ARM ANNUAL MEETING

NEW ORLEANS, 27 SEP 2016

STIFFNESS MODELS

for multi-layer rotomolded parts

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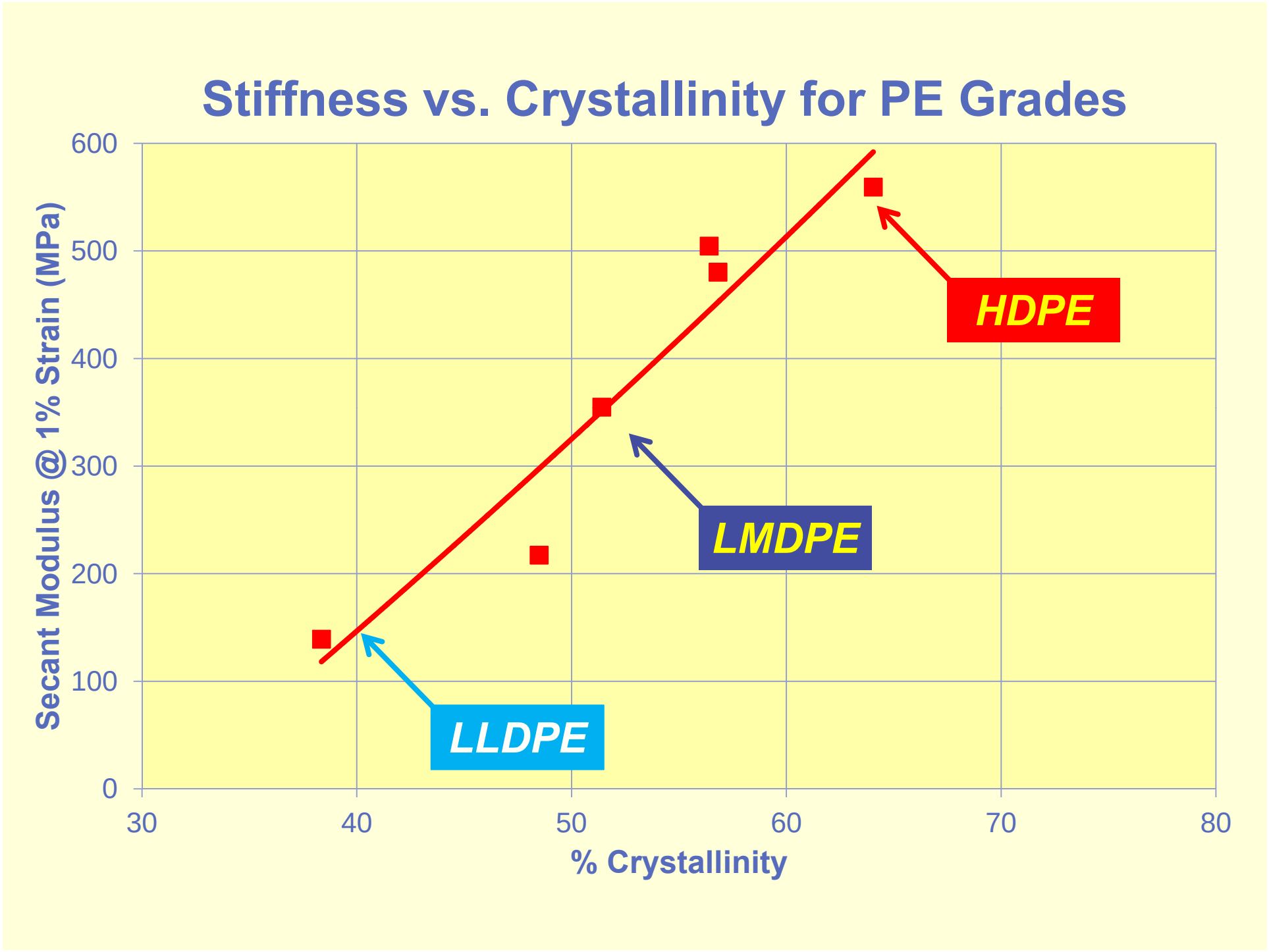
MAJOR MATERIALS ISSUE

- PE represents 95%+ of all material used in rotomolding
- PE has low stiffness
- Can become a real problem for designers of large parts
- Limited strategies exist for enhancing stiffness

USE A HIGHER DENSITY PE

- Stiffness improvements for LMDPE grades are modest – maybe 15%
- 50% increase LMDPE→HDPE
- Moldability may be worse
- Impact strength may be less
- Increased warpage potential
- Costs of some grades are higher


Stiffness vs. Crystallinity for PE Grades
Secant Modulus @ 1% Strain (MPa)
600
500
400
300
200
100
0
30
40
50
60
70
80
% Crystallinity
HDPE
LMDPE
LLDPE

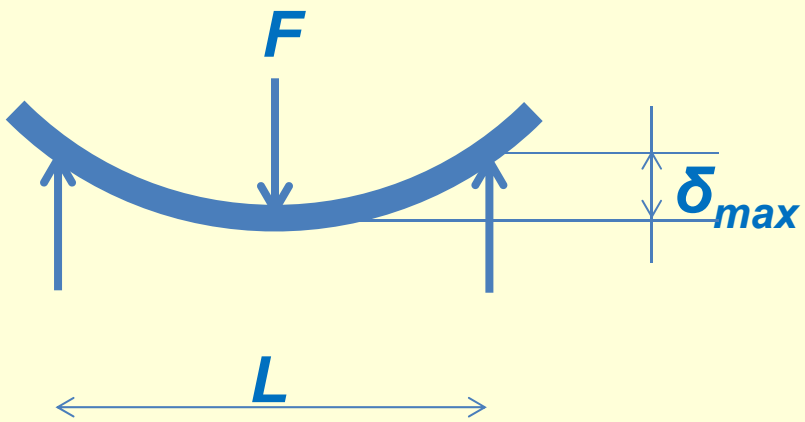
DON'T USE PE

- A few stiffer materials exist (that can be rotomolded)
- PP, PA & PC are 2-3 times as stiff
- PP & PA can have poor impact, especially at low temperatures
- Much more expensive
- Can be significantly more difficult to mold

MAKE IT THICKER

- Extremely effective
- Stiffness increases to power ^{3}
- Adds weight
- Adds cost
- Increases cycle time
- Increases warpage potential

MAKE IT THICKER



Deflection (bend):

$$\delta = \frac{F L^3}{4 E B t^3}$$

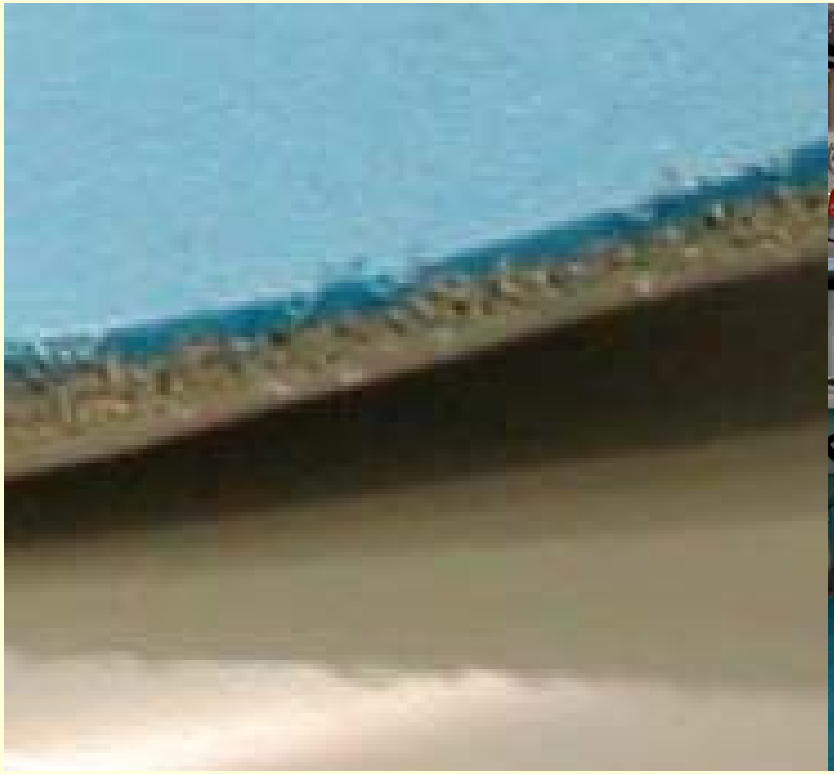
E = Young's Modulus for material

B = Width of beam

t = Thickness of beam

USE MULTI-LAYERS

- PE skin - PE foam - PE skin sandwich
- Improves stiffness with low weight, by creating a thicker section
- “I-Beam” effect: stress concentrates mainly in the outer skins
- Can use HDPE skins?
- Cost effective



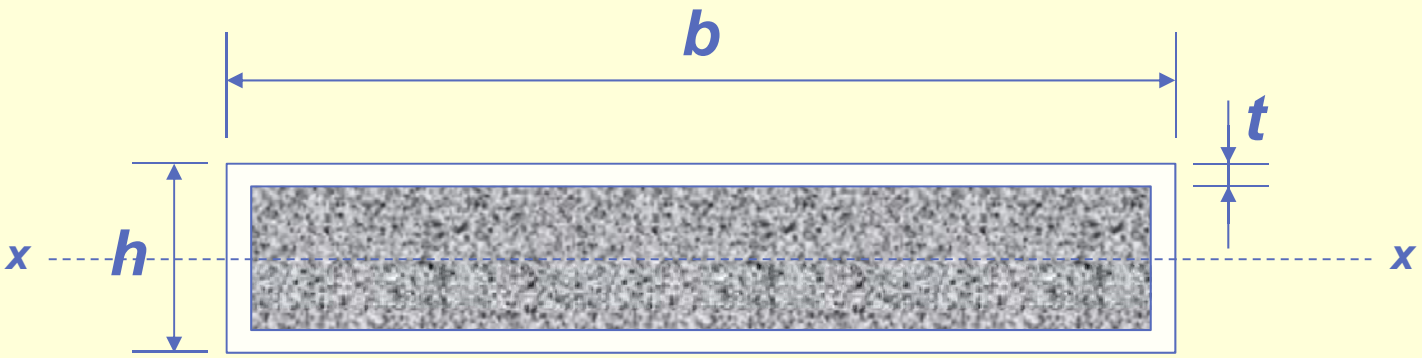

THE ENDEAVOR TROPHY
topper
Xenon
topper
Omega

MULTI-LAYER ISSUES

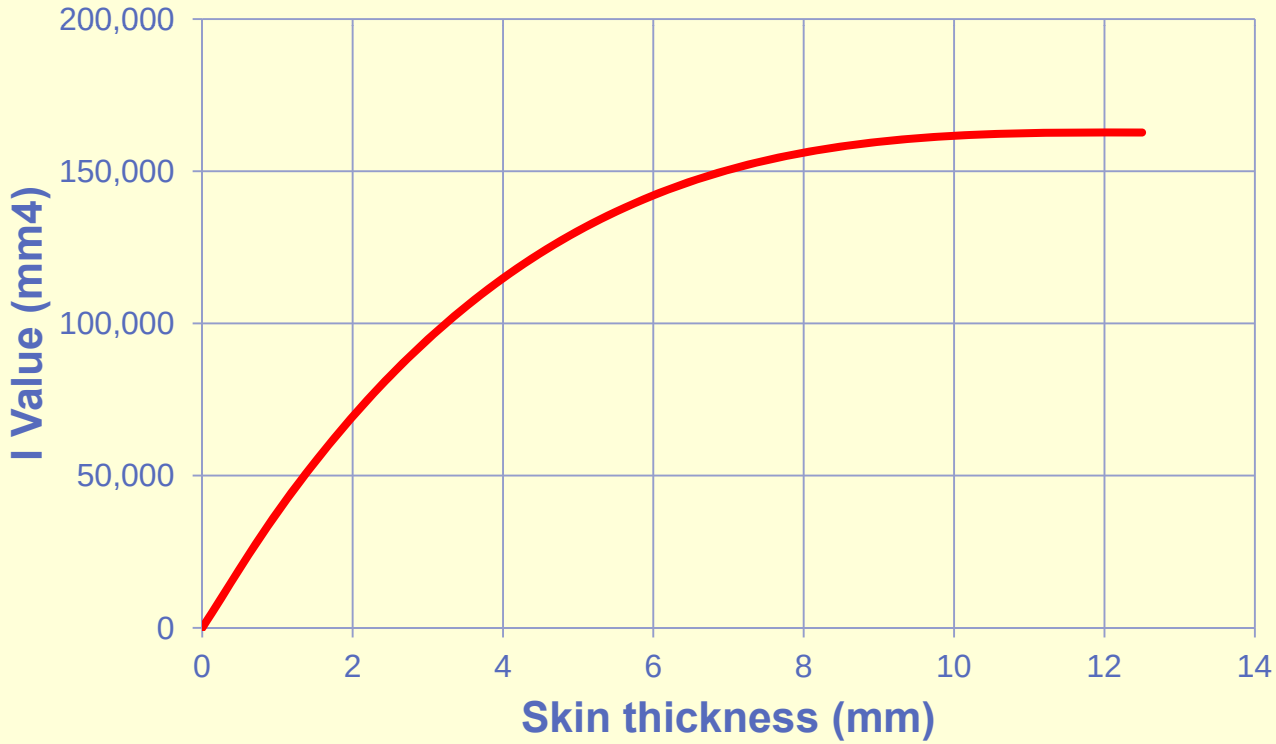
- Increases process complexity on most conventional machines
- Does the foam do anything other than separate the skins?
- Is a “stiffer” foam worth having?
- Real lack of hard data on potential improvements
- Lab tests on foams are inconclusive

MORE REALISTIC TESTING

- Rotomolded planks, 125 mm x 25mm section, variable skin thickness
- Used 2 skin materials: LMDPE & HDPE
- Used 3 PE foam alternatives:
  High, Medium & Low blow-up ratios
- 3-point bend test, 400mm span,
  5 replicates, near-ASTM conditions

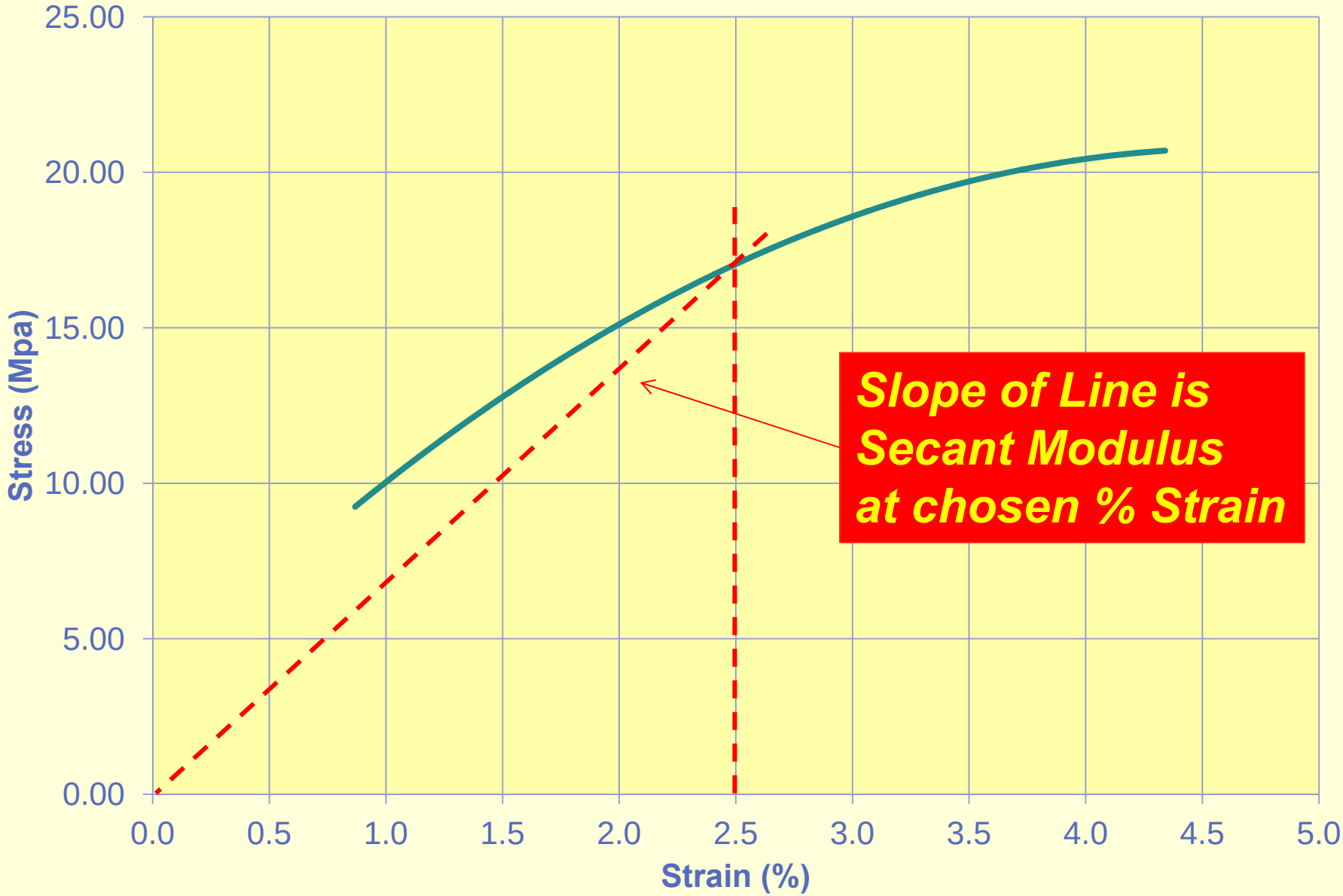


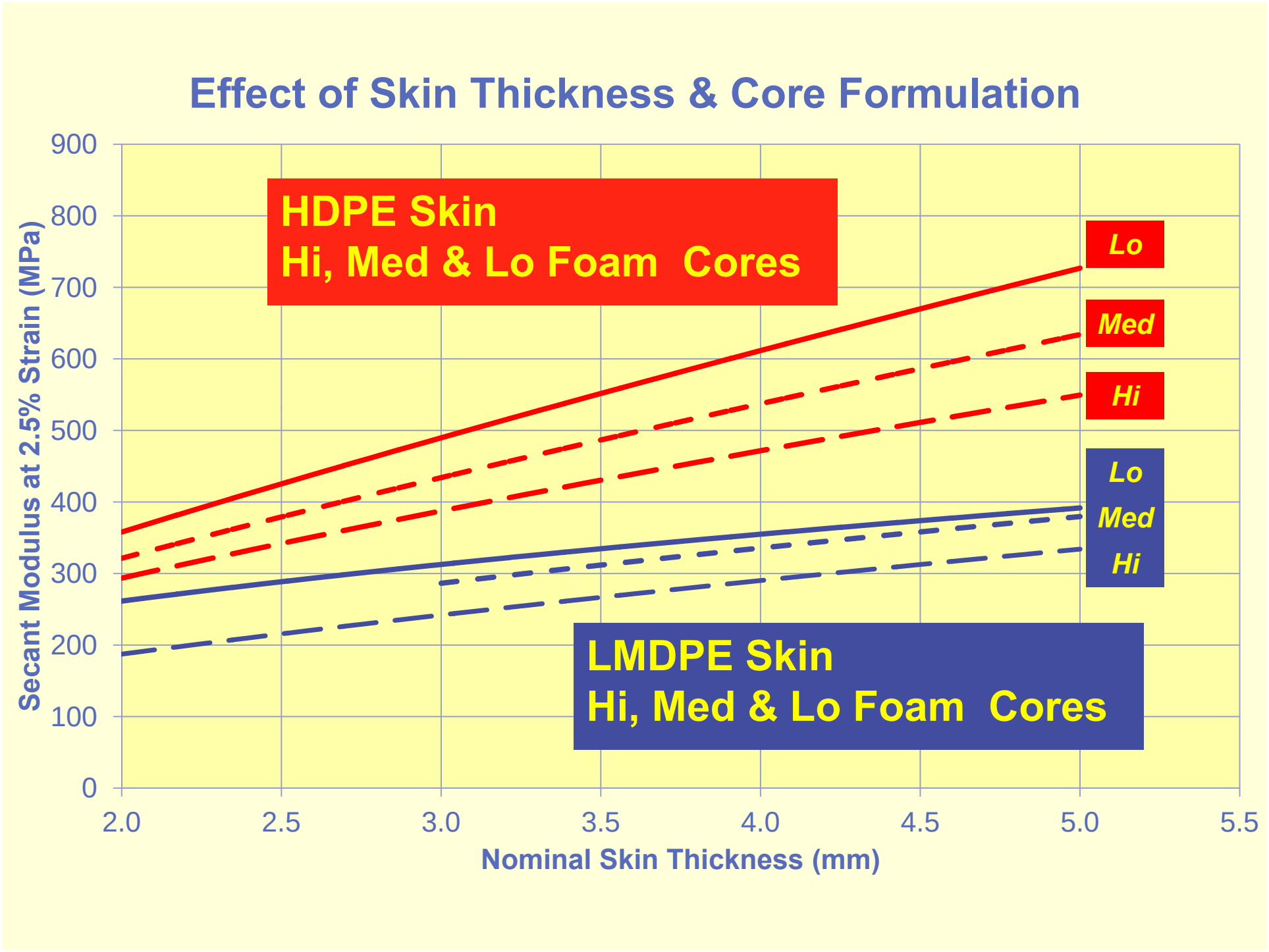
$$I_{x\text{-}x} = \frac{b\,h^3}{12}$$




TOP
FRONT A

Typical Stress – Strain Curve for Rotomoulded Plank




Effect of Skin Thickness & Core Formulation
HDPE Skin
Hi, Med & Lo Foam Cores
LMDPE Skin
Hi, Med & Lo Foam Cores
Lo
Med
Hi
Lo
Med
Hi
Secant Modulus at 2.5% Strain (MPa)
900
800
700
600
500
400
300
200
100
0
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Nominal Skin Thickness (mm)

CONCLUSIONS

- Separating skins enhances stiffness
- Using HDPE as a skin material had a positive effect, but created warpage
- Use of foam sandwich enhances stiffness
- Stiffness mainly due to skin, not foam
- Foam stiffness is much lower than skin stiffness
- Lack of design data makes designers uncertain
- “Plank” testing can produce much more realistic evaluations

HOW ROTOMOTIVE CAN HELP

- Research & consultancy organisation, focused 100% on rotomolding
- Research links with university-based polymer science & FEA design teams
- Able to manufacture sample-sized new materials, rotomold them and test them
- Experience in evaluating full-sized molded parts, including creep testing
- Able to work alone (in-house funding) and/or with development partners