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RESEARCH ARTICLE

CHARACTERIZATION OF THE FLOWING BEHAVIOUR OF TWO (2) POLYMETHACRYLATE METHYL DURING IMPLEMENTATION BY EXPERIMENTAL MEASUREMENT OF THE MELT FLOW FLUIDITY INDEX FOR THE RECYCLING OF USED PLASTICS.

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Abstract

The present study consists in obtaining rheological data of two polymers from the experimental data obtained from the measurements of their melt indices and using a simple apparatus, the "meltindexer" or "meltflixer" currently available in the polymers processing industry. The objective of this work is to model the behavior of two (2) polymethacrylate methyl polymers in the process of implementation. The methodology used consists of conducting tests associated with the metrology of the melt flow index (MFI or IF), replacing the standardized conditions of these tests by a selection of masses and adjustable temperatures. The results obtained made it possible to produce rheograms and a characterization of the non-Newtonian and viscofluidifying behavior of the polymers studied. The pseudo-plastic behavior of the selected polymers was determined for which it was determined: - their yield stress,

1. the consistency K
2. their flow index n,
3. and the limit viscosity η.

From a practical point of view, the lawfulness of these descriptive tests of the polymer for low shear rates [0,1; 10 s^{-1}] applied.
danger of indiscriminate dumping of wastes as they affect human health.

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Introduction:

The rheology of polymers makes it possible to describe the behavioral properties of materials from their glass transition temperature, even beyond their melting temperature. To apprehend this passage, characteristic of each condensed phase of the material, we found it necessary to rely on the results of the annular shear experiments which favor the study of the transitions from the rigid elastic state to the pasty rubbery state [1].

This approach carried out on a viscoelastic meter provides descriptive elements of the evolution of the viscosity of the polymer materials from the temperature where they are in the rubbery state. The relevant values are, however, provided by viscosimeters Couette [2] and others.

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This study is carried out on two amorphous poly methyl methacrylate polymers (PMMA) distinguished by their melt flow indexes of 0.6 and 1.2 g×mn^{-1}. These were selected for their close flowing behavior with estimated glass transition temperature values of 130 ° C. The hypothesis of this choice is to verify a behavior of these materials is characterized by parameters that pass from single to double to thus respect the same order of magnitude of their fluidity indices.

Our study is justified by a general observation where producers of polymers in the form of granules do not provide information on the flow behavior of these polymers. The lack of information on this behavior of the polymers provided bys industrials leads to a practice rather intuitive than scientific during the implementation of these. This study is the beginning of a series of works that will provide practical parameterization data such as viscosity, flow index, melting temperature, etc. for the implementation of polymers derived from recycling plastics.

The objective of this work is therefore to characterize the behavior of these polymers in the process of implementation in order to use the parameters found for the recycling of objects from these plastic materials. To do this, we use as parameters the melt index, the flow index, the consistency and the viscosity characterized by the shear stress.

Material And Methodology:

The apparatus used for this work is a cylindrical viscometer as shown schematically in Figure 1 below. It is a Brookfield type apparatus [3] that allows shearing at low shear rates in a range of 0.1 to 10 s^{-1}. The apparatus delivers the corresponding apparent viscosity according to the tested material.

The selected material is placed in the air gap of two cylinders of coaxial revolution, radii R1, R2 and height H (see Figure 1).

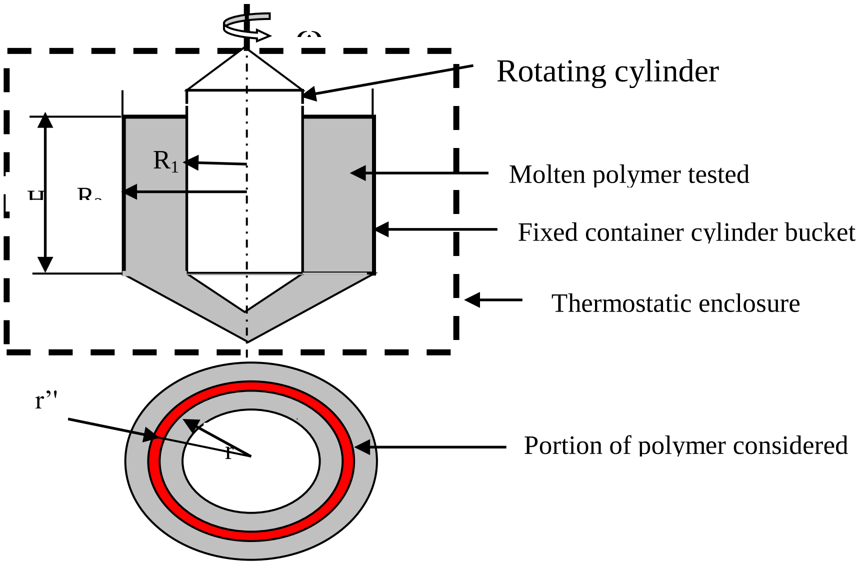

Figure 1:-Schematic representation of the apparatus promoting coaxial cylindrical shear of fluid materials.

A thermostatically controlled enclosure makes it possible to raise the temperature of the material to a set value. Viscosimeters with a cylindrical geometry are in contrast to rheometers with identical geometry that are rarely used to describe the rheological properties of molten polymers [4], [5], although this methodology is often used for polymers with very low viscosity. The limiting factor to their uses is the irregularity of the flow. However, they allow a first evaluation of the evolution of the rheological characteristics of the tested materials.

Shear is here obtained by carrying the inner cylinder at an angular velocity $\dot{\gamma}_0$; the outer cylinder remains motionless. For a ring of fluid polymer between the r and r 'rays (see Fig. 1), each layer is subjected to a torque whose moment relative to the axis of rotation is given by the relation (1) [6], [7], [8], [9], [12], [15]:

$$M^t(r) = F(r) \times r = \tau(r) \times S \times r \qquad (1)$$

According to [6] the sum of the moments is zero in steady state, which leads to relation (2):

$$\tau(r) = \frac{M^t}{2\pi r^2 H} = r\frac{d\omega}{dr} \qquad (2)$$

It is further demonstrated that the shear rate is of the form (relation 3):

$$\dot{\gamma}(r) = r\frac{d\omega}{dr} \qquad (3)$$

We find the expression of the viscosity in Newtonian behavior expressed in the form of the following relation [5], [7], [8], [9], [12], [15] et [16]:

$$\eta = \frac{M^t}{4\pi H\omega_0}\left(\frac{1}{R_1^2} - \frac{1}{R_2^2}\right) \qquad (4)$$

The viscosity thus qualified from the geometric characteristics of the apparatus and the experimental conditions imposed, corresponds to the zeroshear viscosity and makes it possible to describe the behavior of the material at low shear rates.

Results And Discussion:

It was possible, by imposing a stress gradient in the interval [0,1; 10 s^{-1}] to draw the rheograms describing:

for a given polymer, the evolution of τ (θ) as a function of the temperature, the same type of evolution as a function of the melt index (MFI or IF) in the same class of materials.

Table 1 groups together the different measured values of the minimum measured stress from which the various grades of PMMA tested flow.

Table 1:-Value of minimum flow stresses obtained at different temperatures

	Minimum stress recorded as a function of temperature		
MFI (g.mn^{-1})	shear stress τc (Pa) at 300°C	τc (Pa) at 280°C	τc (Pa) at 260°C
0,6	22	40	55
1,2	20	20	34

This test allowed us to approximate the flow index n and the consistency factor K, these two parameters being related to the power law (see equation 5) of each grade tested for a non-Newtonian flow [17].
Table 2 groups the experimental values of the consistency K and the flow index n at 300 °C. of the tested materials. The difference of value of consistency between the two materials is about 5 units but if we consider the flow index, it seems to be identical to the nearest tenth.

Table 2: Experimental values of consistency K and flow index n of PMMA samples differentiated by the melt indexes tested in rotary cylindrical shear mode at 300°C.

Melt Flow Index (g.mn^{-1})	Consistency K (Pa.s)	Flow Index n	Equation

0,6	35,06	0,76	$\eta = 35{,}06 \cdot \dot{\gamma}^{-0{,}24}$
1,2	30,27	0,72	$\eta = 30{,}27 \cdot \dot{\gamma}^{-0{,}28}$

The results obtained allowed us to plot the flow rheograms of the tested PMMA materials (see Fig. 2).

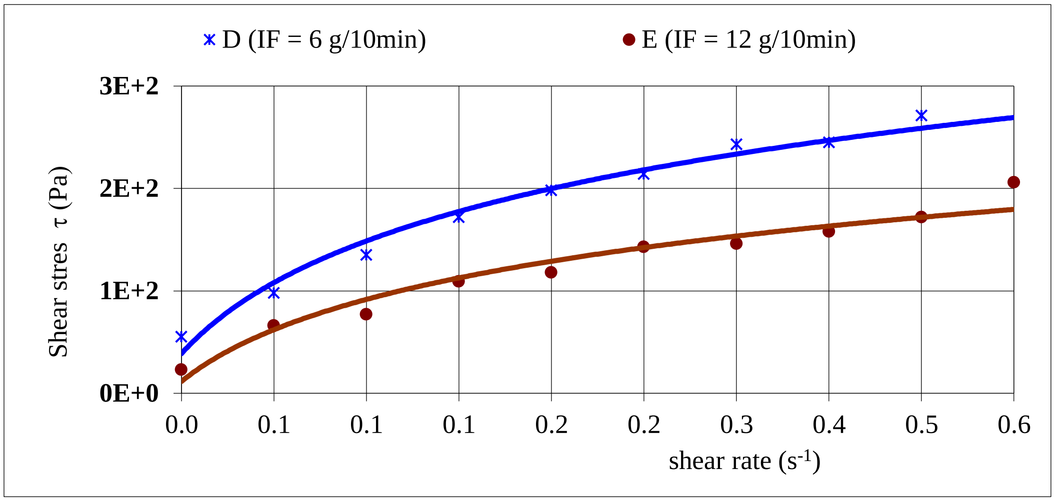

Figure 2:-Rheograms of two (2) PMMA with melt indices of 0.6 and 1.2 g×mn^{-1} respectively, tested in rotary cylindrical shear at 260 ° C.

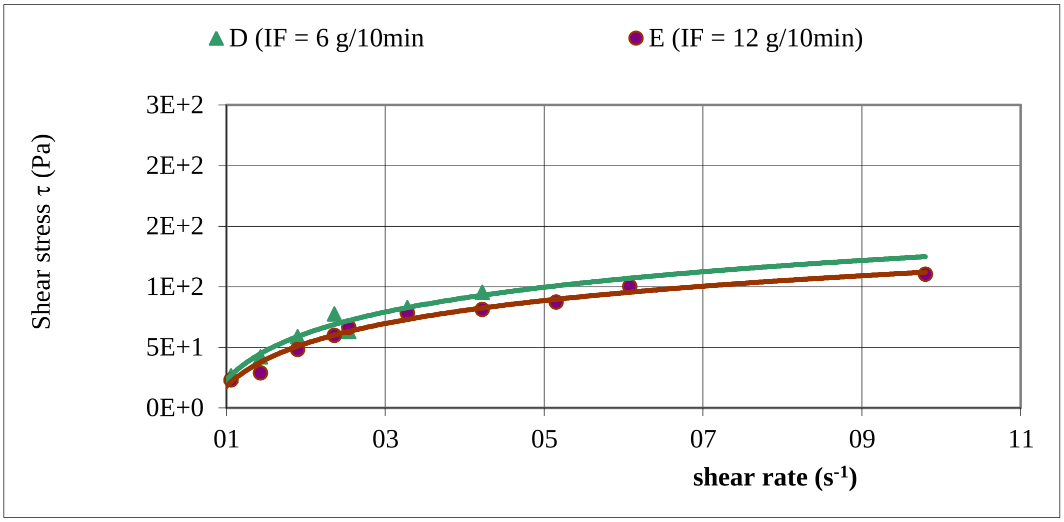

Figure 3:-Rheograms at 300 ° C of PMMA samples tested in rotative cylindrical shear

These rheogram figures show that the polymer flows only from a certain value of the stress τc called the flow threshold which represents the consistency index K according to the power law defined by the equation (5). The flow threshold constraints are in accordance with the values of Table 1 previously established. Let us recall equation (5) which characterizes the consistency and the flow index taken up by [17].

$$\begin{cases} \tau = K \cdot \dot{\gamma}^{n} \\ \eta = K \cdot \dot{\gamma}^{n-1} \end{cases} \qquad (5)$$

where n is the flow index and corresponds to the slope of the linear part of the rheogram. The flow index n is less than 1 for the tested polymers, which makes it possible to say that they are viscofluidifiers.

From Table 1, the various values of the flow index n recorded are less than 1 for all the polymers tested. This confirms their viscofluidifying behavior.

From the previous data we have traced the evolution of the viscosity (see Figure 3) of these materials according to the shear rate applied for isothermal tests at 300 ° C. This temperature of 300 ° C. was chosen because it should correspond to that of low viscosity of the molten polymer in order to facilitate its flow.

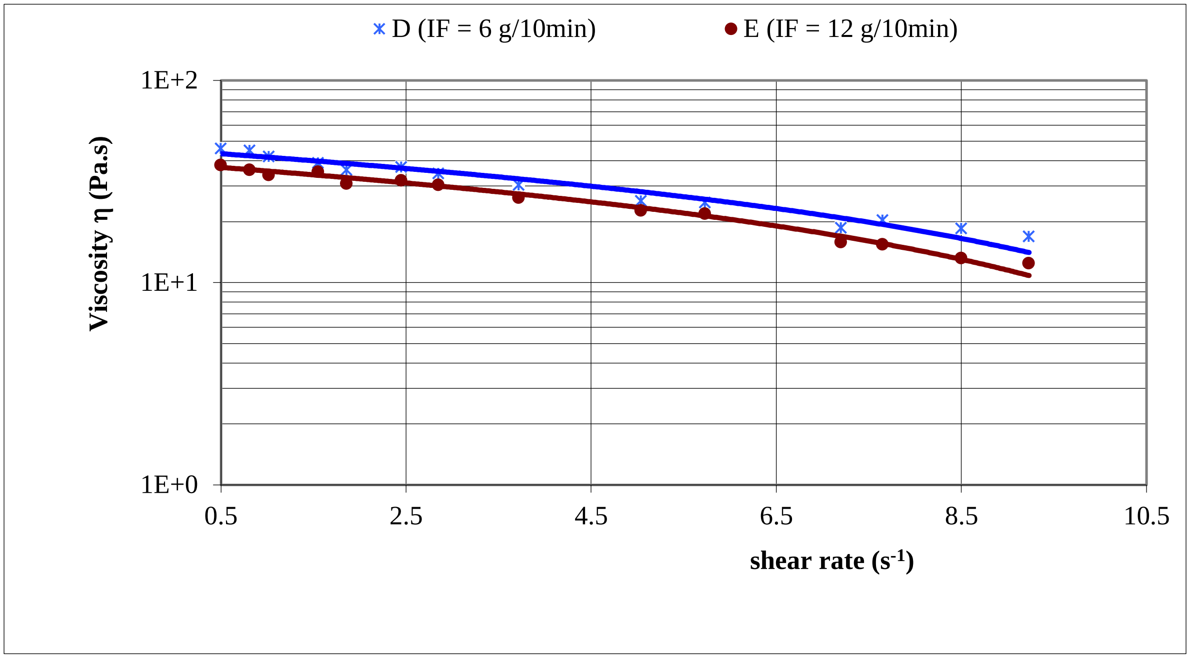

Figure 4:-Viscosity evolution curves at 300 ° C. of PMMA samples differentiated by the melt index and tested in rotary cylindrical shear.

The results relating to the viscosity show that the two PMMA materials just show respect for the flow behavior as a function of their melt index. This is to say that the high melt index material is less viscous and keeps this evolution as the shear rate increases. It should be noted that a large difference in the viscosity value of these materials is not observed, although their melt flow index is doubled. This observation is also respected with regard to temperature. The higher the melt index the material is, the easier it will flow depending on the temperature and the shear rate.

Conclusion:-

The selection of tests using a shear deformation mode made it possible to characterize the behavior of the two retained PMMA materials through the values of:

1. the flow threshold constraint,
2. the consistency K and the flow index n,
3. and viscosity η.

This has been possible thanks to the use of a cylindrical viscometer with geometry using two coaxial cylinders that facilitate the shearing of the polymer material introduced into the gap.

These experiments allowed a representation of the rheograms and the evolution of the viscosity of the polymers studied as a function of the shear rate in the interval [0; 10 s^{-1}]. The most probable viscosity values for temperatures much higher than Tg were obtained using a Brookfield viscometer.

It has been found a viscofluidifying behavior of the two PMMA polymers characterized by a viscosity of less than 100 Pa.s.

As such it has been found a known fact: the type of equipment used allows to have an approach to characterize the behavior of molten polymers during their implementation.

This study is a draft of a work that aims to apply the results obtained to the recycling of commonly used plastic materials such as PMMA known as Plexiglas.

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