

# Characterization of Polyethylene Pipes Used in Ground Heat Exchangers

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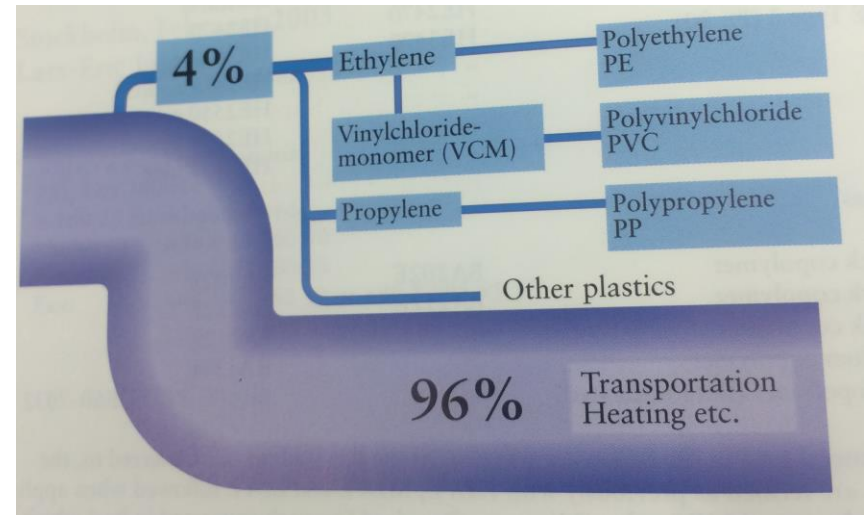
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# Introduction

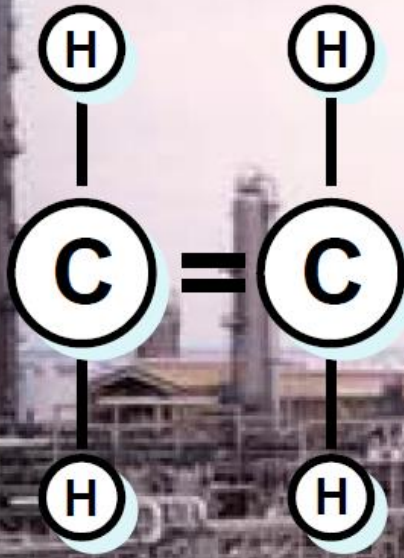
- Bioplastics
- Fossil-fuel plastics
- Biodegradable plastics



Ref.: Palstice pipe for water supply and sewage disposal

# What is Polyethylene?

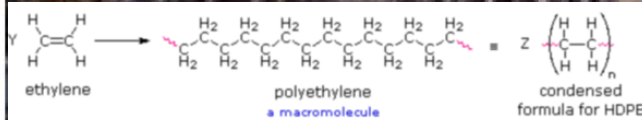
## ETHYLENE



**Colorless Gas**  
**Odor = Slightly Sweet**  
**Origins = Refinery Gas & Liquefied Petroleum Gases**  
**Mol. Wt. = 28**

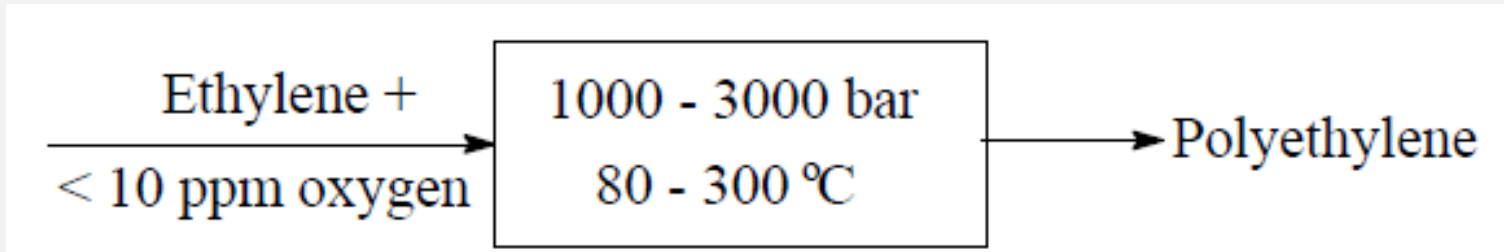
**World Capacity\***  
**128 Million Tons. (2005 est.)**

\* World Petrochemical Review (Oct 2005)

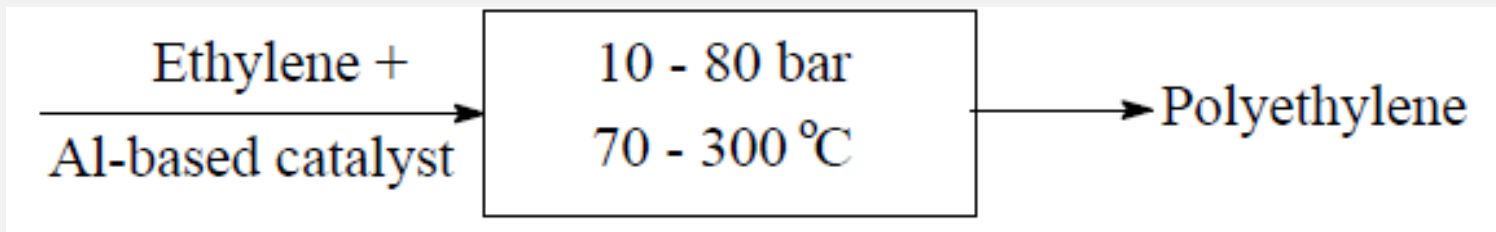


# Polyethylene(PE) Structures

In 1932 by ICI



In 1952 by Ziegler-Natta



# Changing Properties of PE

- **Low density polyethylene (LDPE)**

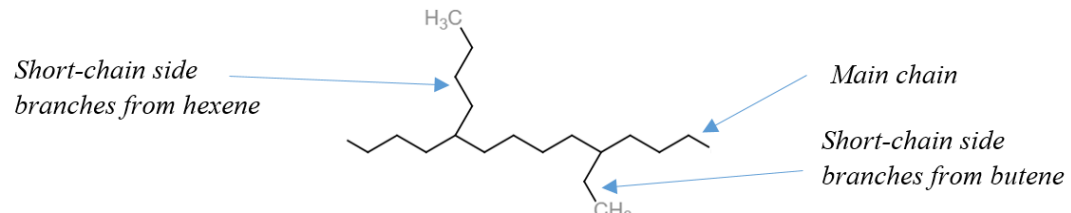
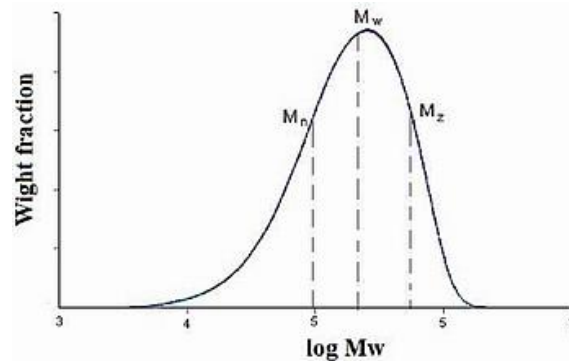
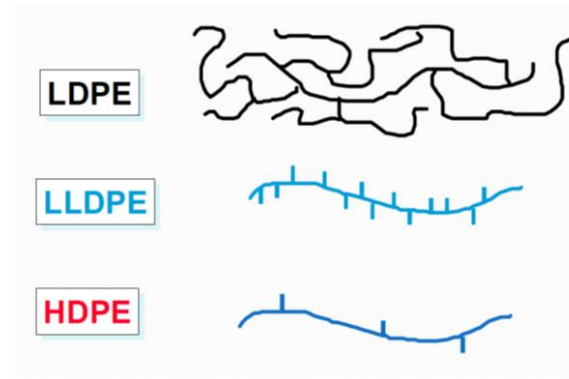
high temp and high pressure, long side chains, low density, (eg. Plastic bags)

**Properties:** soft, flexible and translucent with a waxy surface and hydrophobic

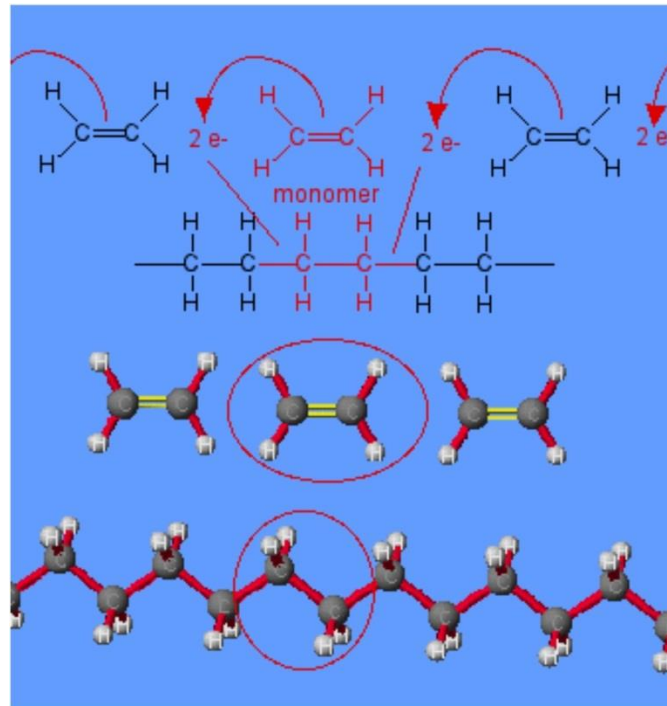
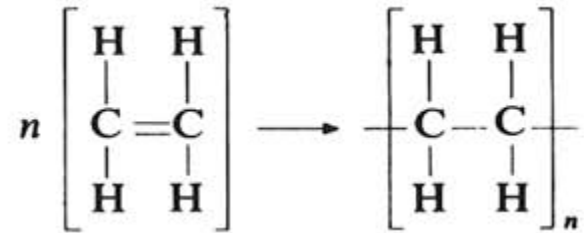
- **High Density Polyethylene**

**(HDPE)** lower temp and pressure, very few short branches, dispersion forces more effective, high density (eg. plastic bottles)

**Properties:** rigid, stronger and less blurry than LDPE, slightly flexible, waxy surface and hydrophobic



# Ethylene & Polyethylene



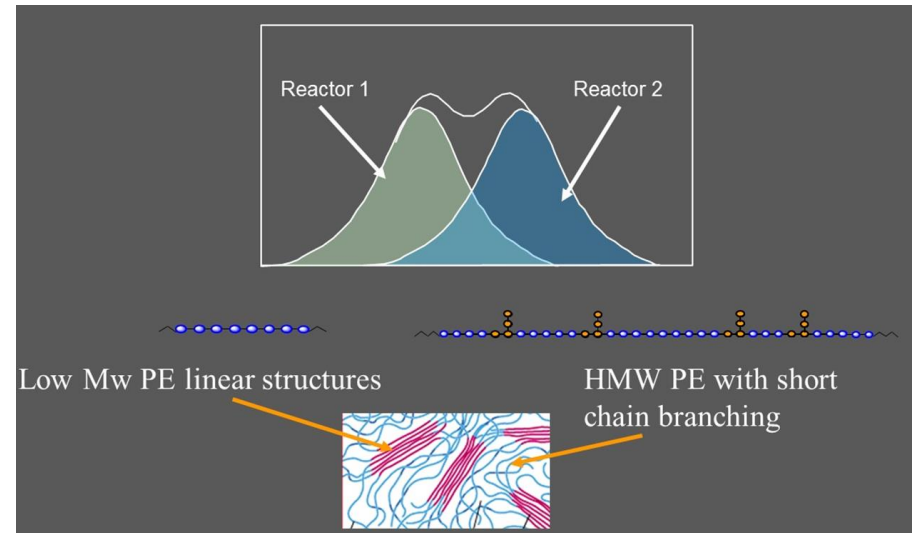
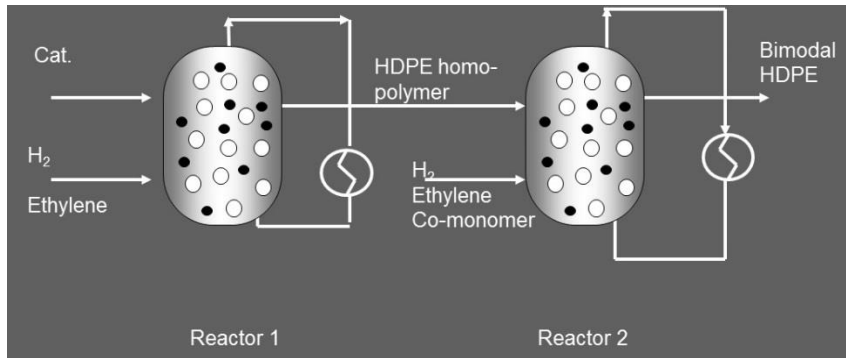
# PE Pipes Development

Generation	Period	Development
1st	~1970' s	LD (PE32, PE40) HD (PE50, PE63)
2nd	~1980' s	MD (PE80) ~1990' s HD (Unimodal PE80)
3rd	~present	MD (Bimodal PE 80) HD(Bimodal PE80, PE100, PE100+)

In US PE4710 introduced to the market in 2005

- 4 shows physical property , density(  $>0,947$  to  $0,955 \text{ g/cm}^3$  )
- 7 shows performance property, SCG (500 h PENT)
- 10 shows design stress for water (1000 psi)

# Bimodal PE Process & Distribution



Source: <http://fr.slideshare.net/yogeshdev7/sabic-pe100-andpe100plusmaterialsandpipesho>



# Advantages of the Bimodal PE

- Low molecular fraction gives:
  - ✓ Good processability
  - ✓ High stiffness
  - ✓ High crystallinity
- High molecular fraction gives:
  - ✓ High resistance to slow crack growth



# PE Pipe Properties

<i>Characteristic</i>	<i>Standard</i>	<i>PE 80</i>	<i>PE 100</i>
Minimum Required Stress, MRS	EN ISO 9080	8 MPa	10 MPa
Density to 23° C	ISO 1183	0.94 g/cm <sup>3</sup>	0.95 g/cm <sup>3</sup>
Melt mass- flow rate (MFR)	EN ISO 1133	± 20% RM	± 20% RM
Min. Tensile strength	EN ISO 6259	15 MPa	19
Elongation at break	EN ISO 6259	350 %	350 %
Oxidation induction time - OIT	ISO 11357-6	>20 min	>20 min
Hydrostatic strength 20°C, 100 h	EN ISO 1167	10 MPa	12.4 MPa
Hydrostatic strength 80°C, 165 h	EN ISO 1167	4.6 MPa	5.5 MPa
Hydrostatic strength 80°C, 1000 h	EN ISO 1167	4 MPa	5 MPa
Resistance to slow crack growth e ≤ 5mm – Cone test	ISO 13480	s ≤ 10 mm/day	s ≤ 10 mm/day
Resistance to slow crack growth e > 5 mm – Notch test	EN ISO 13479	SDR 11 – 8 bar	SDR 11 – 9.2 bar
Resistance to rapid crack propagation – Critical pressure P <sub>c</sub>	ISO 13477	1.5 MOP	1.5 MOP
Longitudinal reversion	EN ISO 2505	≤ 3%	≤ 3%

# Internal Hydrostatic Pressure

- Hoop stress:

$$\sigma_r = \frac{P}{2} (SDR - 1)$$

(e.g.: P =3 bar, hoop stress would be 2,4 MPa for a collector 40\*2,4mm)

- Longitudinal stress:

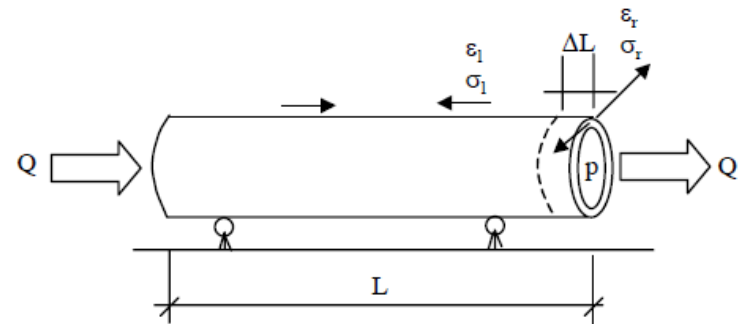
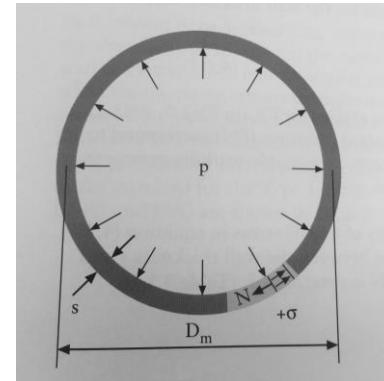
$$\sigma_{lmax} = \frac{v \cdot P}{2} (SDR - 1)$$

Note: the hoop stress shall not be exceeded the design stress for a given PE pipe

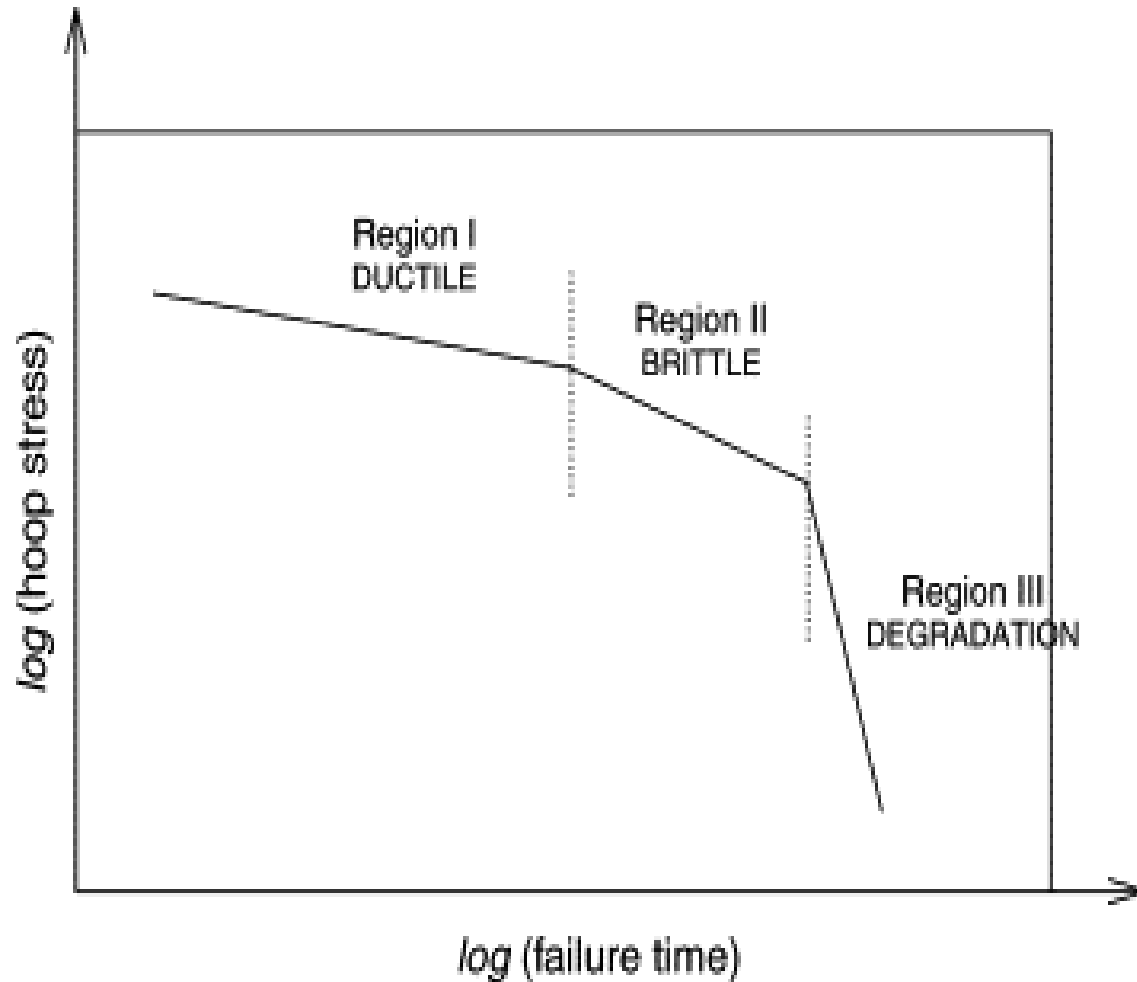
$$\sigma_s = \frac{MRS}{C}$$

- Maximum operating pressure:

$$MOP = \frac{20 \times MRS}{C \times (SDR - 1)}$$



# Temperature-Time-Pressure



# Failures Behaviour

## Brittle



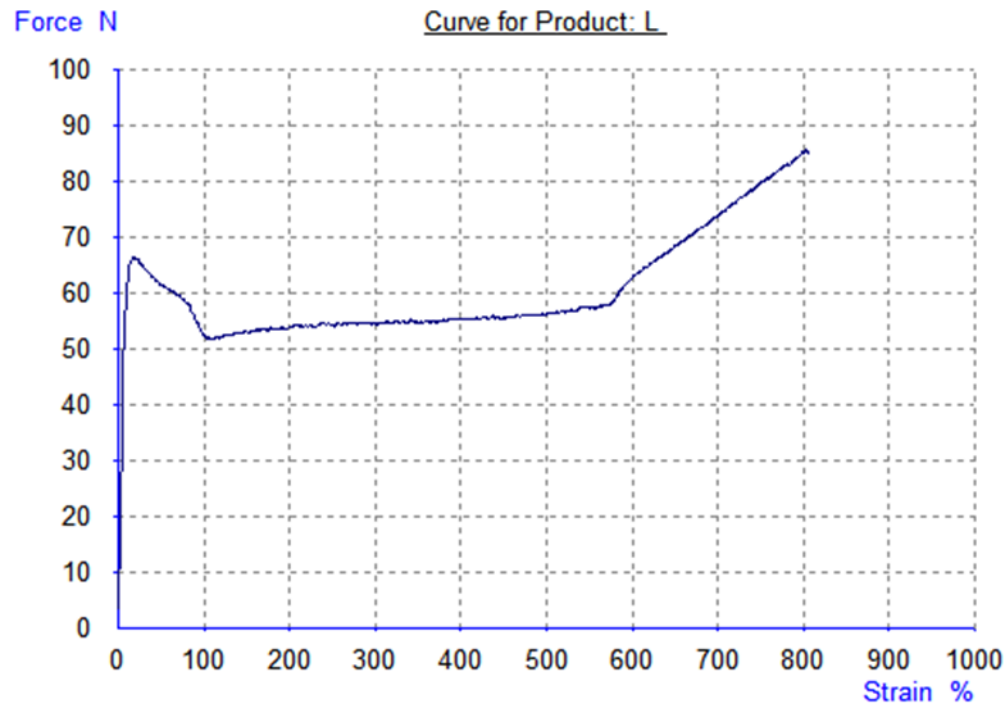
Rapid crack propagation in 315 mm SDR 17 PE80 pipe

## Ductile

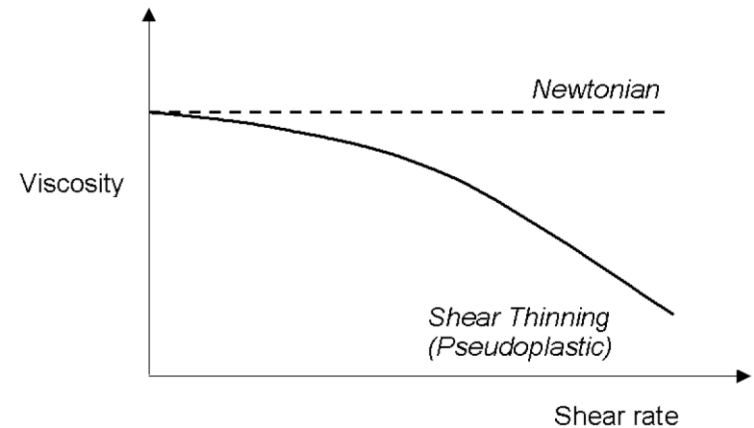
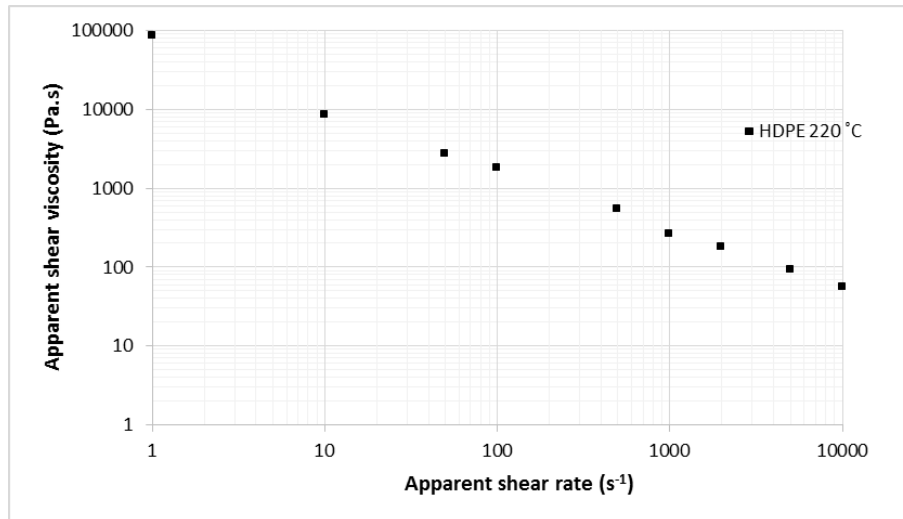


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# Mechanical Properties of PE



# Rheological Properties of PE Melt



# Summery

- PE pipe characteristics:
  - A very wide range of material
  - Light in weight & very flexible
  - Good chemical & corrosion resistance
  - Has long life
  - Can be easily joined by mechanical fittings & welding methods
  - It is needed dedicated standards for GSHP applications
  - More research activities in post-polymerization



For further information and questions contact us:  
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**Thank you!**