



Effect of Formulation and Processing on the Properties of High Performance LLDPE in Heavy Duty Film Applications

Maged Botros Ph.D., Steve Imfeld and Matt Sonnycalb
Application Development & Technical Service
LyondellBasell Industries



Topics

- Background
- Markets and Applications
- Experimental Plan
- Results
- Conclusions
- Acknowledgements

Background



- Objective
 - Evaluate the effect of processing conditions on the performance of LLDPE resin blends in heavy gauge films
 - Compare the performance of High Performance LLDPE resin blends in heavy gauge films
- GS906 is a new *Petrothene* Select High Performance Hexene LLDPE developed for demanding blown film applications
 - Fractional melt index advanced super hexene
 - 0.6 MI (g/10min.), 0.9165 (g/cc) density
 - Superior combination of film strength properties
 - Excellent melt strength
- Target Applications
 - Trash can liners, heavy duty & industrial packaging films and other high performance film applications
- Status: sold commercially

North American Markets Consuming High Performance LLDPE Film Resins

- High performance LLDPE resins are used in many demanding film applications

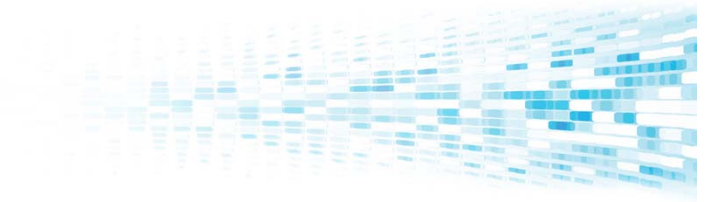
Primary High Strength LLDPE Film Markets	LL Volume MM kg (MM lbs.)
Consumer & Institutional Can Liners	771 (1700)
Heavy Duty Films	726 (1600)
Shipping Sacks, Industrial Liners,	
Construction Film	

Combined Sources: 2011 Mastio Film Study, 2012 PTAI HAO Film Study, ACC LL Industry 2011

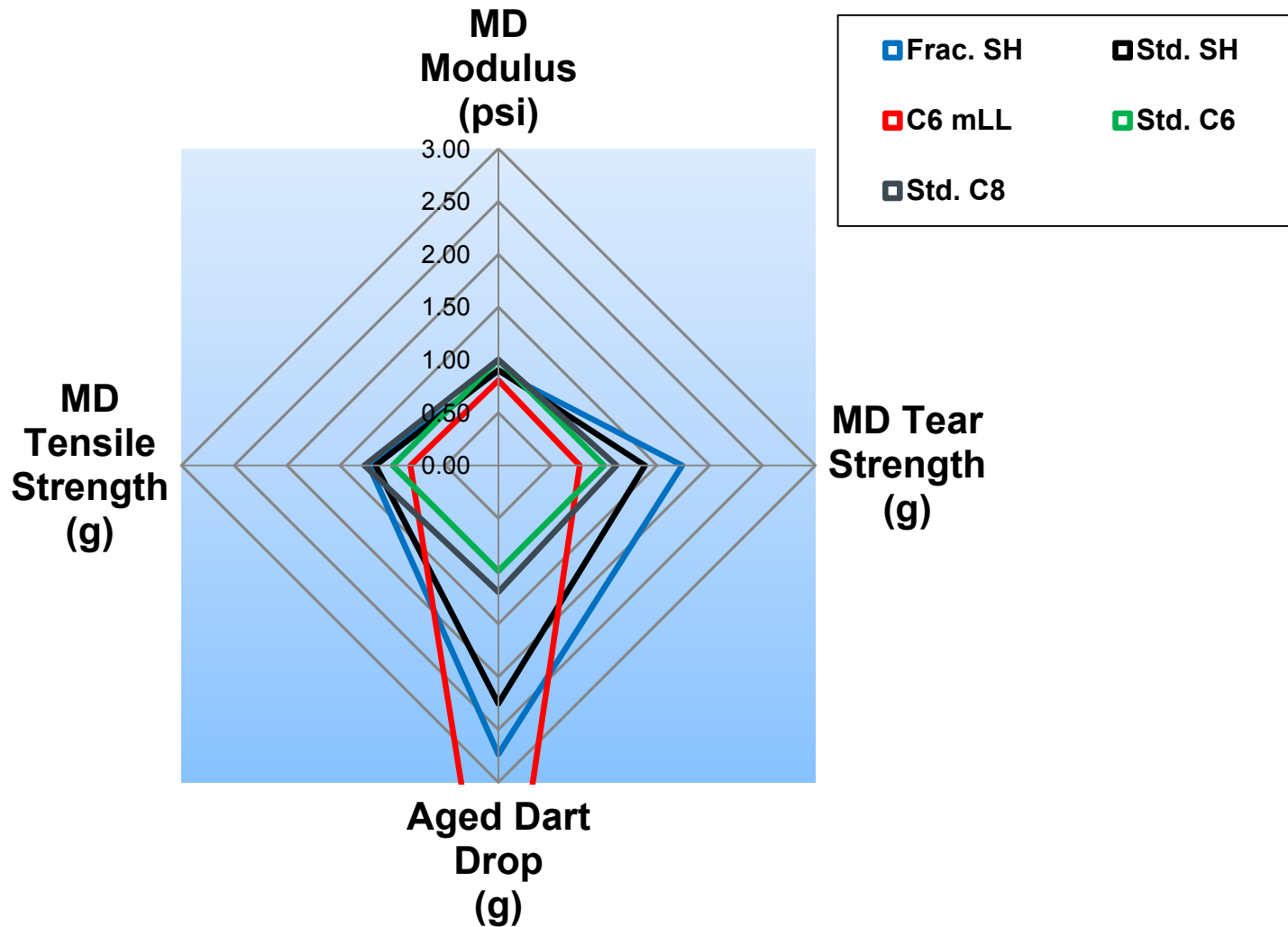


High Strength LLDPE Film Resins

Physical Property Comparison



New Frac. Melt Super Hexene resin offers a good balance of physical properties



LLDPE Blend Study - Experimental Plan

- Study the effect of Blow Up Ratio (BUR), Frost Line Height (FLH) and Melt Temperature (MT) on film performance
- Used face-centered design of experiments with three variables
 - BUR at 1.5, 2.0, 2.5
 - FLH/Die Diameter (FLH/DD) at 2.5, 3.25, 3.75
 - Die diameter: 10.2 cm (4 inches)
 - Melt Temp at 232C (450F), 243C (470F), 254C (490F)
- Produced and tested 3-mil blown films
- Compared film performance at similar stiffness ~276 Mpa (~40,000 psi) and similar melt strength by adding HDPE and LDPE to the formulations as required

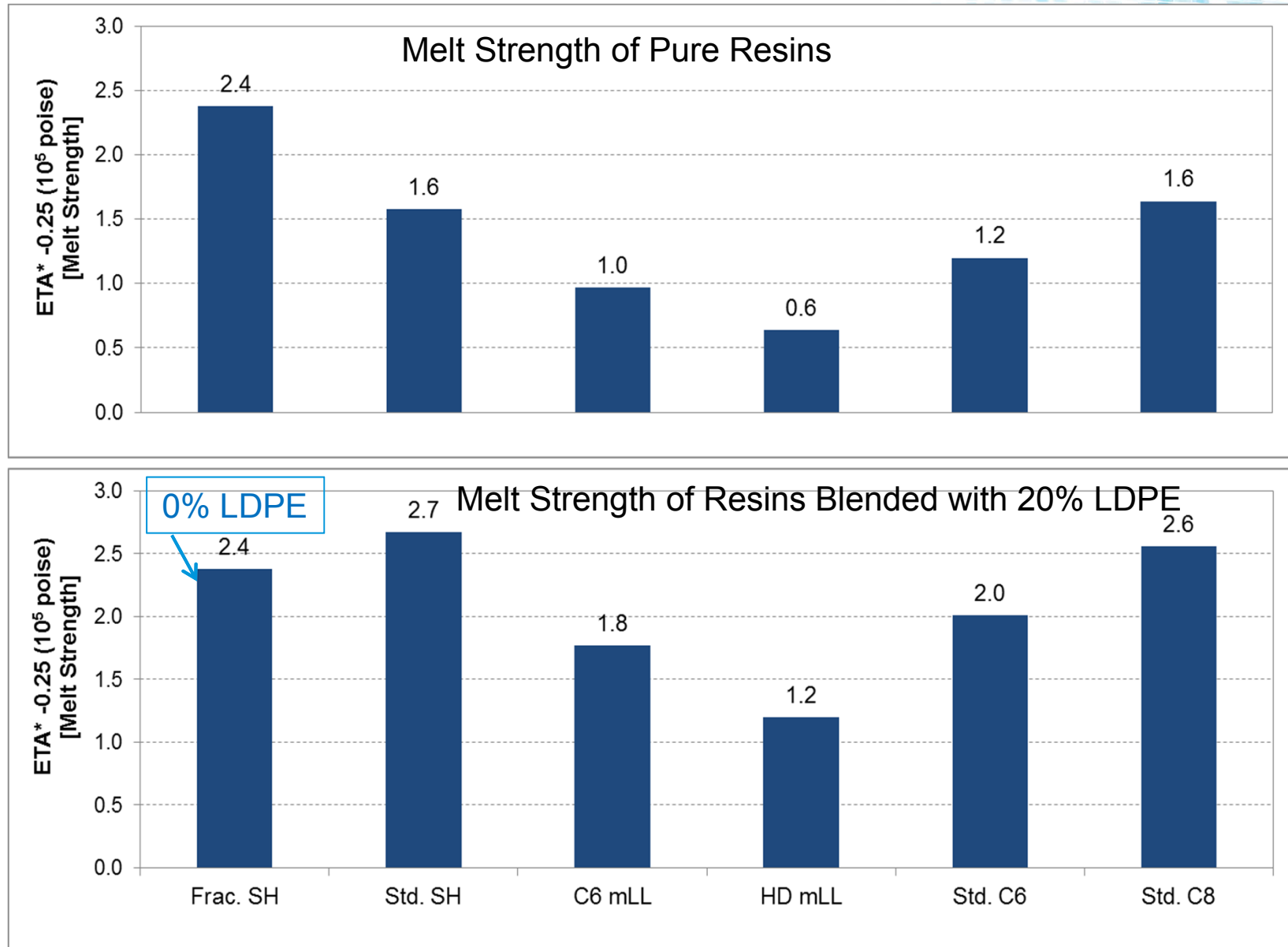
Blends Studied



Formulation ID	LLDPE Resin	% LDPE	%HDPE
Frac. SH	New development - Fractional melt index advanced super hexene	0	25
Std. SH	Typical super hexene	20	19
C6 mLL	Hexene metallocene	20	20
HD mLL	Hexene metallocene at higher density	20	4
Std. C6	Standard hexene	20	16
Std. C8	Standard octene	20	14

- LDPE resin: 0.25 MI, 0.918 density tubular grade
- HDPE resin: 0.45 MI, 0.950 density Z/N grade

Formulations Adjusted for Equivalent Melt Strength

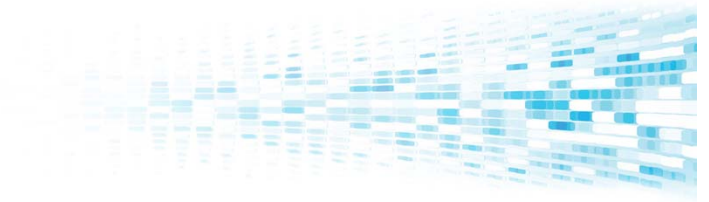


Film Testing Overview



- Tested properties: rheology, modulus, tensile yield, dart impact, tear, puncture, tensile strength, COF, optics
- Properties strongly affected by process variables studied
 - Dart Drop
 - Machine Direction Tear
 - Transverse Direction Tear
 - Transverse Direction Modulus
- Other properties showed minor effects of individual process variables

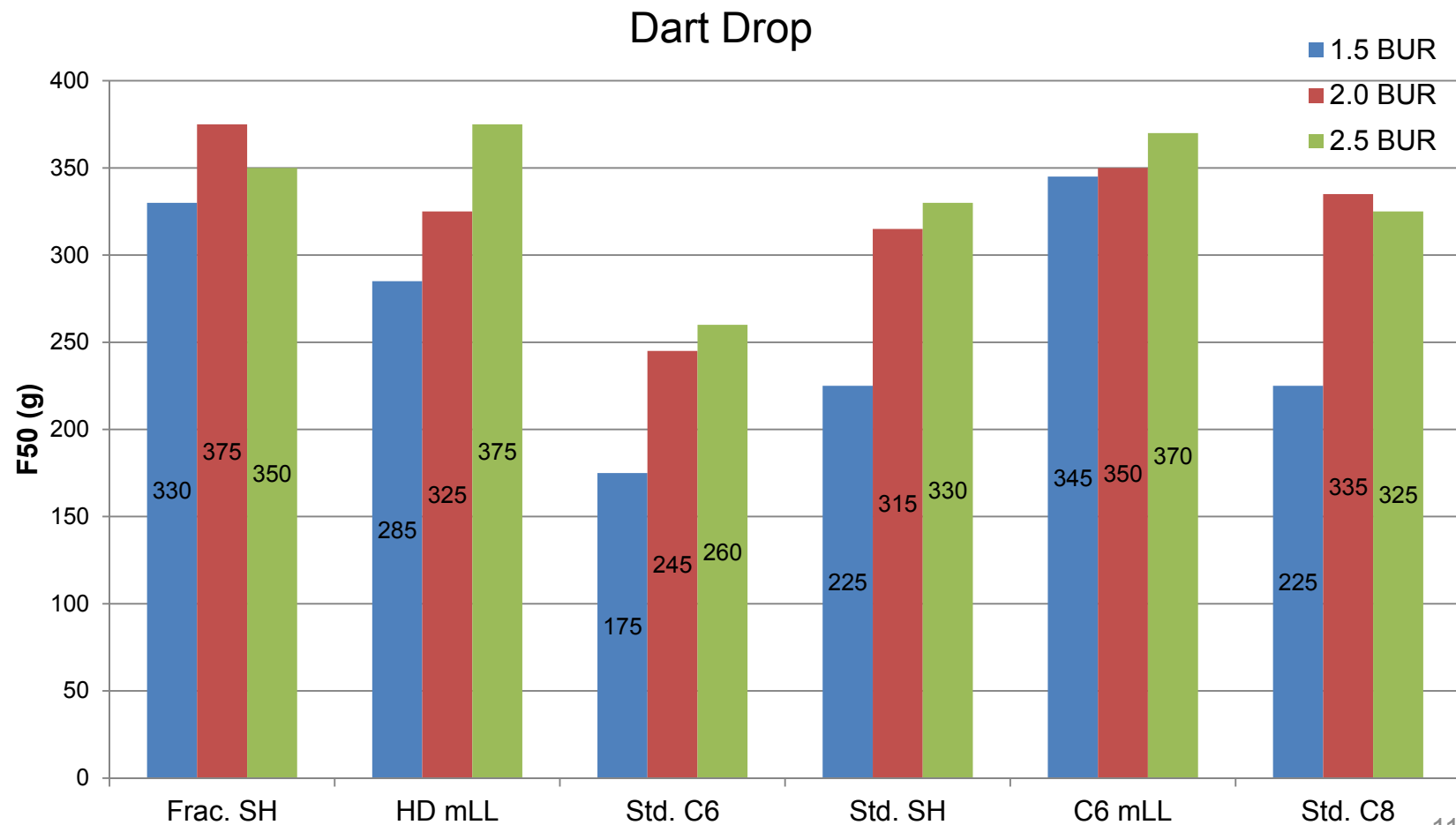
Dart Drop Results



- Dart Drop highly influenced by blowup ratio
 - Melt temperature and frostline height marginally significant
- BUR has roughly double the effect of MT and FLH over the ranges studied
 - BUR: +70 g from 1.5 to 2.5
 - MT: +36 g from 232C (450F) to 254C (490F)
 - FLH/DD: -30 g from 2.5 to 3.75
- Effect of LLDPE Type on Dart Drop Blend Performance:
 - C6 mLL, Frac. SH, and HD mLL > Std. C8 and Std. SH. > Std. C6

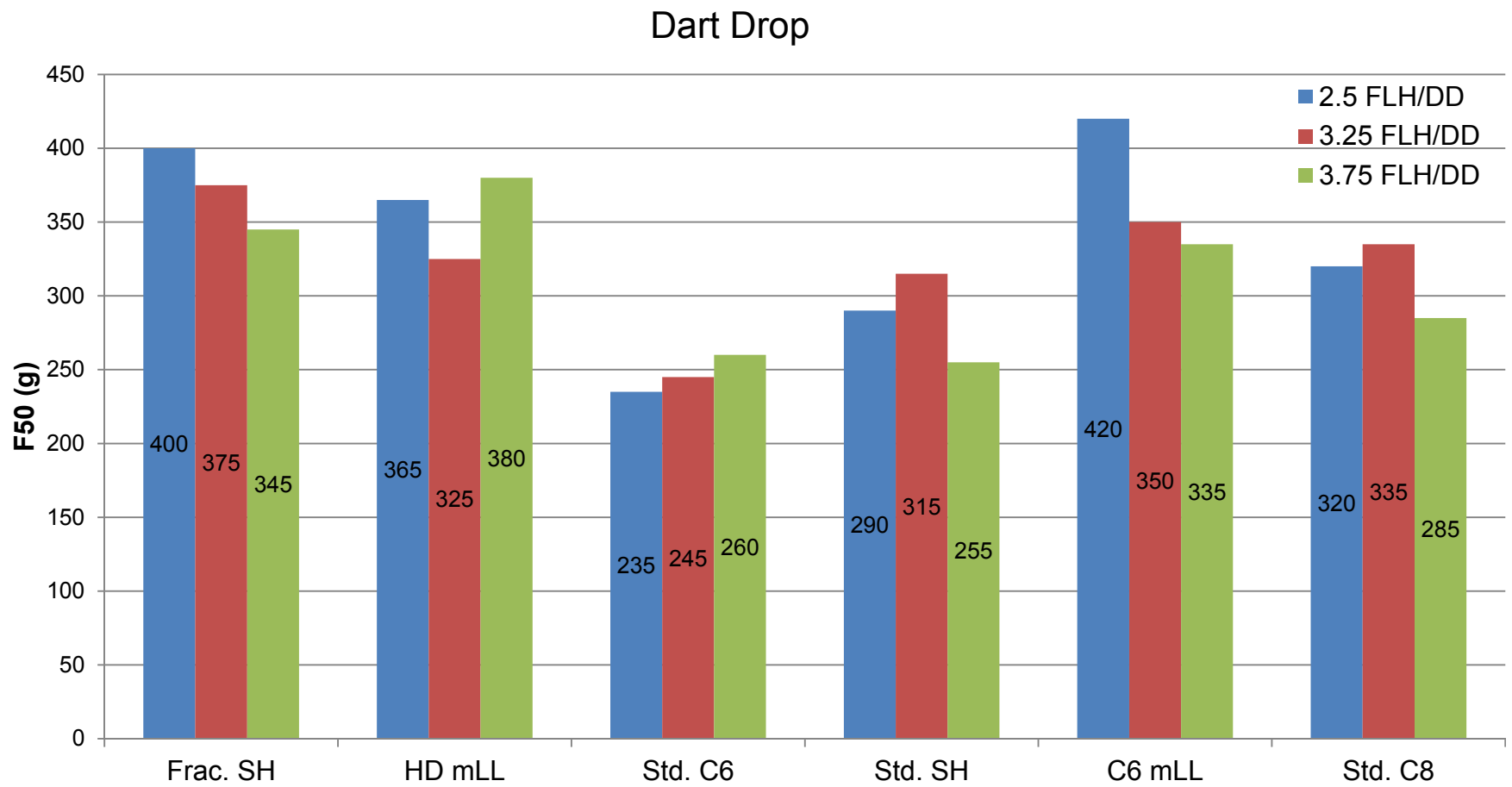
Effect of BUR on Dart Drop Performance

- Dart Drop increases with increasing BUR
- Frac. SH shows robust performance at all BURs



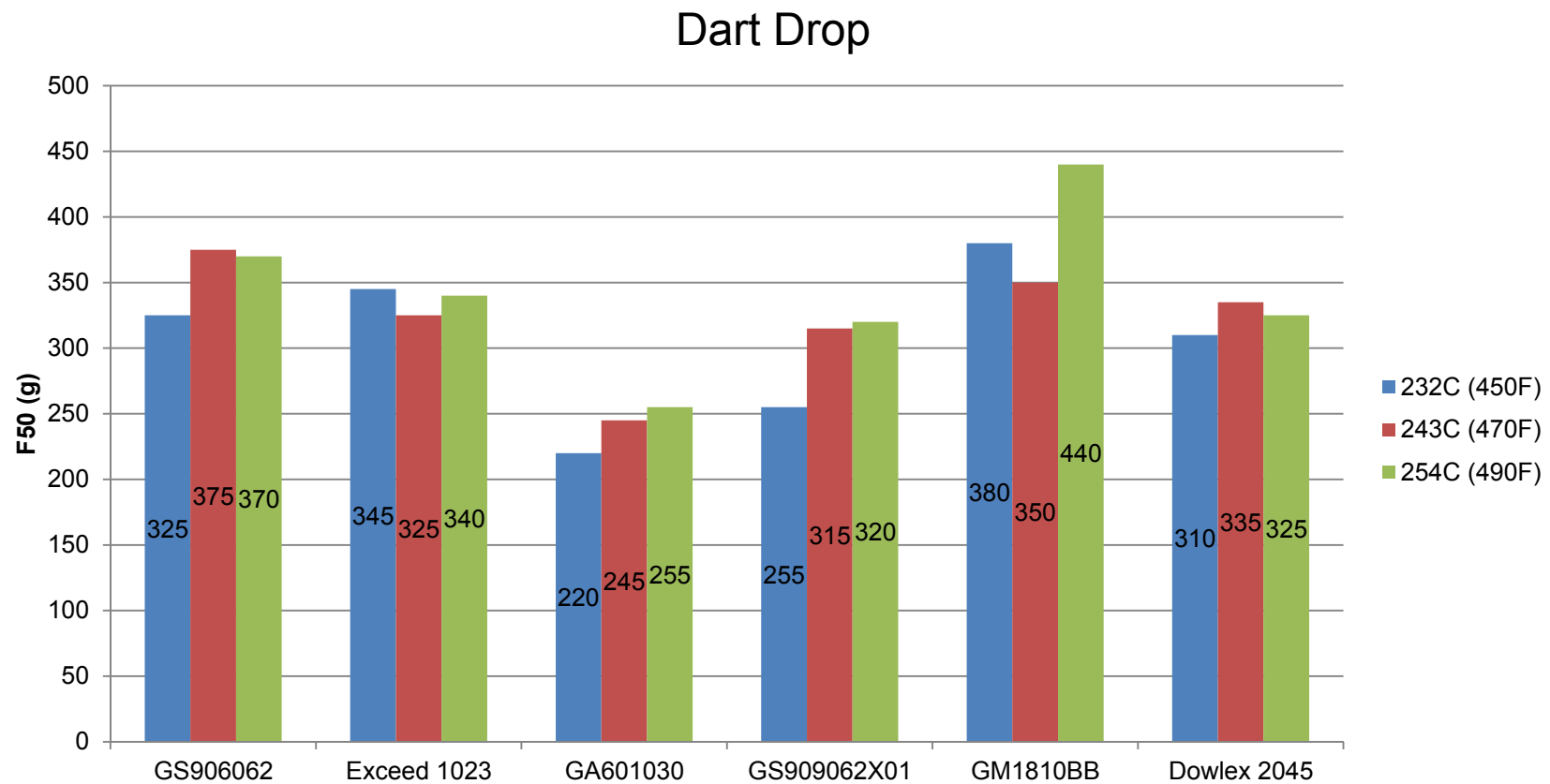
Effect of Frostline Height on Dart Drop Performance

- In general, Dart Drop decreases slightly with increasing Frostline Height



Effect of Melt Temp. on Dart Drop Performance

- Increasing Melt Temp increases Dart Drop slightly



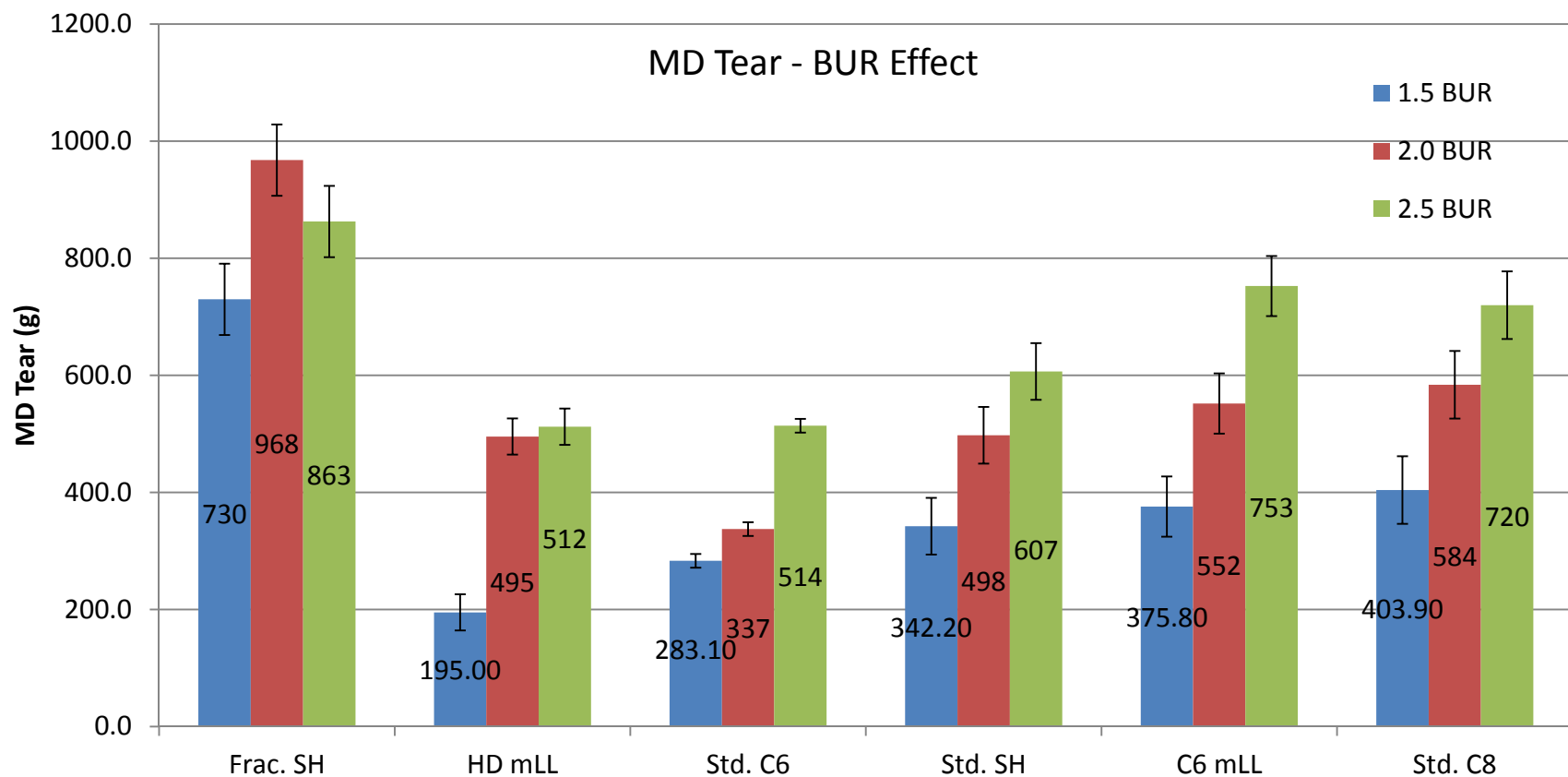
Machine Direction Tear Results



- MD Tear highly influenced by blowup ratio and melt temperature
 - Frostline height is not significant
- BUR has roughly double the effect of MT over the ranges studied
 - BUR: +270 g from 1.5 to 2.5
 - MT: +160 g from 450 to 490
- Effect of LLDPE Type on Dart Drop Blend Performance:
 - Frac. SH >>> Std. C8 & C6 mLL, > Std. SH, HD mLL. & Std. C6

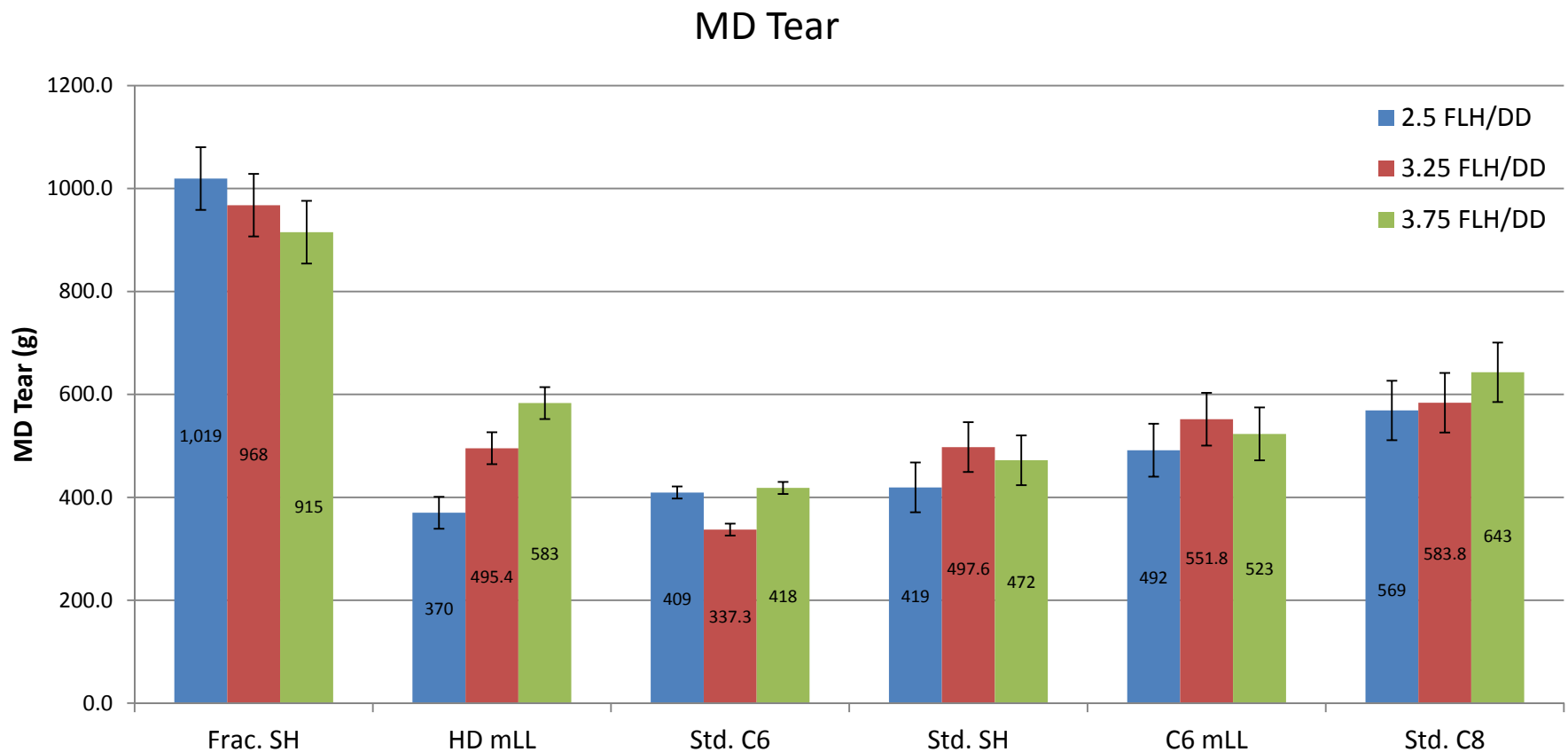
Effect of BUR on MD Tear Performance

- Increasing BUR improves MD Tear
- Frac. SH has superior MD Tear over a broad processing range
- Note: MD tear is typically lower than TD
 - Higher MD tear helps to maintain package integrity



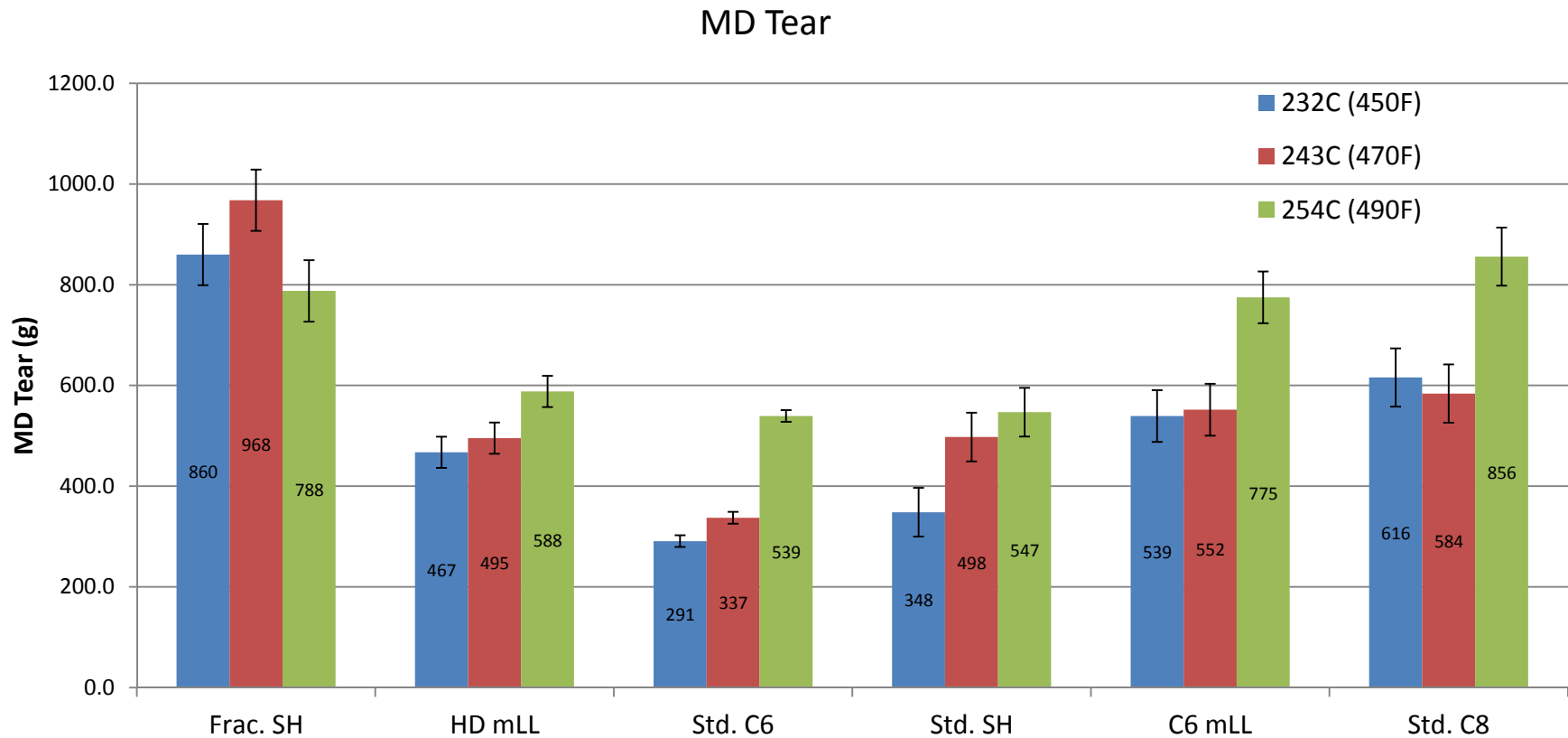
Effect of Frostline Height on MD Tear Performance

- In general, frostline height has no significant statistical effect on MD Tear
- Frac. SH maintains superior performance at all FLH



Effect of Melt Temp. on MD Tear Performance

- In general, increasing Melt Temp increases MD Tear
- Frac. SH has superior MD Tear at all temperatures

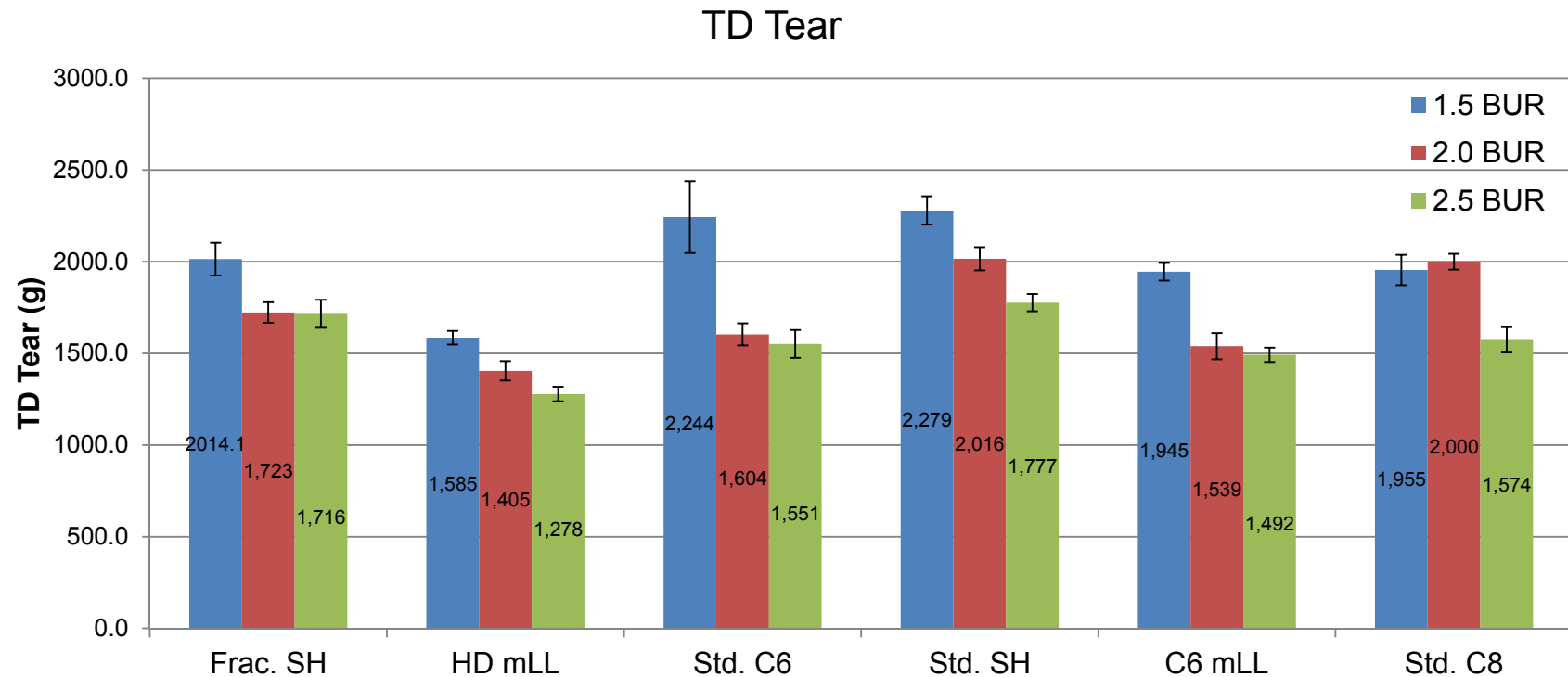


Effect of Melt Temp. on MD Tear Performance

- TD Tear highly influenced by blowup ratio and melt temperature
 - Frostline height is not significant
- BUR has roughly double the effect of MT over the ranges studied (Note the effects are negative)
 - BUR: -440 g from 1.5 to 2.5
 - MT: -260 g from 450 to 490
- Effect of LLDPE type on Dart Drop blend performance:
 - Std. SH, Frac. SH, and Std. C8 > Std. C6, C6 mLL, and HD mLL

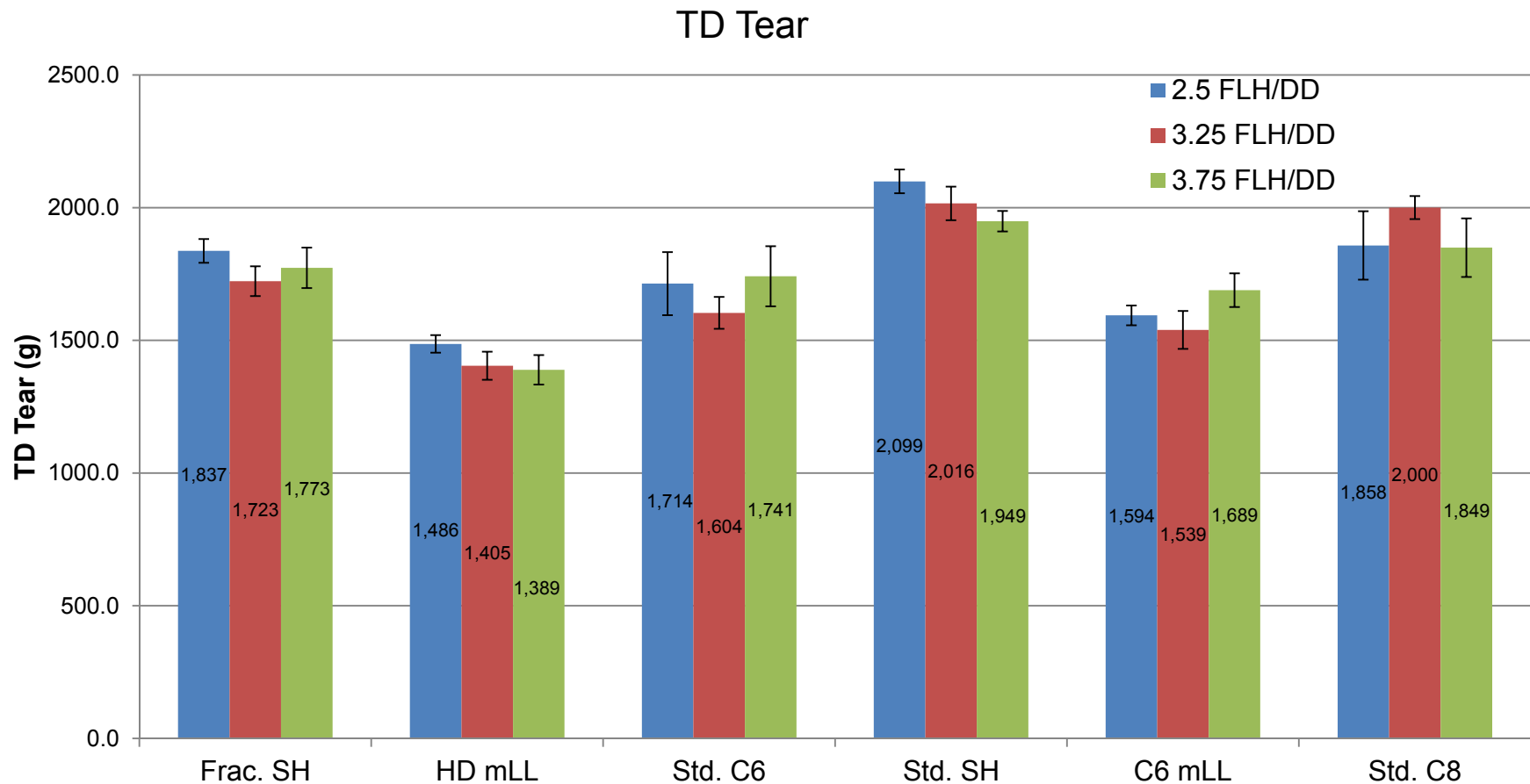
Effect of BUR on TD Tear Performance

- Increasing BUR decreases TD Tear
- TD Tear is comparable for all LLDPE blends
- Note: TD tear values are much higher than MD tear and therefore it is not the weak point in the structure



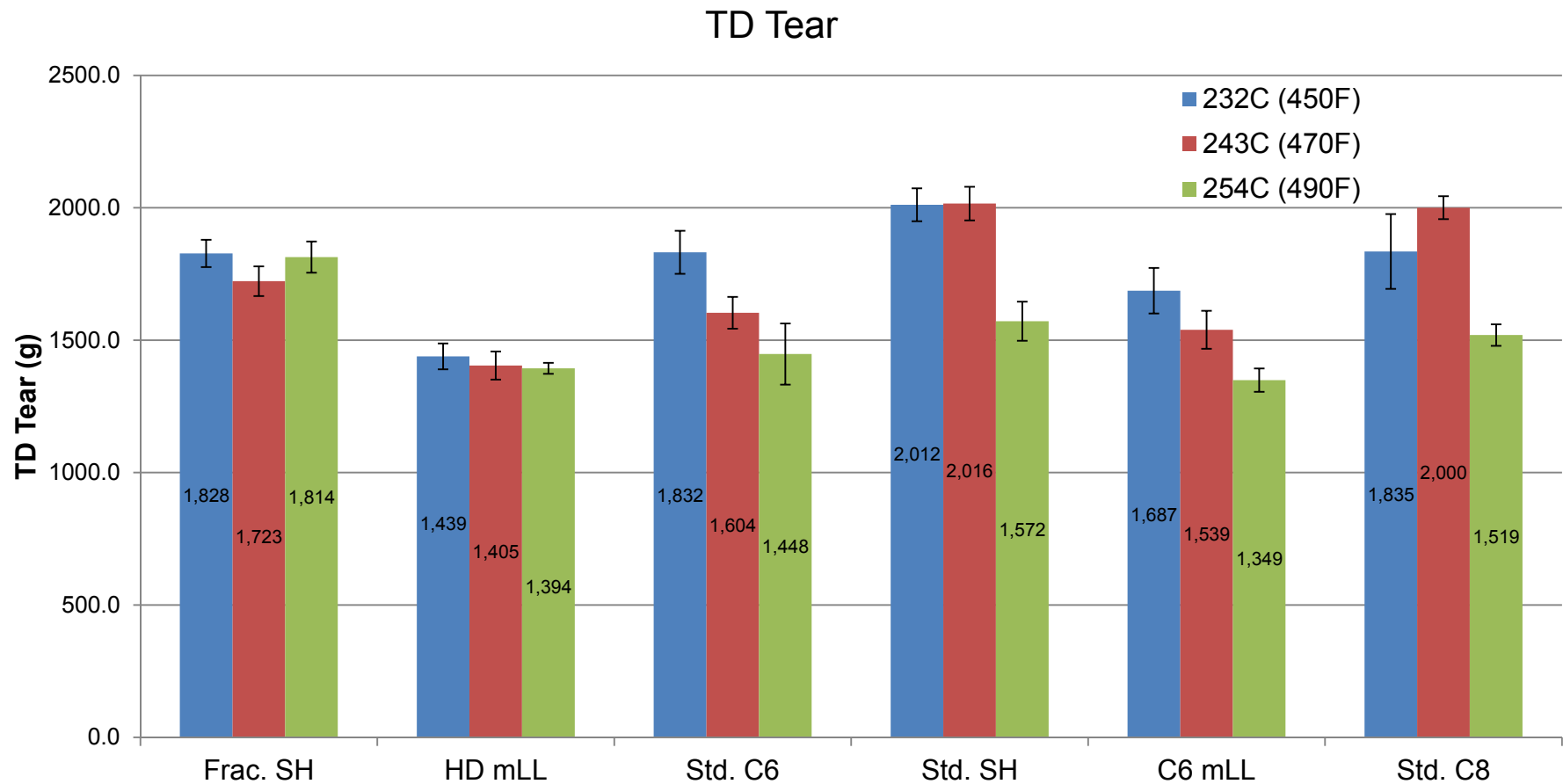
Effect of Frostline Height on TD Tear Performance

- In general, frostline height has no significant statistical effect on TD Tear



Effect of Melt Temp. on TD Tear Performance

- In general, increasing Melt Temp decreases TD Tear

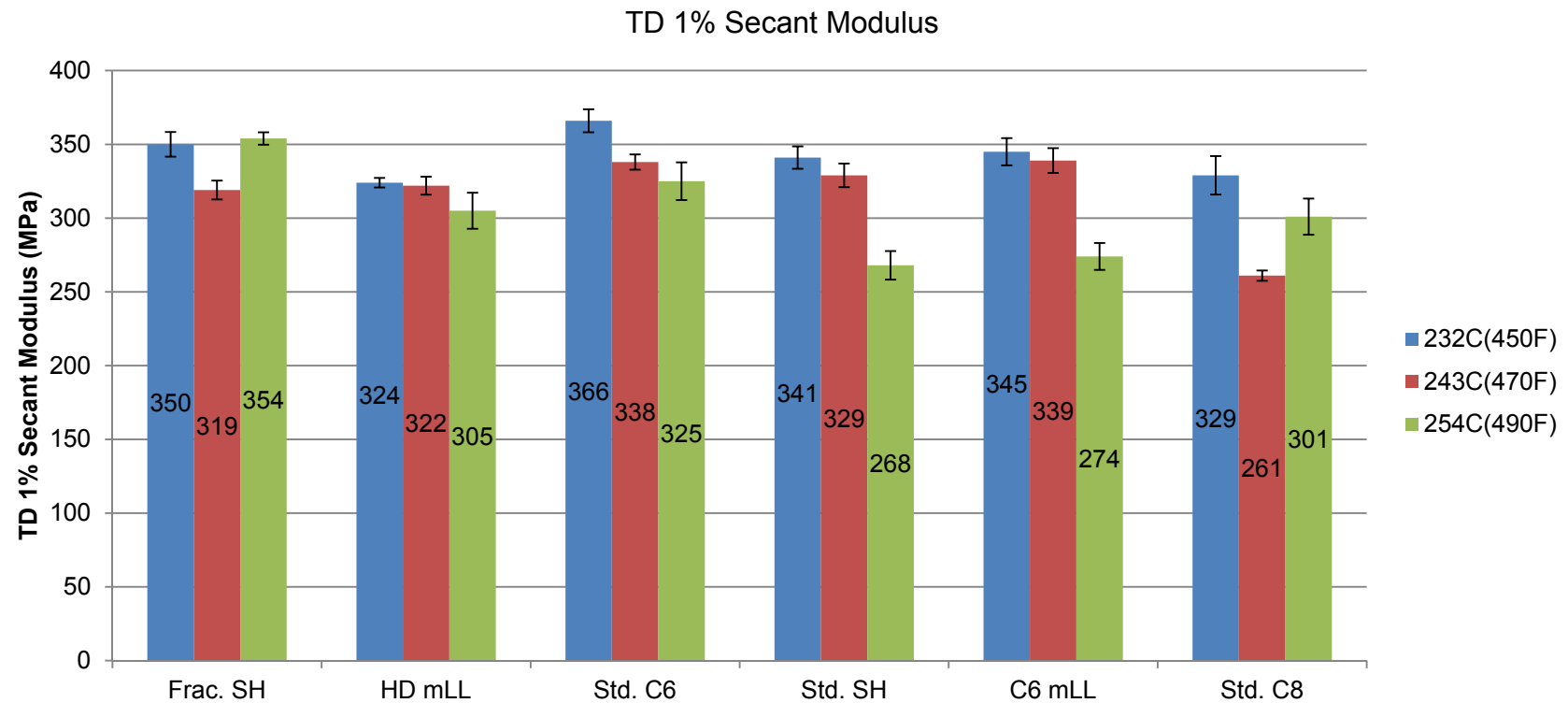


Transverse Direction Modulus Results

- Only melt temperature had a significant effect on the TD modulus values
 - Negative effect
 - On average the TD modulus decreased by about 11% when moving from 232C (450F) to 254C (490F)

Effect of Melt Temperature on TD Modulus

- In general, increasing Melt Temp decreases TD Modulus



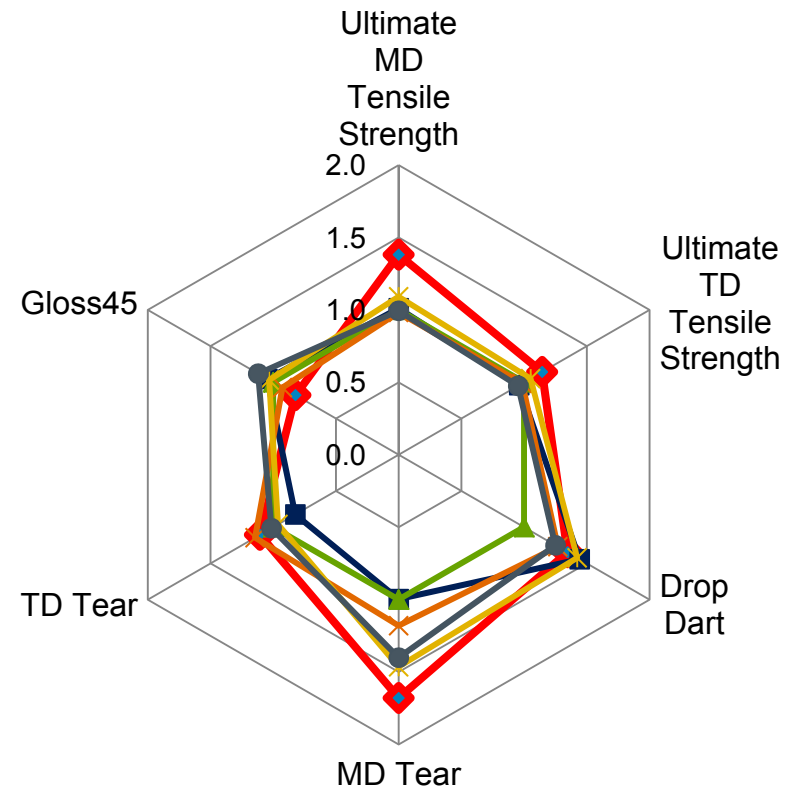
Summary of the Effect of Processing Conditions on the Performance of LLDPE Blends

	Increasing Blow Up Ratio	Increasing Frost Line Height	Increasing Melt Temp
Dart Drop	++	-	+
MD Tear	++	0	++
TD Tear	--	0	--
TD Creep	--	++	--
TD Modulus	0	0	--

Key	Meaning
++	Improved
+	Slight Improved
0	No Change
-	Slight Decrease
--	Decreased

Conclusions

- Summary of the Effect of Process Variables:
 - Overall effect of processing variables on film properties:
BUR > MT > FLH
- Overall LLDPE Blend Performance Comparison:
 - Resin Blends Compared Using the Following Optimal Processing Conditions:
 - BUR = 2.5
 - FLH/DD = 3.25
 - Melt Temperature = 232C (450F)
- Frac. SH LLDPE Blend offers:
 - Exceptional tear performance
 - Good balance of physical properties



◆ Frac. SH ■ HD mLL ▲ Std. C6
 ✕ Std. SH ✱ C6 mLL ● Std. C8

Thank you

PRESENTED BY

Maged G. Botros, Ph.D.

Application Development & Technical Service

LyondellBasell Industries

Maged.botros@lyb.com

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Dinshong Dong

Bob Holweger

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