Physical Property Modeling of Multilayer Heavy Duty Sack Films

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Agenda

- HDS market challenges
- Purpose of the work
- Model design principles
- Model validation
- Putting the models to use
- Conclusions and recommendations

Applications

Heavy duty shipping sacks have diverse needs

Purpose of the Work

- Develop **predictive, virtual design tool** that allows customers to make heavy duty bags that are…
  - **Higher performing**
  - **More cost effective**

- … while getting to market **faster** using **less resources**

Study Design Principles

- Study **3-layer**, coextruded **PE films**
- Use **Design of Experiments** (DOE) to study wide range of film design criteria and processing conditions
- Use resins that are **widely accessible** to bag producers
- Create model as **simple as possible** by limiting number of second order coefficients

Design of Experiments Setup

- Modified **4 factor, 3-level Taguchi** L18 model
  - 27 primary films
  - 6 validation films

- Key Inputs:
  - **Layer:** distribution, composition
  - **Film:** thickness, stiffness
  - **Processing:** blowup ratio, process time
  - **LDPE content** in film held constant

- Key Outputs
  - Secant Modulus (MD, TD)
  - Puncture
  - Haze
  - Dart
  - Tear (MD, TD)

Resins Used in This Study

Resin Type	Resin Code	Melt Index g/10min	Density g/cm^3	Properties
Single site octene LLDPE	sLLDPE	0.85	0.921	High performance seal
Z-N octene LLDPE	o-LLD	0.80	0.926	General purpose seal
Z-N hexene LLDPE	h-LLD	0.80	0.926	Bulk layer
Z-N butene LLDPE	b-LLD	0.80	0.921	Bulk layer
HDPE	HD	0.72	0.962	Stiffener
LDPE	LD	0.25	0.920	Processing aid

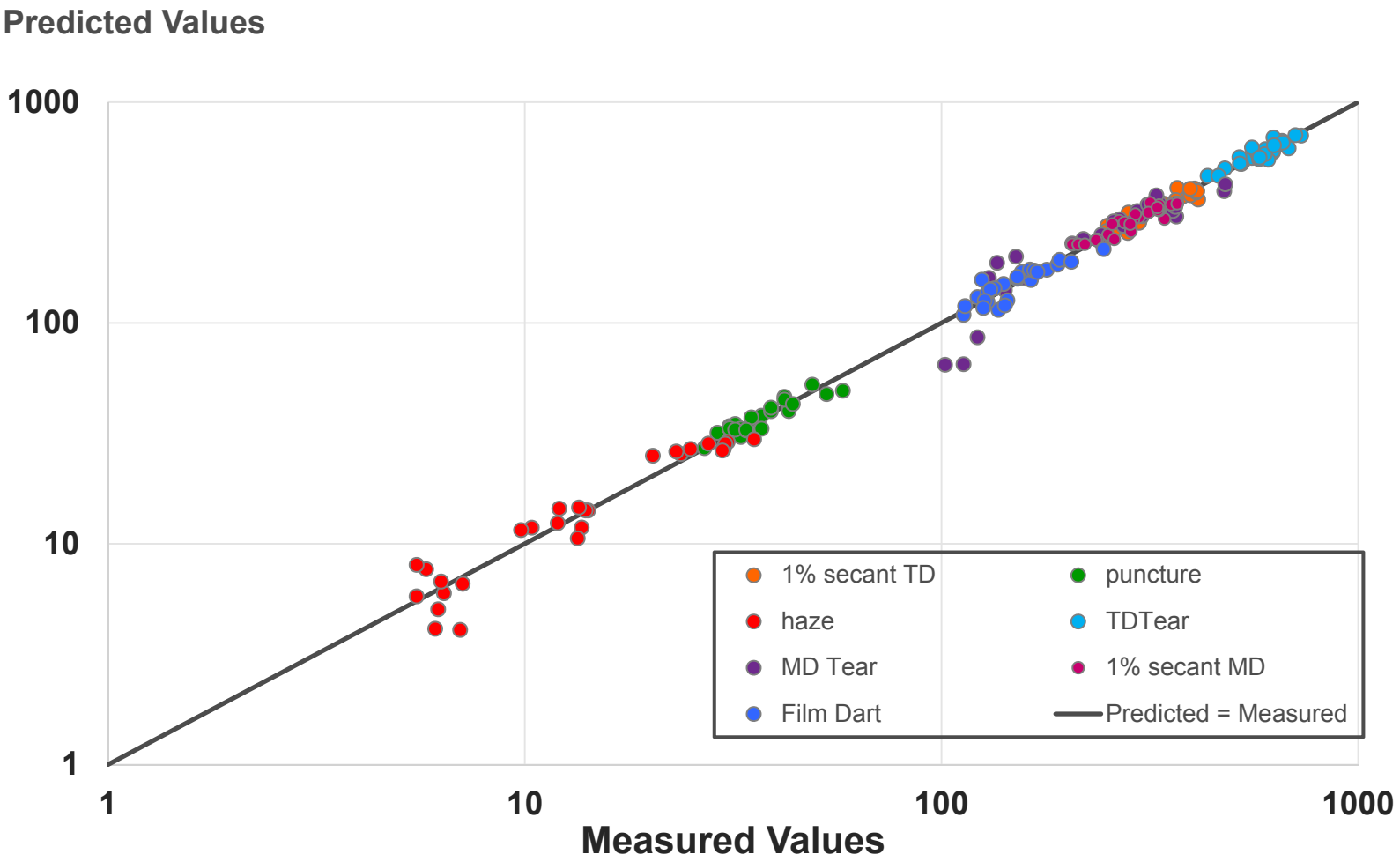
Wise Words from a Famous Statistician

George Box (1919-2013)

"All models are wrong, but some are useful."

"The ability to devise **simple but evocative** models is the signature of the great scientist… **over-parameterization** is often the mark of **mediocrity**."

Model Results: Highly Predictive



The Model in Use: Salt Bag Redesign

Performance of Commercially Available Packages

	Salt Pellet Bag	Rock Salt Bag A	Rock Salt Bag B
Layers	3 – LLDPE/ MDPE/ LLDPE	2 – LLDPE/LLDPE	3- All LLDPE
Thickness, mil	6.5	7	6.75
Secant 1% MD, MPa	243	256	252
Secant 1% TD, MPa	262	293	265
Tear MD, g	819	1100	884
Tear TD, g	4277	4389	4151

Model in Use: Salt Bag B Redesign

Film	Core Resin*	BUR	Dart, g	MD tear, g	Puncture j/mm	1% Secant MD MPa
Target, 6.75 mil			675	884	--	252
All sLLDPE	sLLDPE	1.7	1200	3060	42	251
Butene core	b-LLDPE	2.5	1130	2750	31	251

Film	Core Resin*	BUR	Dart g	MD tear g	Puncture j/mm	1% Secant MD MPa
Target, 6 mil			675	884	--	273
Butene core	b-LLDPE	1.7	770	2064	29	276

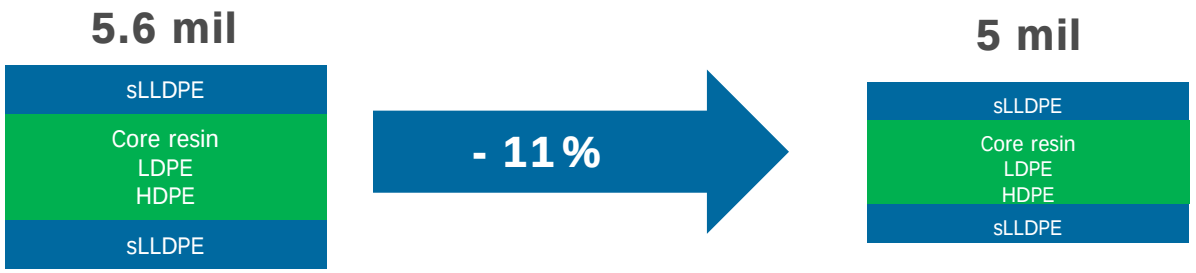
* Includes LDPE in the core

Model in Use, part 2 - Resin Bag Redesign

	Existing	Downgauged targets
Thickness, mil	5.6	5.0
Secant 1% MD, MPa	294	330
Dart, g	560	560
Tear MD, g	1300	1300
Puncture, j/mm	21	24

Model in Use, part 2 - Resin Bag Redesign

Film	Core Resin*	BUR	Dart g	MD tear g	Puncture j/mm	1% Secant MD MPa
Target, 5.6 mil			560	1300	21	294
All sLLDPE	sLLDPE	1.7	1200	3060	42	251
Butene core	b-LLDPE	2.5	1130	2750	31	251



Film	Core Resin*	BUR	Dart g	MD tear g	Puncture j/mm	1% Secant MD MPa
Target, 5 mil			560	1300	24	330
All sLLDPE	sLLDPE	1.7	685	1650	34	336
Butene core	b-LLDPE	1.7	495	1200	24	336
Butene core	h-LLDPE	2.5	680	1410	28	336

* Includes LDPE in the core

Conclusions and Future Work

- Simple model successfully developed to **predict performance** of **complex 3 layer** coextruded films
- Model enables **creation** of new applications and **optimization** of existing ones
- Future work includes:
  - Expanding model to **5 layer** films
  - Predicting **creep and dimpling** performance

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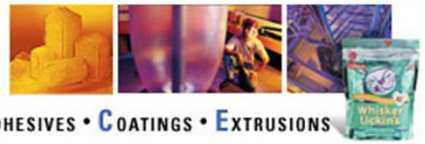

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