Correlation of Molecular Properties with Mechanical Behaviour for High Density Polyethylene

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Overall research objectives

- *Civil engineering*: mechanical properties such as creep are important to characterize the behavior of the polymeric material, including structural failure characteristics.
- *Chemical engineering*: material properties such as molecular weight averages, molecular weight distributions and branching indicators offers insight into the molecular microstructure of polyethylene.
- *Collaboration of chemical and civil engineering*: the goal of the project is to develop a theoretical model for predicting mechanical behavior of polyethylene based on its chemical properties.

Materials

- Industrial HDPE resin
  - Different mechanical properties
  - Similar chemical characteristics

Chemical Properties	PE1	PE2	PE3
Density	0.963	0.963	0.95
Melt index	0.25	0.73	0.3
Melt point (°C)	130.06	134.84	134.53
% crystallinity	53.68%	56.32%	59.81%
Mechanical Properties			
Tensile Strength at Yield (Mpa)	27	32	31
Elongation at Yield (%)	9	7	8
Elongation at Break (%)	600	35	450
Tensile Modulus (Mpa)	1,790	2,620	2,340
Flexural Modulus3 (Mpa)	1,200	1,720	1,620
Impact Brittleness Temperature (°C)	-76	-76	-76
Environmental Stress Crack Resistance4 (hours)	65	10	15

- More resins tests are planned

Experimental methods

- Tests used in this project
  - One objective of our project is to find test that are most useful in our investigations.

Chemical	Rheological	Mechanical
GPC	Capillary rheometer	Creep and relaxations
DSC	DMA -Parallel plate rheometer	Constant strain and stress rate
NMR		
CRYSTAF		

- Rheological test is very sensitive to molecular structure of the material, but it is difficult to quantify the results. Conclusion can only be drawn base on relative terms.

Preliminary results

- The question we are trying to answer is "What essential molecular quality makes these resins have all the different mechanical properties?"
- So far chemical tests could not detect any significant property differences for the three resins
- Mechanical behavior of these HDPE are very different, especially between PE1 and PE2
  - Environmental stress cracking resistance (ESCR) of PE1 is six time greater than ESCR of PE2
  - PE2 have greater tensile strength and tensile modulus than PE1

Based on **DSC**, PE1, PE2 and PE3 all have similar percent crystallinity. The shape of the melting heat flow curve also do not indicates any major composition differences. (**Figure 1**)

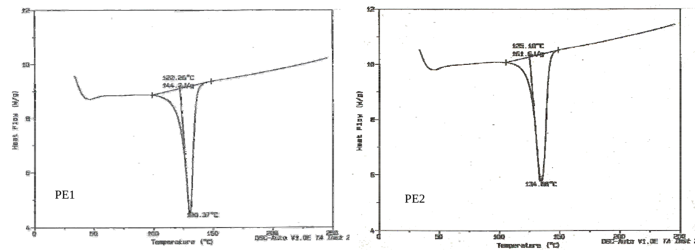

Figure 1: DSC results for PE1 and PE1

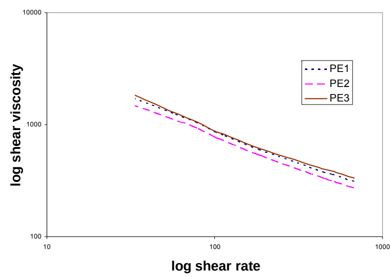

Figure 2: Capillary shear viscosity measurements at 230°C

Capillary rheometer results showed all three resins behaved similarly, even at elevated temperature (**Figure 2**). Further investigation was carried out using parallel plate rheometer.

Results from **parallel plate rheometer** indicates there is MW difference between the resins (**Figure 3**). Detailed information about MWD will be obtained using GPC.

Rheological test seems to be the most promising in detecting molecular property difference for our resins. More focus will be put on using DMA techniques as the primary analysis tool.

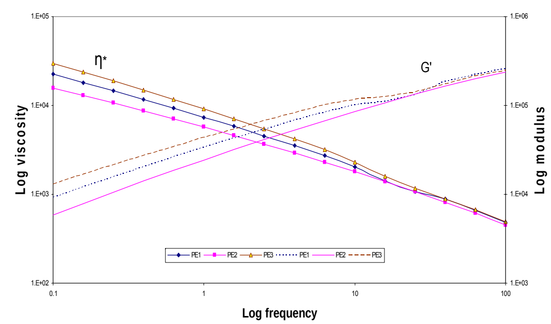

Figure 3: DMA frequency scan results at 150°C

Issues and Obstacles

- Pipe piece and resin contain fillers which interfere with chemical testing (e.g. fillers blocking GPC columns)
- Methods for filler removal is needed

Next step

- Applying statistical method to resin testing. To investigate whether the small differences observed in chemical tests are statistically significant or not.