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Physical and morphological Properties of Polycarbonate (PC)/Acrylonitrile-Butadiene-Styrene (ABS)/Waste Urea Formaldehyde (WUF) Polymer Blends

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Abstract: In this study, high density polyethylene matrix contributes to ground urea formaldehyde powder is handled as 0, 5, 10, 20 and 30 wt% ratio will be mixed in the extruder. Mixture obtained from the extruder to be granulated and then the granules will be obtained as appropriate standard test sample of the injection molding machine. Physical and morphological tests will be applied such as heat deflection temperature, vicat softening point, melt flow index, moisture content, limit oxygen index, war rate and static coefficient of friction. Also, SEM examination will be conducted to evaluate the microstructure of urea formaldehyde particles as well as material distribution in these experiments.

Keywords: Polycarbonate, Acrylonitrile butadiene styrene, Urea formaldehyde, Physical properties, Polymer blends

Introduction

The current economic crisis has led to an increase in competition between companies, who in turn have had to significantly reduce production costs in order to remain competitive. These reductions must be found in areas such as raw materials, waste reduction, process optimization, etc. In the case of companies who transform polymer materials, the economic crisis, alongside a dependence on the price of petroleum, have led many companies to use recycled materials to obtain raw materials at a more stable price. There is also the added incentive of the environmental benefits gained by reusing waste materials [1]. The increased amount of polymer waste has become a serious issue globally and also caused depletion of petroleum resources without which the modern life become impossible for mankind. In many applications thermosets are the materials of choice for long-term use because they are insoluble and infusible high-density networks. Recycling of thermosetting polymers is regarded as one of the urgent problems to be settled because of its technological difficulty. The increased production of thermoset blends and composites in recent years has greatly increased the amount of waste materials [2]. Urea-formaldehyde (UF) accounts for about 15% of the total thermoset resin production. Currently, one of its major applications is in molded products, including electrical equipment, dinner ware, buttons, cosmetic caps, and bottles. However, the same factors that make UF a good choice for many applications, namely its chemical, thermal, and mechanical stability, are also what make recycling such a big challenge [3]. Much research on the wear performance of polymer has been reported elsewhere [4-9]. However, no one has been reported on the wear performance of the PC/ABS/WUF polymer composites. Further, research into the wear of polymers has usually investigated the effects of a single factor-such as sliding distance, sliding speed, or contact pressure on the wear performance. Balart studied the properties of acrylonitrile–butadiene–styrene (ABS) derived from the electrical and electronic sector, to be more precise, from streetlights. These pieces are extremely exposed to atmospheric phenomena. Balart improved the properties of the waste material by mixing it with polycarbonate (PC) and then studied the miscibility of the mixture [10].

In this study, polyethylene matrix contributes to ground urea formaldehyde powder is handled as 5, 10, 20 and 30 % ratio will be mixed in the extruder. Mixture obtained from the extruder to be granulated and then the granules will be obtained as appropriate standard test sample of the injection molding machine.

Experimental

Compositions and Materials

Five different polymer blends were prepared. Compositions of PC/ABS/waste urea formaldehyde (WUF) polymer blends that were formed are given in Table 1.

Table 1. Composition of the PC/ABS/WUF polymer blends formulations

Groups	PC(wt %)	ABS (wt %)	WUF (wt %)
1	50	50	-
2	47.5	47.5	5
3	45	45	10
4	40	40	20
5	35	35	30

PC used in this study was obtained from GE (USA), with the trade name Lexan and the code number 144 R. MFI value is 19 g/10 min (220°C, 10 kg), vicat softening point is 142°C. ABS is also a GE (USA) product with 750 SW code number. Melting point is 230–260°C. Waste urea formaldehyde was supplied Viko by Panasonic Company (Istanbul-Turkey).

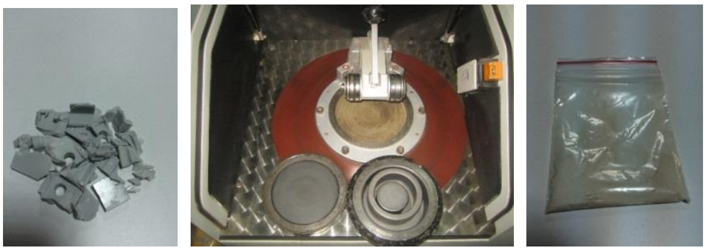
Sample Preparation

UF was dried in a Yamato vacuum oven ADP-31 (Yamato/VWR Scientific Products, Japan) at 105 ^oC for 24 hours before being blended with PC/ABS. Mechanical premixing of solid compositions was done using a LB-5601 liquid-solids blender (The Patterson-Kelley Co., Inc. east Stroudsburg, PA-USA) brand batch blender for 25 min. Samples with various proportions of PC/ABS/WUF polymer blends were produced between 250-300 ^oC at 25-35 bar pressure, and a rotation rate of 25 rpm, with a Microsan **co-rotating** twin-screw extruder (Microsan Instrument Inc. Kocaeli - Turkey). PC/ABS/WUF polymer blends were also dried in vacuum oven at 105 ^oC for 24 hours after extrusion. Subsequently, test samples were molded in injection molding machine. Extrusion and injection conditions are given in Table 2.

Table 2. Extrusion and injection conditions of the PC/ABS/WUF polymer blends

Process	Extrusion	Injection
Temperature (^{o} C)	250–300	250–300
Pressure (bar)	25-35	110–130
Waiting time in mold (s)	-	20
Screw speed (rpm)	25	25
Mould temperature (^{o}C)	-	40

Waste urea formaldehyde dry grinded with Siemens simatic C7-621 control system device to obtain unsegregated powders. The size of urea formaldehyde particles varied between 10–80µm. Powder preparations steps are given in Figure 1.



WUF granulation powder

Figure 1. Waste urea formaldehyde powder preparation steps

Test Procedure

Heat deflection temperature (HDT) and Vicat softening point tests were done according to ISO 75 and ISO 307 standard with determined by CEAST 6521 HDT-Vicat test equipment. Flow behavior testing of all the mixtures was done according to ISO 1133 standard with Zwick 4100 MFI equipment. Moisture testing of all the mixtures was done according to ASTM D 6980 standard with Kern DBS 60-3 equipment. Limit oxygen index (LOI) testing of all the mixtures was done according to ISO 4589 standard with Devotrans LOI equipment. The wear tests were done according to the DIN 53 516 method with Devotrans DA5 (Devotrans quality control test equipment Istanbul-Turkey) abrasion test equipment. The thickness of the test specimens was 7.0 mm and diameter was 15.5 mm. Cylinder rotational speed was selected as 40 rpm and normal load (F_N) of 10N was used. Total sliding distance (L) was 20-80 m. The mass loss of the samples (Δm) was measured after the wear process, and the specific wear rates (Ws) were calculated using the following equation:

$$Ws=(\Delta m)/\rho.F_N.L \ (mm^3/Nm) \qquad (1)$$

Where Δm is the specimen's mass loss, ρ is the density of specimen, F_N is the normal load applied, and L is the total sliding distance.

Static coefficient of friction test was done according to the ISO 8295 method with Devotrans friction coefficient measurement equipment. The dimensions of the tested specimens were 80x200x4 mm and the dimensions of the sled specimens were 63x63x4 mm. Speed was selected as 100 mm/min.

Static coefficient of friction (μs): The force increases linearly to a maximum which represents the static frictional force F_S. Measurements made at a high friction drag permit the dynamic coefficient of friction to be calculated, but not the static coefficient of friction. The static coefficient of friction μs is given by the equation,

$$\mu s=F_S/F_P \qquad (2)$$

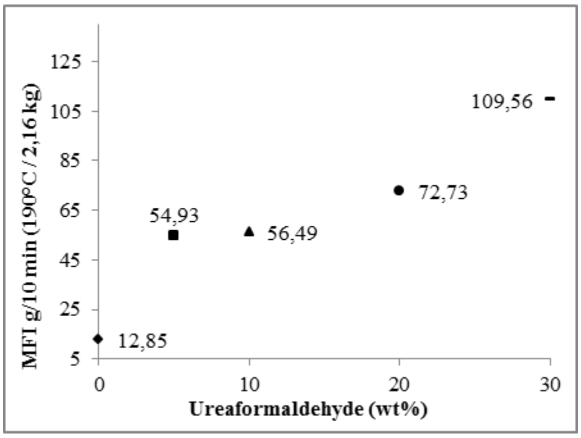
Where F_S is the static frictional force, expressed in Newton, F_P is the normal force exerted by the mass of the sled, expressed in Newton.

The fractured surfaces of the PC/ABS/WUF polymer blends were coated to thickness of 20 Å of a gold (Au) to prevent electrical charging by Polaron SC7640 (high resolution sputter coater) (United Kingdom). The surfaces of the prepared samples were observed by the FEI Sirion XL30 FEG (Nederland) scanning electron microscopy (SEM) at an acceleration voltage of 5-20 kV.

Result and Discussion

Physical properties of PC/ABS/WUF polymer blends

The relationship between the melt flow index (MFI) and the percentage of the waste urea formaldehyde powder of PC/ABS blend is shown in the Figure 2-A. The melt flow index of PC/ABS/WUF blend increases as the urea formaldehyde concentration increases from 0 to 30 wt %. The maximum melt flow index is observed at the 30 wt % WUF concentration for PC/ABS. In comparison with the melt flow index of PC/ABS, the melt flow index increased by 756% for the composites with a 30 wt % WUF concentration. The relationship between the ratio percentage of the waste urea formaldehyde and limit oxygen index (LOI) of PC/ABS blends is shown in the Figure 2-B. Limit oxygen index of blends shows an decrement as the waste urea formaldehyde concentration increases from 0 to 30 wt %. The minimum limit oxygen index is observed at the 30 wt % waste urea formaldehyde concentration for PC/ABS. In comparison with the limit oxygen index of PC/ABS, the limit oxygen index decreased by 20 % for the composites with a 30 wt % urea formaldehyde concentration. The moisture content of waste urea formaldehyde filled blends was measured, as shown in Figure 2-C. With increased loading, the moisture content of blends filled with waste urea formaldehyde is increased. The maximum moisture content is observed at the 30 wt % waste urea formaldehyde concentration for PC/ABS. In comparison with the moisture content of virgin PC/ABS, the moisture content increased by 9 % for the blends with a 30 wt % waste urea formaldehyde concentration. The relationship between the head deflection temperature (HDT) and the percentage of the waste urea formaldehyde powder of PC/ABS blend is shown in the Figure 2-D. The head deflection temperature of PC/ABS/WUF blend decreases as the urea formaldehyde concentration increases from 0 to 30 wt %. The minimum head deflection temperature is observed at the 30 wt % WUF concentration for PC/ABS. In comparison with the head deflection temperature of PC/ABS, the head deflection temperature decreased by 44% for the composites with a 30 wt % WUF concentration. The relationship between the vicat softening point and the percentage of the waste urea formaldehyde powder of PC/ABS blend is shown in the Figure 2-E. The vicat softening point of PC/ABS/WUF blend decreases as the urea formaldehyde concentration increases from 0 to 30 wt %. The minimum vicat softening point is observed at the 30 wt % WUF concentration for PC/ABS. In comparison with the vicat softening point of PC/ABS, the vicat softening point decreased by 36% for the composites with a 30 wt % WUF concentration. Static friction performance is shown in Figure 2/E when speed was 100mm/min; load separately was 1.96, 2.94, 3.92, 4.90 and 6.86 N respectively. It is seen that the WUF ratio and load had a great effect on the static friction coefficient of the PC/ABS blends. As the WUF ratio and load increases, the static friction coefficient of all kinds of composites increases.



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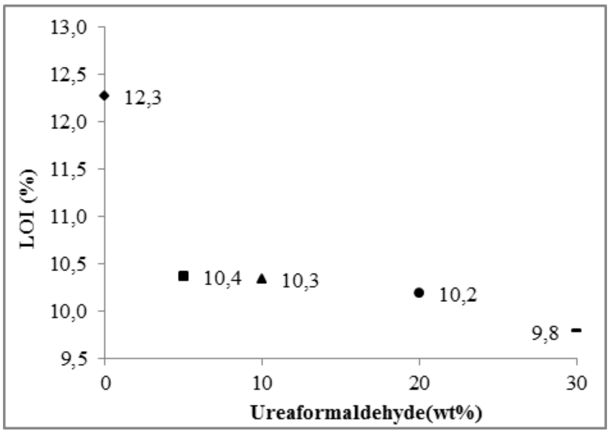

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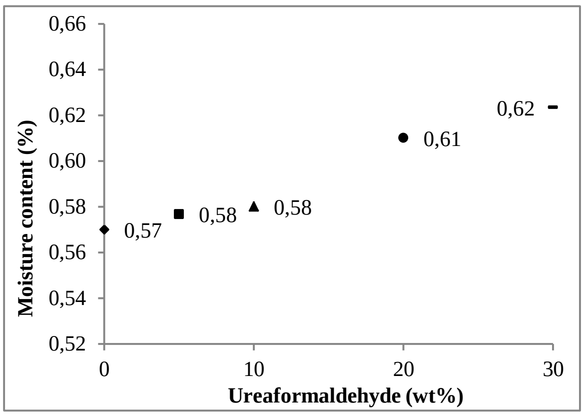

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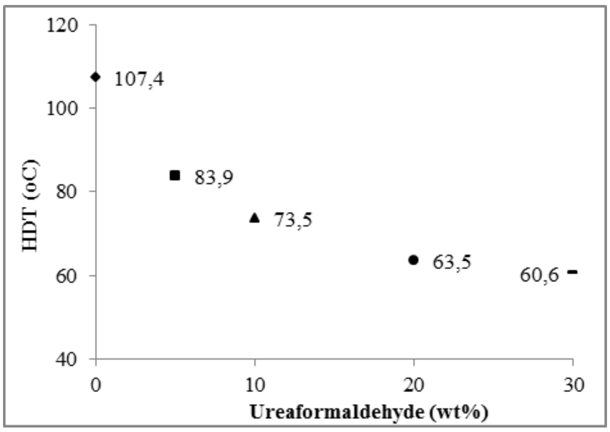

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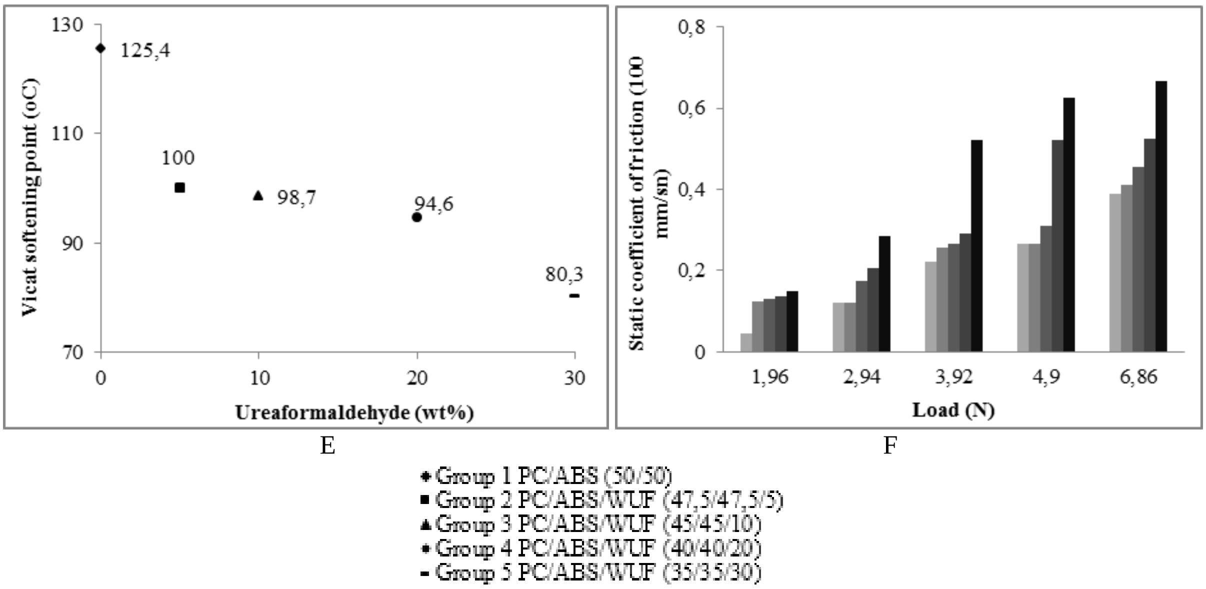


Figure 2. Physical properties of the PC/ABS/WUF polymer blends

Wear properties of PC/ABS/WUF polymer blends

Obviously, the wear processes involved in this investigation are complex. The effects of sliding distance and urea formaldehyde content on the wear behaviors of PC/ABS blends were examined. The wear rate for various specimens sliding distance against the sand paper (#60) under 10N load and 0,32 m/s abrasion speed. It can be seen that the wear rate of blends increase with increasing urea formaldehyde content. The values of wear rate are shown in Figure 3. The wear rate of PC/ABS/WUF blends increases as the urea formaldehyde concentration increases from 0 to 30 wt %, which could be attributed to the weakened adhesion between the urea formaldehyde and PC/ABS matrix in the presence of an excessive amount of urea formaldehyde particulates. The weak bond led to the urea formaldehyde particles detaching from the PC/ABS matrix and the matrix pulling out more easily, which could increase the wear rate of the blends. So, a high level of the urea formaldehyde led to the high wear rate of the composite.

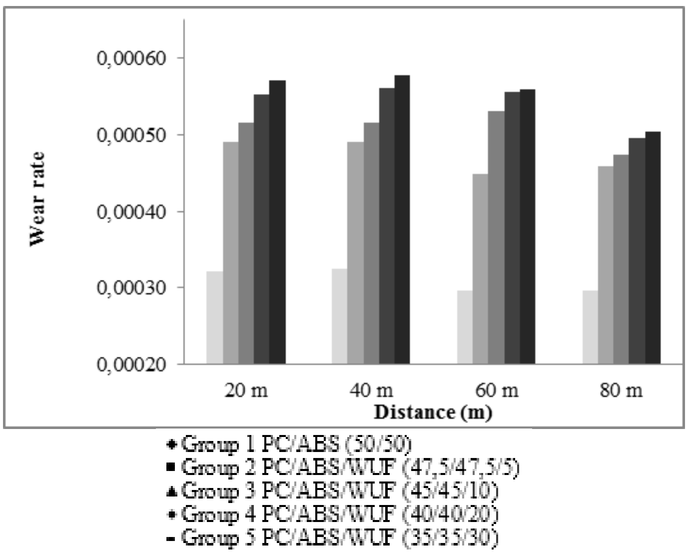
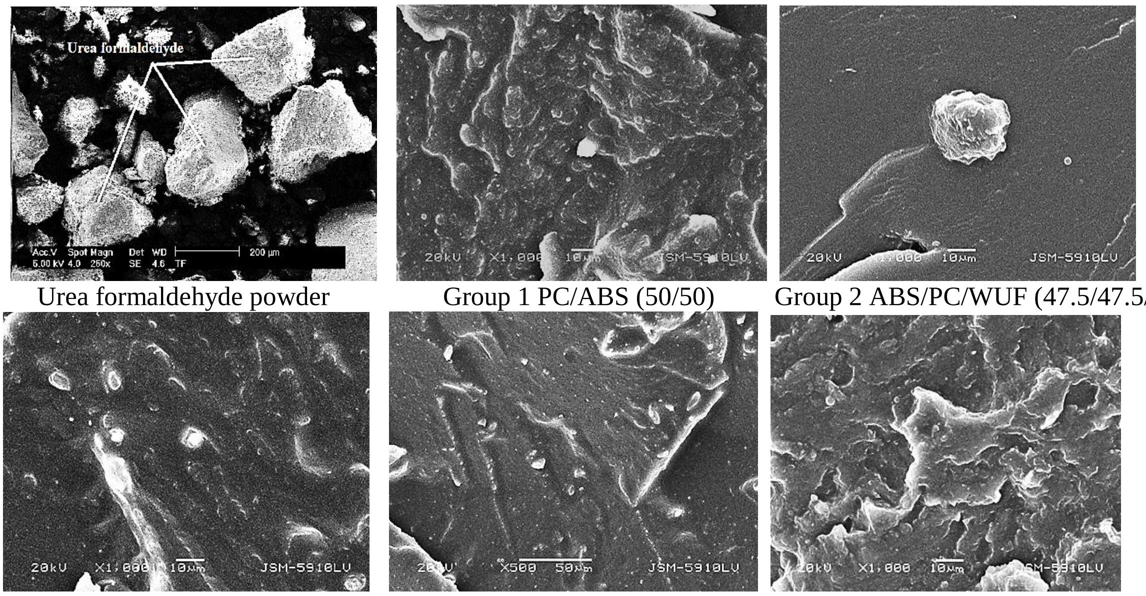


Figure 3. Wear rate of the PC/ABS/WUF polymer blends

Morphological properties of PC/ABS/WUF polymer blends

The SEM study was carried out to study the dispersion of waste urea formaldehyde in the PC/ABS matrix. The boundaries and the contrast can be obviously seen between the urea formaldehyde and PC/ABS matrix on the fractured surfaces of polymer matrix (Figure 5). The micrographs indicate that the WUF particulates are homogeneously dispersed on the fractured surfaces of PC/ABS polymer matrix.



Urea formaldehyde powder | Group 1 PC/ABS (50/50) | Group 2 ABS/PC/WUF (47.5/47.5/5)

Group 3ABS/PC/WUF (45/45/10) | Group 4ABS/PC/WUF (40/40/20) | Group 5 ABS/PC/WUF (35/35/30)

Figure 5. SEM micrographs of the PC/ABS/WUF polymer blends

Conclusions

The effects of waste urea formaldehyde on the physical and morphological tests will be applied such as heat deflection temperature, vicat softening point, melt flow index, moisture content, limit oxygen index, war rate and static coefficient of friction of PC/ABS/WUF blends were investigated. The following results were obtained: Melt flow index, moisture content, static coefficient of friction and war rate increased gradually as the waste urea formaldehyde content increased. Heat deflection temperature, vicat softening point and limit oxygen index decreased gradually as the waste urea formaldehyde content increased. The micrographs indicate that the urea formaldehyde particulates are homogeneously dispersed on the fractured surfaces of PC/ABS polymer matrix.

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