

## NOTES

*Melt Flow Rate–Intrinsic Viscosity Correlation for Polypropylene*

## INTRODUCTION

Melt flow and intrinsic viscosity are very commonly used by polymer industrial laboratories as parameters relating to molecular weight of the polymer being tested. Yet, hardly any studies have been attempted to correlate these two molecular parameters. This paper deals with melt flow rate–intrinsic viscosity correlation for polypropylene homopolymers.

## EXPERIMENTAL

The following materials and methods were used in this study:

**Materials.** These were Diamond Shamrock Corporation's polypropylene homopolymers. They are listed in Table I.

TABLE I  
Molecular Parameters for Polypropylene Homopolymers

No. of sample	Melt flow rate, g/10 min	$[\eta]_{\text{TCB}}$ , dl/g	$[\eta]_{\text{DEC}}$ , dl/g
1	0.28	2.570	3.624
2	0.35	2.472	3.486
3	0.99	2.042	2.879
4	1.10	1.886	2.662
5	2.30	1.753	2.472
6	2.89	1.538	2.169
7	4.00	1.412	1.991
8	4.48	1.410	1.988
9	5.30	1.408	1.985
10	8.78	1.250	1.762
11	13.50	1.045	1.473
12	13.70	1.072	1.512
13	14.50	1.076	1.517
14	22.20	0.880	1.241

**Methods.** Melt flow rates (or melt flow, *MFR*) of the polymers were determined by the ASTM D-1238-65TL procedure. Their intrinsic viscosities,  $[\eta]$ , were measured in 1,2,4-trichlorobenzene (TCB) and in decahydronaphthalene (Decalin, DEC) at 135°C using a capillary viscometer.

All calculations were carried out by an IBM 1800 computer with a least-squares programming. The confidence limits reported were obtained for the 95% limit. The statistical indicators  $R^2$ ,  $F$ , and  $STE$  were defined as follows:

$R^2$  is multiple correlation coefficient squared, i.e., the fraction of the variation of *MFR* about average *MFR* that is explained by the equation. The closer  $R^2$  is to 1.0, the better.

$$R_2 = \frac{\sum (MFR_o - \overline{MFR})^2 - \sum (MFR_o - MFR_c)^2}{(MFR_c - \overline{MFR})^2}$$

where

$$\overline{MFR} = \frac{\sum MFR_o}{\text{number of data points}}$$

and  $F$  is multiple  $F$ , a measure for the significance of the fit, i.e., it equals the ratio of MFR variation explained by the equation to the MFR variation not explained by the equation. The higher  $F$ , the better:

$$F = \frac{\text{number of data points} - \text{number of constants}}{\text{number of constants}} \left( \frac{R^2}{1 - R^2} \right)$$

$STE$  is the standard error of estimate. The lower  $STE$ , the better:

$$STE = \sqrt{\frac{\sum (MFR_o - MFR_c)^2}{\text{number of data points} - \text{number of constants}}}$$

In the above relations,  $MFR_o$ ,  $\overline{MFR}$ , and  $MFR_c$  denote  $MFR$  observed,  $MFR$  average, and  $MFR$  calculated.

## RESULTS AND DISCUSSION

Melt flow rate and intrinsic viscosity data for the polypropylene homopolymers studied are presented in Table I. Intrinsic viscosity in DEC and in TCB were found to fit the following relation which was established elsewhere<sup>1</sup>:

$$[\eta]_{\text{DEC}} = (1.41 \pm 0.06) [\eta]_{\text{TCB}} \quad (1)$$

$$R^2 = 0.982, F = 1041, \text{ and } STE = 0.051.$$

Equation (1), then, is a satisfactory correlation as seen from the examination of the statistical indicators.

In Figure 1,  $MFR$  has been plotted as a function of  $[\eta]$ . The equations for the resulting plots were found to be the following:

$$\log MFR = (1.257 \pm 0.057) - (4.203 \pm 0.338) \log [\eta]_{\text{TCB}}$$

or

$$MFR = 18.1 \left( \frac{1}{[\eta]_{\text{TCB}}} \right)^{4.20} \quad (2)$$

and

$$\log MFR = (1.883 \pm 0.074) - (4.203 \pm 0.338) \log [\eta]_{\text{DEC}}$$

or

$$MFR = 76.6 \left( \frac{1}{[\eta]_{\text{DEC}}} \right)^{4.20} \quad (3)$$

For eqs. (2) and (3), the statistical indicators were as follows:

$$R^2 = 0.984, F = 733, \text{ and } STE = 0.070.$$

Equations (2) and (3) were the  $MFR$ - $[\eta]$  correlations established for polypropylene homopolymers which could be characterized by 0.27  $\langle MFR \rangle$  22.10, 0.87  $\langle [\eta]_{\text{TCB}} \rangle$  2.56, and 1.23  $\langle [\eta]_{\text{DEC}} \rangle$  3.60.

It should be pointed out here that a 3.4 power dependence of melt viscosity on molecular weight has been predicted,<sup>2</sup> also, that  $MFR$  and viscosity are inversely related.

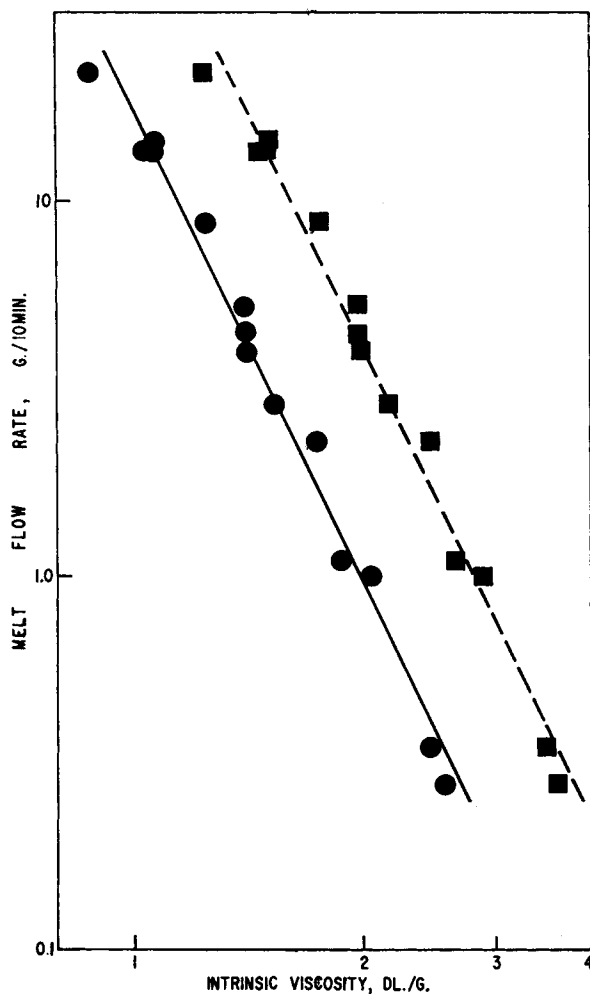


Fig. 1. Melt flow rate as a function of intrinsic viscosity for polypropylene homopolymers: (●)  $[\eta]_{\text{TCB}}$ ; (■)  $[\eta]_{\text{DEC}}$ .

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#### References

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