufted on a backing with an infill of sand and rubber granules. The total height of the artificial turf is between 50 and 60 mm with a free pole height of the fibres from 5 to 25 mm. The thickness of the respective layers is between 15 and 25 mm.

### 3. CHOICE OF POLYMERS FOR MONOFILAMENTS

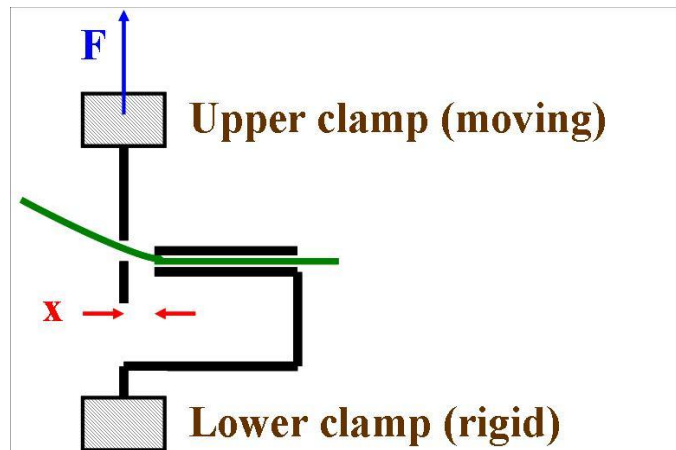
The polymers used for the production of fibres or yarns in the form of monofilaments or fibrillated tapes are chosen from the family of polyolefines or polyamides. The monofilaments can be characterized by different geometries such as cylindrical, rectangular, bilobal or trilobal [4,5]. Some of the polyolefines are characterized by a low coefficient of friction. This is an important parameter or characteristic of the fibres for artificial grass applications. This coefficient of friction is related to the nature of the polymer, polar or non-polar nature of the polymers, and to the mechanical properties such as the elasticity modulus [6]. The coefficient of friction is in this way also influenced by the temperature due to the variation of the elasticity modulus with temperature.

Ball roll behaviour is currently tested by FIFA and UEFA by means of a standard ball roll test. A ball is released from a ramp from 1 m high, and the rolling distance of the ball is measured. In order to get the FIFA two star certificates, which correspond to an international level, the ball roll should be between 4 and 8 m [3]. Artificial turf yarn producing companies need feedback on the ball roll behaviour of different types of artificial turf.

### 4. MATERIALS AND METHODS FOR RESILIENCE MEASUREMENTS

The first method is a cyclic bending test on a single filament. The apparatus used for this test is a Favimat R (from Textechno) which has been modified for this purpose, making it possible to flex a one-side-clamped filament.

The test can also be done on 8 monofilaments. One end of the filament(s) is clamped, while the other free end is subjected to a perpendicular force on a distance of 2.87 mm from the fixed point. The total free length of the filament is 17.5 mm.

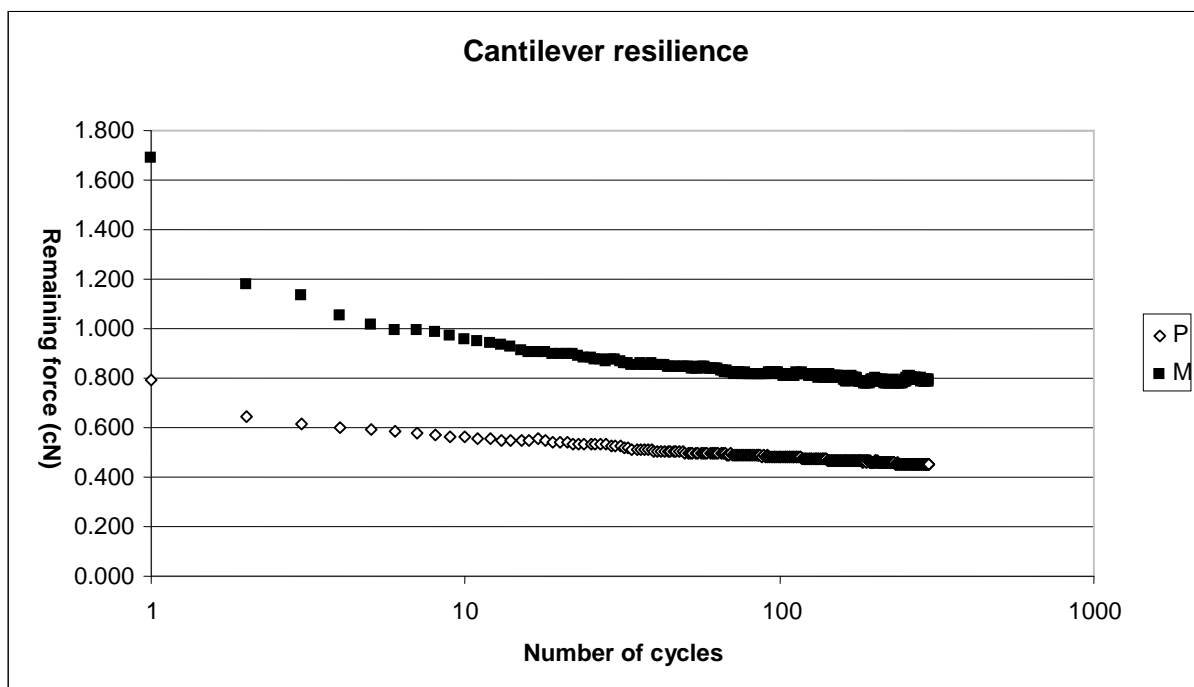


**Figure 2:** Cyclic bending test setup

The filament(s) is bended 300 times. The resilience is expressed as being the ratio between the maximal force of the 300<sup>th</sup> bending and the maximal force of the first bending.

The second resilience method is the 12m-lisport. This apparatus runs on a sample of 12m by 1m. This makes it possible to determine the degradation in ball roll as a function of the number of cycles. The rolls are 1m long and weigh 100kg each. The speed can be varied, but for these tests the speed is kept constant at  $0.25\text{m}\cdot\text{s}^{-1}$ . One roll is rolling 40% faster than the other roll.

As mentioned above, the results of Cantilever fatigue tests on two different polyethylene fibres are represented on the two following figures.



**Figure 3:** Remaining force as a function of the number of cycles for two different polyethylene monofilaments used for artificial turf applications.

The filaments have the same rectangular geometry with a mean thickness of 0.21 mm for filament P and 0.31 mm for filament M. The two polyethylenes have a linear macromolecular structure and the monofilaments have the following mechanical characteristics:

- Elasticity modulus = 385 MPa; maximum elongation at rupture = 241% for M and 124% for P and maximum stress at rupture = 95.6 MPa for P and 89.5 MPa for M.

The maximal force of filament M decreases from 1.70cN to 0.80cN and the force of filament P decrease from 0.80cN to 0.45cN after 300 cyclic deformations. These maximal forces are directly related to the thickness of the monofilaments, corresponding to the following equation:

$$\text{Maximal force} = E_f * b * d^{2.43}$$

$E_f$  is the flexural elasticity modulus,  $b$  the width of the monofilament and  $d$  the thickness of the monofilament. In this experiment,  $E_f$  and  $b$  of the two monofilaments were the same.

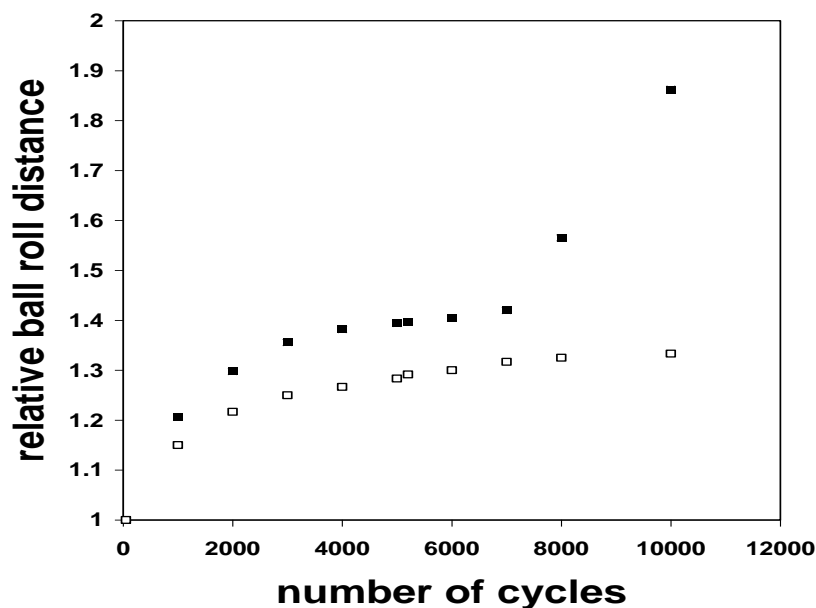
As a result, the monofilament with the highest thickness seemed to be more sensitive to the bending deformation and this is probably a result of the internal fibrillation of the tested monofilaments at the outer surface.

## 5. EXPERIMENTS WITH THE 12m-LISPORT

The yarns M and P were woven into a mat and used in the artificial turf structure. For a fibre height of 60 mm, 17.5 mm was filled with sand and 31.3 mm with SBR granules. The resulting free height was 11.2 mm. The 12m-lisport is done on those two samples and after every 1000 cycles the ball roll is determined.

The ball roll distance of the artificial turf structure with yarn M increases from 6.5m to 9.1m after 7000 cycles and further to 12.2m after 10000 cycles. The ball roll distance of the artificial turf structure with yarn P increases from 6m to 7.78m after 10000 cycles.

A better image can be obtained by plotting the relative ball roll distance as function of the number of applied cycles. The relative ball roll distance is hereby defined as measured ball roll distance/initial ball roll distance.



**Figure 4:** Relative ball roll distance as a function of the number of cycles (open squares = yarn P, filled squares = yarn M)

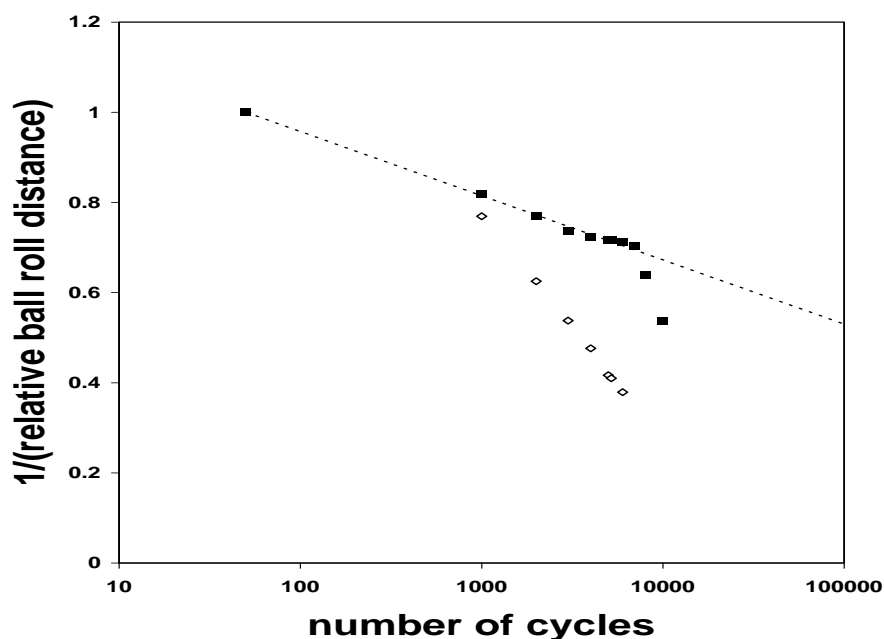
To compare these results with the resilience measured during the cantilever-bending test, the inverse value of the relative ball roll distance has calculated.

The measured value of the inverse value of the relative ball roll distance can be divided into two parts: an asymptotic value reached after a sufficient number of cycles and a difference between the inverse of the measured values of the relative ball roll distance and the asymptotic value. For the experiments with the P-yarns, the asymptotic value equals 0.772 and the difference is 0.228. This means that 22.8% of the resilience is loosed during the experiment with the 12m-Lisport and explains the increase of the ball roll distance from 6m to 7.78m. For the M-yarns, the asymptotic value is 0.66 and the difference is 0.34. This means that the M-yarns are loosing 34% of their initial resilience in this experiment. Afterwards, after 7000 cycles, the yarns started to fibrillate visually and the resilience is further decreased due to this fibrillation.

As conclusion, the relative resilience behaviour of yarn P is better then yarn M supported by the relative ball roll distance and is the result of the difference in geometry in this experiment.

An important increase of the ball roll distance is observed for an artificial turf structure using filaments produced from the same polyethylene as yarns M but the filaments are characterised by a higher value of the elasticity modulus. The flexural modulus of elasticity increased from 385 MPa to 1003 MPa and the elongation at rupture decreased from 241% to 70%.

The artificial turf structure, indicated as M1003, had a different behaviour compared to the previous one, indicated as M385. Up to 1000 cycles, the structure followed the classical decrease of resilience and related increase of the ball roll distance. After 1000 cycles, the ball roll distance increased severely. This gave an indication of the complex behaviour of the artificial turf structure.



**Figure 5:** Differences in ball roll distance between a woven and tufted artificial turf structure with the same yarns L (open squares = M1003 structure; filled squares = M385 structure)

The asymptotic values were also calculated for the experiments of the ball roll distance with the 12m-Lisport on these artificial turf fields. These values are lower than the values obtained with the woven structures, 0.3 for monofilaments M and 0.7 for monofilaments P. These values can also be correlated with the measured tear resistance of the monofilaments. The tear resistance of monofilament M1003 was 1.33N/mm and 6.97 N/mm for monofilament P.

## 6. CONCLUSIONS

Lack of resilience and fibrillation are the major problems encountered in the applications of thermoplastic fibres and artificial turf systems, resulting in bad sport-technical field properties, especially a too large ball roll distance.

The aim of this study was therefore to develop a new testing method to assess the resilience of a single filament when subjected to repeated bending. The test allows a quick assessment of the fibre itself (and thus the type of polymer) when used in the production of a pile surface meant for sport applications. The new method is a cyclic bending test on a single filament. The information obtained from this test is checked with a newly developed apparatus: a 12m Lisport. It makes it possible to evaluate the ball roll distance before and after use.

A correlation between the flexural behaviour and the resilience of the fibres has been developed and used for artificial turf applications. This correlation can be extended to other long time applications of thermoplastic fibres, especially under flexural deformations in the absence of visual fibrillation. The influence of the thermoplastic polymer used for the production of the fibres on the resilience of the fibres has been studied. More specifically, the influences of different polyethylenes have been studied and a direct correlation between the elasticity modulus and the resulted resilience has been measured for the long-term behaviour.

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