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Polymer Composites for Industrial Safety Helmets: A Review

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Abstract : Fiber reinforced polymers are achieving its existence in diverse application areas due to its inherent mechanical properties. Among these polymers based composites, natural fibre reinforced polymer composites are gaining popularity among material scientists and industries working in the field of material processing, because these natural fiber based composites reduces burden on the environment as these are biodegradable. In the current study, a review has been carried out towards the work done in the field of replacing existing industrial safety helmet material acrylonitrile butadiene styrene (ABS), with variety of polymer composites. The study shows that hybrid polymer composites have good potential to replace ABS in safety helmets.

Keywords: Natural fiber, polymer composite,acrylonitrile Butadiene styrene (ABS), hybrid polymer composite.

I. INTRODUCTION

Now a day, the increase in environment related problems and growing demand for sustainable materials give rise to thoughts about the replacement of existing materials by eco-friendly materials. The existing materials are replaced by those materials which are biodegradable and renewable and this leads to the development of natural fiber composite [1-2]. When two or more materials having different physical and chemical properties are combined to form a new material having superior properties then the individual materials are known as composite material. They are classified on the basis of matrix and reinforcement material. On the basis of matrix, they are categorizing as metal matrix composite, polymer matrix composite and ceramic matrix composite and on the basis of reinforcement they are categorizes as continuous fiber composite, short fiber composite, particle filled composite, laminar composite and flake composite. In metal matrix composites, matrix material is metal and reinforcement material may be metal or another material. In polymer matrix composite, matrix material is polymer and reinforcement material are may be fiber or other organic material. In ceramic composite, matrix material is ceramic and reinforcement material may be metal or non-metal [3-5].

Now a day, Natural and synthetic fibers or organic and non-organic materials are combined together with matrix material known as hybrid composite. Hybrid composites are developed to meet the properties of both synthetic and natural fiber reinforced composites [6-7]. The fibers are classified as natural fiber and man-made fiber and the detailed classification shown in figure 1 [8].

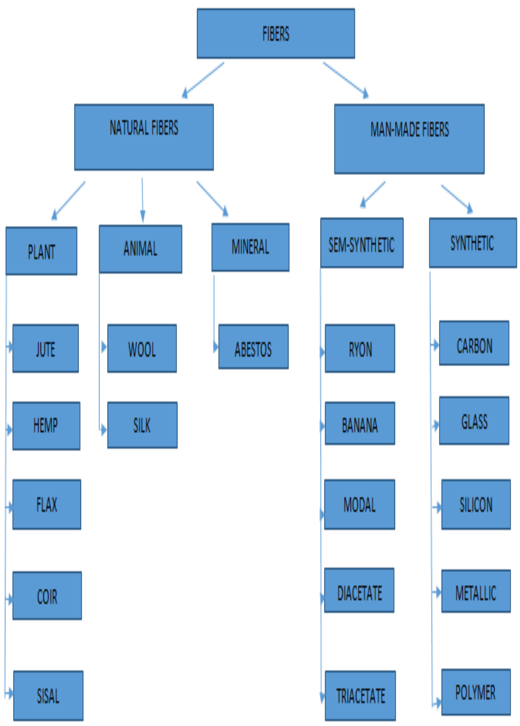

Figure 1 Classification of fibers

Natural fibers are those which are obtained from nature with or without processing. Natural fibers are categorized on the basis of their source such as plant, animal and mineral. Fibers that obtained from plants are (jute, flax, hemp, sisal and coir) that obtained from animals are (wool, silk etc.) and that obtained from minerals are (asbestos etc.). The natural fibres are the most suitable material to replace at the place of conventional materials because of their superior properties such as light in weight, non-toxic, easily available and cheap [9]. Man-made fibers are categorizing on the basis of their fabrication process such as semi-synthetic fibers (ryon, bamboo, modal, diacetate and triacetate etc.) and the synthetic fibers (carbon, glass, silicon, metallic, and polymer etc.). In recent, Hybrid composites are widely used in every field of engineering such as automotive, aerospace, ship industry, construction etc. In aerospace industry hybrid composites are widely use because they are light in weight and their mechanical properties are nearly equal to the conventional materials that's why the 60 percent parts of the aerospace industry are made by the composite materials. In automotive industry the composite materials are widely used to fabricate the various parts such as dash board and bumper of the car, the whole body of sports car is made from the composite material [10]. In this study the work done by different authors on the replacement of recent helmet material such as polycarbonate (PC), acrylonitrile butadiene styrene (ABS),polypropylene, and Expanded polystyrene Styrofoam (EPS) by thefiber reinforced polymer composite is present.

I. MATERIALS FOR INDUSTRIAL SAFETY HELMETS

Obele et al. [11] fabricate coir fiber reinforced epoxy composite for helmet shell using hand layup technique. The weight percentages of coir fiber are 10, 20, 30, 40 and 50 the fiber length 30mm. The authors compare the impact strength, tensile strength and flexural strength of the developed composites with existed material of industrial helmet shell made of polycarbonate (PC) and acrylonitrile butadiene styrene (ABS). They observed that the maximum impact strength of coir fiber reinforced epoxy composite 26.43 KJ/m^2 and tensile strength $23.68N/mm^2$ at 30 wt. % of coir fiber. The impact strength for PC is 20-30 KJ/m^2 and for ABS is 10-29 KJ/m^2 and the tensile strength for PC is $60N/mm^2$ and for ABS is $46N/mm^2$. They concluded that 30 wt. % coir fiber reinforced composite has good properties for industrial safety helmet as compared to PC and ABS material. Murali et al. [12] fabricate the sisal/banana/jute particle reinforced epoxy composite for industrial safety helmet using hand layup technique. The authors compare the weight, impact strength and flexural strength of sisal/banana/jute particle reinforced composite with ABS Plastic and they observed that the weight, impact strength and tensile strength of sisal/banana/jute are 252 gm,53.06J/m and 0.12KN and for ABS Plastic 370 gram, 50J/m and 1.10KN. They concluded that sisal/banana/jute particle fiber reinforced epoxy composite helmet weight is less as compared to the ABS plastic helmet so sisal/banana/jute particle fiber reinforced epoxy composite material is use as an alternate material of ABS plastics for industrial helmet. Natsa et al. [13] fabricate the military helmet using coir fiber reinforced epoxy composite. The weight percentage of fiber for different composition is 20, 40, 50, 60, 70, 80, and 85 taken. The authors observed that the specimen having 70 wt. % of fiber has maximum impact strength (8.733 J/mm^2), hardness (30.03 HRF) and flexural strength (31.88 N/mm^2). They concluded that the composite having 70 wt. % of fiber volume can be used as an alternate material to fabricate military helmet.

Rajasekar. K [14] analysis the properties of natural fiber helmet and polypropylene helmet using Creo simulate 2.0 software. The authors concluded that the maximum and minimum displacement, maximum and minimum von-misses stress for natural fiber helmet is 6.89 e^{-2}mm and 4.148 e^{-2}mm, 0.085KPa and 0.0003KPa and for polypropylene helmet is 23.42mm and 1.646 mm, 4.4 e^{-7}KPa and 1.197 e^{-9}KPa. V. Kostopoulos at el. [15] analysis the effect of the composite shell stiffness and the effect of impact on the dynamic response of safety helmet made of carbon, glass and Kevlar fiber using LS-DYNA 3D finite element analysis code.The helmet shell has two layers' outer layer made of carbon, glass or Kevlar fiber continuous woven mat and the inner layer is made of continuous glass fiber. The authors concluded that the dynamic response of helmet is almost similar for carbon and glass fiber continuous woven mat reinforcement. The Kevlar mat shown better response for safety helmets because it has low shear strength and stiffness. Yogesha et al. [16] examined the mechanical properties of jute/E-glass fiber reinforced epoxy hybrid composite fabricated using hand layup technique. They fabricate four composite having composition L1 ten layers of glass fiber, L2 J/J/G/G/G/J/J, L3 has six layers of jute fiber and L4 has G/G/J/J/J/J/G/G. The maximum tensile strength of composition L1 (280.25 N/mm^2), flexural strength (359.14 N/mm^2) and impact strength (11.4 J). The authors concluded that jute/E-glass fiber reinforced epoxy hybrid composite has achieved better properties than the jute fiber reinforced epoxy composite. Yogesha et al. [17] fabricate the jute/glass fibers reinforced polyester composite by varying the weight fraction of jute/glass as 50/50, 40/60, 30/70. The tensile strength, flexural strength and impact strength of the developed composite were examined and the authors concluded that tensile strength (84.59 MPa) and impact strength (7.12 J) of 50 wt. % jute and 50 wt. % glass fiber reinforced polymer is found higher as compared to other developed compositions and the flexural strength (113.93 MPa) of 40 wt. % of jute and 60 wt. % of glass fiber reinforced polyester composite is found higher other developed composite.

Arthanarieswaram et al. [18] fabricate the randomly oriented banana, sisal fibers with woven E-glass fiber using compression moulding technique. They fabricate nine composites by placing the layers of fibers as B, S, BS, G/B/G, G/S/G, G/BS/G, G/B/G/B/G, G/S/G/S/G and G/BS/G/BS/G. the authors concluded that the tensile strength increases by a factor of 2.34 and 4.13 by the addition of two and three layers of E-glass fiber. The maximum tensile strength (104 MPa) for the G/BS/G/BS/G the maximum flexural strength (192 MPa) when the outer layers are glass fiber and the maximum impact strength (13.3 J) for G/S/G/S/G composite sample. Gopinath et al. [19] examined the mechanical properties of jute/epoxy and jute/polyester reinforced epoxy composites with fiber length of 5-6 mm. The composite synthesized at 18:82 fibers resin weight percentages. The authors concluded that jute reinforced epoxy composites exhibited better mechanical properties than jute-polyester composites. Terano et al. [20] examined the mechanical properties of woven jute fabric reinforced polylactic acid composites. The authors concluded that woven structure exhibited excellent behavior under tensile, flexural and impact loading as compared to non-woven composites. Mishra et al. [21] fabricate the bi-directional jute fiber reinforced epoxy composites using hand layup technique. The authors concluded that the formation of voids decreases with the increase in fiber volume fraction. The hardness, tensile strength and impact strength of bi-directional jute fiber reinforced epoxy composite increase with increase in fiber volume fraction. The flexural strength first decreases with increase in weight percentage of fiber content and then increase by the increase in weight percentage of fiber. The void content greatly affects the flexural strength and inter-laminar strength of the composite.Berhanu et al. [22] fabricate the jute fiber reinforced polypropylene composites using compression moulding technique by varying weight percentage of fiber as 30, 40, 50. The authors concluded that 40 weight percentage of jute fiber reinforced polypropylene composite exhibit maximum tensile and maximum flexural strength.

Ramesh et al. [23] fabricate the banana fiber reinforced epoxy composite having weight percentage of banana fiber 40, 50, 60 using hand layup technique. The authors concluded that maximum tensile strength (112.58 MPa) and maximum flexural strength (76.53 MPa) at the 50 wt. % of banana fiber. The maximum impact strength (11.22J) at the 60 wt. % of banana fiber. They suggest that 50 wt. % of banana fiber can be used as an alternate material for the application of conventional fiber reinforced polymer composite. Nuhu A. Ademoh et al. [24] fabricate the helmet shell from hybrid of oil palm male flower bunch stalk fiber and oil palm frond fiber using hand layup technique. The authors observed that the impact strength (41.11 J/m), hardness (80.66 No) and toughness (2.59 J) of developed hybridized composite. The authors concluded that the hybrid oil palm male flower and oil palm frond composite has great potential to replace the existing ABS Plastic which is used in present for the production of helmet. The authors also suggest that the further research on the increase in weight percentage of fiber, change in fiber length and use of continuous fiber woven mat improve the properties of the developed hybrid composite. B.Arunprasath et al. [25] fabricate the helmet outer shell by using coconut shell powder, coconut leaf midrib and glass fiber reinforced epoxy composite using hand layup technique. The authors analysis the helmet using LS Dyna and compare the experimental and analysis result. The authors concluded that coconut shell powder, coconut leaf midrib and glass fiber reinforced epoxy composite showed better properties and it can be used as an alternate material for the fabrication of safety helmet.

Nuhu A. Ademoh et al. [26] fabricate the anti-crash helmet using the male bunch stalk fiber of palm oil treat with concentrated 5% sodium hydroxide (NAOH) and polyester as a matrix material using hand layup technique. The authors observed that the impact strength (24.22 J/m) hardness (71 No) and toughness (3.28J). the result showed that the treatment of male bunch stalk fiber with sodium hydroxide improved the mechanical properties of the composite. The 20 wt. % of bunch stalk fiber of oil palm reinforced polyester composite have suitable material for the production of anti-crash helmet. The authors also suggest that the developed hybrid composite has also great potential in the fabrication of car bumpers, dash board, and military and industrial safety helmet. Ariff et al. [27] fabricate the inner shell of a safety helmet using coconut fiber reinforced epoxy composite. The modelling and the analysis are performed using CATIA and ANSYS are performed using finite element analysis to compare the mechanical (tensile strength and mechanical strength) and cost analysis with the lowest price safety helmet. The tensile strength and flexural strength of the developed coconut fifer reinforced epoxy composite have good stress absorption as compare to Expanded Polystyrene Styrofoam (EPS). So the developed composite can be used as an alternate material for the fabrication of safety helmet because of it eco- friendly nature as compare to EPS and its weight is similar to that of EPS. Muthuvel et al. [28] investigate the mechanical properties (tensile strength, flexural strength and impact strength) of hybrid glass/jute fiber reinforced epoxy composites prepared by hand layup technique. The total weight percentage of fiber is upto 42 and they fabricate the four composite samples. The authors concluded that the hybrid composites have better properties and they reduce cost by 20% and weight saving of 23% compare to synthetic fiber reinforced epoxy composite. So the hybrid glass/jute fiber reinforced composite can be used as an alternate material where the low weight structure is required and they are eco- friendly material. Surendra et al. [29] fabricate the sisal fiber reinforced polymer composite and sisal/jute/okra fiber reinforced hybrid composite using the weight percentage of sisal/jute/okra is 35/35/30. The author concluded that the mechanical properties of sisal/jute/okra fiber reinforced polymer hybrid composites are better than the sisal fiber reinforced polymer composite. The impact energy of the hybrid composite 33.6 % higher than the sisal fiber composite and the maximum flexural strength of the hybrid composite is 4.7 % higher than the sisal fiber composite. These results show that the hybrid composite can be used as an alternate material for automotive industry and for the production of safety helmets. Chand Bashah SBVJ et al. [30] fabricate the glass/ coconutfiber reinforced polyester composites using hand layup technique. The mechanical properties (tensile strength, flexural strength) of the developed composites are evaluated using ASTM standards. The authors concluded that the amount of force required in tensile test is increase with increase in fiber content. The force required to break the coconut fiber reinforced polyester composite is slightly less as compared to the force required in glass fiber reinforced polymer composite and to get the strength equal to the mild steel the glass fiber content is increased 50 to 60 weight percentage and for coconut fiber content is increase 70-80 weight percentage. They also shown that the coconut fiber reinforced polyester composite has low manufacturing cost as compared to the glass fiber reinforced polyester composite.

Saifee et al. [31] studied the properties and application of coconut fiber in the various engineering fields. The authors concluded that the coconut fiber has high tensile strength, torsion, toughness due to such properties it can be used as an alternate material for the steel. The coconut fiber is easily available, cheaper and eco-friendly. The authors suggest that the application of coir fiber in (1) used as a plaster material (2) using as a roofing materials (3) used in slabs (4) used in wall panels (5) as house constructing material (6) slope stabilization (7) used as an alternate material for the fabrication of safety helmet. Yuhazri et al.[32] fabricate the coconut fiber reinforced epoxy composite for safety helmet. The authors observed the impact strength (9.95 J/mm^2), hardness (80.45 No) of the developed composite. The authors concluded that the developed composite can be used as an alternate material for the fabrication of safety helmet and it is cheap and biodegradable in nature. Nermin M.aly et al.[33] compared the composite shell material for helmet with the Acrylonitrile Butadiene Styrene (ABS) for the safety helmet. The drop test carried out to measure the impact strength of the developed composite. The authors concluded that the fibers in continuous mat form and polyester/glass fiber woven fabric has better properties than the other composites. The composite material is an alternate material of ABS plastic for safety helmet. Johnson et al. [34] develops and analysed a hybrid bio-composite in form of pultruded layers manufactured with jute bio-fibers, combine with glass fibers. The authors concluded that the composite materials can be used as an alternate material for conventional materials. B. Murali et al. [35] fabricate the construction helmet by using hybrid composite material. The authors concluded that banana, sisal and jute hybrid composite has better strength and the weight reduce up to half of the present helmet. So, hybrid composites are better material to replace the As4Polyphenylene Sulphide Plastic in construction helmet.

II. Conclusions

The present review study shows that percentage plastic consumption in safety helmets can be reduced to a greater extent by the use of polymer composites with enhanced mechanical properties. Also, natural fiber reinforced polymer composites give comparable results.

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