Analysis of Mechanical Strength of Processed Aluminum Laminates

M. Aniber Benin, B. Stanly Jones Retnam, M. Edwin Sahayaraj

Abstract--- The aim of this research work is to prepare the titanium ceramic powder reinforced into the matrix of polypropylene and polyvinylchloride foam and analyze the mechanical behavior of these composites and their laminates combinations. The laminates combination has three layers. The center core is aluminum sheet and the others are either polypropylene or polyvinylchloride. The reinforcement of titanium ceramic powder with the thermoplastic polymer has more interest in this research work because it replaces the conventional reinforcement of synthetic fibers in the polymer matrix. The mechanical behavior of the composites and their laminates were analyzed by tensile, flexural and impact test. The physical morphology of the composites was studied using scanning electron microscope. The test result showed that the addition of titanium ceramic powder enhanced the above said properties in polypropylene matrix and the rigidity of the polyvinylchloride increased to reduce its impact strength. The detailed analysis is discussed in the result and discussion section.

Keywords--- Aluminum Laminates, Mechanical behavior, Polypropylene composite, Polyvinylchloride composite, Titanium ceramic powder.

I. INTRODUCTION

The reduction in the production of greenhouse gases in need of lightweight motor vehicles increases the fuel efficiency. The composite material formation reduces the weight of the vehicle in automotive, aircraft and marine industries. Therefore, the researchers concentrate on their research work to form a composite material and analyze the same. The composite materials offer high strength to weight ratio, resistance to corrosion and fatigue in contrast weak in resistance to impact [1]. One material of this kind is polyvinyl chloride (PVC) closed cell foam. PVC is widely used as core material in sandwich structures for certain composites which requires damage tolerance and saving in weight [2]. The foam plastics are classified into closed cell and open cell. The closed cell foam is almost spherical in shape and its wall is enclosed by the core of foam metal. In contrast, the open cell types of individual cells are interconnected to make a sponge like structure [3]. The energy absorption of closed cell foam is higher than the open cell foam due to entrapped gas within the cell. The entrapped gases act as a medium for energy absorption.

Moreover during mechanical loading, these gases are compressed or sheared to withstand the given load up to break its wall / boundary. When heated gases present inside the foam cell can be whipped into solution of the plastic mixture and volatilized. This improves the strength of the plastic composites by releasing and interacting gases like carbon di oxide and nitrogen di oxide [4]. In general, foam of PVC has low thermal and dimensional stability than their solid counterpart. In contrast, the microcellular foams of PVC by a cell size less than 10 micro meter and cell density higher than 10^9cells/cm^3 offers higher mechanical properties such as strength, toughness, fatigue life and electrochemical property [5]. Once the PVC polymer network is changed, the transition temperature is enhanced [6]. Several researchers investigated to improve the properties of PVC resin through copolymerization [7], halogenation [8], blending [9] and crosslinking [10]. Also, the addition of nano clay enhances the mechanical properties of the foamed PVC [11].

Polypropylene (PP) is one of the plastic materials which comprises of semi-crystalline polymer. It shows easy manufacturing, resistance to chemicals, weight less and reasonable cost [12, 13]. However, polypropylene has certain demerits as high shrinkage ratio, high brittleness at low temperature and less impact strength. PP resin is extracted from the used plastics and blend with calcium carbonate nano-composite [14] and clay composites [15] which enhance the mechanical properties of the PP. Fiber reinforced polymer and aluminum alloys of lightweight materials are used in various fields of engineering application. However, these materials have impact damage and fatigue crack growth [16]. These failures due to damages of both metal and composites are overcome by an idea of combining both to make laminates also called hybrid composites [1].

The recent trend is to make a fiber metal laminates (FML) consisting of alternate metal and reinforced fiber in the plastic polymer matrix layer which are bonded together by adhesives. These laminates enhance the impact strength and reduce production time; thereby its demand has increased in transport sector [17]. The plain aluminum sheet in the FML with the reinforcing item as glass fiber in epoxy resin matrix has been studied by Syed Ahmed et al.[18]. They suggested that the tensile and flexural strength of the FML was increased. In general, the thermoplastic such as PP has been widely used as the bonding polymer for the FML development and it is reinforced mostly with glass fiber. These laminates have great tensile strength compared to unprocessed polypropylene matrix. This work is aimed to prepare a FML laminates containing polypropylene, polyvinylchloride foamed sheet and aluminum metal sheets

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as the inner core and to analyze their physical and mechanical properties.

II. MATERIALS AND METHODS

2.1 Materials and preparation

Polypropylene (PP) of C86/50 AM 120 N grade, Kottayam traders Pvt. Ltd., Kerala, India was used for this purpose and polyvinylchloride of grade SPVC FS: 6701, Plast alloys india ltd., new delhi, India, Finolex Industries, Pune, India. Epoxy glycidyl methacrylate compatiblizer was purchased from Merck, India. CTAB purchased from Central Drug House, Delhi, India. Titanium Oxide Ceramic powder, Merck, India. Foam forming agent was Azodicarbonamide, Ajantha chemicals purchased from New Delhi. Lubricant added was Loxiol12 which was purchased from agarwal merchanties, New Delhi. The titanium ceramic powder was added during processing of polypropylene sheet. The formed sheet had 3 mm thickness. The manufacturing process used for forming this sheet was Injection moulding process. Similarly a titanium ceramic powder was mixed with PVC matrix during the foaming process. The sheet was prepared by hot extrusion process with the thickness of 3 mm and then the sheets were cut into pieces for the required dimensions for test. The aluminum sheet of 3 mm thickness was purchased from Keshariya metal pvt. Ltd. Mumbai. India. The aluminum sheet was cut into required dimensions as per the test. The pieces were joined together to make laminates using anabond grade 112 (anabondpvt.Ltd. India).Anabond is a anaerobic type adhesive. The combination of laminates used for this purpose was PVC/Al /PVC (A), PVC / Al / PP (B) and PP/Al /PP (C).

2.2 Tensile Test

The laminate samples and single sheets were prepared for the standard as ASTM D638 as shown in fig. 1. The test was conducted on the computerized servo controlled UTM machine. The laminates were placed in between the gripers of the UTM machine. The gauge length of the specimen is 50 mm and the cross head speed was fixed to 2 mm/minute. The tensile strength and elongation of the specimens were directly got from the machine data system. The obtained values were taken for the analysis.

2.3 Flexural test

The laminate samples and single sheets were prepared for the standard as ASTM D790 as shown in fig. 2. The test was conducted on the computerized servo controlled UTM machine using special attachment. The gauge length of the specimen is 50 mm and the cross head speed was fixed to 2 mm/minute at room temperature. The flexural strength of the specimens were directly got from the machine data system. The obtained values were taken for analysis.

2.4 Impact test

The laminate impact strength was measured using a charpy impact tester with the laminate specimen and single sheet standard was ASTM D 6110 as shown in fig. 3. After the test, the energy absorption of the specimen was obtained from the machine data.

Fig. 1: Specimens for tensile test

Fig. 2: Specimens for flexural test

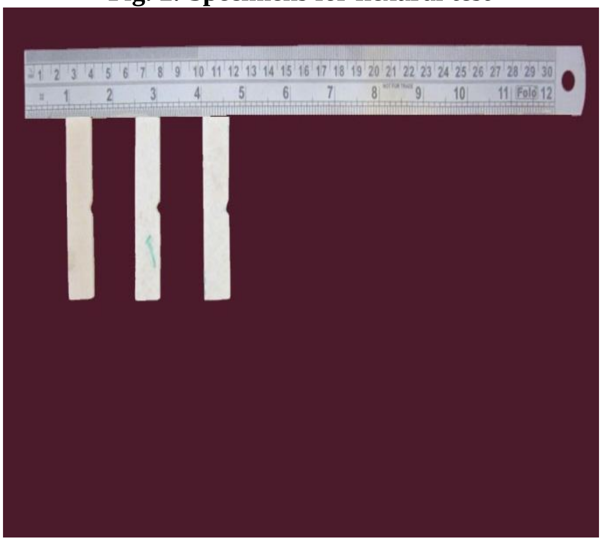

Fig. 3: Specimens for impact test

2.5 SEM

A JEOL made JSM 6390 model electron microscopy system was used to analyze the morphology of laminates. The function of this electron microscope is similar to that of its optical counterpart except that a focused beam of electron is employed instead of light to image the specimen and to gain information on its structure.

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III. RESULT AND DISCUSSION

The polypropylene sheet of 3 mm thickness having 0.7 gram per cubic centimeter of density was used for the test. The obtained tensile strength is 82 kg/cm^2. Similarly the PVC foamed sheet of 0.55 g/cm^3 density has 24 kg/cm^2 tensile strength at yield. In general, the density of both PP and PVC increases to increase the mechanical strength. In this work instead of increasing density, titanium ceramic powder of 50 μm in average is added during processing the sheet formation and the tensile strength of the both PP and PVC sheets are analyzed. The addition of titanium powder into the PP matrix increases the tensile strength of the PP samples as shown in fig. 4.

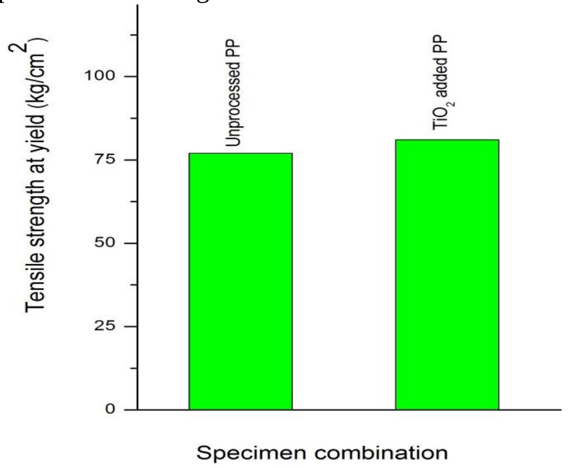

Fig. 4: Tensile strength of various combination of PP sheets

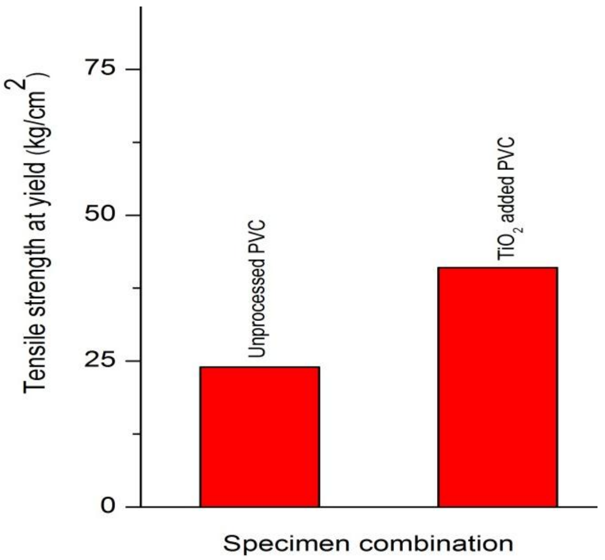

Fig. 5: Tensile strength of various combination of PVC sheets

The tensile strength of the processed (adding titanium powder) PVC sheets increased its tensile strength as shown in fig. 5. This could be due to the reduction in porosity of both PP and PVC sheet by the addition of titanium powder. Also, the addition of titanium powder increases the stiffening of polymer matrix due to increasing local stiffness of the composite. The stiffened matrix might absorb the applied force due to localized strain effect. When comparing the addition of titanium powder in the PP and PVC matrix, titanium influenced more effect on PVC matrix than the PP matrix because the tensile strength of the PVC matrix increased from lower level to higher level. This rate of increasing tensile strength of PVC had not occurred in the tested PP samples. This could be due to the addition of titanium powder strengthens the walls of the foam bubbles of formed PVC because during tensile test these bubbles were elongated and tear off after higher loads.

Further, the increasing trend of increasing tensile strength was obtained by the PVC sheets with aluminum to form a FML as shown in fig. 6. This could be due to the increasing thickness of the sheets (laminates) and the aluminum sheets properties. Aluminum has higher tensile strength than brittle strength. During tensile test PVC foam elongated up to the rupture of air bubbles. After the air bubbles were broken, the inner core of the aluminum sheets were gone for yield. Therefore, the tensile strength of the laminates of PVC has increased. Therefore, the tensile strength of the second combination was increased. While comparing the first and second combination, the second combination has higher tensile strength than the first one because at the second combination the tensile strength of the PP and aluminum sheets influenced and enhanced the tensile strength of the laminates. For the third combination as shown in fig. 6 has higher tensile strength than previous two combinations. This could be due to the higher tensile strength of the PP matrix. During tensile test, the PP matrix could absorb the tensile stress up to its maximum limit then it slowly deformed or strained. At this point the core aluminum metal could have gone for deformation therefore the tensile strength of the laminate combination could increase.

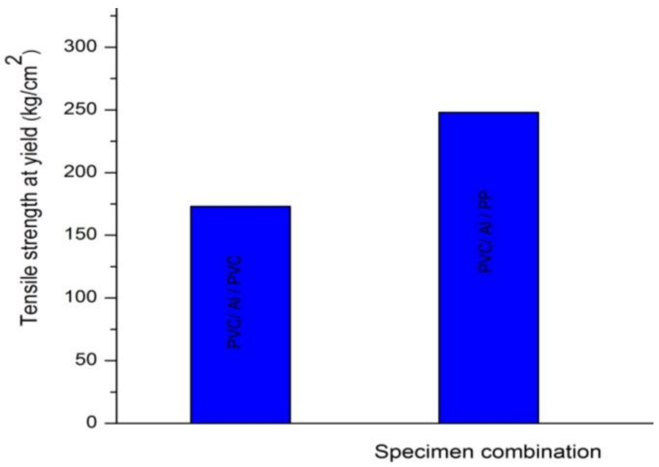

Fig. 6: Tensile strength of laminates combination

The flexural test results showed that the reinforcement of titanium ceramic powder in the PP and PVC matrix has enhanced the flexural modulus of both. This enhancement was high in PP matrix than the PVC matrix. This improvement in flexural modulus could be due to the restriction in mobility of the polymer matrix chain caused by high localized stiffness produced by the ceramic particle present in the polymer matrix. When comparing this effect from the obtained result, PVC foamhad higher flexural strength than the PP matrix.

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This could be due to the improper mixing of ceramic powder in the PP matrix and the agglomerated titanium ceramic powder in the PP matrix as shown in fig. 7. On comparing the laminate combination, combination A had lesser flexural modulus than the combinations B and C. the combination B had higher flexural modulus than the other two. The order of increasing flexural modulus is as follows: combination A, C and B. shown in fig. 8.

The combination B has two outer layers one as PVC and the other is PP. During flexural test the outer layer PP goes for tension and the inner layer PVC had gone for compression. During compression the foam wall were withstanding higher forces due to higher rigidity of titanium ceramic powder formed at the walls of the foam. At the same time the PP matrix with stood the higher tensile forces. The combined effect of these two layers enhanced the flexural modulus of the laminates. But in the combination C the alternate tension and compressive forces acting on the PP matrix reduces the flexural modulus compare to the combination B.

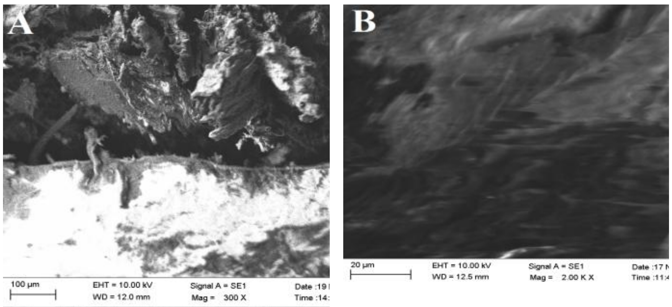

Fig. 7: Scanning electron micrographs of samples (a) PP and (b) PVC

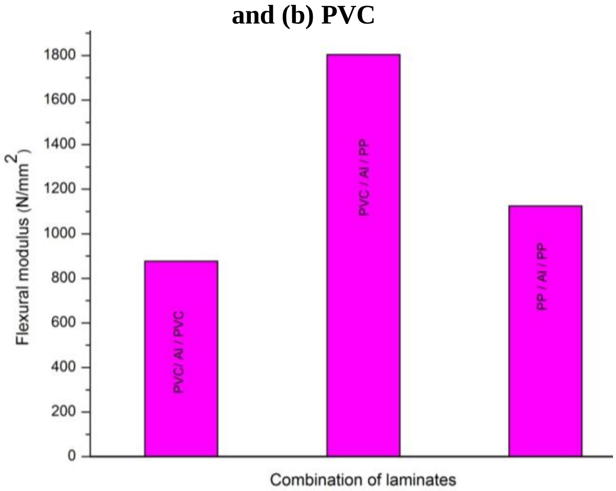

Fig. 8: Flexural modulus of laminates combination

The obtained impact energy absorption capability of the PVC foamed sheet was 15.3 J/mm^2 and this value was deteriorated by the addition of ceramic powder. Because, the added TiO_2 powder increased the rigidity of the polymer matrix by being present on the walls of the foam bubbles. As stated earlier, the reinforcement of the titanium ceramic powder might be agglomerated on the polymer matrix. The agglomerated powder could be further amplified by the rigidity of the matrix at higher concentrated areas causing brittle fracture under impact loading. The same type of result was obtained by Jamel et.al. [19]. The deterioration effect of reducing impact strength in PP polymer matrix is higher than the PVC matrix. On comparing, the laminate combinations, the combination C had higher impact strength than the combination A and C as shown in fig. 9. The density of PP used for this test is higher than the density of PVC that is one of the reasons for this higher energy absorption. And the formation of laminates, the layer of PVC might be compressed to busting of air bubbles (foam) present in the polymer matrix which is the reason for the reduction of impact energy.

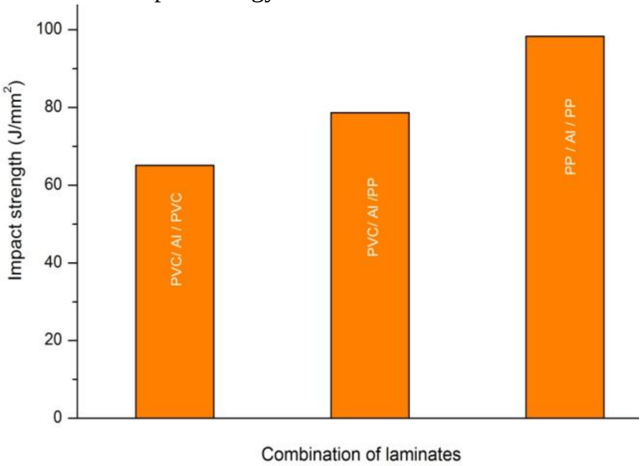

Fig. 9: Impact energy of laminates combination

IV. CONCLUSIONS

- The polypropylene and polyvinylchloride composites sheets were successfully prepared
- The prepared composites sheets were successfully cut into samples as per the ASTM standard for the prescribed test.
- Theobtained result of tensile test showed that the tensile strength of both the titanium ceramic powder reinforced polypropylene and polyvinylchloride composites were enhanced.
- The flexural strength of both the matrix was enhanced by the reinforcement of titanium ceramic powder
- The impact strength of the polypropylene matrix was enhanced by the reinforcement of titanium ceramic powder but the polyvinyl chloride matrix was deteriorated.
- The outer layer of PP and the inner layer of the PVC improved the flexural strength of the laminates
- The tensile and impact strength of the outer layer of PP in the lamination combination could be improved.

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