

RHEOLOGY, PROCESSING AND MECHANICAL PROPERTIES OF A STARCH BASED POLYMER.

C. Bastioli¹, A. Rallis¹, F. Cangialosi², F.P. La Mantia²,
G. Titomanlio², S. Piccarolo²

¹FERTEC (Ferruzzi Ricerca e Tecnologia), Via Fauser 8, 28100
Novara.

²Dipartimento di Ingegneria Chimica dei Processi e dei Materiali,
Viale delle Scienze, 90128 Palermo.

Aim of this work is to study rheology and processing of Mater-Bi LF04L starch based polymer in film blowing operations. This grade, considered of first generation inside Mater-Bi products, is characterized by:

- Starch and natural additive content of 60%
- Synthetic resin content of 40 %
- Semi-interpenetrated micro structure at molecular level.

Differently from the other Mater-Bi grades, wholly biodegradable, it contains a not biodegradable synthetic component like ethylene acrylic acid.

Film blowing has been performed by a laboratory screw extruder with a film blowing unit.

Shear characterization has been performed both in capillary and rotational viscometers, elongational characterization has been carried out in non-isothermal conditions.

Bagley corrections and entry pressure were found very low at any temperature and shear rate, also compared to that of low density polyethylene.

A strong non-Newtonian behaviour is shown by the viscosity curves at high shear rates, at intermediate shear rates the polymer seems to approach a Newtonian plateau, whereas at low shear rates (or stresses) a viscosity upturn is observed as shown in the figure 1, suggesting the presence of a yield stress.

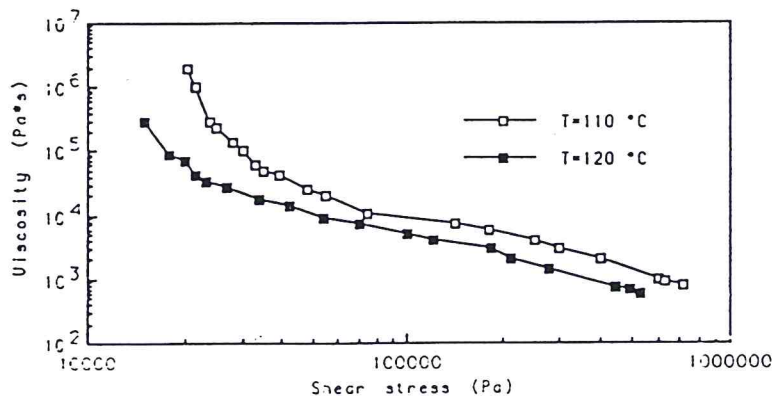


Figure 1

Yield stress values, evaluated by using the Casson's equation:

$$\tau^{1/2} = \tau_s + \dot{\gamma}^{1/2}$$

strongly decrease with temperature (T=110 °C $\tau_s=19000$ Pa, T=120 °C $\tau_s=11600$). The presence of yield stress could be related to the

existence of strong hydrogen bonds due to the presence of hydroxyl groups between starch and synthetic component macromolecular chains. These hydrogen bonds create a sort of a structure whose viscosity becomes extremely high; this means it is possible to promote the melt flow only when a sufficient energy is applied to break down the hydrogen bonds and to exceed the yield stress limit. Consequently, in film-blowing operations, conditions of high shear and engines with high deflecting torque are preferred.

All viscosity measurements were made on polymer samples conditioned at room humidity (the absorbed water is about 4-4.5 % for relative room humidity of 40-45 %). For dried polymer, the viscosity increases of about 25%. This feature can be related with the plasticizing action of the water.

At low shear rates the extrudates show superficial roughness, which disappears on increasing shear rate. The shear rate at which these irregularities disappear increases with both temperature and capillary length whereas it decreases with capillary diameter. Furthermore irregularities were not observed on dried samples.

Melt strength and breaking stretching values are reported in figures 2 and 3, also the values of a film blowing LDPE grade at its standard processing temperature are there considered for comparison. Breaking stretching values are well above those of the LDPE, while, at temperature below $T=120\text{ }^{\circ}\text{C}$, the melt strength becomes larger than that of the polyethylene. Thus this starch based polymer could be processed by all operations which involve elongational flow.

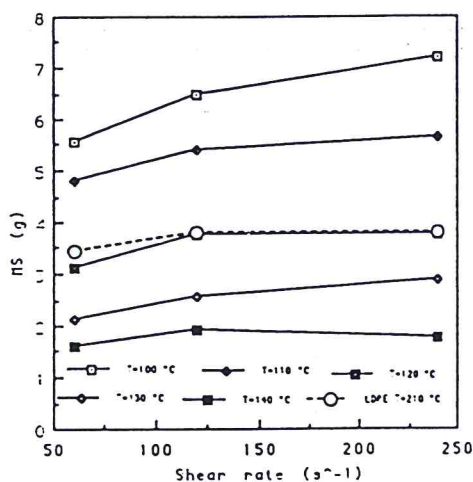


Figure 2

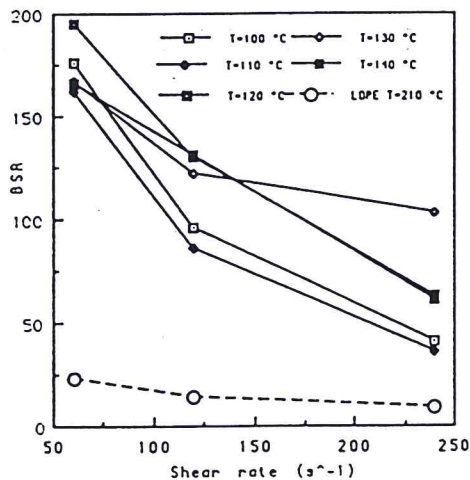


Figure 3

10-15 μm film were easily obtained with a final thickness reduction ratio of about 100. Mechanical properties were found to be only slightly influenced by draw ratio at least in the conditions investigated in this work, this is in relation to the difficulty to induce molecular orientation in the polymer. A strong influence of absorbed water on mechanical properties, especially tensile modulus and elongation at break, was observed.