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REVIEW

Utilization of textile fabric waste as reinforcement for composite materials in car body applications: A review

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Abstract: Materials are one of the basic elements or needs for continuing human beings' life living and they are used for structural and nonstructural, biomedical, thermal, or other applications. In many types of materials, Composite materials are used in different sectors. The increasing need for eco-friendly, low-density, and lightweight product production prompted the development of fiber-reinforced polymer composites for usage in a variety of home items and automobile parts. The automobile manufacturing sectors have recently attempted to manufacture lighter and lighter parts. Shortly, automobiles must be lighter to meet demands for lower fuel usage and fewer CO_2 emissions. On the other side that textile waste is still simply thrown into a landfill in the environment resulting in and causing pollution. So, the objective of this review was to show the ability of these waste materials used as reinforcing material for composite fabrication products like car hoods, Car bumpers, and lightweight automotive parts. also, it tries to explain the roles of lightweight materials for automotive body parts and also the reduction of wastes in the textile industry by recycling and converting them into useable products, making the environment free of pollution. This waste reduction is a current world issue.

Keywords: automotive body, composite material, environmental pollution, textile waste

1 Introduction

Vehicles have become a significant economic factor. Vehicles can make it easier for someone to get somewhere else transferring or moving. The sources and accessibility of transport-based energy are critical issues for this vehicle. As a research report indicted the Organization of Petroleum Exporting Countries (OPEC) estimates that the global oil demand for transportation is 43.6 million barrels per day. Because oil is a nonrenewable resource, it is critical to raise awareness about how to reduce its use. In addition to this, the number of people using vehicles as transporting toot increases from time to time [1, 2]. On the other side, On-road cars have evolved dramatically in terms of design and other functional characteristics in the current world. In a short period, the market requires faster and greater transportation. Vehicle makers are building big load-carrying vehicles to satisfy this market demand. These large-load transport trucks offer the benefit of speedier, heavy transportation in a short period. On the other hand, the safety of the big load-carrying vehicle must be ensured [3], [4]. Passenger transportation accounts for 60% to 70% of total transportation energy consumption. The most popular method of transportation, yet they have poor energy efficiency, despite significant advancements since the 1970s, owing to rising energy prices and regulations. Because of the weight of automobiles, only 12% of the fuel used by a car creates momentum. One of the biggest causes of traffic bottlenecks in major cities is the car's heavy design and low occupancy. Most highly designed cars (dimension and mass wise) are driven by a single person to get to work in most cities, where the majority of the energy provided by the engine/motor is utilized to droop [5, 6]. The need to reduce fuel consumption for better performance and the wide availability of materials with improved mechanical properties for automotive applications has led to the use of composites and lightweight alloys. They are being evaluated as a possible replacement for today's metal-based parts of vehicle bodies [7]. Many automobile manufacturers attempt to minimize vehicle weight by altering the materials used. Another important reason is the existence of expectations from severe European Union legislation as well as Asian country recommendations addressing the end of life in the automobile business. When choosing the raw materials and future possibilities of the vehicle, environmental considerations must be considered [1]. Starting with company founder Henry Ford, Ford has long been a leader in plant-based material development and application. Manufacturers are focusing on producing lightweight parts and decreasing the CO_2 emission of their vehicles as resources grow more limited. This is being driven by increasing environmental consciousness among consumers and governing agencies [8]. According to the studies [9], Major car manufacturers use natural fiber composites for automotive interiors parts. The advantage of using bio composites is a weight reduction of up to 30%, which reduces fuel consumption. Some of the application areas of bio composites for car manufacturers are shown in Table 1.

Table 1 Use of bio composites by various car manufacturers [9]

Manufacturer BMW	Applications
Mercedes-Benz Volkswagen	Doors, headliner panel, seatback, boot lining Bumper
Volvo Toyota	Bumper, engine insulation, wheel box, roof cover
Manufacturer BMW	Door, seatback, boot lid finish panel, boot-liner Cargo
Mercedes-Benz Volkswagen	Cargo floor tray, seat padding, natural foam Spare
Volvo Toyota	Spare wheel cover, door panels, floor mats

As Table 1 indicates different auto industries try to fabricate different types of parts in bio composite materials. This can be fabricated using the wasted cotton fabric and different textile waste materials if it is studied and characterized perfectly. Recycling these waste materials can have many advantages:

(1) Make free pollution environment;
(2) Implement zero waste fabrication system in the textile and garment industry;
(3) It will also improve the circular economy system as indicated in Figure 1.

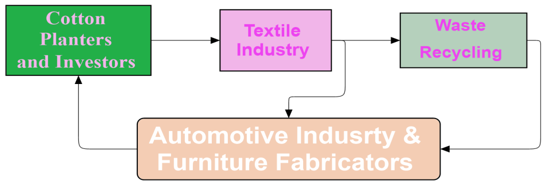

Figure 1 Flow charts of the proposed waste minimization and recycling mechanism of solid textile and cotton fabric

Figure 1 explores that, Automakers are exploring new methods of reducing vehicle weight as consumer satisfaction and the need for more fuel-efficient. To achieve this local reinforcing fillers, such as glass or fibers are used in upgrading plastics to improve mechanical qualities. Natural fibers were used to replace the high-density fillers [8, 10].

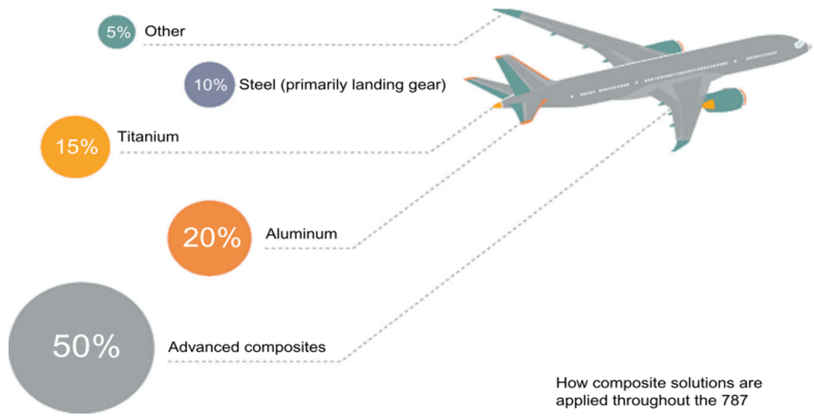

Figure 2 Application of Composite Materials in the Boeing 787 aircraft industry [11]

As shown in Figure 2, the roles and uses of the advanced composite materials in the application of Boeing 787 aircraft are more than 50%. This composite material work includes bio composite materials.

When we compare the composite material with metal, the application of steelwork is around 10% of the total work.

Polymeric materials currently account for nearly half of the volume of materials used in automobiles. Plastics make up 10-12% of the total weight of vehicles in developed countries and around the world. According to the research report on Corporate Average Fuel Economy when we reduced the car's weight by 10%, we can save 6-8% of fuel consumption [12–14].

Figure 3 The different Automotive Components and parts that can fabricate directly from Natural fiber composite materials [15]

As the Figure 3 shows and the researcher discussed many components of the vehicle, especially small automobile components can be fabricated using natural as well as synthetic fibers. From those fiber-reinforcing composite materials, the textile waste may include if it is studied well and recycled regularly.

As the research defined that bio-based composites have many advantages over synthetic fibers, including increased availability, low density, reusable, high stiffness, high degree of flexibility, lower energy consumption, lower health risk, and low abrasiveness [6, 16–19].

Figure 4 The Life cycle of biodegradable bio composite materials [20]

As indicated in Figure 4, Bio composite develops the circular economy in the composite sector. From the fiber extraction up to the final disposal removal mechanism and the landfilling system is safer and better than the synthetic and plastic composite materials. So, recycling and working in this area in the automotive industry will improve such types of the economic cycle as well as free of environmental pollution. The textile and cotton fabric solid waste material can be also included in this process and making it a zero-waste environment if it will be studied under this circumstance.

Figure 5 The different Garment and cotton fabric wastes released to landfill

Figure 5 shows the different waste material which is released into landfill and causes different environmental pollution. Recycling and removing such types of materials into useable products as well as developing a circular economy should be the current research issue. The review points of view of this paper concerned also these issues.

2 What are the current problems and opportunities in the automotive industry?

Until today as many researchers and scholars mentioned that automotive manufacturing industry is trying to fabricate simple weight vehicles. Shortly, it must be lower weighting to fit the demands of consumers for lower fuel consumption and maximum passenger safety, like electric charging cars. As a result, researchers are attempting to develop very lightweight vehicles that operate on electricity and are safe for consumers. Besides that, the development of lightweight automobile body parts using locally available materials provides easy replacement of the part during accidental damage, and it will reduce the human death rate during crushing. Also, the use of locally available materials will increase the country's social, economic, and political awareness. Based on this, the economic effectiveness of cotton rag waste has not been studied, and it is still rejected by the environment and has no use. But studying and using this local waste cotton rag material saves the environment from warmth, pollution, and greenhouse effects. Regarding this, the use of locally produced natural fiber and textile solid waste will help the country's economy in addition to creating a pollution-free environment. Totally to days air pollution and global warming problems come from different participants. From those participants, the transportation sector is the one which affects two ways economically by fuel consuming and environmentally polluting the environment. So, today there are many opportunities for reducing such problems. From those opportunities converting fabric waste materials and using initiate the use of biocomposite materials in the areas of auto industries can provide economic as well as environmental advantages like the replacement of materials and metal-based parts.

3 Light-weight materials in the automotive industry

Many researchers are working on metal alternatives for automobiles to reduce overall vehicle weight, which has an impact on vehicle exhaust emissions. Several vehicle manufacturers in the United States, Japan, Korea, and Europe have begun to use renewable materials. The current difficulty is being conscious of the long-term demand for natural fiber, which will undoubtedly have an impact on ecosystems and biodiversity [1]. The main parts of the car body are made of steel, aluminum alloys, plastics, and glass. Moreover, the advantage is given to low-carbon sheet steel in the thickness with thickness impact factors [21].

As discussed, Emerging advances in fiber-based hybrid composite constructions, in addition to slight weight metallic and multi-material design alternatives, offer a varied answer in the improvement of simple weightless vehicle parts. Recent advancements in the use of cellulose and carbon fiber-based composite compositions have revolutionized not just standard but also luxury vehicle design [2, 21]. Because of their uncommon requirements and qualities, reinforced polymers play a big and vital role in modern engineered applications [10]. Composites now outperform metallic alternatives in certain applications in terms of cost thanks to design flexibility and improved part integration. Due to its unmatched weight-specific qualities and high-tech image, carbon fiber composite has been employed in structural parts in the sports goods, military, and racing industries, similar to the automotive industry. They have been able to do this because clientele who are not concerned with costs value these qualities. The automotive industry, in contrast to these sectors, must be able to adopt carbon fiber composites to reduce structural weight while simultaneously developing a viable economic case for these pricy material systems. Given that the car sector has little practical experience with structural composite materials, the challenge only gets more difficult [2, 23–25].

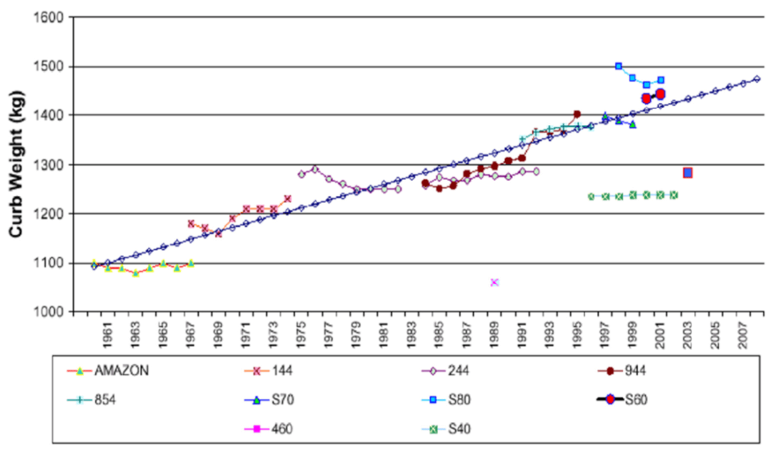

Figure 6 The weight variation developments of the cars in the automotive industry in 1961 – 2007 [23, 26]

As described in the research data in Figure 6, the weight reduction from time to time is different. The maximum weight reduction is shown from the 944 code and the minimum variation is shown from the S80 code of car manufacture. The overall observation and much research data show there is a great weight reduction from time to time due to the modifications and development of new composite lightweight materials.

3.1 Aluminum alloys in the automotive industry

Due to its high deformability and 2.69 g/cm3 density, aluminum is a great steel substitute in the automotive industry. Aluminum alloys may be manufactured as castings, extrusions, stampings, forgings, impacts, and machined components despite having a lower modulus of elasticity (69 GPa) than steel (210 GPa). The final shape of the product is consolidated by casting and extrusion pieces, which lowers the overall component count needed to produce a vehicle [27]. The research and development of new aluminum alloy materials for automobiles are primarily focused on three aspects: the whole body or large aluminum materials; the albuminization of some structural parts like doors; and, if aluminum is used in place of steel in automobile parts, the weight of automobile parts can be reduced by 30% to 50%; and the alienation of the automobile structure can reduce the mass of the entire automobile. Nevertheless, there are still a lot of inexperienced uses for aluminum as a material for vehicles [28]. For automotive applications, aluminum alloys provide the following benefits over steel: Aluminum alloys have a lower density (2.7 g/cm3 vs. 7.87 g/cm3 for steel), higher crash energy absorption per unit weight, and better thermal conductivity for radiator cores and other heat exchanger applications. Aluminum alloys, both cast and wrought, are employed in a variety of automotive applications. 319 for intake manifolds and gearbox housings, 383 for engine blocks, 356 for cylinder heads, and A356 for wheels are the most common cast alloys. Silicon (Si) is the main alloying ingredient in these alloys, which contributes to their great fluidity. They can be made using a variety of methods, including sand casting and die casting [29]. Even though most automakers favor steel today, increased customer demand and new legal regulations concerning fuel consumption and environmental protection have accelerated OEM automakers' weight-reduction efforts. Aluminum could be a viable technical option in certain cases: its density is around one-third that of steel, and high-strength aluminum alloys meet the torsion and stiffness criteria of an automotive component. However, aluminum raw materials are more expensive than steel, which is one of the main reasons why aluminum has long been used largely in the premium part of the automotive industry [30]. Generally, according to many researchers, high-strength steel, titanium alloy materials, magnesium alloy materials, aluminum, and aluminum alloy materials, and plastics and composite materials are the most popular lightweight car materials, according to the automobile industry's development history [28, 31]. (see in Figure 7)

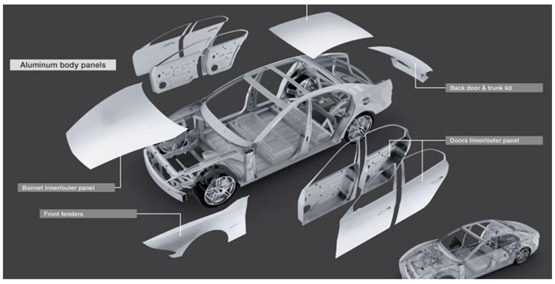

Figure 7 Automotive body parts fabricated from Aluminum alloy composite materials

3.2 Magnesium alloys in the automotive industry

Magnesium is the element that is most common with a density of 1.74–2.0 g/cm^3. It is 77% lighter than steel and 33% lighter than aluminum [32–34]. Increasing fuel economy, meeting regulatory criteria, and meeting consumer needs all require reducing vehicle weight. Magnesium alloys are among the lightest structural metals and have enormous weight-saving potential; but, due to obstacles in production and processing, assembly, service performance, and cost, their usage in today's vehicles and trucks is limited [35, 36].

3.3 Thermoplastics and Thermosets for lightweight automotive structures

The two most common forms of polymers are thermoplastics and thermosets. Thermoplastics are a form of polymer that may melt and become pliable under heat. In contrast, thermosets cannot be melted by heating. In comparison to thermosets, thermoplastics are more ductile, impact-resistant, and recyclable, and they can be produced more quickly. Because thermoset polymer has a lower viscosity than thermoplastic, it may be used with long, continuous fibers to produce high-strength composite structures. Composite structures include but are not limited to, bumper beams, fenders, hoods, roof panels, radiator supports, deck lids, and external and interior body parts.

In today's automobile industry, high-performance plastic applications are crucial. This tendency is projected to continue. The design of automobiles, their usefulness, and more economical construction, as well as lower fuel consumption, are the most important factors in choosing high-performance plastic materials over other materials used in automobiles. Every 10% reduction in vehicle weight is projected to result in a 5% to 7% reduction in fuel consumption [37–42]. (see in Figure 8)

Figure 8 Automotive frontal parts fabricated polymeric composite materials

4 Textile and Garment waste in the application of automotive bodies

In recent years, global textile waste production by the apparel and textile sectors has reached millions of tons annually. One of the materials that are thrown away is textile waste, and the total amount of these materials is growing every year. This makes the chance to recycle and reuse textile waste as a resource while reducing environmental pollution truly unique.

As many researchers stated, the second-largest polluter, accounting for 10% of all environmental pollution in the world, textile waste is widely distributed around the globe. There are major environmental concerns when there aren't enough facilities to dispose of post-consumer garbage in a lot of developing nations. To reduce pollution and avoid landfills, it is far more crucial to recycle and make use of waste materials as resources. However, the use of textile waste fabric as reinforcement in the composite for ceiling boards and other applications was not very widespread. Some researchers tried to create composites using textile waste. The key issue was the resin's and the fibers' compatibility and adhesiveness. This is because the textile waste properties contained a variety of fibers, including polyester, cotton, wool, and acrylic. 100% cotton fiber is suggested as reinforcement to enhance the mechanical properties of the composite, and it is anticipated that strong compatibility and adhesion between reinforcement and matrix will result in good mechanical strength [43, 49, 50].

Figure 9 Examples of the Cotton fabric waste from the cotton processing step in the textile factory (the photo taken during data collection time from Bahir Dar Textile Factory, Ethiopia)

Figure 9 shows this cotton waste is a pure material and it can be used as a reinforcing material for different applications, especially for the development of lightweight auto parts like the bumper, hood, and external bodies. This is the limitation of such types of industry and it should be recycled to make a zero-waste environment.

According to research, the three primary categories of fabric used are for clothes, home goods, and technical textiles, and each of the aforementioned fabric types has the broadest range of applications. In the case of woven fabrics, various technical applications for filtration in industrial activities have been reported, such as the mechanical shaker cleaning method, together with air filtration in automobile engineers, or sound control and speak quality in the electronic devices (acoustic, loud-speakers, and microphones), liquid filtration techniques for chemicals in the paper and pulp industry, and precipitation of metal oxides from solvent. Fabrics that are 2D or 3D, woven, braided, knitted, or non-woven are commonly used to create structural parts like knot elements (beams, shells, exhaust, seats, etc. fabrics to satisfy general requirements of easy manufacture, low cost, sound, and energy absorption, and corrosion resistance. Additionally, all of them are used for ballistic applications as protective apparel or items since they have incredibly high strength and modulus, the capacity to absorb energy and sound, and the ability to fight against chemical and biological warfare agents. Woven and braided fabrics are used in soft space suits for astronauts, space shuttle parts, and airplane seat cushions in aerospace applications, and also as in the airbags or car seat portion of an automotive interior [51].

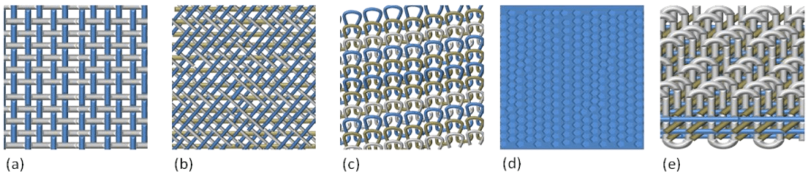

Figure 10 2D and planar and 3D planar fibrous structures of composite reinforcement. (a) woven, (b) braid, (c) knit, (d) nonwoven, (e) tridimensional. [51–53]

Figure 10 shows the reinforcing materials materials of the cotton fabric can be used in different forms like woven, braid, knit, and also nonwoven forms. This gives different properties according to its orientation and can give a chance to select better strength material.

According to the study, 10% of the world's carbon emissions are produced by the textile industry, which is the second most polluting sector globally, contributing to the 92 million tons of post-consumer garbage that was anticipated to be produced in 2015, which is complicated, abundant, and growing at an unprecedented rate. The relevance and the main benefit of this end-of-life waste stream rest on the hidden potential of a material mixture rich in complex polymers and bio-polymers, for which the conventional waste management protocol of incineration or landfill disposal has become ineffective due to its significant negative environmental consequences [54, 55]. The idea of textile recycling should be viewed as a way to gain economic and environmental benefits for several reasons, as it helps to minimize the amount of landfill space needed, the need to generate new materials, and the issues with water contamination. Used clothing, fibrous materials, and production waste from the garment manufacturing process are all included in textile recycling. There are issues with soil and surface water contamination since some items comprised of synthetic fibers do not naturally disintegrate. Although cotton fibers naturally break down, the process results in the production of methane, which contributes to global warming [56]. According to a study in the Ethiopia fabric industry, the majority of waste was discovered to be fabric, with production losses amounting to an average of 28.55 percent of the total fabric. The cutting sector accounts for the majority (64.5 percent) of the overall fabric waste due to the low average marking efficiency of the surveyed enterprises (81.5%). Few businesses dispose of their waste in landfills; the majority sell it to small businesses. Concerning corporate size, but not concerning market orientation, there is minimal variation in the waste management approach. The majority of businesses don't have a plan for reducing waste. Only a small percentage of them (18.2%) think about using other markers to cut down on waste patterns [57–59].

4.1 Automobile front part (bonnet and bumper)

To make cars, the automotive industry requires a huge variety of materials, including copper, steel, glass, rubber, aluminum, steel, and many others. Over the years, these materials have undergone significant development, becoming more advanced, better constructed, and safer. Over time, as new technologies for car manufacturing have evolved, they have altered and are now utilized in ever-more creative ways [60]. The bumper is a structural element that is intended to withstand abrupt or impact loads that are intentionally or inadvertently imposed on cars. When the automobile is subjected to abrupt or impact loads as a consequence of a collision, the bumper's inclusion works to absorb impact energy, protecting both the vehicle and its occupants [60, 61]. To protect the car and people, it is necessary to replace the traditional bumper of an automobile with composite material due to its repeated failures [62, 63].

4.2 Automobile hood design and pedestrian Safety

In many nations, traffic accidents are a dreadful affliction, especially in emerging nations where transportation policies are twisted like a web of yarn. The hood of a contemporary compact car can aid to control the impact energy of a pedestrian's head in a vehicle-pedestrian collision in addition to serving as an engine compartment cover. Given that pedestrians make up the third-largest group of traffic fatalities, vehicle safety criteria should take both passenger and pedestrian safety into account. The majority of pedestrian fatalities are caused by traumatic brain injury, which is brought on by the forceful collision of the human head with the rigid hood or windshield of the car.

Generally, as many researchers and scientists described, to increase fuel efficiency and address issues with fuel-cell and hybrid propulsion systems' range, performance, size, and cost, vehicles must be lighter. The body structure of the Revolution weighs 187 kg, which is 57 percent less than a traditional steel body structure of a similar size but offers higher crash protection, increased stiffness, and good thermal and acoustic qualities. Surface finish, reparability, crash performance, weight, packaging restrictions, and cost are all factors that must be balanced in the design. A sophisticated composite passenger safety cell makes up a sizable portion of the Revolution's body structure. Its design enables a cutting-edge, high-volume manufacturing method that Hyper Car is currently developing [64, 65].

Figure 11 Composite materials safety during a pedestrian emergency [65]

Figure 11 shows the advantages of composite materials during the accident. This provides low injuries to the person than metallic materials as indicated in Figure 11b. The maintenance is also very changeable with minimal cost and materials. But as shown in the Figure 11c and 11d metallic materials are dangerous to life. The composite hood and frontal part can easily bend or crash out during such types of emergencies. During this time the person can easily or may be injured very low than metallic materials. If it is a metallic material, that will crush and damage the drivers of the passengers because that cannot easily regain.

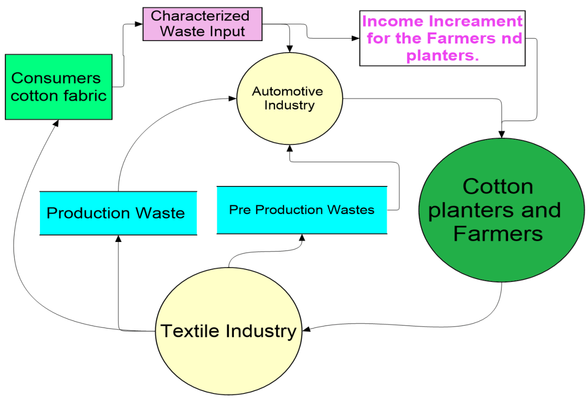

Figure 12 The recycling and circle economy diagram of the textile industry, automotive industry, and cotton planters.

As indicated and explained in Figure 12, basically four main organizations are benefited if this waste is implemented in this way; the producer of cotton, the textile industry, garment factories, waste recyclers, and finally the automotive industry by itself. So, if this waste is recycled the environment also free from pollution and develop a circular economy. Finally, the zero-waste production system also will be developed.

5 Conclusion and recommendation

Nowadays the rapid growth of the manufacturing industries, there is a need for materials that have better properties in terms of strength, stiffness, density, and lower cost with improved sustainability and availability in addition to the simple fabrication process. Natural fiber-based composite materials and garment waste composite materials are one of the most popular materials which possess such properties. From those fiber-based materials, cotton rag fiber is not well studied in the previous related to engineering products like automobile hood body parts, boat bodies, aircraft structures, and other structural applications. Most of the previous researchers deal with cotton fiber with others for different applications but have not focused on the garment waste cotton rag fiber. These cotton rag fibers are the wastes of textile industries. This waste has different impacts like pollution. So, this review indicates found that studying, characterizing, recycling, and developing a composite material from it will provide lightweight composite materials for automobile body applications and will play its environmental pollution reduction, as well as economic advantages for the industry. From this study, we observed that the textile, and automobile manufacturing industries, and society will be benefited if this material is well studied. The country's automotive, boat, and aircraft industries will get the following advantages if this waste material is well recycled and studied: Automotive components such as doors, roof liners, various damping and insulation parts, heed rest, bumper, and hoods can fabricate easily & economically, Lower embedded energy compared to steel and aluminum, Producible with low investment at low cost. Mostly it will apply the future electric discharge-driven vehicles.

Authors contribution

Mr. Melese Shiferaw: Conceptualization, writing original draft, Methodology, and compressive review. Writing - review & editing, Visualization, data analysis. Dr. Asmamaw Tegegne and Dr. Assefa Asmare: Formal analysis, Resources, and also commenting on the overall work.

Conflict of interest

The authors declare that they have no competing financial interests.

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