Enhancement of the Injection Grade Polypropylene using Extrusion Grade Polypropylene and Calcium Carbonate

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***Abstract* -** This work studied composite properties of polypropylene injection grade using polypropylene extrusion grade and calcium carbonates. Four formulations of $PP_{injection}$ and $PP_{extrusion}$ viz. 95/5, 90/10, 85/15 and 80/20 in ratio of weight percentage were prepared for injection molding machine. This $PP_{injection}$/$PP_{extrusion}$ 80/20 blend is selected and investigated at different three fractions of calcium carbonate. The mechanical properties such as tensile strength and elongation were investigated. The rheological properties such as melt flow index and melt density were evaluated. The work obtained blending $PP_{injection}$ with $PP_{extrusion}$ in most cases decreased the tensile strength, elongation, melt density and melt flow index. The results indicated that incorporate calcium carbonate to blend increased the tensile strength, melt flow index and melt density while elongation decreased.

Keywords—*Polypropylene, Blend, Calcium Carbonate, Mechanical, Rheological*

المستخلص – في هذا البحث تمت دراسة خصائص البولي البروبلين خامة الحقن الذي تم مزجه بالبولي بروبلين خامة البثق وكربونات الكالسيوم كمادة مضافة. تم عمل أربع خلطات من مزيج الحقن والبثق وهي 5/95 ، 10/90 ، 15/85 و 20/80 كنسبة مئوية. بعد ذلك تم أختيار الخلطة 20/80 من المزيج ومن ثم إضافة ثلاثة نسب مئوية من كربونات الكالسيوم لها. الخصائص الميكانيكية مثل مقاومة الشد و الإستطالة تم أختبارها. الخصائص الريولويجية مثل معامل إنسياب المصهور وكثافة المصهور تم أختبارها وتقييمها أيضاً. العمل أظهر أن مزج البولي بروبلين خامة الحقن مع البولي بروبلين خامة البثق أدى إلى نقصان قوة الشد, الإستطالة, كثافة المصهور ومعامل إنسياب المصهور. النتائج دلت على أن أضافة كربونات الكالسيوم إلى المزيج أدى إلى زيادة كل من معامل إنسياب المصهور، كثافة المصهور و قوة الشد بينما أظهرت النتائج نقصان في الإستطالة.

INTRODUCTION

Interest in polypropylene (PP) and polyethylene (PE) is specifically due to the fact that; both these polymers are widely used as important engineering materials in the automotive, electrical appliances and packaging industries due to their excellent properties such as rigidity and stiffness, oil resistance and their thermal stability [1]. Apart from these good properties that polypropylene has, its applications as often limited due to its low impact strength and Young's modulus, particularly at low and high temperature loading conditions. These polypropylene drawbacks can be considerably improved by blending polypropylene with other polymers [2]. Polypropylenes offer a good balance of properties and cost unachieved by most other thermoplastics polymer. Polypropylene has good mechanical, electrical and chemical properties and good resistance to tearing [3]. Long fiber and continuous fiber reinforcement technology with Polypropylene produce molding material with higher tensile strength and semi-finished materials such as sheet and tape which are beginnings to find applications, mainly in structural parts. This shows that the Properties of Polypropylene can be improved by adding a fibers or other reinforcement material. If additional stiffness or strengthen agent is needed, reinforcement can be added to Polypropylene.

A very important property that has led to many applications for Polypropylene is its superior resistance to cracking from mechanical stress [4]. The mechanical properties of Polypropylene depend on several factors and are strongly influenced by the molecular weight. The molecular weight of PP is normally estimated from the simple measurement of viscosity. Melt flow rate is more commonly used to measure the viscosity. General observations suggest that an increase in molecular weight, keeping all other structural parameters similar, leads to a reduction in tensile strength, stiffness, hardness, brittle point [5,6].

The use of inorganic fillers has been a common practice in the plastics industry to improve the mechanical properties of thermoplastics, such as heat distortion temperature, hardness, toughness, stiffness and mold shrinkage. The effects of filler on the mechanical and other properties of the composites depend strongly on its shape, particle size, aggregate size, surface characteristics and degree of dispersion. Stiffness, Flexural strength, Ultimate modulus, heat deflection temperature and some other mechanical properties can be increase by filling suitable percentage of talc and modifier with PP for various new mechanical and electrical applications [5, 7]

Calcium carbonate has been one of the most commonly used inorganic fillers for thermoplastics, such as poly vinyl chloride (PVC) and polypropylene (PP) [8]. The incorporation of $CaCO_3$ in PP is a common practice to improve the heat distortion temperature, dimensional stability, stiffness and hardness of the polymer. However, the addition of micron-sized-$CaCO_3$ particles to PP has not shown significant improvement in the mechanical properties of the composites [7]. In the art, several attempts have been made to improve the mechanical and optical properties of polypropylene films by adding organic or inorganic filler materials and especially calcium carbonate [9].

Khartoum Petrochemical Company (KPC) Sudan produces two grades of polypropylene homo polymer under ASTM standard those are extrusion grade (PP_{KPC113}) and injection grade (PP_{KPC114}) [1]. `The present work aimed to study the properties of KPC polypropylene injection grade to overcome the processing and products problems.

MATERIALS AND METHODS

Table 1 shows specifications of Polypropylene (PP_{113})–extrusion grade supplied by Khartoum Petrochemical Company, in powder with the following particulars.

Table 2 shows the specifications of Polypropylene (PP_{114}) extrusion grade product supplied by Khartoum Petrochemical Company (KPC, Sudan), in powder with the following particulars.

Calcium carbonate ($CaCO_3$) used on experimental of present work as additives (fillers) in granules form (white granules).

A. Experimental Work

In the experimental study, blends of PP_{114}/PP_{113} were prepared according to the required compounds formulated as: 95/5, 90/10, 85/15 and 80/20 to make up a total of 100 g (wt. /wt. %). The samples were prepared to an injection molding machine at (180–250˚C). The processed samples were allowed to cool at room temperature for 48 hours. Then different tests were carried out such as tensile test and elongation. Also melt flow index and melt density of the blend. Shown in Table 3.

TABLE 1: SPECIFICATIONS OF POLYPROPYLENE PP 113

Trade Name	KPC Polypropylene (PP 113)
Density	0.900 g·cm^{-3}
Melting Point	230 °C
Melt Flow Index (MFI)	3g/10min (230°C, 2.16 kg)
Tensile Stress at Yield	27.5MPa
Flexural Modulus	1000MPa
Izod Impact Resistance	25 J/m
Heat Deflection Temp	74°C

TABLE 2: SPECIFICATIONS OF POLYPROPYLENE PP 114

Trade name	KPC Polypropylene (PP 113)
Density	0.910 g·cm^{-3}
Melting Point	230 °C
Melt Flow Index (MFI)	8 g/10min (230°C,2.16kg)
Tensile Stress at Yield	27.5MPa
Flexural Modulus	950MPa
Izod Impact Resistance	20 J/m
Heat Deflection Temp	71°C

TABLE 3: FORMULATIONS OF PP_{114}/PP_{113} BLENDS

Blend No	Materials	
	PP114 (wt. %)	PP113 (wt. %)
1	95	5
2	90	10
3	85	15
4	80	20

In the experimental study; three different calcium carbonate concentrations were added to PP_{114}/PP_{113} (80/20) by weight to produce composites make up a total of 1kg as in Table 4. The samples were prepared to an injection molding machine at (180 – 220°C). Then the tensile strength and elongation were carried out. The melt flow index and melt density determined.

TABLE 4: FORMULATIONS OF $PP_{114}/PP_{113}/CaCO_3$

Blend No	Materials		
	PP_{114} (wt. %)	PP_{113} (wt. %)	$CaCO_3$ (wt. %)
1	80	20	7.5
2	80	20	15
3	80	20	22.5

TESTING AND RESULTS

A. FIRST BATCH : PP_{114}/PP_{113} BLENDS

1. Mechanical test:

Tensile strength test

The Tensile strength of PP_{114}/PP_{113} is shown in Figure 1. Tensile strength of (PP_{114}) was 34.37 N/mm^2. Addition of (PP_{113}) (5, 10, 15 and 20wt %) to (PP_{114}) was decreased the tensile strength of (PP_{114}).

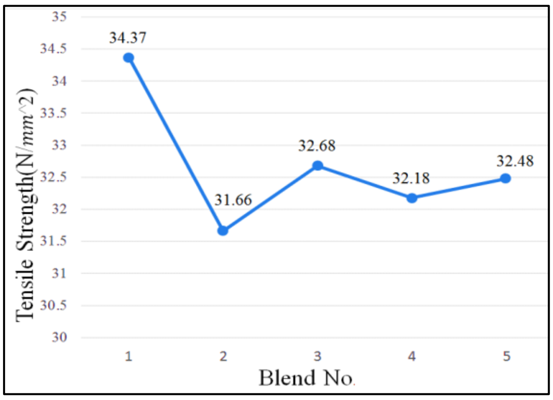

Figure 1: Tensile strength of PP_{114}/PP_{113} blends

Elongation Test

The elongation of PP_{114} was 7.52mm. Addition of PP_{113} (5, 10, 15 and 20wt %) decreased the elongation of PP_{114}.as in Figure 2.

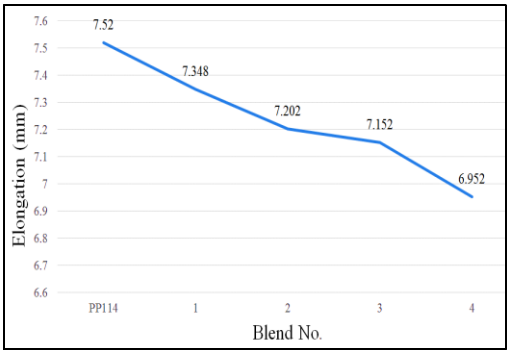

Figure 2: Elongation OF PP_{114}/PP_{113} BLENDS

2. Rheological Test:

Melt flow index (MFI) test:

This test is used to investigate the flow properties of PP_{114}. Figure 3 show the effect of PP_{113} contents on the MFI of PP_{114}. The MFI of PP_{114} was 8.2 g/10 min. The addition of PP_{113} (5, 10, 15 and 20 wt. %) to PP_{114} decreased the MFI.

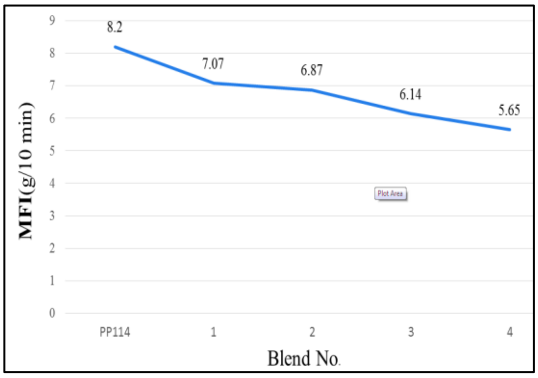

Figure 3: MFI of PP_{114}/PP_{113} BLENDS

Melt density Test

The melt density tests of PP_{114}/PP_{113} blends are shown in Table 8 and Figure 4. The melt density of PP_{114} was 1.124 g/cm^3. The result showed addition of PP_{113} (5, 10, 15 and 20wt %) to (PP_{114}) decreased melt density of PP_{114}.

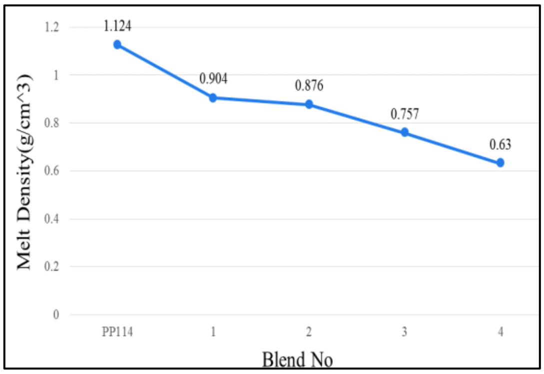

Figure 4: Melt density tests of PP_{114}/PP_{113} blends

3. PP_{114}/PP_{113} Blends Tests Summary:

The summary of PP_{114}/PP_{113} blend is shown in Table 5.

TABLE 5: PP_{114}/PP_{113} BLENDS TESTS SUMMARY

Blend No	MFI (g/10min)	Melt density (g/cm^3)	Tensile Strength (N/mm^2)	Elongation (mm)
PP_{114}	8.2	1.124	34.37	7.52
1	7.07	0.904	31.66	7.348
2	6.87	0.876	32.68	7.202
3	6.14	0.757	32.18	7.152
4	5.65	0.630	32.48	6.952

Results showed addition of polypropylene (PP_{113}) to polypropylene (PP_{114}) in most cases decreased the tensile strength and elongation of polypropylene (PP_{114}). These results indicate that the decrease in tensile strength with the increase of (PP_{113}) is related to the bonding strength between PP_{114}/PP_{113} compared to the intermolecular bonding of PP_{114}. From these results, it is assumed that the decreased tensile strength related to the decreased brittleness and stiffness of the blend, due to the addition of (PP_{113}).

The $PP_{injection}/PP_{extrusion}$ 80/20 blend is selected which provided balance the good performance. Also the results obtained decrease melt density and melt flow index of PP_{114}.

B. SECOND BATCH :PP_{114}/PP_{113} $CaCO_3$ COMPOUNDS

1. Mechanical Test:

Tensile Strength Test

The tensile strength of PP_{114}/PP_{113} blend was 32.48N/mm^2. The result showed addition of (7.5, 15 and 22.5 wt. %) calcium carbonate increased tensile strength as in figure 5:

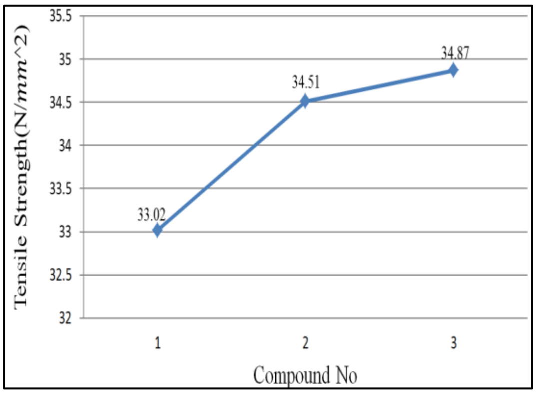

Figure 5: Tensile strength PP_{114}/PP_{113} / $CaCO_3$

Elongation Test

The elongation of PP_{114}/PP_{113}blend was 6.952mm.

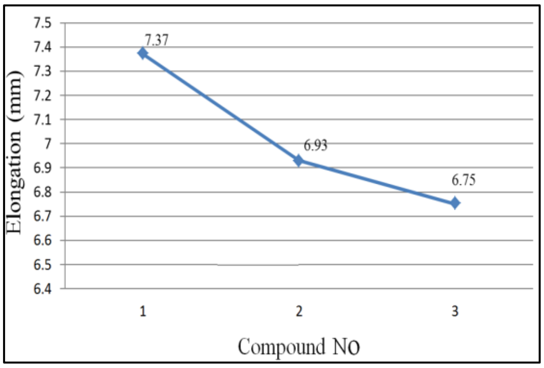

FIGURE 6: ELONGATION OF PP_{114}/PP_{113} /$CaCO_3$

2. Rheological test

Melt Flow Index (MFI) Test

The melt flow index test is used to investigate the flow properties of PP_{114}/PP_{113} and compound are shown in Figure (7). MFI of PP_{114}/PP_{113} blend was 5.65g/10min. The result showed addition of calcium carbonate increased (MFI).

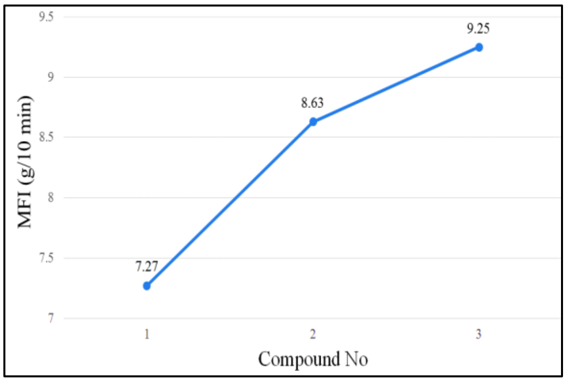

Figure 7: MFI of PP_{114}/PP_{113}/ $CaCO_3$

Melt Density Test

Melt density test of PP_{114}/PP_{113} and compound are shown in Figure (8). The melt density of PP_{114}/PP_{113} blend was 0.630 g/cm^3. The result showed addition of (7.5, 15 and 22.5 wt. %) calcium carbonate increased melt density.

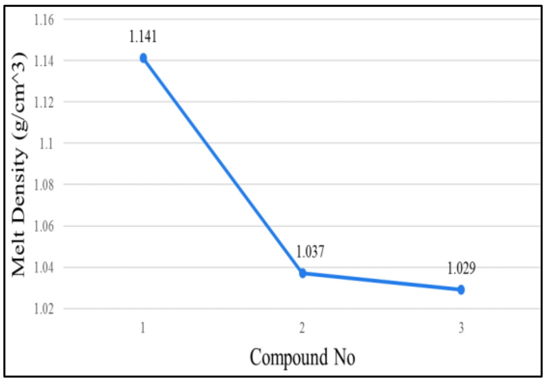

Figure 8: Melt density of $PP_{114}/PP_{113}/CaCO_3$

3. $PP_{114}/PP_{113}/Caco_3$ Tests Summary:

Table 6 shows the mechanical and rheological test of $PP_{114}/PP_{113}/CaCo_3$ compound. The result showed addition of (7.5, 15 and 22.5 wt. %) calcium carbonate increased melt flow index and melt density of PP_{114}/PP_{113}. This result may be directly related to the undeform ability of the filler and its lack of contribution to the flow.

The result showed addition of calcium carbonate increased tensile strength with the increase of calcium carbonate is related to the improved bonding strength between PP_{114}/PP_{113} compared to the intermolecular bonding of PP_{114}.

From these results, it is assumed that the increased tensile strength related to the increased brittleness and stiffness of the blend, due to the addition of calcium carbonate. While the work assumed that the decrease in elongation with the increase of calcium carbonate is related to the improved bonding strength between PP_{114}/PP_{113} compared to the intermolecular bonding of PP_{114}.

TABLE 6: $PP_{114}/PP_{113}/ CaCO_3$ TESTS SUMMARY

Compound No	MFI (g/10min)	Melt density (g/cm^3)	Tensile strength (N/mm^2)	Elongation (mm)
PP_{114}/PP_{113} (80/20)	5.65	0.630	32.48	6.95
1	7.27	1.141	33.02	7.37
2	8.63	1.037	34.51	6.93
3	9.25	1.029	34.87	6.75

CONCLUSION

Blending $PP_{injection}$ with $PP_{extrusion}$ in most cases decreased the tensile strength, elongation, melt density and melt flow index. The work obtained blending $PP_{injection}$ with $PP_{extrusion}$ in most cases decreased the tensile strength, elongation, melt density and melt flow index. Also indicated that incorporate calcium carbonate increases the melt flow index, melt density and the tensile strength while elongation decreased. The results showed enhancement on the mechanical and rheological properties of $PP_{injection}$.

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