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Rheological Behaviour of VPVC/RPVC Blends

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SUMMARY: Different blends of virgin pipe-grade PVC and PVC recyclate according to their rheological behaviour, processability and mechanical properties have been investigated. Our results showed that an easy and simple way to improve processability of PVC compounds for pipes was to blend them with recycled PVC obtained from postconsumed oil bottles, which indicated very good processing behaviour. Energy and time savings up to 80% depending on the amount of the added recyclate without depressing the mechanical properties have been noticed. In addition, lower processing temperature has been achieved.

Introduction

Limited natural resources and concerns for the environment as well as for quality of life have recognize the need for more efficient and conservative use of resources. On the list of options for the environmentally safe disposal of plastics, recycling has a preferred position because it recovers most of its inherent value. In this paper we present some of our results and observations, to which we came working on "homopolymer" blends consisted of compounds based on PVC. In that context, experiments with virgin PVC compound for pipes (VPVC) (one of the standard formulations for pipes in OHIS-Skopje), PVC recyclate of postconsumed oil bottles (RPVC) and their blends (VPVC/RPVC) have been performed concerning their processing behaviour, rheological and mechanical properties.

Rheological behaviour is an important property of polymeric materials, because most of them are processed in a molten state by making use of their flowing behaviour. Consequently, rheology of these materials will dictate whether or not polymers can be processed, shaped, and formed into a desired profile with specified quality and dimensional stability in an efficient and economic manner. Therefore, it is very important to possess information about this behaviour because in many cases available rheological data can be used to predict processing performances, to serve as a guidance in determining optimum operating conditions, as well as suggest the choice of compound formulation which will enhance end-use performances [1].

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Processability is another key parameter that plays an important role in tailoring products with desired final properties under reasonable conditions, meaning production with lower cost and energy savings. As processability is a very complex characteristic, it can not be defined solely by testing melt viscosity, but requires knowledge of the total plastication behaviour and heat and shear stability of the material [2].

Experimental

The subject of our investigations were blends with different weight ratios of virgin pipe-grade PVC (VPVC) as a matrix and postconsumed PVC chopped oil bottles (RPVC) as a second polymer constituent (VPVC/RPVC 100/0, 90/10, 80/20, 70/30, 50/50 and 0/100).
Rheological measurements of VPVC/RPVC blends have been conducted in a A.Macklow-Smith capillary rheometer under steady shearing conditions at temperature range 170-190°C. Processability of blend samples with different compositions has been tested in a Brabender Plasti-Corder PL-2000 rheometer at shear rates 30 and 50 rpm and temperatures 170 and 180°C. These temperatures were lower than the operating temperature of the industrial process of extrusion of PVC compounds for pipes (190°C). From the obtained plastograms, blend processing behaviour (fusion time and fusion energy) has been determined.

Results and Discussion

The shear stress vs. shear rate curves of VPVC/RPVC blends follow the power law relationship with a very low flow behaviour index ($n \approx 0.2$), while the consistency coefficients (k) depend on the amount of the added recyclate (table 1). These blends showed monotonical shear thinning behaviour, i.e. high pseudoplasticity (figures 1 and 2). Because noticeable decreasing of viscosity occurs during blend processing, a positive effect on energy consumption has been observed. Blends' flow and viscosity curves are between curves obtained from their polymer constituents. This information about the nature of the rheological response of the VPVC/RPVC blends confirmed the integrity of the blends and their rheological compatibility, despite the fact that they have been consisted of two different compounds based on different grades of PVC and ingredients.

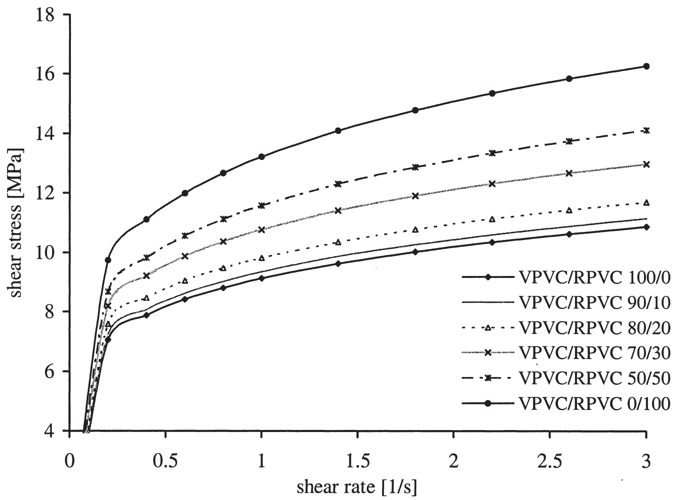

Figure 1. Flow curves of VPVC/RPVC blends at 170°C

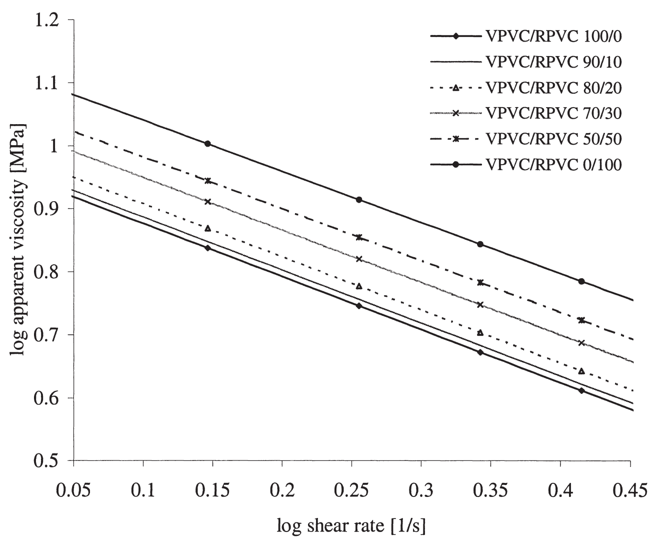

Figure 2. Viscosity curves of VPVC/RPVC at 170°C

Processability changes expressed in terms of fusion characteristics are given in tables 2 and 3. The addition of PVC-recyclate in PVC pipe-grade compound up to 50wt% caused improvement in blend processability compared to that of PVC compounds for pipes. Namely, one can notice energy and time savings in blends' processing of about 80% (table 4).

Table 1. Rheological properties of VPVC/RPVC blends

	170°C		180°C	
VPVC/RPVC	$k \cdot 10^{-6}$ [Pas^n]	n	$k \cdot 10^{-6}$ [Pas^n]	n
100/0	9.1250	0.16	7.9068	0.20
90/10	9.3497	0.16	8.2947	0.20
80/20	9.8130	0.16	8.7418	0.21
70/30	10.7721	0.17	9.0282	0.22
50/50	11.5830	0.18	9.1517	0.24
0/100	13.2190	0.19	10.7420	0.26

Table 2. Fusion time [s] of VPVC/RPVC blends at different temperatures and shear rates

	170°C		180°C	
VPVC/RPVC	30 rpm	50 rpm	30 rpm	50 rpm
100/0	342	196	244	108
90/10	214	122	198	62
80/20	138	100	118	50
70/30	100	56	68	46
50/50	62	42	44	32
0/100	40	32	10	8

Table 3. Fusion energy [kJ] of VPVC/RPVC blends at different temperatures and shear rates

	170°C		180°C	
VPVC/RPVC	30 rpm	50 rpm	30 rpm	50 rpm
100/0	13.0	7.9	9.4	6.3
90/10	8.5	5.9	8.2	3.8
80/20	8.1	5.2	5.0	3.5
70/30	5.4	3.6	3.6	3.4
50/50	3.3	2.6	3.0	2.3
0/100	3.0	1.2	1.2	0.9

However, mechanical characteristics of mixtures have not been affected negatively, which can be seen from table 5, where modulus E, tensile stress σ_y, stress at break σ_r and elongation at break ε_r are given.

Table 4. Time and energy savings [%] in processing of VPVC/RPVC blends compared to that of PVC pipe-grade compound at temperatures 170 and 180°C and shear rate 30rpm

	170°C		180°C	
VPVC/RPVC	time [%]	energy [%]	time [%]	energy [%]
90/10	37.4	34.6	18.8	12.8
80/20	59.6	37.7	51.6	46.8
70/30	70.8	58.5	72.1	61.7
50/50	81.9	74.6	81.9	68.1

Table 5. Mechanical properties of VPVC/RPVC blends

VPVC/RPVC	E [MPa]	σ_y [MPa]	σ_r [MPa]	ε_r [%]
100/0	1400	27.2	22.7	312
90/10	1380	25.5	20.4	237
80/20	1370	21.2	19.5	227
70/30	1370	20.0	17.8	216
50/50	1320	19.5	17.5	210
0/100	1180	18.7	17.2	204

Conclusion

When virgin PVC compounds for pipes were blended with PVC recyclate of postconsumed oil bottles up to 50wt%, better processability at lower operating temperature has been achieved without any negative effects on rheology and mechanical properties. Thus, with this approach of "homopolymer" blending, the two goals, ecological and economic benefits, set up at the beginning of our research have been reached.

References

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