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REVIEW THE MECHANICAL PROPERTIES OF REINFORCING AGENTS IN POLYPROPYLENE MATRIX OF CAR BUMPER

Mohd Amran Md Ali[1,2,3], Abu Abdullah[1,2,3], Shamshulizam Dahaman[2], Azrifin Amin[2] and Suhaimi Mansor[2]
[1]Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, Melaka, Malaysia
[2]Perusahaan Otomobil Nasional Sdn. Bhd., HICOM Industrial Estate, Batu Shah Alam, Selangor, Malaysia
[3]Precision Machining Group, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal, Melaka, Malaysia
E-Mail: mohdamran@utem.edu.my

ABSTRACT

This paper reviews the effect of reinforcing agents in polypropylene (PP) on mechanical properties for car bumper. PP is one of the main plastic materials used for making car bumper. PP as a matrix is mixed with reinforcing agents that are talc and rubber. Types of rubber employed as reinforcing agents are ethylene-propylene diene monomer (EPDM) and polyolefin elastomeric (POE). Result was shown that PP filled with talc increased the modulus strength however yield strength and its strain decreased. Meanwhile, PP filled with rubber shown that impact strength and percentage of elongation increased however its yield strength and bending strength decreased. Furthermore, this paper also found that the higher the processing temperature the lower the mechanical properties of virgin PP. Thus, it shown that adding reinforcing agents into PP matrix increased and/or decreased certain properties of PP composites. Therefore, some companies have their reasons used talc and/or rubber as reinforcing agent for production their car bumper.

Keywords: mechanical properties, polypropylene matrix, reinforcing agents.

INTRODUCTION

Bumper is a structure attached to the front and rear of an automobile to absorb impact force in a minor collision and to minimize repair costs [1]. Originally bumpers are made from rigid metal bars as shown in Figure-1(a). Historically, in 1968 General Motors fixing plastic front bumper at Pontiac GTO to absorb low-speed impact without permanent deformation as shown in Figure-1(b) [2]. Similar elastomeric bumpers were also installed on the front and rear of the Plymouth Barracuda in 1970 [3] and then in 1972, Renault introduced a plastic bumper on the Renault 5 [4].

Figure-1. Car bumper; (a) Chrome plated front bumper made from metal assembled at Ford Taunus in 1958 and (b) front bumper made from plastic assembled at Pontiac GTO in 1968 [2].

In current design practice, the bumper structure on modern automobiles consists of a plastic cover over a reinforcement bar made of steel [5]. In most jurisdictions, bumpers are legally required on all vehicles. Regulations for automobile bumpers have been implemented for two reasons that are to allow the car to sustain a low-speed impact without damage to the vehicle's safety systems and to protect pedestrians from injury. These requirements are in conflict where bumpers can withstand impact well and minimize repair costs tend to injure pedestrians more [6]. Although a vehicle's bumper systems are designed to absorb the energy of low-speed collisions and help protect the car's safety and other expensive components located nearby however most bumpers are designed to meet only the minimum regulatory standards [7].

Virgin polypropylene as a matrix filled with talc and rubber are commonly composite plastic materials used

in manufacturing car bumper [8]. The percentage of talc and rubber compounded in polypropylene is practically more than 5% and below than 40% [9-11]. Several researchers reported that the strong influence of different compounded talc or rubber on the microstructure and on the mechanical behavior [12-15]. Even though, there are varieties of reinforcing agents added in PP matrix studied by various researcher to enhance its properties. However in general, basically, there are two types of reinforcing agents added in PP matrix there are organic [16-19] and inorganic [20-23]. Organic reinforcing agents such as wood powder, jute, kenaf fibre, and hemp fiber meanwhile for inorganic reinforcing agents such as silica oxide, calcium carbonate, glass fibre and talcum [24]. Therefore, to understand clearly effect of reinforcing agents in PP for car bumper, this paper reviews particularly the main components of reinforcing agents that are talc and rubber in PP matrix on mechanical properties that were used for manufacturing car bumper.

CAR BUMPER MATERIALS

Capability of polypropylene as car bumper materials

It well known that in the early stage metal is used for fabricating the car bumper. Due to the metal having high weight as compare to the plastic materials, therefore metal materials are replaced by plastic materials. Figure-2 shows the density and Young modulus of polypropylene as compare to others materials which density of PP is approximately 1.0g/cm3 and Young Modulus is around 1.0GPa [25]. Due to the PP has low density, competitive strength and having good processing ability using injection moulding process therefore PP is suitable plastic material for manufacturing car bumper.

Figure-3 shows the qualitative selection chart which is simplified from reference [26]. This qualitative selection chart is used to determine those which fit certain categories of toughness, strength and flexibility. Those materials along the top of the chart are considered the toughest, while those near the bottom are considered to be more brittle. Materials along the left edge are more rigid while those along the right edge are more flexible. From the figure, it shows that polypropylene high toughness, strength and good in flexibility.

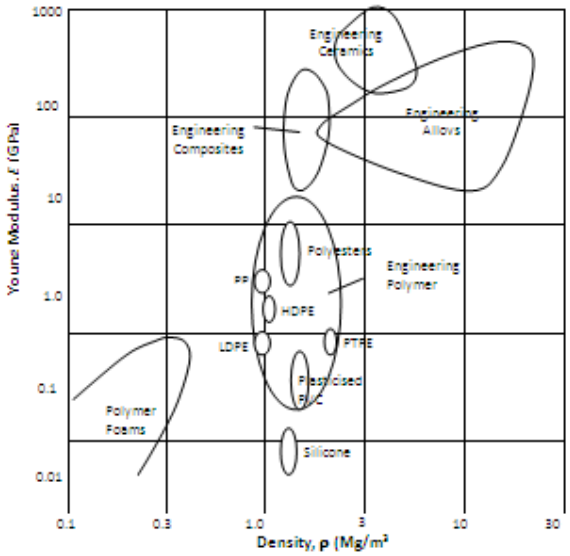

Figure-2. Young modulus (E) plotted against density [25].

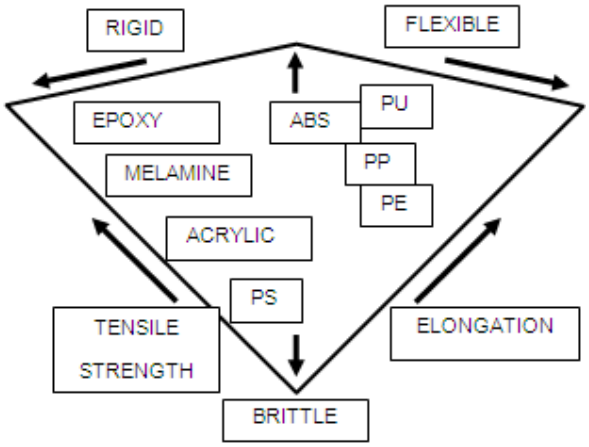

Figure-3. Qualitative selection chart for various plastic materials [26].

Types of plastic materials for car bumper

Table-1 shows the type of plastic materials of car bumper used at various countries extracted from autoreverse web site; www.a2mac11.com/autoreverse [27]. It shows that PP as matrix mixed with reinforcing agents was dominant plastic materials used for almost all car makers in the world. For example, European country used polypropylene filled with talc (PP-TD) meanwhile some other countries used polypropylene filled with rubber (PP-EPDM).

Table-1. Results from CGS.

Country	Year	Position	Weight (kg)	Thickness (mm)	Part materials
Italy	2010	Front	5.284	3	PP-TD
		Back	3.732	3	PP-TD20
Germany	2011	Front	3.569	3	PP-EPDM-TV20
		Back	3.841	3	PP-EPDM-TV20
Japan	2013	Front	3.022	3	PP
		Back	4.419	3	PP
Japan	2013	Front	3.487	3	PP (PP+E/P-TD20)
		Back	3.942	3	PP+E/P-D20

MECHANICAL PROPERTIES

Effect of processing temperature of virgin PP

Strapasson *et al*. investigated on the tensile and impact behavior of virgin polypropylene [28]. The specific gravity of the virgin PP is 0.905g/cm^3, with melt flow index of 10.0g/10 min. Each of them was processed at different injection molding temperatures (170, 180, 190 and 200 ^{o}C). It was found that the higher injection molding temperature applied in processing the lower the yield strength of the virgin PP. The result found were 170 ^{o}C (27.8MPa), 180 ^{o}C (25.1MPa), 190^{o}C (23.4MPa) and 200 ^{o}C (16.9MPa) as shown in Figure-4. Further, the elastic modulus and elongation at break also decreased with increasing injection molding temperatures. The impact strength also decreased with increasing injection molding temperatures that were 170, 180, 190 and 200 ^{o}C to the impact strength 12.2, 10.3, 8.5 and 4.5J/m, respectively.

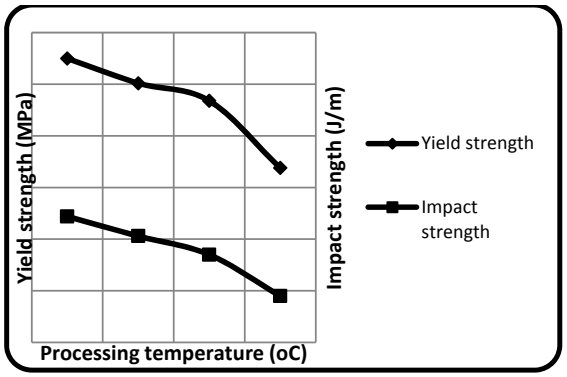

Figure-4. Impact strength and yield strength plotted against processing temperature of virgin PP [28].

PP filled with talc

Zhou and Mallick [14] studied the tensile behaviour of virgin PP and PP filled with 40% talc. The melt flow rates of these two materials were reported as 4g/10min and 6.8g/10 min, respectively. The higher melt flow rate for the PP filled with talc was due to the presence of talc fillers. It was found that the addition of talc in PP matrix increased the elastic modulus but the yield strength and strain were reduced as shown in Figure-5. Maiti and Sharma [15] explained that the increased of tensile modulus was due to the mechanical restrain imposed by the talc particles on the molecular mobility or deformability. Meanwhile, the decreased of yield strength and strain at break were attributed to decreased crystallinity and formation of stress concentration points around the filler particles. Furthermore, they revealed that izod impact also decreased with increased talc content.

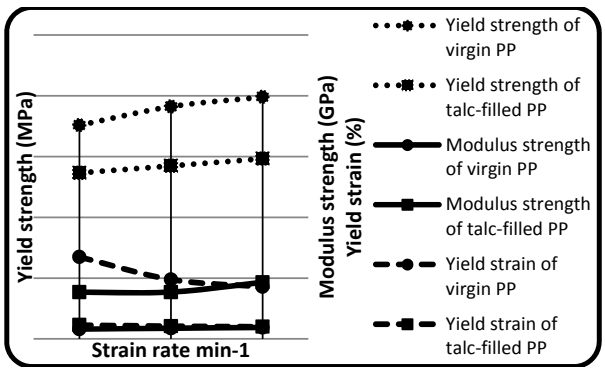

Figure-5. Yield and modulus strength of virgin PP and PP with talc filled at various strain rate [14].

Effect of size of talc in PP matrix also plays an importance effect on the mechanical properties. According to Morotomi *et al*., izod impact strength increased as the talc particle size decreased however flexural modulus increased as talc aspect ratio increased [29].

PP mixed with ethylene-propylene diene monomer (EPDM)

EPDM is known as thermoplastic olefin elastomeric (TPO) where isotactic polypropylene blended with ethylene-propylene diene monomer. Szostak mentioned that neat TPO was good for car front bumpers due to its elasticity properties however for car rear bumper TPO blended with talc was preferred to lower the production costs [30]. Lourenco *et al*. studied the PP filled with 30wt% of EPDM on the impact resistance, tensile strength, young modulus and strain at break as shown in Figure-6 [31]. It was found that impact strength and strain

at break increased however tensile strength and Young's modulus decreased by adding EPDM in PP matrix.

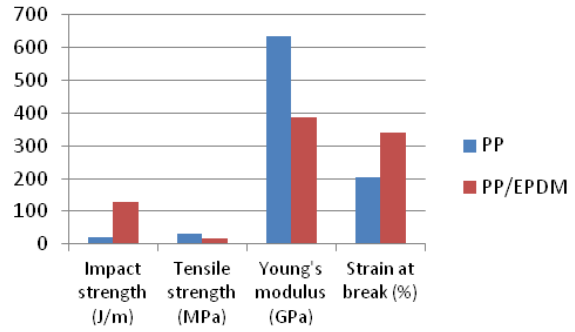

Figure-6. Mechanical properties of PP and PP/EPDM [31].

PP mixed with polyolefin elastomeric (POE)

Lie and Qiu studied the mixing of PP with polyolefin elastomer (POE). The PP used had MFI of 10g/10min with 20% ethylene propylene rubber. The POE used was 39% octene. They revealed that polyolefin elastomer (POE) improved the impact strength and percentage elongation of PP/POE blends [32], however, its yield strength and bending strength decreased as shown in Figure-7. Further, their result showed that DSC analysis result indicated that the percentage of crystallinity of PP decreased with increased of POE content. Further, their result showed that the most useful content of POE was 15-20%. The advantage of POE as compare to EPM and EPDM that easier to disperse than traditional modifiers, EPM and EPDM, during compounding [33].

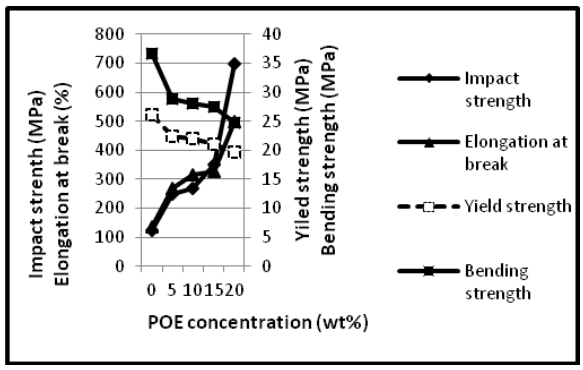

Figure-7. Effect of POE concentration on various mechanical properties [32].

CONCLUSIONS

The effect of reinforcing agents on mechanical properties in PP matrix which employed for car bumper manufacturing is reviewed. It is found that PP is the main plastic material used as matrix. Reinforcement agents used were clay and rubber, i.e., EPM and EPDM. Talc and rubber were found to be main additive materials for enhanced the certain mechanical properties. PP filled with talc increased the modulus strength however yield strength and its strain decreased. Meanwhile, PP filled with rubber increased the impact strength and percentage of elongation however its yield strength and bending strength decreased. Thus, addition of reinforcement agents in PP matrix increased and/or reduced certain mechanical properties. Therefore, selection PP matrix with its reinforcing agent is depended the desirable properties of car bumper.

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