Materials Science of Resiliency in Artificial Turf Yarns

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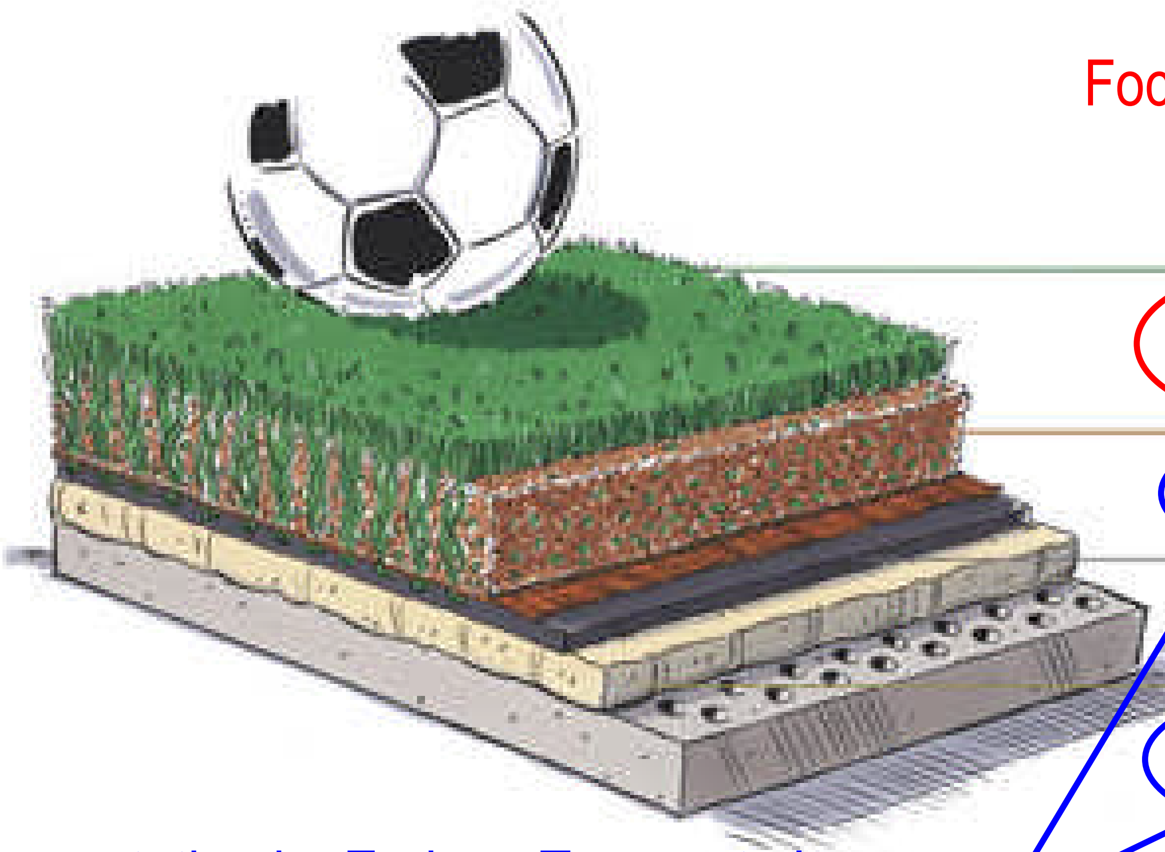
THE DOW CHEMICAL COMPANY

AMI: The Grass Yarn & Tufters Forum 2008, Zurich, Switzerland

Dow's Systems Approach for Artificial Grass



Focus of this presentation

Yarn
DOWLEX™
ELITE™
AFFINITY™

Infill
ENGAGE™ / VERSIFY™
NORDEL™

Backing
ENFORCER™ (PU)
DL552 SB Latex Binder

Shock Absorption
ENHANCER™(PU Foam)
VORAMER™(PU Binders)

Presentation by Enrique Torres et al.:

SHOCK ABSORPTION SYSTEMS FOR ARTIFICIAL TURF SURFACES

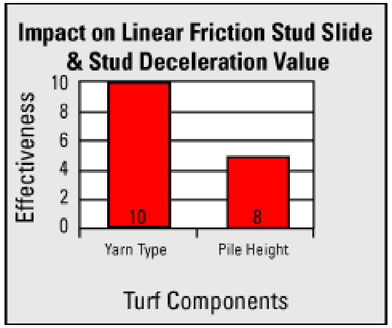
Dow's Background in Artificial Grass

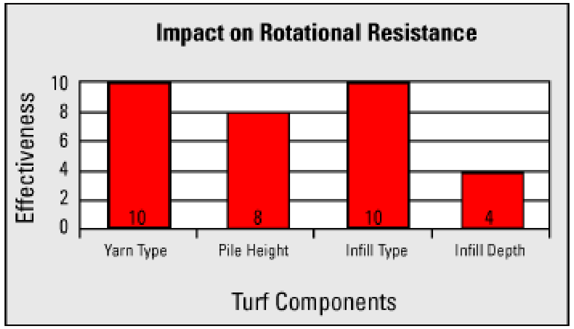
- Dow is the leading supplier of chemical and plastic components for artificial turf systems on a global basis.
- DOWLEX™ SC 2108G has a long successful history in artificial turf yarn, both in fibrillated tape and monofilament.
- Dow is developing the science and technology in artificial turf systems to accelerate the growth in the market.
- Creating differentiated value for the customer and Dow by combining the commercial and technical expertise of several Dow businesses to generate the 'best' next generation artificial turf systems.
- Educating and influencing the stakeholders and value chain participants on key raw materials to their manufacturing processes.

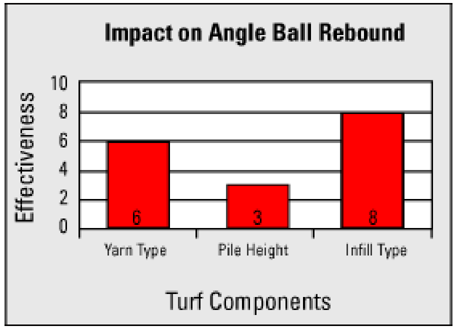
System Performance – The Influence of Yarn

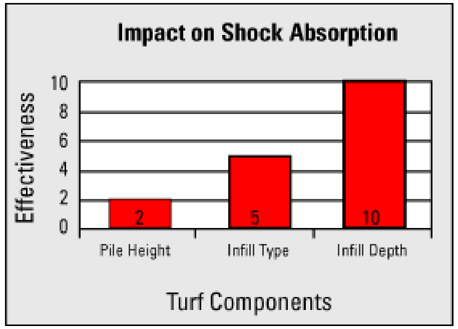
http://www.dow.com/artificialturfsolutions/systemdesign/index.htm

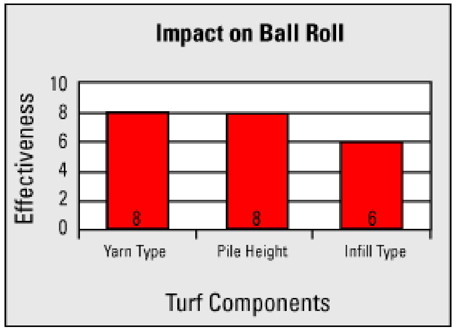
Yarn performance influences **vs.** Infill, Shock pads, etc. influences

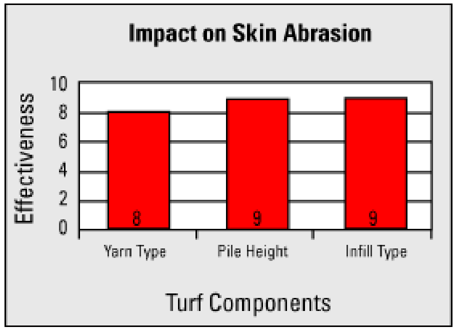


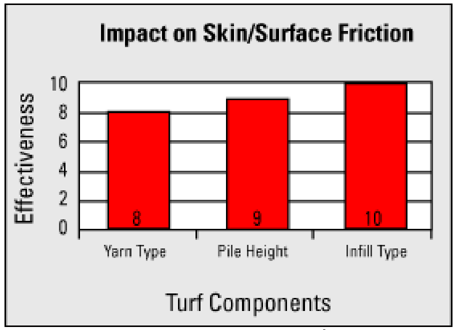


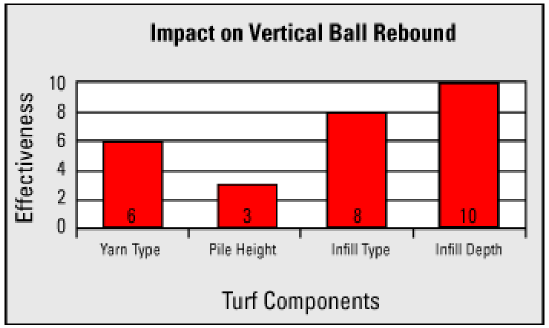












*Data source: Dow research, Voice of Customer

Yarn influences:

- Linear friction
- Rotational resistance
- Ball roll
- Skin abrasion
- Skin surface friction
- Angle ball roll

⇒ Yarn greatly determines the quality of artificial turf.

Performance / Quality Criteria for Yarn

Requirements affected by material choice for artificial grass yarn

FIFA Quality Concept

- Ball rebound.
- Angle ball rebound.
- ✓ Ball roll.
- Shock absorption. (force reduction).
- Standard vertical deformation. (deformation/force).
- ✓ Rotational resistance.
- ✓ Linear stud slide friction and stud deceleration.
- ✓ Skin/surface friction (CoF).
- ✓ Skin abrasion.
- ✓ Lisport test.
- ✓ Artificial weathering (UV).

Additional performance criteria

- ✓ Softness
- ✓ Durability - wear resistance, UV stability.
- ✓ Resistance against lay-flat and deformation

Material Science – Yarn Performance

Material performance requirements derived from above information.

- Resistance to multidimensional stresses
- Resistance to stress/strain cycles
- Balance of stiffness and elasticity for recovery (resiliency)
- Resistance to tear and embrittlement
- Resistance to scratch, abrasion and wear (surface stresses)
- UV stability
- Low COF with skin
- High tuft-lock
- Softness

⇒ ***Making the connection between requirements and material properties***

Polyethylene – The Artificial Grass Yarn Material

Structural Model for Constrained Geometry Catalysts Polymers

Tear resistance

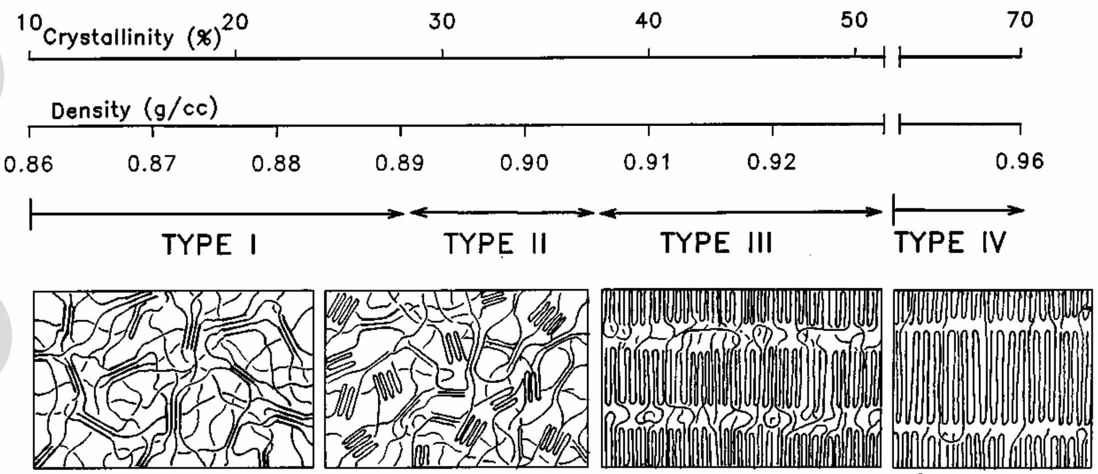
Softness

Elastic recovery

Elongation

Shrinkage

Orientation



We have unique answers and concepts for all these requirements

ELASTOMER | PLASTOMER | LLDPE–LIKE | HDPE

Elastic modulus

Temp resistance

Tensile strength

Yielding, creeping

Low COF

Lower Density, >0.86 g/cc

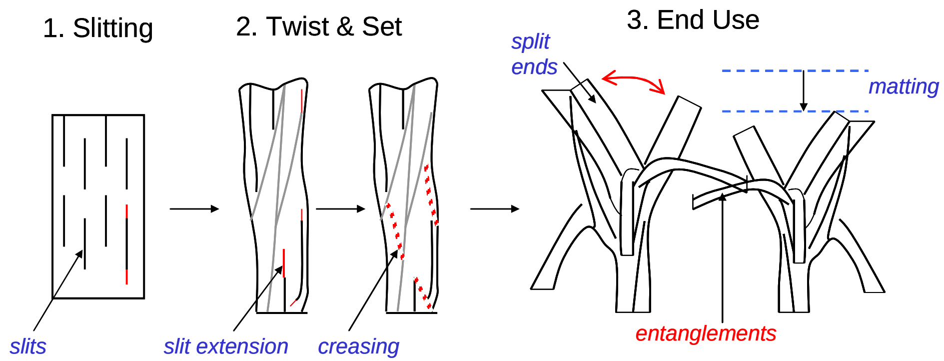
Higher Density, <0.96 g/cc

Durability: Tear Resistance Increases Lifetime of Yarn

Yarn splitting tendency related to tear resistance of the material.
- for fibrillated tape, monotape and monofilament.

Analysis of tape tear behavior

Preliminary Model for Wear Behavior of Artificial Turf



- •Cracks can extend from existing slits.
- •Twisting can extend slits
- •Creasing can initiate new cracks
- •Cracks that propagate to the end of the yarns form split ends.
- •Split yarns can splay apart and entangle to form a matted structure.

Tie chain model for tear resistance

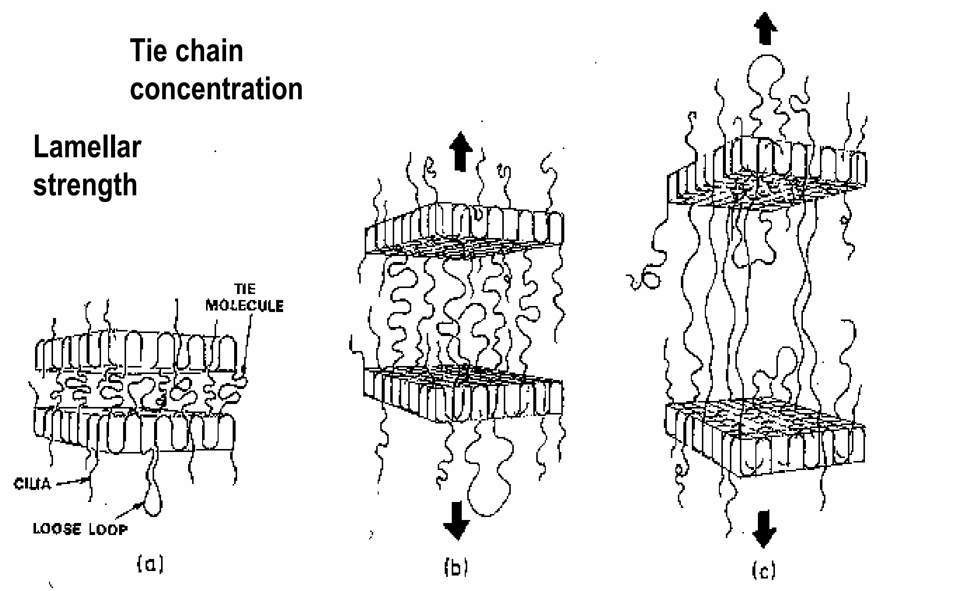
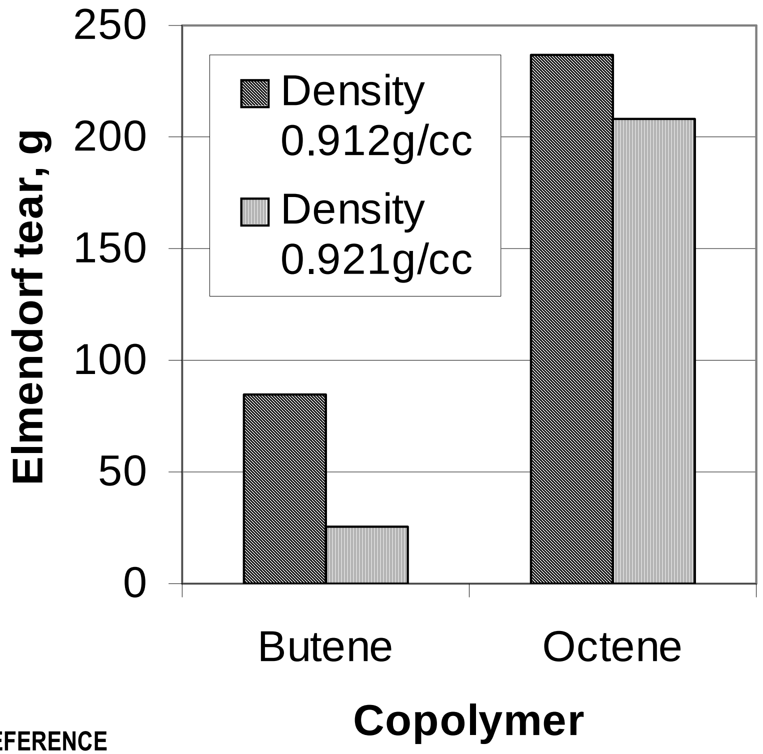


Fig. 16.4.8. Initial steps in the deformation of polyethylene (© 1983, Butterworth Scientific).

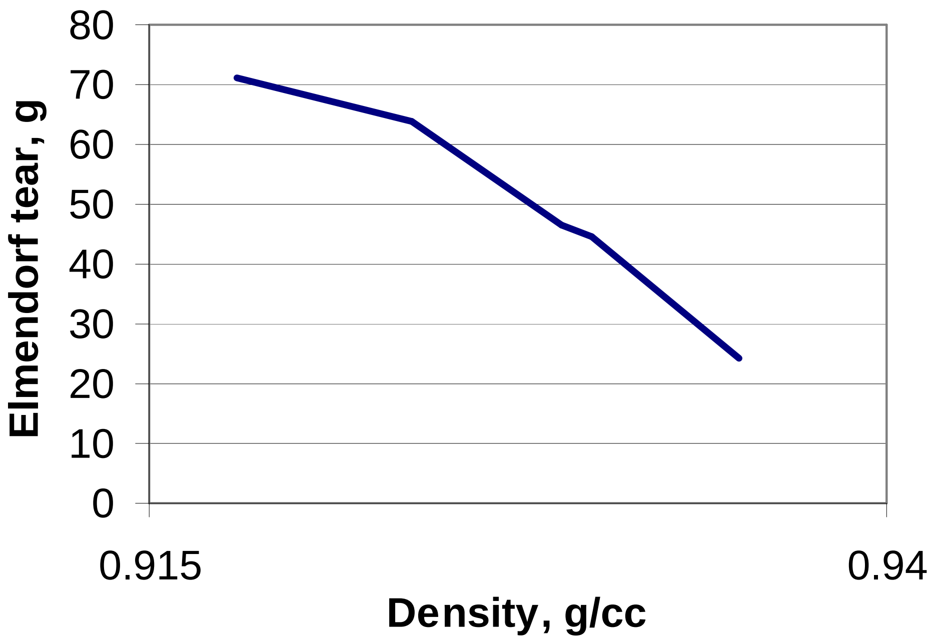
Tear resistance can be designed through choice of resin parameters

What Improves Tear Resistance?

Tie-chain concentration and crystal connectivity as function of density and comonomer improve material toughness



Tear data on stretched tapes based on DOWLEX™ resins



REFERENCE

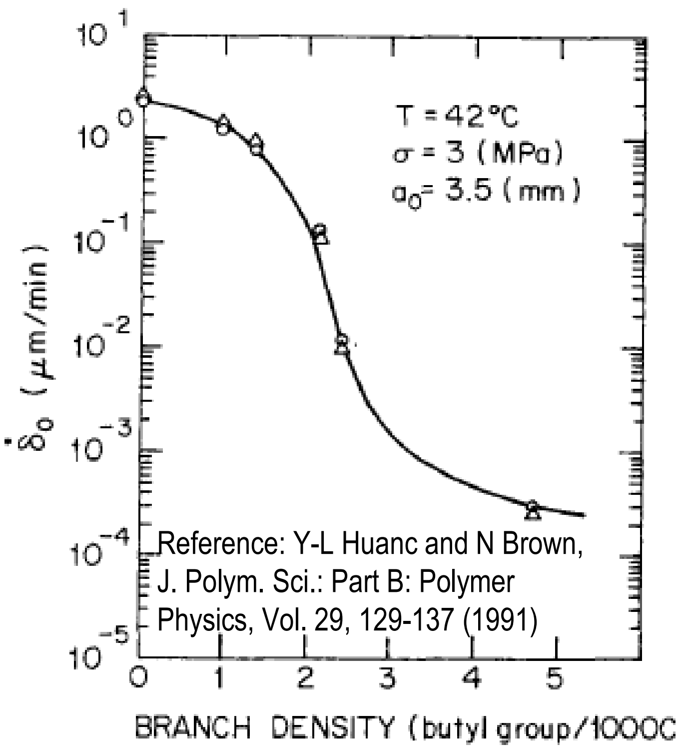
Kale, LT, et al.:, "Structure-Property Relationships of Ethylene/1-Octene and Ethylene/1-Butene Copolymers made Using INSITE™ Technology", SPE ANTEC, 1996

Copolymer choice is critical to final tear resistance.

Durability – Material Fatigue Resistance

Resistance to stress cycles tested till material failure.

Comonomer (branch density) content important for material toughness



Reference: Y-L Huanc and N Brown, J. Polym. Sci.: Part B: Polymer Physics, Vol. 29, 129-137 (1991)

Figure 1. The rate of initial COD, $\dot{\delta}_o$, versus branch density, d. (Δ) normalized to the molecular weight $\bar{M}_w$ = 130,000.

Branch density inversely related to density for LLDPE.

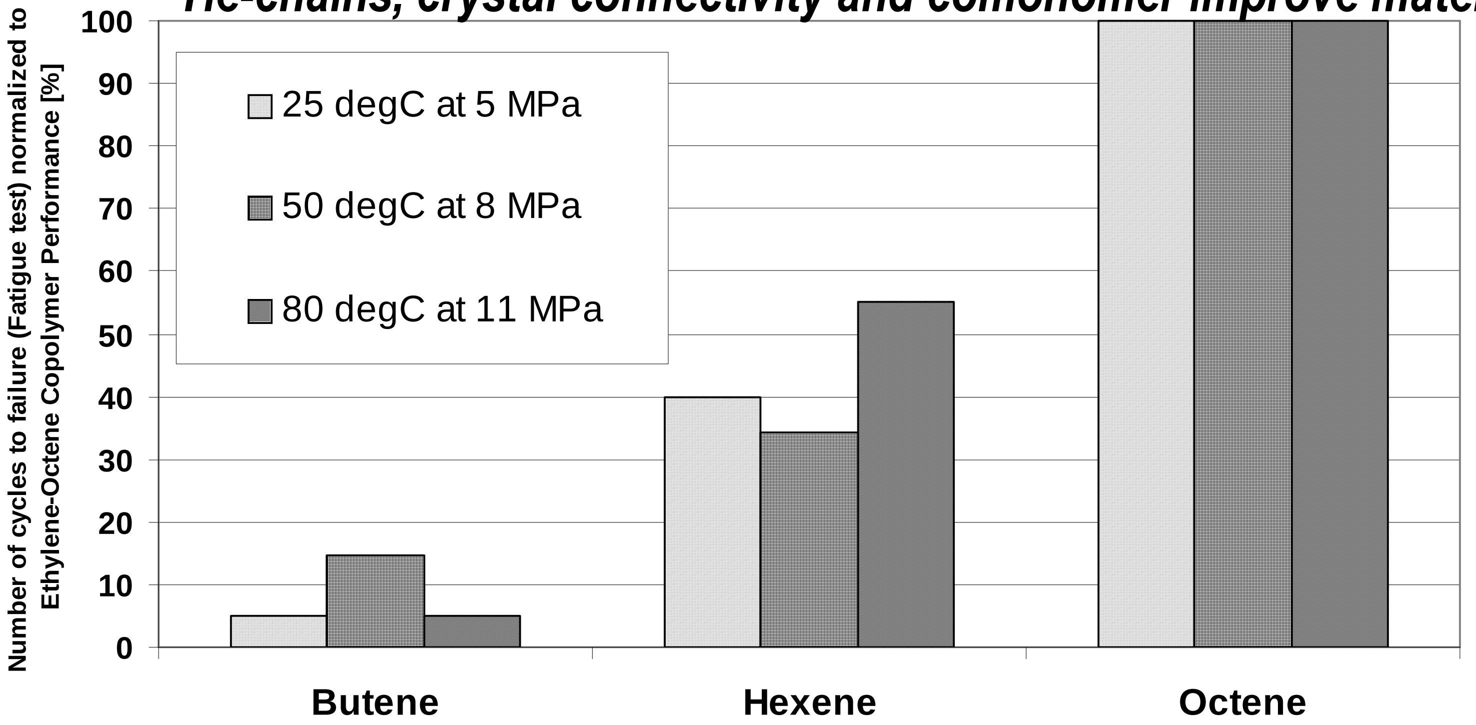
The higher the amount of comonomer, and the longer the comonomer chain,

the lower the stress crack initiation.

Durability – Material Fatigue Resistance

Resistance to stress cycles tested till material failure.

Tie-chains, crystal connectivity and comonomer improve material toughness

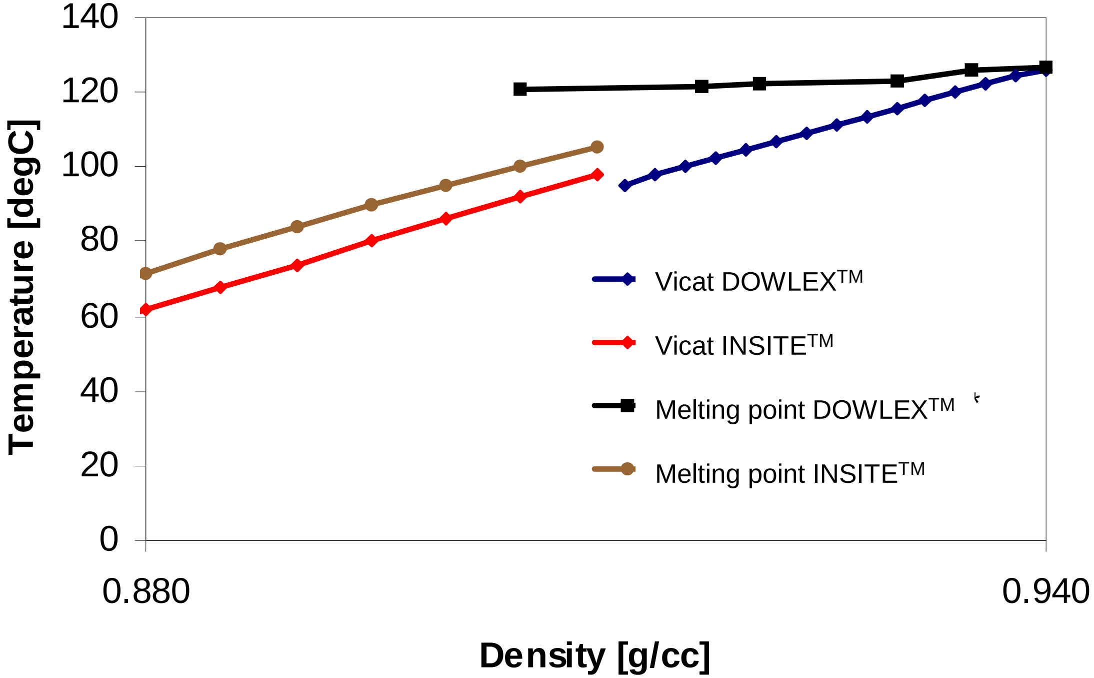


Reference:
J-t Yeh, H-s Hong; Macromol. Chem. Phys. 196, *705-714 (1995)*

Comonomer type plays significant role for the durability of LLDPE polyethylene material exposed to stress cycles.

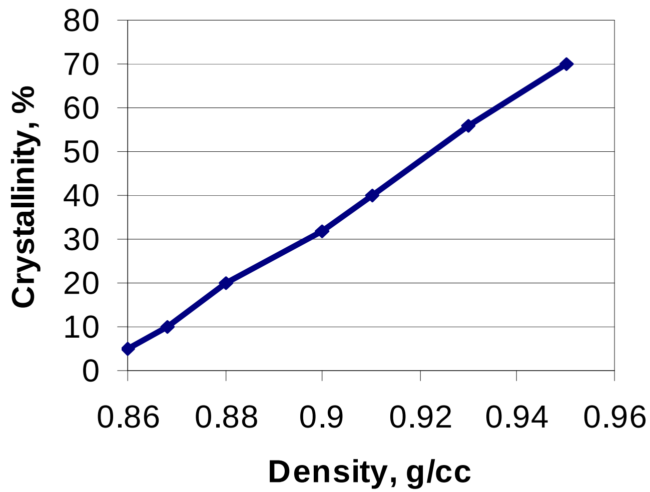
Need for a Temperature Resistant Yarn

"Pitches take up heat from radiation and pitch temperatures can reach above 70°C"



Vicat
- Polymer starts to soften, small crystals start melting; yarn can yield under stress.

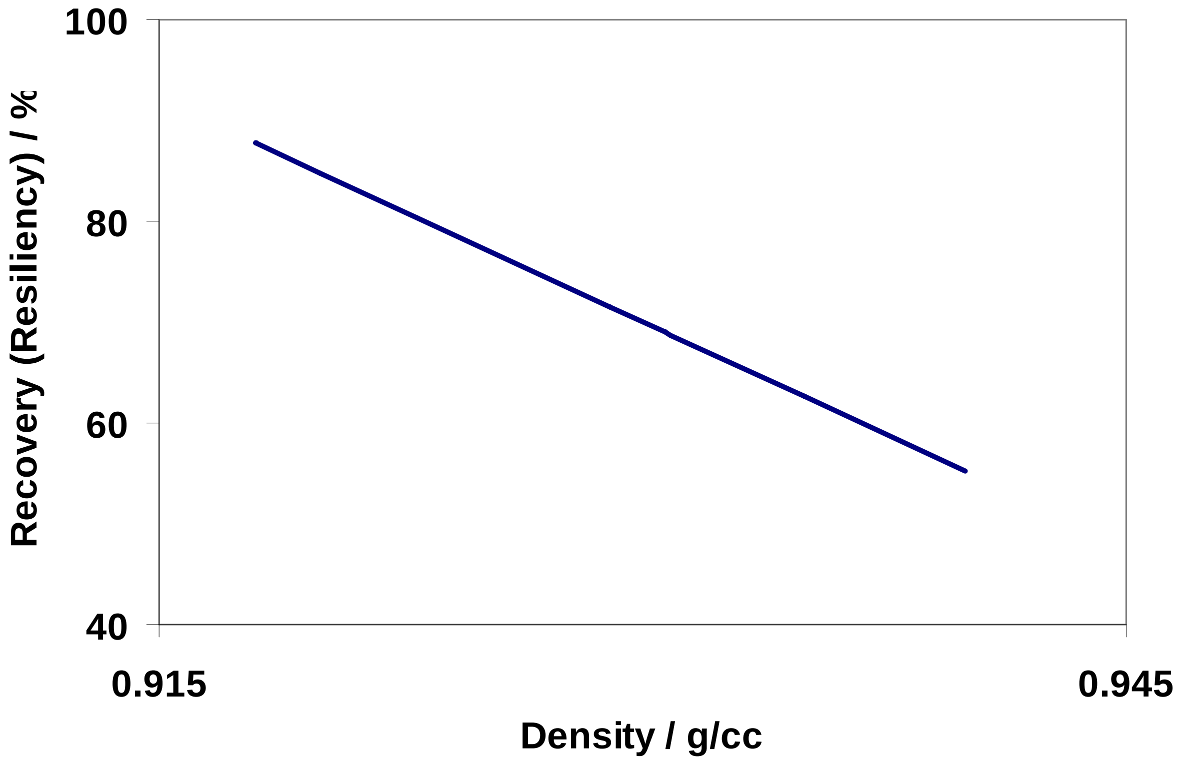
Melting point
- Crystalline phase is melting.



A lower <u>density and crystallinity</u> results in lower temperature resistance because the polymer softens and partially melts.

Resiliency – Elastic Recovery

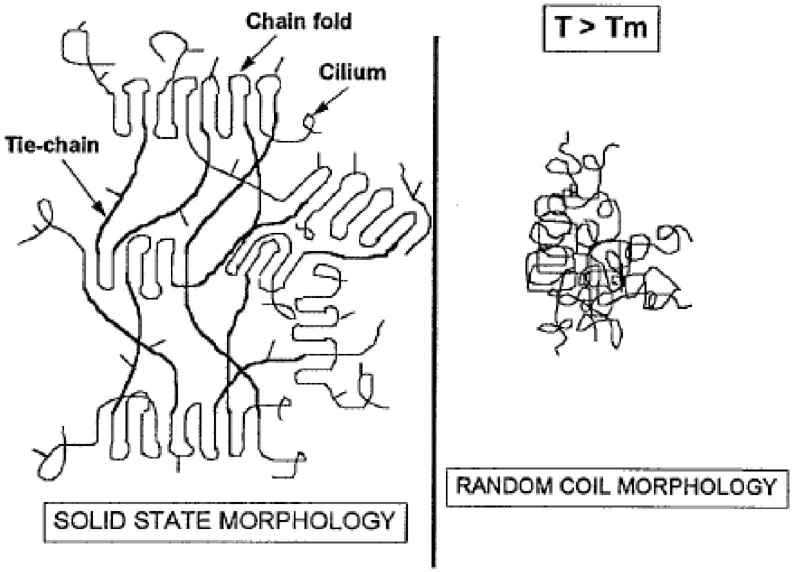
Recovery after forced bending of yarn under defined conditions.

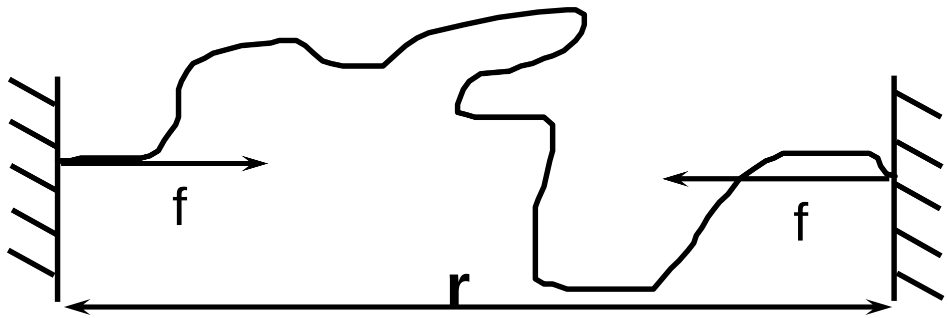


⇒ ***Lower density results in the best resilience and higher softness***

Shrinkage – Understanding: Shrink Tension as an Entropy Spring

Stretched filaments have a high degree of polymer orientation. The crystal phase is connected by stretched polymer chains, the tie chains.





(Gaussian approach)

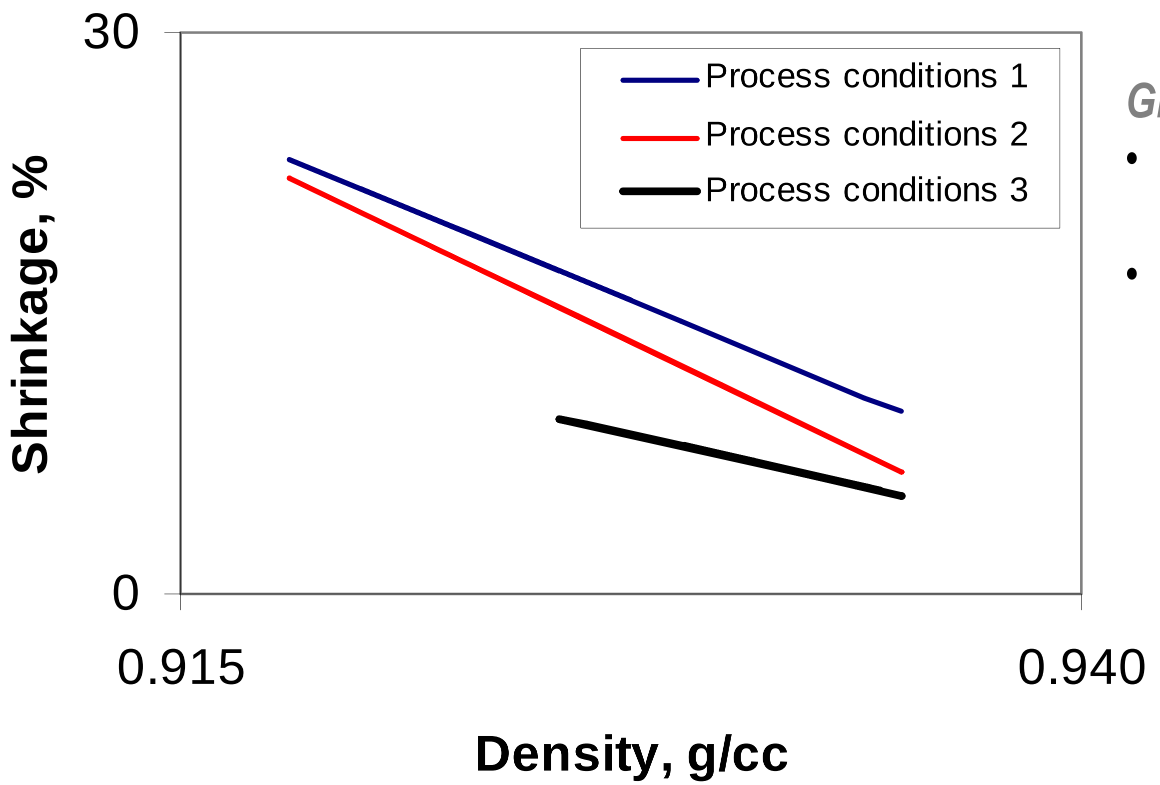
Force acting on an isolated, freely rotating chain kept at constant length **r** is given by

$$\mathbf{f} = \frac{\mathbf{3\,k\,T}}{\mathbf{a}}\left(\frac{\mathbf{r}}{\mathbf{L}}\right)$$

In case of oriented semi-crystalline polymers above T_g, **tie chains** are locked in the extended state by crystallites.

Shrinkage: Density Dependence – Controlling it

In general shrinkage of stretched tapes increases with decreasing density



GENERAL

- **Process conditions can be adjusted to minimize shrinkage.**
- **Optimizing the density to control the shrinkage within the required limits.**

Coefficient of Friction – Effects of Polymer Choice

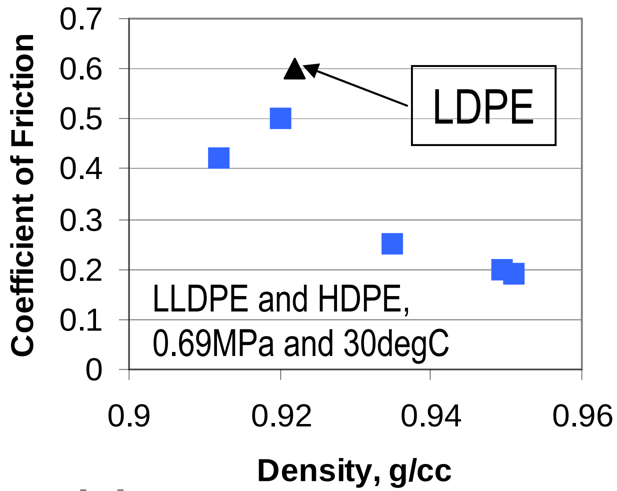
Skin friction and stud friction depend on how "sticky" the polymer surface is.

GENERAL

- **Lower density (<0.92g/cc) has higher metal-polymer and polymer-polymer friction with high density (>0.94g/cc) typically having lower friction.**
- **Ultra high molecular weight polyethylene has low COF and low wear.**
- **Surface roughness influences friction.**
- **Lubrication (aqueous) reduces friction**

CONSIDERATIONS

- **Stud friction will be higher at lower PE densities.**
- **Slip additives can temporarily modify the coefficient of friction.**
- **Slip additives can also influence the wear and polymer attrition in the Lisport test.**



Ref.: Spalding et al; Polym Eng & Sci 1995, 35, 557

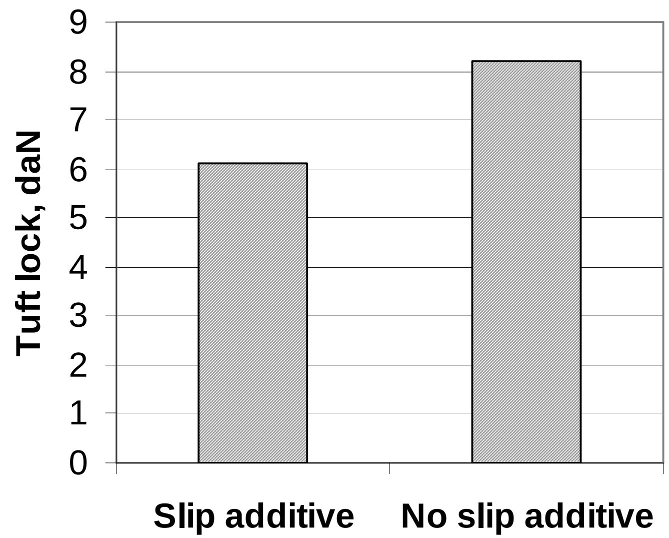
Lower density results in higher friction coefficients; more work is needed to understand the friction at the skin-polymer interface.

Tuft Lock – Some Key Influences

Tuft lock for monofilaments is influenced by polymer-polymer friction, polymer additives and the backing material.

GENERAL

- **Slip additives reduce polymer-polymer friction in bundle of monofilaments ⇒ lower tuft lock**
- **Without additives LLDPE at densities 0.916 to 0.940 g/cc will give good tuft lock (small density dependence).**



- ***Enhancements of tuft lock by DOW™ ENFORCER™ PU backing.***
- **Novel heat laminated film backing has been developed.**
- **Polyolefin dispersions (HYPOD™ technology) can be used as carpet backing to improve tuft lock to PE yarn.**

Working with Dow to Improve Your Yarn; and Turf System

- New grade design for artificial turf as result of material science: Developmental LLDPE Resin **XZ 89438.00**; I_2=2.3g/10min, density=0.930g/cc.
- Dow has the broadest portfolio of Polyolefin resins to match your yarn performance requirements.
- Dow’s leading polyethylene resins are ideally positioned as high performance materials in artificial grass yarn.
- Excellence in material science and technical service expertise to support your needs in yarn developments and processing.
- **Dows materials are used in yarn, infill, backing and shock absorbency – we can advise you in the system design.**

In Summary

"A lot of parameters determine the final quality and properties of artificial turf yarn"

But DOW has some answers for you!

We invite you to talk to us – not least at the conference dinner tonight!

– together we can develop the right polymer for your artificial grass yarn needs.

- **Balancing the various yarn requirements by polymer properties.**
- **Optimizing the processing influences to obtain best possible yarn.**

Thank you – we care for artificial turf