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Equistar Technical Tip

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Controlled Rheology Polypropylene Resins

INTRODUCTION

Almost everyone dealing with polypropylene (PP) has heard the expressions "controlled rheology" (CR) or "vis-broken" (VB) used to describe specific grades. These terms describe a process used in the manufacture of PP to decrease the average molecular weight of the grade. This decrease results in an increase in the Melt Flow Rate (MFR) and, at the same time, a decrease in the breadth of the Molecular Weight Distribution (MWD). Other advantages for certain molding and extrusion processes and end use applications are described in the "Benefits" section below.

THE PROCESS

PP is susceptible to degradation. If and when PP degrades, the very long molecular chains break up into smaller lengths, decreasing the average molecular weight of the resin. This process is called "chain scission".

Obviously, when chain scission occurs spontaneously, the process is very random and there is no control over the degree of degradation. Undesirable effects, such as discoloration and loss of physical properties, result.

However, chain scission initiated intentionally under carefully controlled conditions results in products with unique and desirable characteristics.

By introducing various peroxides – which act as catalysts to the degradation process – at controlled rates during the pelletization step, resin manufacturers can carefully control the amount of degradation. Since this controlled degradation occurs rapidly, the reaction is not random and is reproducible. The more peroxide used, the more chain scission takes place. Concurrently, the average molecular weight decreases, resulting in a higher MFR. The MWD also narrows as more "vis-breaking" takes place.

The effect of vis-breaking on MWD can be shown on a series of MWD plots using a technique known as Gel Permeation Chromatography (GPC)(see Figure 1). Lower average molecular weight equates to higher MFRs that equate to lower viscosities and easier flow and filling characteristics. A narrower MWD reduces the shear sensitivity, especially at high shear rates (**see Figure 2**).

BENEFITS

All factors being equal, a resin with a narrow MWD has a number of advantages over a resin of the same MFR with a broader MWD:

1. Warpage is reduced.
2. Shrinkage is more uniform (flow vs. cross-flow).
3. Drawdown is more uniform, generally resulting in higher extrusion rates for fibers and films.
4. Elongation at break is significantly increased.

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These factors are all essentially related to the polymer chain lengths being more uniform when the MWD is narrow and, as a result, reacting more uniformly to applied stresses.

▪ LIMITATIONS

Since a narrow MWD product is not as shear sensitive as a broad MWD product with the same MFR, the viscosity of the narrow MWD product at higher shear rates is higher and may create mold filling problems or excessive pressure requirements. High molecular weight chains accelerate the crystallization of PP and, as the amount of these "high-ends" is reduced, there will be a less-oriented skin layer formed on the molded part. The less-oriented skin reduces the stiffness by 10-15%. Extrusion processes such as blow molding, sheet/ thermoforming and extrusion coating, require some level of "melt strength", a property which is derived from the '"high-ends". Since "high-ends" are not present to a great extent in a narrow MWD material, problems with extrudate or sheet sagging may be experienced.

▪ SUMMARY

"Vis-breaking" or "controlled rheology" is a means of producing a polypropylene with a narrow molecular weight distribution in order to achieve certain benefits that include less warpage, more uniform shrinkage and better drawdown characteristics. However, there is some loss of processability (due to lower shear sensitivity), less stiffness and a loss of melt strength.

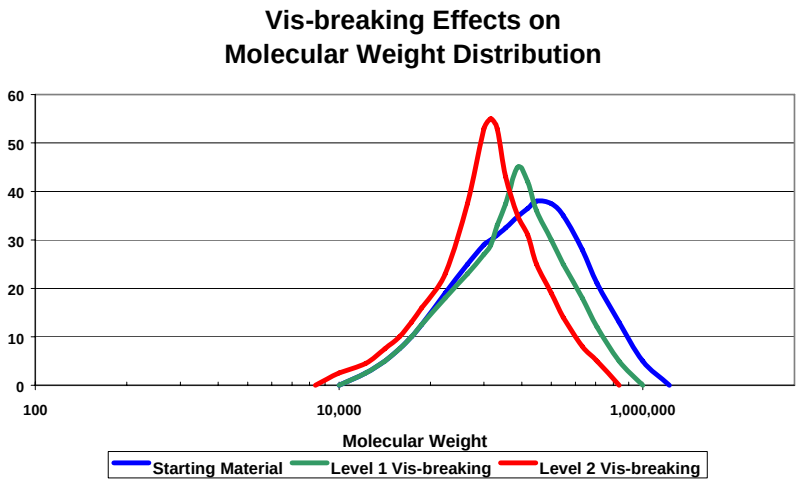

Figure 1: Simple GPC plot showing two levels of vis-breaking

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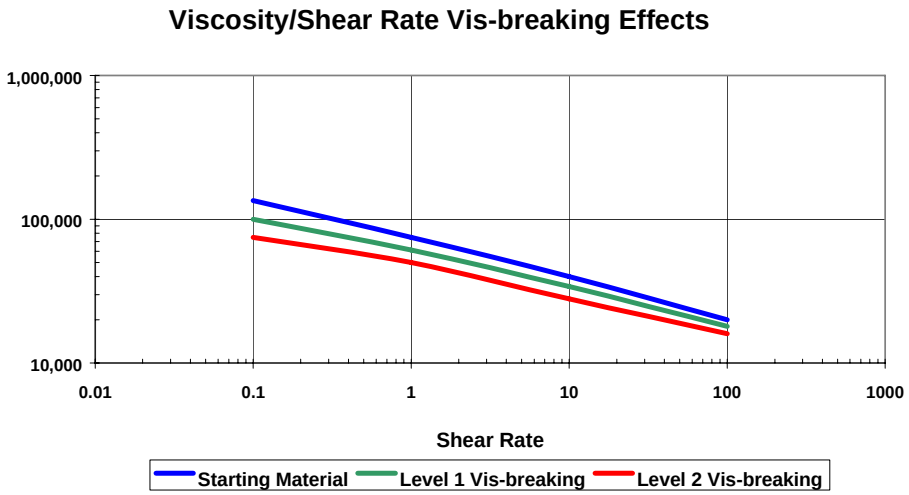

Figure 2: Simple shear rate/viscosity rate plot showing the same two levels of vis-breaking.

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