



Selecting LLDPE for Down-gauged Films

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Objectives

- Present down-gauging as an optimization problem
- Compare the dependence of key physical properties on gauge for some high performance LLDPE film grades
- Demonstrate an easy way to choose the 'best' product and gauge
- Illustrate a multilayer alternative to overall film down-gauging

Framing the problem

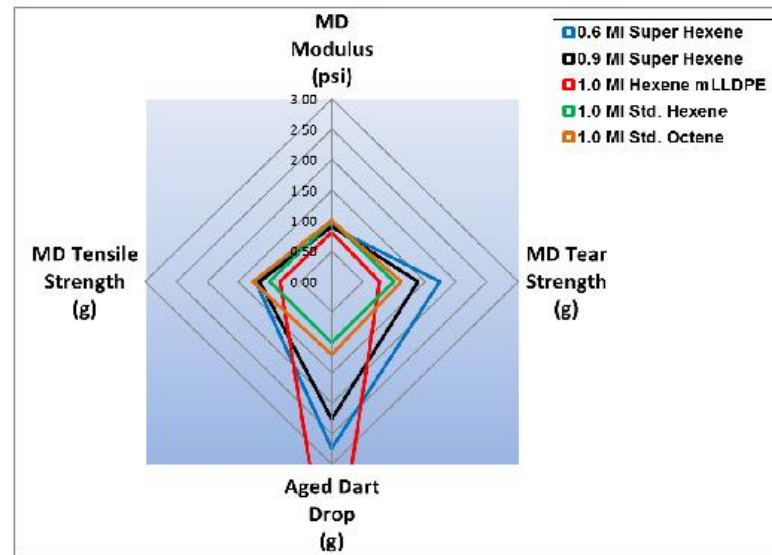
- 3 questions of optimization:
 1. *What is our objective?*
 - Minimize film cost, material usage, etc.
 2. *What are we trying to decide?*
 - LLDPE to use and at what thickness
 3. *How are we constrained?*
 - Physical properties that have to be met
- Having the right data is critical

Typical physical property comparisons

- Property comparisons between products often difficult
 - Different film production conditions
 - Single gauge, often different than desired
 - Different relationships of properties to gauge

High Strength LLDPE Film Resins Physical Property Comparison

Super Hexene resins offer a good balance of physical properties



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Datasheets seldom provide the 'right' data. Products have to be evaluated across a gauge range.

Generating the relevant data

- Produced films ranging in nominal thickness from 0.5 to 2.5 mil
- All films produced on a monolayer lab line under the following extrusion conditions
 - 4 inch die with 100 mil die gap
 - 55 lbs/hr
 - 2.3:1 blowup ratio
 - 12 inch frost line height (3 DD)
 - Typical LLDPE temperature profile (~425 F melt temperature)
- All films tested for actual gauge and typical physical properties such as Dart Drop & Elmendorf Tear

Resin Type	Melt Index (g/10 min)	Density (g/cc)
Superhexene	0.6	0.9165
Hexene mLLDPE	1.0	0.918
Standard Octene	1.0	0.920
Standard Hexene	1.0	0.918

26" Dart Drop results

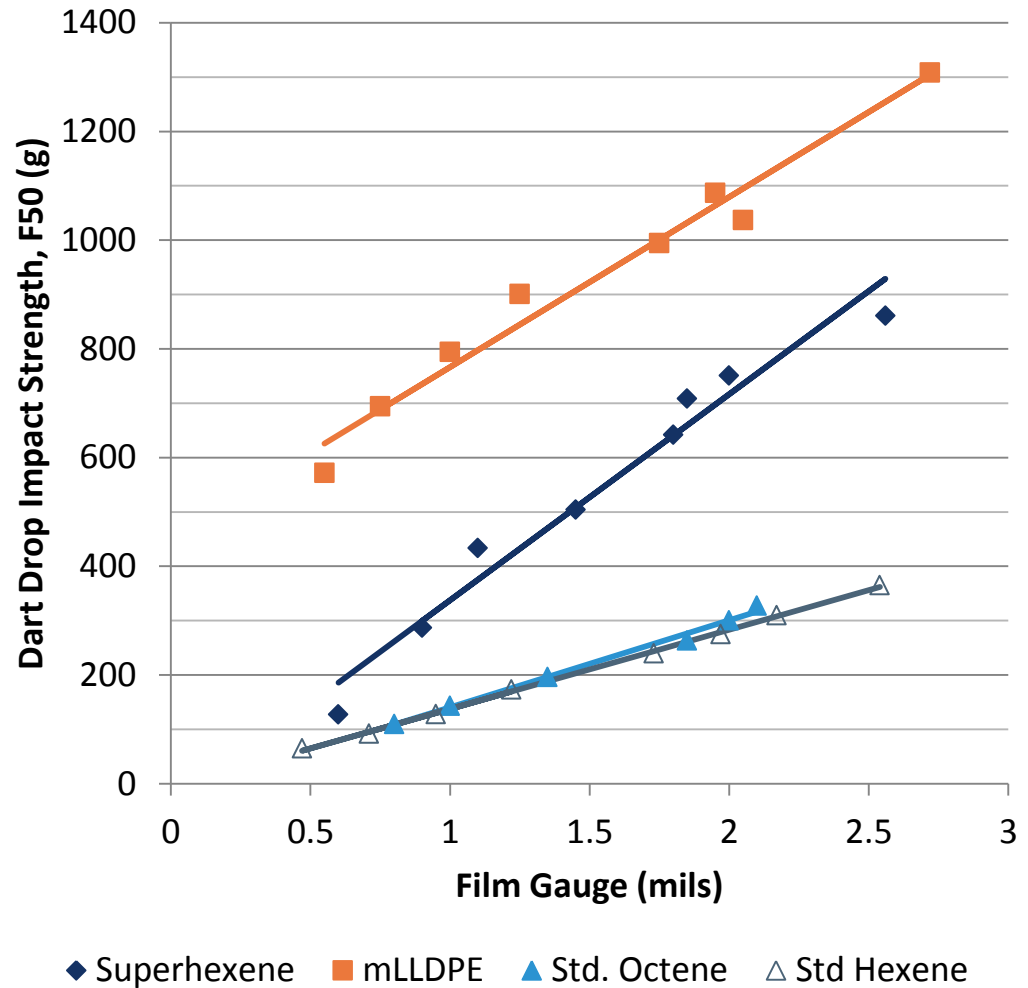
ASTM D1709-Method A

Observations

The hexene mLLDPE studied has higher dart drop impact strength than the other products, especially at thin gauges.

The superhexene product provides higher dart drop versus the std. octene and std. hexene grades studied.

The dart drop of the mLLDPE and superhexene grades increases faster with gauge than the std. hexene and std. octene grades.



1% Secant Modulus (Machine Direction) results

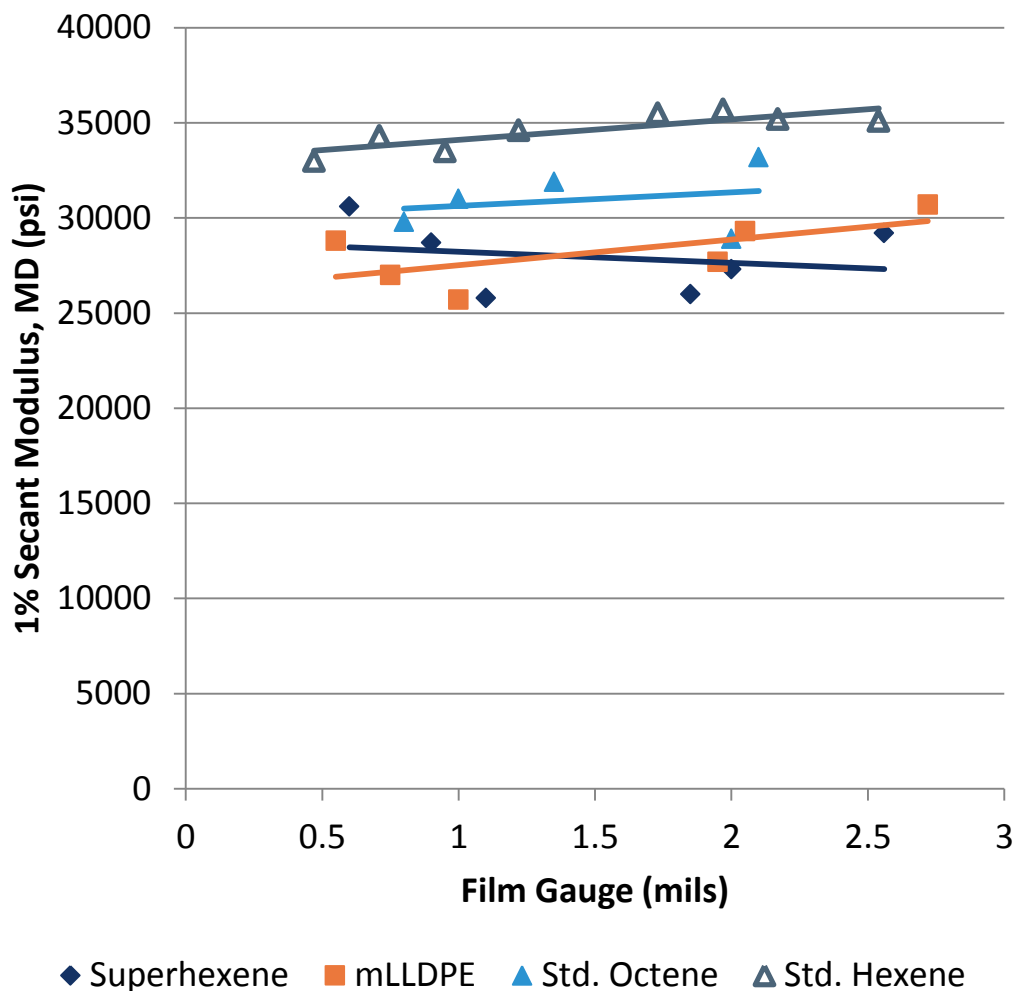
ASTM D882

Observations

Modulus mostly unchanged with increasing gauge.

The std. hexene grade has the highest modulus of the products studied, followed by std. octene.

Other products studied have comparable modulus values.



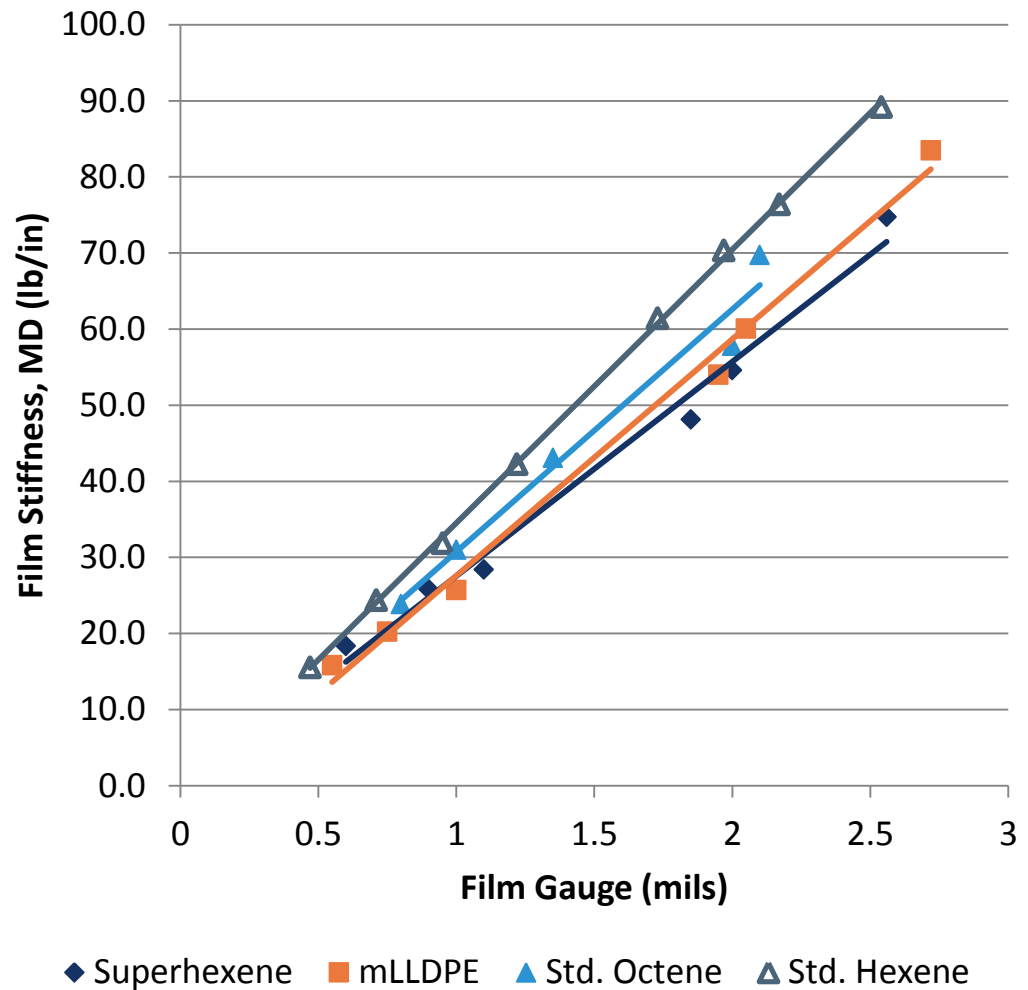
Film 'stiffness' (modulus x thickness) results

Observations

'Stiffness' is modulus multiplied by gauge. Represents the film resistance to strain/extension, but depends on both modulus and gauge.

At similar gauges, the relative stiffness values are consistent with the modulus results (std. hexene > std. octene > superhexene = mLLDPE).

The products tend to cluster together at thinner gauges.



Elmendorf Tear (Machine Direction) results

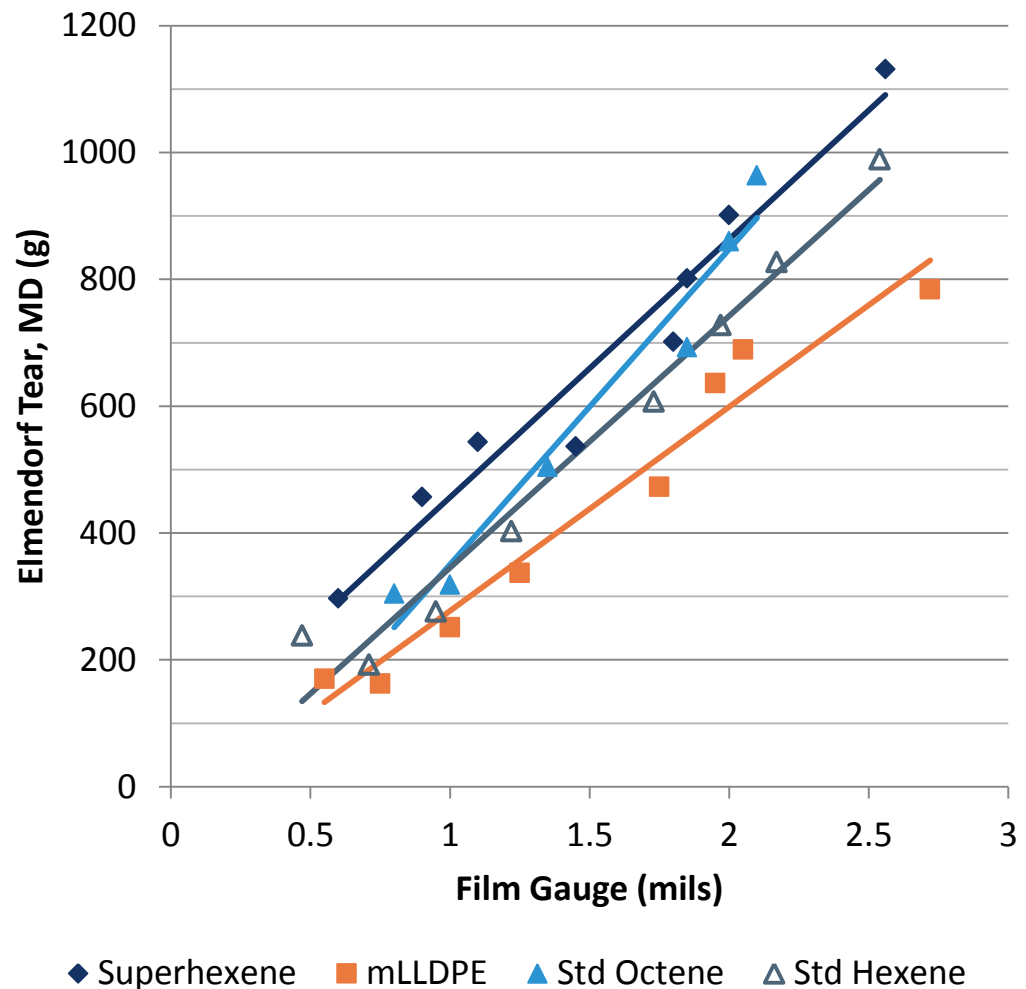
ASTM D1922

Observations

Below 2 mils, the superhexene grade has the highest machine direction tear strength of the products studied.

Below 1 mil, the superhexene product retains tear advantage while other products cluster together.

Above 2 mils, the superhexene and std. octene grades both provide higher tear strength versus the std. hexene and mLLDPE grades.



Summary of observations

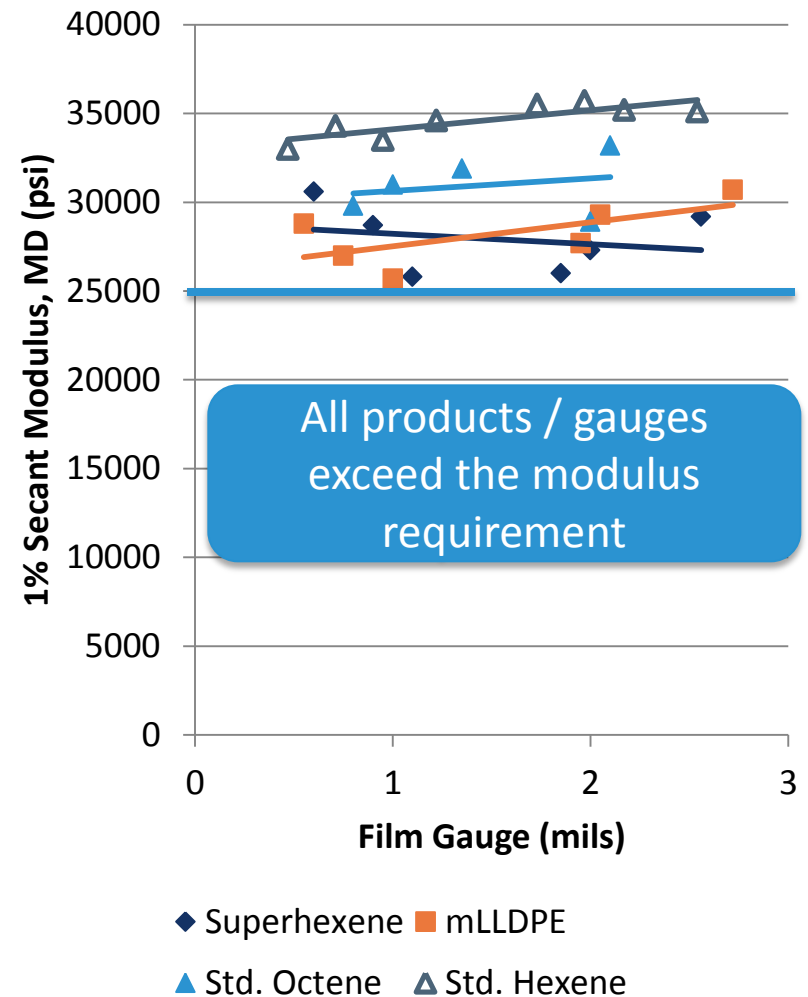
- Superhexene LLDPE offers an excellent balance of dart drop and tear resistance in the gauge range studied
- The superhexene grade offers higher dart drop than the std. octene and std. hexene grades studied
- The superhexene grade offers increased tear resistance versus the other products studied, especially at thinner gauges
- The superhexene product provides comparable modulus values to most of the products studied

Using the data to make choices

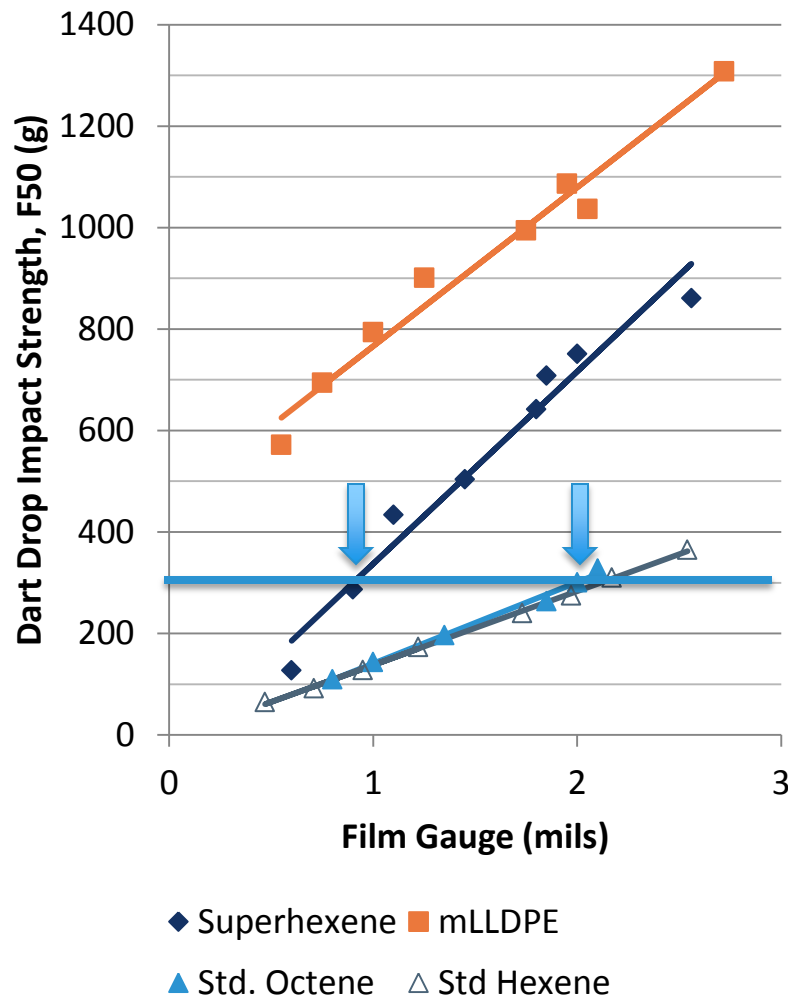
- Could use a spreadsheet optimization model to choose ‘best’ combination of product and gauge
 - Mixed integer linear (or nonlinear) programming model
 - Better suited to larger scale problems
- Easier graphical method for simple down-gauging choices
 - For each property
 - Plot the property data vs. gauge for each product
 - Draw a line at the minimum acceptable value
 - Find the minimum gauge for each product that meets the minimum acceptable value
 - The largest minimum gauge for each product is the overall minimum

Example of graphical method (modulus)

- Theoretical application that requires the following minimum physical properties
 - 25,000 psi 1% secant modulus (MD)
 - 300 grams dart drop
 - 300 grams Elmendorf tear (MD)
- Consider stiffness at starting gauge in addition to modulus
 - 2 mil film @ 25 kpsi = 50 lb./in
 - 1 mil film @ 25 kpsi = 25 lb./in

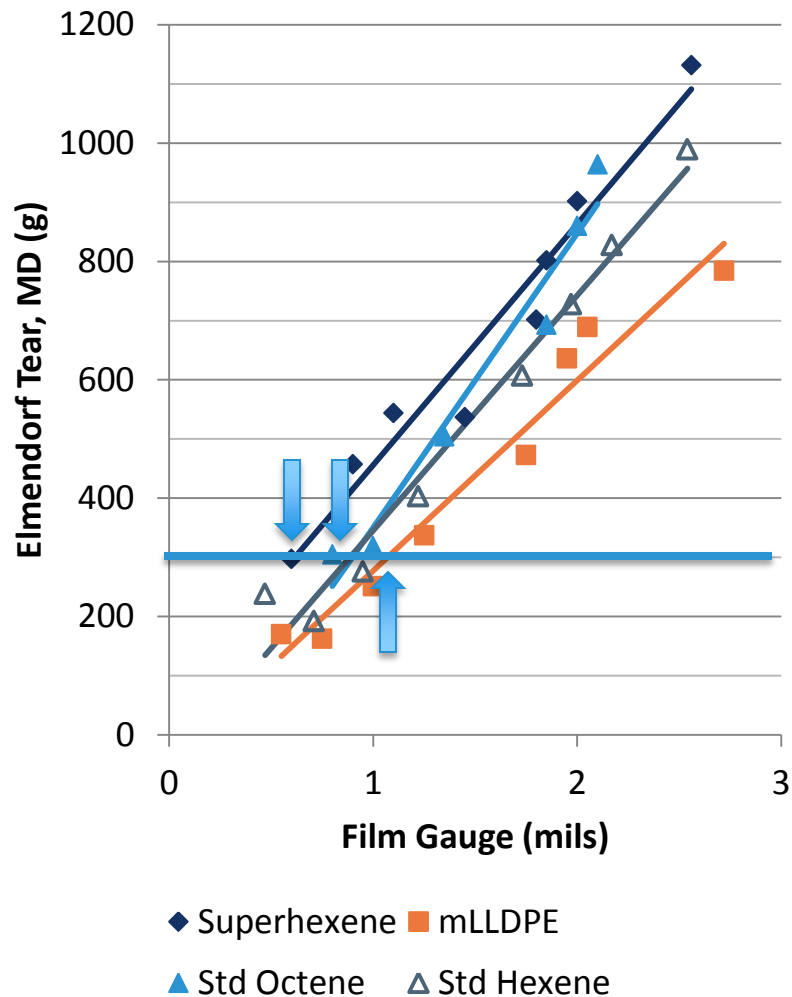


Example of graphical method (dart drop)



- Minimum required gauges to meet the dart drop requirement (300 grams)
 - mLLDPE = any
 - Superhexene = 0.9 mils
 - Std. Octene = 2 mils
 - Std. Hexene = 2.15 mils

Example of graphical method (Elmendorf Tear)



- Minimum required gauges to meet the Elmendorf tear requirement (300 grams)
 - mLLDPE = 1.1 mil
 - Superhexene = 0.6 mil
 - Std. Octene = 0.9 mils
 - Std. Hexene = 0.9 mils

Graphical method example results

Observations	Film gauge to meet minimum requirement				
	Product	Modulus (MD)	Dart Drop	Elmendorf Tear (MD)	Overall Minimum
<ul style="list-style-type: none"> For this hypothetical combination of properties, superhexene provides the most down-gauging potential mLLDPE is limited by its tear strength Std. octene and std. hexene limited by dart drop Have to consider all property requirements when down-gauging 	Superhexene	any	0.9	0.6	0.9
	mLLDPE	any	any	1.1	1.1
	Std. Octene	any	2.0	0.9	2.0
	Std. Hexene	any	2.2	0.9	2.2

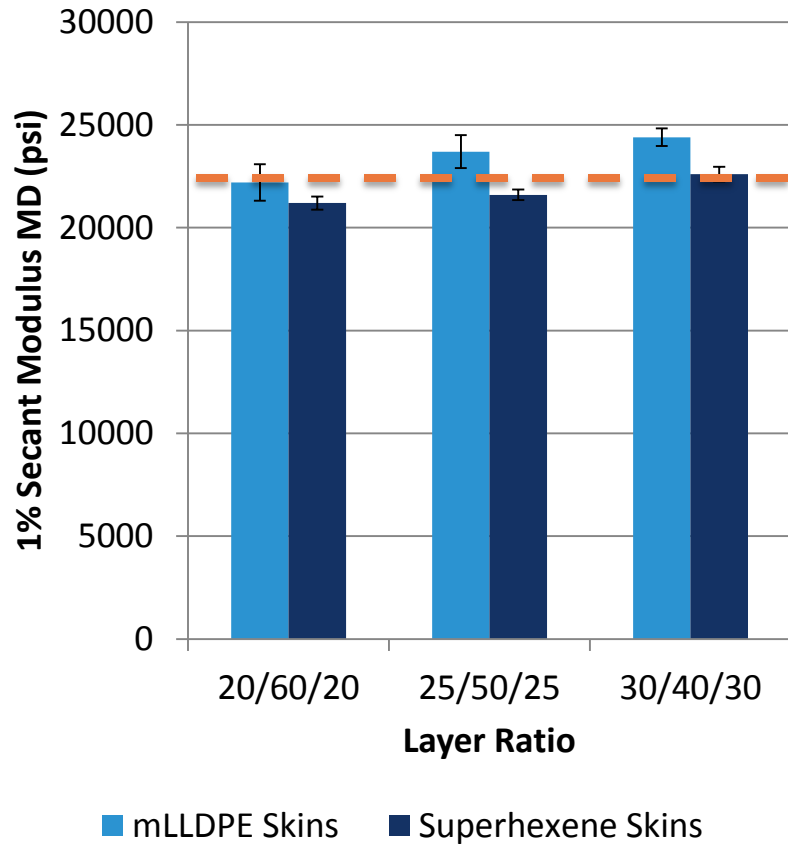
Multilayer structure alternatives to 'down-gauging'

- Can 'down-gauge' individual layers in multilayer films
- Could decrease overall film cost but maintain same overall thickness and properties
- Looked at a high performance stretch-hooder structure
 - 3 layer film
 - mLLDPE skins, Adflex core
 - 4 mil gauge
 - 20/60/20 layer distribution
- Studied two variables
 - Substituted superhexene for mLLDPE
 - Increased skin layer percentages
- Evaluated standard physical properties

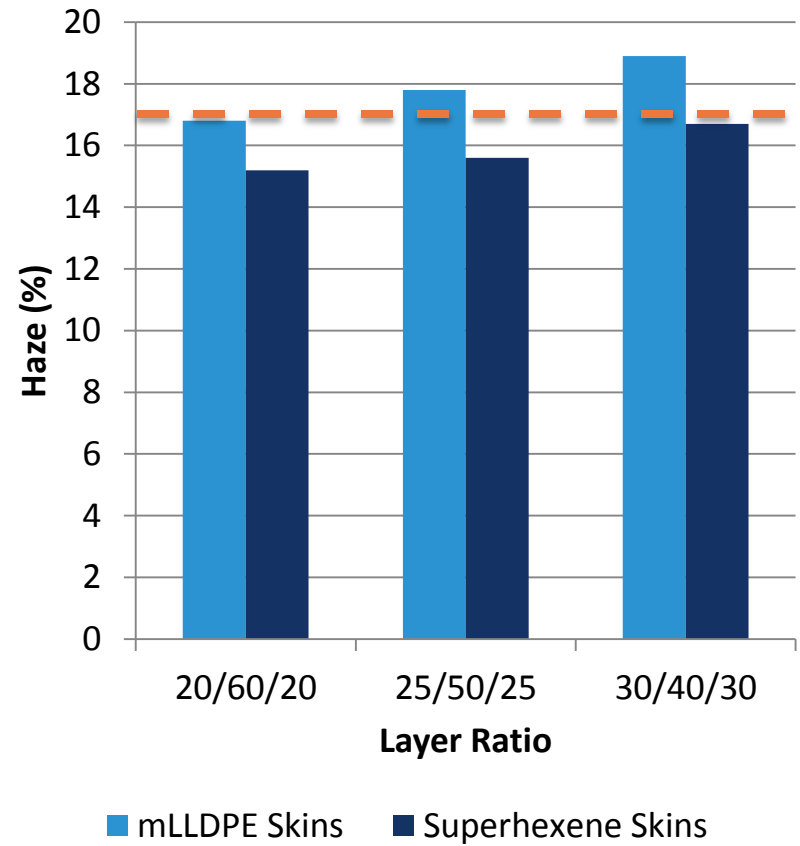
1% Secant Modulus (MD) and haze results

ASTM D882 and D1003

Superhexene skin layers reduce modulus vs. mLLDPE. MD modulus increases with increasing skin %.



Superhexene skin layers reduce haze vs. mLLDPE. Haze increases slightly with increasing skin %.

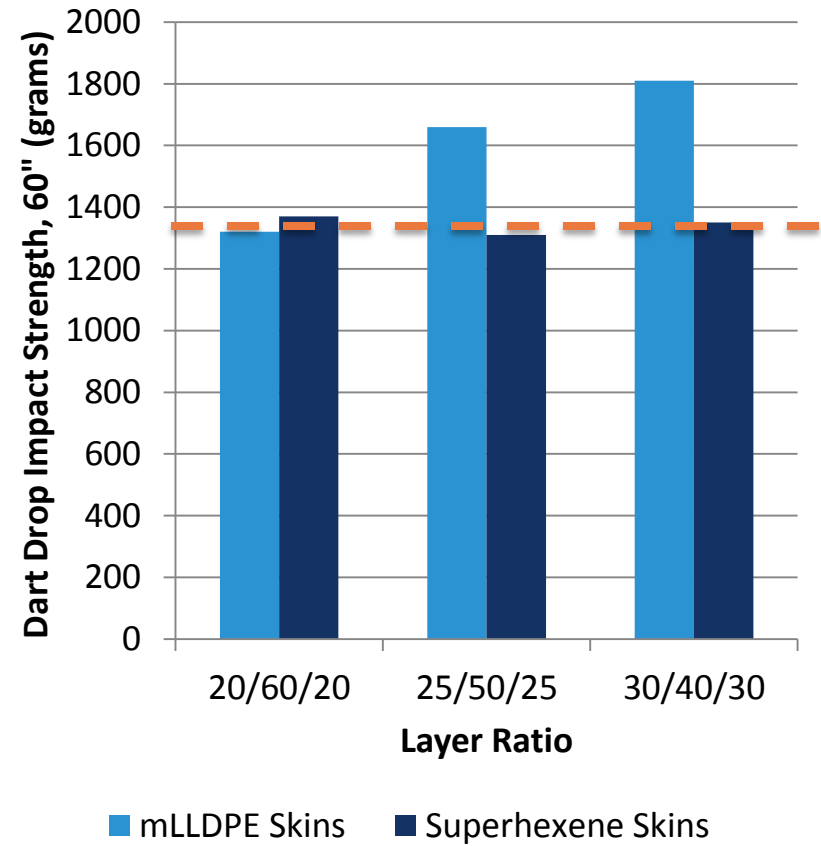
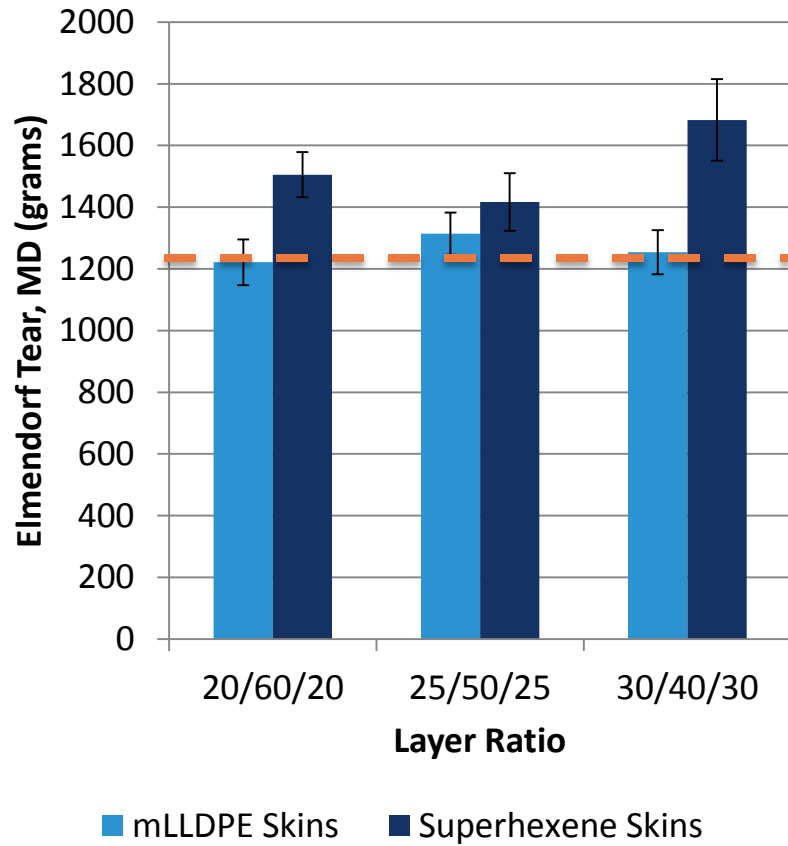


Elmendorf tear (MD) and 60" Dart Drop results

ASTM D1922 and D1709-Method B

Superhexene improves MD tear vs. mLLDPE. Increased skin layer % provides similar tear to control (20/60/20).

Increased skin layer % provides similar or improved impact to control. mLLDPE improves impact vs. superhexene.



Multilayer results summary

- Obtained physical properties similar to control with increased LL skin layer percentages
- Versus control film:
 - Increased mLLDPE percentages provide higher impact resistance
 - Increased superhexene percentages provide higher tear resistance
- Versus mLLDPE skin layers:
 - Superhexene skin layers provided lower haze and modulus
 - Superhexene skin layers provided higher tear and lower/similar impact

Summary and conclusions

- Viewing down-gauging as an optimization problem can provide a clear framework to make product and gauge choices
 - Graphing important properties and requirements makes decisions easier
- Superhexene LLDPE offers excellent down-gauging potential when tear and impact are both important
 - Improved dart drop versus std. hexene and octene grades studied
 - Improved tear versus mLLDPE grade studied
- Superhexene LLDPE provides comparable performance to mLLDPE in typical 3 layer stretch-hooder films
 - Could allow for reduced core layer percentages

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