Review Article: Joining Technologies for Lightweight Automotive Structures

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Abstract

One of the most crucial sectors for society and economic development is the transportation sector. This is particularly true for road transportation everywhere, which is a vital component of trade, employment, and economic growth. The difficulty lies in maximizing efficiency and minimizing expenses and energy while maintaining safety and comfort. This is the impetus behind technology advancement, which is transforming the movement of people and products in tandem with societal shifts (such as shifting consumer preferences and increased environmental consciousness) and political shifts. However, the choice of lightweight materials is minimal; innovative joining and manufacturing technologies may be used. Since 2003, Jaguar Land Rover (JLR) has been one of the leading automakers using aluminum alloys. 90% of the aluminum stamping components of a typical JLR monocoque are composed of aluminum alloys from the 5xxx and 6xxx series. An alternate interpretation of enhanced lightweight frame architecture is the Audi Space Frame (ASF), which is distinguished by its more than 80% aluminum content and CFRP residuals utilized for the tunnel, rear panels, and components that contribute to increased torsional stiffness. Compared to equivalent elements made of conventional steel, a 30% weight reduction is achieved. With the aim of lowering bulk and enhancing sustainability without raising costs or compromising safety, this analysis provides a broad overview of the potential and problems facing automotive body structures in the upcoming years. In order to minimize carbon emissions and create recyclable constructions, this paper first assesses ways to reduce vehicle bulk. Given the design limitations and the technology selection, the potential of novel materials will be demonstrated. The prospects for engineering innovation brought about by this time of significant needs and change will be covered in the closing remarks.

Keywords-Joining technologies, material behavior, lightweight vehicle design, mechanical bearing, welding technology

1. Introduction

The transportation business is one of the most important for people and the economy. For example, this is especially true for road transport in Europe even in all over the world, which is a key part of trade, jobs, and economic growth. It's hard to make sure that comfort and safety are maintained while minimizing energy and cost and increasing efficiency. This is what makes technological progress possible. Together with changes in society and politics, such as shifting consumer tastes and a greater awareness of the environment, technological progress is changing the way people and goods move. On top of that, new trends are having a big effect on the auto industry and are changing the whole value chain. It's becoming even more important in the auto industry to use lightweight materials to lower vehicle mass.

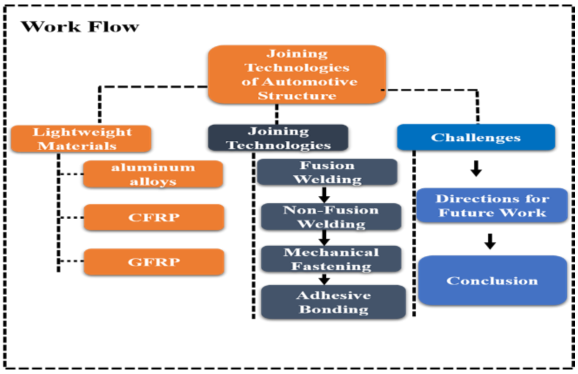

Figure1. Schematic Diagram for Joining Technologies for Lightweight Automotive Structures.

This helps the cars handle better and cuts down on carbon emissions in internal combustion engines (ICEs) and battery range in electric vehicles (EVs). One of the most useful goals in this review has been thought to be using lightweight materials to make cars lighter [1] Mayyas et al [2] say that a 10% weight loss can lead to a 30% reduction in the total weight of the vehicle and a 5% reduction in fuel use [3] .These are the main issues that the auto industry is working to solve in order to make a big weight loss happen. Nevertheless, using lighter materials is not a small change; it might require new ways of making things and putting them together [4]. Since 2003, Jaguar Land Rover (JLR) has been one of the most well-known car companies to use aluminum alloys. 90% of a typical JLR monocoque is made up of stamped aluminum parts made from 5xxx and 6xxx series aluminum alloys. The Audi Space Frame (ASF) is a different way of thinking about how to make a better, lighter frame. It is mostly made of aluminum (more than 80%), with some carbon fiber reinforced plastic (CFRP) used for the rear panels, the tunnel, and parts that give the frame more torsional stiffness. Compared to traditional steel elements that do the same job, 30% less weight is lost. Even though the aluminum and CFRP design saved a lot of weight compared to traditional steel construction, it required a lot of changes to how the parts were put together. Because lightweight materials must be assembled from a variety of materials with varying mechanical and chemical properties, new joining technologies have had to be developed. The joining technologies are frequently divided into three categories: mechanical fastening, adhesive bonding, and fusion and non-fusion welding. Resistance Spot Welding (RSW) is without a doubt the most widely used joining technique among fusion welding processes used in automotive products. Although this technique is now widely used for steel, there are still issues with welding aluminum because of the metal's chemical reaction to airborne oxygen, which results in an oxide layer on the metal side. Despite protecting the metal from corrosion [5], this oxide layer needs to be removed to make room for the growth of the weld [6]. It takes a lot more resistance heating to dissolve the oxide film because of its higher melting point [7]. As a result, spot welding aluminum alloys typically requires twice as much welding current as steel. Furthermore, compared to steel, the electrode lifetime for spot welding aluminum alloy is 2.5–5 times shorter [8]. Spot welding of aluminum alloys can guarantee a high-quality joint, as many researchers have shown, but its application in mass vehicle production is more difficult due to processing conditions like current and electrode life.

The joining technique known as adhesive bonding involves applying an adhesive between materials and interfaces. Good stress distribution and the opportunity to achieve a lower weight of components due to the elimination of mechanical fasteners are the technique's most significant benefits [9]. Nonstructural elements are the most significant application of bonding in the automotive industry, and its use for sheet metal components of load-bearing components is expanding [1, 10]. Adhesive bonding, for instance, can be used in conjunction with self-piercing riveting or resistance spot welding. Furthermore, it is still unclear how long-lasting the adhesives will be [11]. Mechanical joining, such as bolt fastening and riveting, is the preferred method for joining lightweight materials in automotive due to the challenges of welding aluminum alloys and mixed metal/composites joints, as well as the limitations of adhesive bonding as a standalone process.

With the aim of lowering mass and enhancing sustainability without raising costs or compromising safety, this review provides a broad overview of the opportunities and challenges facing automotive body structures in the upcoming years. In addition to giving a general overview of new developments in lightweight material joining, this review also discusses how less established technologies have changed and adjusted to address fresh difficulties in the automotive sector. Given the limitations of the design and the technology selected, the potential of new materials will be demonstrated. The opportunities for engineering innovation brought about by this time of significant needs and change will be covered in the closing remarks.

2. Fusion welding processes

In order to form a joint, fusion welding entails melting the surfaces or edges of materials. Fusion welding is well-established for conventional materials like steel, but it has serious problems with lightweight materials like CFRPs and aluminium. Classifying the various welding processes that have been developed over time aids in understanding their benefits, drawbacks, and areas of application. These processes can be categorized in a variety of ways, including by energy source, phase reaction, pressure versus non-pressure welding, fusion versus non-fusion welding, and others [12, 13]. The classification "Fusion versus Non-Fusion welding process" is used in this work to describe the various welding processes of interest in the design and manufacturing of lightweight automobile bodies. The edges or surfaces of the components to be joined are typically heated locally above their melting point during fusion welding. After solidifying, the two materials in contact combine in a liquid state to form numerous bonds [14]. Resistance spot welding, arc welding, and laser welding are the three fusion welding processes that will be covered in greater detail in this section.

2.1 Resistance spot welding

The most popular joining technique in the production of automotive body-in-white (BIW) is resistance spot welding. In order to connect overlapping metal sheets, electrical resistance is used to generate localized heat. In contemporary automobiles, between 2,000 and 6,000 spot welds make up roughly 75% of the body assembly workload [15, 16]. The most popular joining technique used in the production of vehicle body-in-white (BIW) is resistance spot welding (RSW). A modern vehicle typically has between 2.000 and 6.000 spot welds, which makes up roughly 75% of the body assembly workload. High operating speeds, suitability for automation or robotization, and suitability for high-volume production are the reasons behind the RSW's widespread use [17]. In order to clamp the parts together, the RSW process entails inserting two or more overlapping metal sheets between two water-cooled electrodes. Throughout the process, a limited area of the sheets is subjected to constant pressure. This is illustrated in Fig.2 . Therefore, the need to access both sides of the joint is a drawback of this technology. Electrical resistance is used to heat the material. The two electrodes quickly provide the work piece with electrical current. A small volume of material melts locally and then coalesces to form the weld nugget due to the heat generated by the high contact resistance at the joining surfaces.

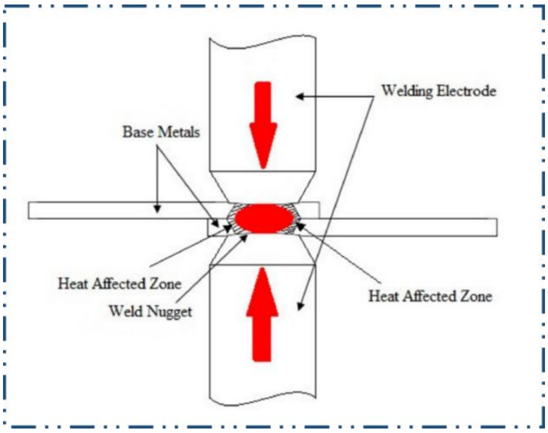

Figure 2. Resistance spot welding (RSW) process. [18]

The characteristics of the weld nugget, which are influenced by the process parameters, define the joint's quality [19, 20]. The type of electrode, the base material's mechanical, thermal, and geometric characteristics (like sheet thickness), and the surface conditions of the sheets in the contact zones. In this regard, one of the primary causes of vehicle crash test failure is resistance spot weld joint failure. The vehicle's overall safety and comfort levels as well as its torsional stiffness may be impacted by sport weld failure [21]. A good weld nugget is produced within a certain current range for each material mix; too much heat input may cause the liquid metal to be ejected from the nugget, while too little heat input may cause insufficient melting [19, 20, 22] . While joining steel sheets is a well-established process, joining aluminum alloy sheets—which has quickly emerged as the preferred material for designing lightweight, eco-friendly automobiles—is not. The physical-chemical characteristics of aluminum are the cause. Specifically, the following challenges are emphasized: (i) Excessive energy usage. This is due to aluminum's low electrical resistance and the fact that it naturally forms an oxide layer with a melting point that is significantly higher than aluminum when exposed to the atmosphere. As a result, a higher thermal input is needed to produce an acceptable weld nugget [5-7]. Short electrode life (ii). High pressure, high temperature, and a quick alloying process all contribute to the electrodes' rapid deterioration during resistance spot welding of aluminum. This electrode life, or the quantity of welds produced before tip dressing or tip replacement is required, is between 400 and 900 welds during RSW of aluminum, which is a shorter lifespan than during RSW of steel [14]. Lastly, this technology cannot be used to join materials with significant melting temperature differences, such as aluminum and steel (Melting Point: Steel 1460C Aluminum 660C). The use of interface materials between steel and aluminum is typically the answer in this case; for instance, a sheet of steel coated in aluminum can serve as a transition material between the two [5].

2.2 Arc welding

In automotive applications, arc welding methods such as Gas Metal Arc Welding (GMAW) and Gas Tungsten Arc Welding (GTAW) are frequently utilized to fuse steel and aluminum. These techniques offer excellent mechanical strength and automation adaptability. For some applications, they are less desirable due to their susceptibility to heat-induced distortions. Arc welding of gas metal and arc welding of gas tungsten. Because they have the immediate benefit of being well-known and tested technologies, arc welding techniques like gas metal arc welding (GMAW–Figure 2(a)), also known as metal inert gas (MIG), and gas tungsten arc welding (GTAW Figure 3(b)), also known as tungsten inert gas (TIG), are utilized in the construction of BIW vehicles.

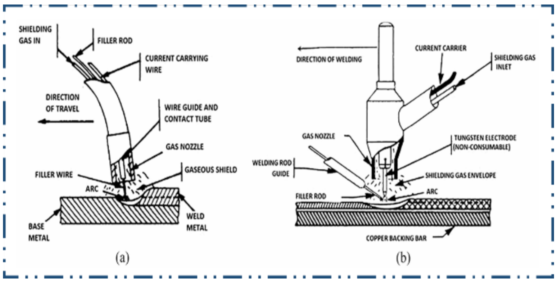

Figure 3. (a) Gas metal arc welding and (b) gas tungsten arc welding [23].

This technology is widely used due to its high mechanical and quality properties, access to only one side of the joint, and proper process parameter design. The creation of the Audi A8 is a noteworthy illustration of the application of arc welding. where extruded components are joined to die-cast nodes using this technique [24]. However, a considerable amount of part distortion is caused by the technology's high heat input requirements. In fact, noncompliance with tolerances frequently results in mating issues between parts in a production BIW operation. One Elise Lotus engineers claimed that they did not favor welding as a joining technique primarily because of this factor (heat-induced distortions) [25].

In arc welding, the metals are melted by the heat of an electric arc that forms between the electrode and the components that need to be joined. Arc welding technology is primarily divided into two categories based on the type of electrode: consumable and non-consumable. The consumable electrode (i) functions as a filler material in addition to conducting current (as in the case of GMAW–Figure 2 (a)-). The electrode consists of a solid wire whose composition is selected to best match the base metal's strength. As with GTAW–Figure 2(b)), the non-consumable electrode (ii) only conducts current in the region that has to be welded. A filler material, which is inserted into the weld site using a separate rod or wire, may be necessary even in the latter scenario [14]. Typically, the arc creates a pool of liquid metal in the welding area by heating the electrode tip to about 3500C. A metallurgical bond is formed between neighbouring components as the pool gradually solidifies. Arc current, arc voltage, wire feed rate, electrode travel speed, current density, and preheating temperature are the welding parameters that have an impact on the final quality of the welding joint.

2.3 Plasma arc welding.

One type of non-consumable electrode arc welding process is plasma arc welding (PAW). Plasma arc welding is used in the automotive industry, where it is favored over alternative welding techniques for joining steel exhaust system pipes and structural components composed of various materials [26]. Although the procedure is very similar to gas tungsten arc welding, it is distinguished by the presence of a converging nozzle that increases the energy density, plasma velocity (which approaches the sound velocity), and temperature (to roughly 25.000C) of the arc by decreasing its cross-sectional area [27]. The electrode in plasma arc welding is also composed of tungsten, but it is positioned inside the welding torch, shielding it from the elements. By extending the electrode's useful life, this offers a significant benefit in terms of higher output and less downtime. In Figure 4, plasma arc welding technology is schematically depicted.

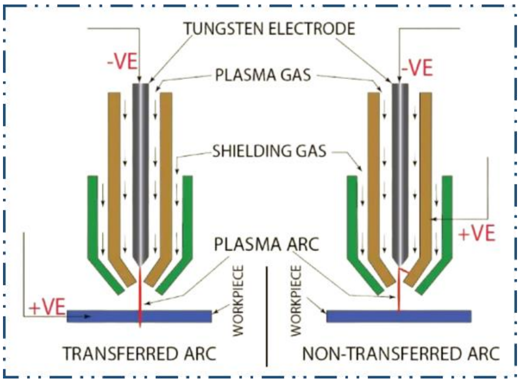

Figure 4. Plasma arc welding.

It ionized and created a plasma arc between the electrode and the work piece. The plasma welding current, nozzle size, and plasma gas flow rate all affect the energy associated with plasma. Even work pieces with greater thicknesses can be successfully joined because the highly concentrated high thermal energy increases beam penetration and decreases weld bead width. Both in terms of regulating energy consumption and the technology's adaptability, the ability to modulate the current supplied is advantageous. There are three distinct types of plasma arc welding that can be identified based on the plasma forming current: (i) micro plasma arc welding ($I_p > 15$ A) for thin sheets, (ii) melt-in mode plasma arc welding ($15A < I_p < 400$ A) for sheets up to 2.4 mm thick, and (iii) keyhole mode plasma arc welding ($I_p > 400$ A) for sheets thicker than 2.5 mm thickness.

2.4 Laser Beam Welding (LBW) and Electron Beam Welding (EBW)

Processes for high-energy beam welding, like LBW and EBW, provide accurate, superior welds with little thermal distortion. Because it can function in atmospheric conditions and is compatible with automation, LBW is especially beneficial [12]. Both procedures are widely used in the automotive sector, where implementing new or improved technologies is constantly hampered by the need to increase production volumes. Gear transmission components, engine housings, detectors, radiators, crankshafts, piston rods, valve heads, filters, catalysts, turbo-compressors, wheel rims, airbags, and many other items are specifically welded using EBW [28], whereas more recent uses of LBW include not only joining delicate or challenging metals but also creating customized blanks for use in car body construction with sheets of various thicknesses [29]. To project free electrons directly onto the work piece during electron beam welding, electric and magnetic fields that define their path accelerate and focus the electrons as they are released from the cathode. In addition to creating a deep, narrow weld bead, such a well-defined beam with a high energy density also lessens the work piece's deformation. The comparison of various weld bead shapes produced by fusion welding technologies in Figure 5 highlights this idea. However, a significant drawback of the technology is that the electron beam must travel through a vacuum chamber because it would not travel very far in air [25]. To address this issue, research has made significant progress in this area. Actually, the automotive industry was the first to use non-vacuum electron beam welding [30, 31]. Here, the electron beam is progressively raised to atmospheric pressure while travelling through a number of pressure chambers. The distance between the nozzle and the work piece should be kept to a minimum in order to maintain positioning tolerances because the electrons are undoubtedly deflected as they collide with air particles as they exit the nozzle. This issue is resolved by laser beam welding; in fact, it can transmit the laser beam through the air efficiently without the use of vacuum chambers. These and other benefits make laser beam welding especially appealing to the automotive sector.

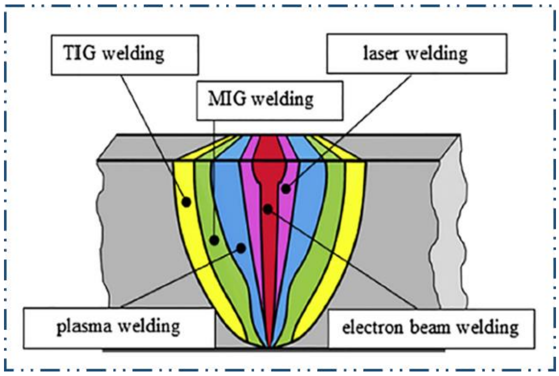

Figure 5. Comparison of the weld bead shape produced by fusion welding technologies [1].

3 Non-fusion welding processes

Non-fusion welding techniques form joints without melting the base materials by using frictional heat or plastic deformation. These techniques are especially useful for overcoming the drawbacks of fusion welding and joining disparate materials [32]. The main method used in non-fusion welding is plastic deformation, which is achieved by applying pressure or creating friction at temperatures lower than the base material's melting point. Because different materials have different thermomechanical properties, it can still be challenging, if not impossible, to weld them together. As a result, the scientific community is interested in and actively researching solid-state welding.

3.1 Friction stir welding and friction stir spot welding

The manufacturing sector is now concentrating on finding sustainable processes and cutting-edge materials due to the rising demand for energy and environmental concerns. In order to reduce fuel consumption, the automotive industry is concentrating on developing novel lightweight materials with a high strength-to-weight ratio [33]. New or enhanced technologies are needed for new materials. In order to reduce weight and manufacturing costs for body-in-white (BIW) car structures without sacrificing passenger comfort and safety, two technologies that satisfy the aforementioned requirements are friction stir welding (FSW) and friction stir spot welding (FSSW). It is more energy efficient because it uses a fraction of the energy needed for fusion welding, which eliminates the issues of cracking, porosity, formation of second phases, and thermal distortions resulting from heat input [34, 35]. This is because both processes utilize the plastic deformation of materials to form a metallurgical bond without the need to reach the melting temperature of materials and, consequently, without the use of filler material.

3.2 Magnetic pulse welding and ultrasonic welding

Magnetic pulse welding (MPW) and ultrasonic welding (USW) are two additional solid-state welding technologies that are of interest to the automotive Industry. Magnetic pulse welding (MPW) employs electromagnetic pressure to accelerate a work piece and generate an impact against another work piece with a high kinetic energy. This collision generates sufficient pressure to form a weld. The primary application of magnetic pulse welding is the joining of hybrid tubular structures [36]. In reality, Dana, a significant US organization that specializes in magnetic pulse welding, was optimistic about the prospect of creating space structures that combine the strength of steel and the lightness of aluminum, thereby surpassing the limitations of single-material structures that were considered obsolete. Also, Pulsar, a small Israeli company that is a member of the extensive Cl al Industries group, has implemented magnetic pulse welding to weld aluminum fuel filters, tubular seat components of steel and aluminum materials, transmission shafts, and hydro formed parts [37, 38]. Conversely, ultrasonic welding generates mechanical vibrations with a low amplitude by employing high-frequency ultrasonic energy. The mechanical vibrations at the interface generate heat, resulting in a metallurgical bond without melting the base material, when the parts are clamped under pressure. The primary applications of ultrasonic welding are the assembly of electric vehicle battery components and the formation of a single junction from multiple stranded copper cables, which are employed in automotive wire "harnesses" [39, 40].

4 Mechanical joining

Traditional bolt-and-screw mechanical joints are uncommon in the automotive industry for large assemblies like the vehicle body. The labor-intensive operations and lengthy cycle time are the primary causes. In actuality, the fastener cannot be inserted until the components have been properly positioned and the parts have been preliminary drilled. To prevent issues during the assembly process, the pre-holes on the two (or more) pieces that need to be joined must also be extremely precise. Welding is unquestionably more competitive for large assemblies, like the body of white vehicles, than traditional mechanical joining techniques, which are only utilized for chassis and suspension components. Self-drilling rivets EJOT [41] are an exception, as an integrated drilling/forming head as shown in figure.6, creates the hole. When only one side of the joint is accessible, they offer a good compromise. However, self-piercing riveting and clinching demonstrate good potential for auto motive applications.

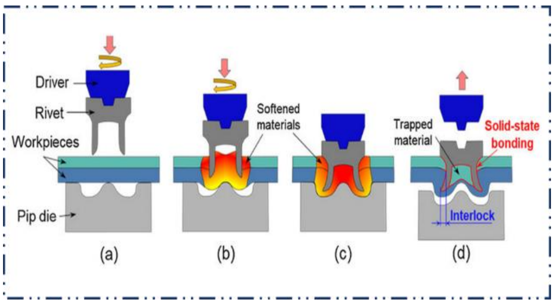

Figure.6 Self-piercing riveting process [49].

4.1 Self-piercing riveting and clinching

The SPR is essentially a cold-forming procedure. The jointing is done quickly, cheaply, and in a single step; in fact, no holes are needed. Furthermore, robots can easily automate the SPR process, significantly increasing the production rate [42]. The Audi A8 was the first to use self-piercing riveting technology to join aluminum structural panels, and the Audi A2 was the first to use it in a space frame structure [43]. Later, Jaguar used mechanical joining in the Jaguar X350 model's monocoque [44]. Direct rivets are inserted into plates that are clamped between a die and a blank holder. A mechanical interlock between two or more plates is created when the punch pushes the rivet through the upper plate and the die's shape deforms the rivet inside the lower plate. It is evident that the technology can seamlessly fuse disparate materials, allowing it to concentrate entirely on the emerging challenges of the automotive sector. It is ideal for joining materials that pose major challenges during the welding process, like magnesium alloys and aluminum. The mechanical characteristics of the substrate materials to receive the fastener, access to both sides of the joint, and a relatively high forming force (usually of the order of about 40kN) that needs to be appropriately designed and calibrated to avoid inducing cracks in the material that would significantly reduce the fatigue life of the joint and the structural part are some drawbacks in this context [42, 45]. The only significant difference between clinching joining and self-piercing riveting is the lack of the actual fastener.

5 Adhesive bonding technologies

Adhesive bonding techniques have grown in popularity as an alternative to conventional assembly technologies in the industrial sector, particularly in the automotive industry, during the past few decades. There are two primary causes for this growth: the first is environmental, and the second is related to the adhesives' superior qualities and price. Actually, new regulations that require a gradual decrease in harmful exhaust gas emissions have been introduced by the European Commission [46]. One potential tactic to meet the recommended emission limits is weight reduction. Even though this method only slightly reduces the weight of the vehicle, it is still interesting to replace the joint by welding or bolts with adhesives. Additionally, a significant weight reduction is made possible by the previously mentioned ability to glue materials of different types, such as aluminum or high-strength steel, to composite materials. In fact, research indicates that a vehicle's CO2 emissions can be decreased by 3% to 5% by reducing its weight by 100 kg [47].

5.1 Hot-melt adhesive

The thermoplastic compound known as hot-melt adhesive (HMA) demonstrates its adhesive properties when it is liquid. A hot-melted adhesive's cooling curve shows three distinct phases: liquid, plastic, and solid. When the substrates to be bonded come into contact with the molten adhesive (about 160C), a thermal gradient is created in the system that causes heat transfer across the substrate area. As the temperature drops, the adhesive solidifies again by gaining a cohesive force that holds the two members together. The HMA is especially intriguing for the automotive industry, where production speed is crucial, because cooling happens naturally in a matter of seconds. Despite being a thermoplastic adhesive with a lower mechanical strength and operating temperature than thermosetting adhesives, HMA's use in the industry has expanded since the 1970s because of its adaptability, quick turnaround times, and strong bond. The ability to join parts made of various materials, which lowers expenses, production times, and weight, is another advantageous aspect of using hot-melted adhesives in this industry.

6 Disassembly issue

The use of adhesives may be hampered by the challenge of separating the adherends without causing harm to the surfaces involved. A glued joint can be disassembled using a number of technologies, including mechanical cutting and the use of acids and solvents, but these methods damage the parts, making their reuse challenging or even impossible [9]. In order to address this issue, new technologies are being researched. One of these involves heating a thermoplastic adhesive that has been modified by nanotechnology via electromagnetic induction [48]. The adhesive in question is specifically a hot-melt adhesive that contains Nano fillers that are sensitive to electromagnetic fields. The nanoparticles can raise their temperature through an inductor because of losses that are reliant on the electromagnetic fields that are generated, which enables the adhesive to melt. The electromagnetic field is produced by a second technology that uses microwaves. The movement of the electrons sensitive to the generated field, resistive heating, electron reorientation, and the presence of permanent dipoles are the causes of the adhesive heating up to its melting temperature [49]. In addition to providing an efficient solution for incorrect joints during production, such technology would enable the possibility of separating glued components, allowing parts to be reused at the end of the vehicle's life. It would also make it simple to replace damaged parts. Therefore, the benefits to the economy, environment, and process that come from the potential for reversible glued joints outweigh the increased cost resulting from the addition of nanoparticles to the adhesive.

7 Joining of automotive lightweight structures in the future

Any mobility development must take into account the required pollutant reduction given the current regulations. For car manufacturers, weight is a crucial factor, and choosing the appropriate material for a given application is increasingly important during the design and manufacturing stages. Numerous market studies predict that composites will be used and applied more frequently. To improve the use of composites in mass-production vehicle manufacturing, more advancements are necessary. We'll soon be entering a market with higher demand than it is now, and it's likely that only those companies that have been able to innovate and take advantage of economies of scale will survive. Two distinct trends in composite materials for automotive applications—carbon fiber and glass fiber reinforced materials (CFRP and GFRP)—have been identified by the requirement for high rigidity and mechanical resistance. Because of their high strength and stiffness, these materials are typically used to create lightweight body structures.

8 Complex challenges for joining

Nevertheless, joining technology faces new obstacles with the use of CFRP and GFRF. This is especially true when joining composites to different substrates. Screwing or riveting such materials is not only laborious, but it also damages their laminar structure, which is a major contributor to their strength. Furthermore, it is crucial to meticulously seal the hole to prevent delamination of the material. Corrosion is also a major concern when CFRP is joined to metal. Welding is frequently considered as a joining method because it ensures stable joints and efficient processes, which are both dependent on the integrity of the laminate product. Nevertheless, there are a number of major downsides to this approach, the most notable of which are the high energy consumption and the fact that it is limited to materials that contain a thermoplastic matrix. Therefore, adhesive bonding is the way to go when assembling composite materials with other parts. It offers excellent resistance to dynamic forces, is versatile in its combination with various substrate materials, and is a non-damaging joining technique. Bonding can also be auto-mated, which greatly improves efficiency by cutting down on cycle time. That is why it satisfies the standard criteria for manufacturing in general, including the automobile industry.

9 Combine glue and screws

An alternative bonded bolt technology called ONSERT has been developed by the insert-specialist Bollhoff and the adhesives-specialist DELO for the joining of composite materials with other materials. ONSERT is based on stud welding. Instead of welding threaded bolts to fiber composite materials, intricate drilling, screwing, or riveting can be avoided by bonding them [50]. The optimal pin and base geometry configuration is created using ONSERT. The process begins with bonding the adhesive to the underside of the base before moving on to the composite material. Typically, spacers—also known as spacers—are used to set the adhesive layer thickness, which ranges from 0.1 to 0.2 mm. One unique aspect of this method is how quickly it can be applied. This is because the base is composed of an amorphous material, which has a translucent surface and ensures shorter cycle times. You can fully automate the hardening process, which takes place in about 4 seconds under an LED light. The plastic component rapidly acquires a stable thread, allowing for unrestricted screwing and unscrewing, and the formed joint can be stressed instantly. The transparent base of the ONSERT can be made of polycarbonate, polyamide, or polyethersulfone; the choice is dependent on the mechanical properties needed and the operating conditions. For the adhesive to harden, these must be amorphous plastics because they let enough blue light with a wavelength of 400nm to pass through. For many purposes, including those requiring the repair of components without their structural joining, ONSERT are an excellent choice. Every year, planes get hundreds of thousands of pins. Cover plates, insulating materials, and floor panels can all be fastened in this manner; in the future, ONSERT could also be used for this purpose. The usage of carbon fibre reinforced plastic (CFRP) is on the rise in the automobile industry, particularly for the B- and C-pillars. For instance, a set of power cables could be attached to these posts with the help of ONSERT. Clips, holders for sensors, and accessories are some other potential uses for this adhesive. Because of its more versatile production options, this method can also be seen as a substitute for welding. Glued points, in fact, allow for easy modification even after construction is finished, unlike welded points. Bollhoff and DELO [51] used ONSERT technology to bond CFRP and other materials. They then put these joints through a battery of industry-standard tests, including the 85/85 test (where components are kept at 85C with 85% humidity) and the VDA climate test, to ensure the method was suitable for these kinds of applications. Here, it has been proven that the ONSERT can achieve high threaded foot tensile and shear strengths, even under the most extreme test circumstances. Both tests confirmed that the ONSERT remained stable after being immersed in Skydrol, an aeronautic hydraulic fluid, for four weeks and after one thousand hours of testing in salt spray. The fitting's strength remained relatively unchanged after being exposed to these atmospheric agents. Finally, DELO and Bollhoff also checked the room temperature thread failure torque on a CFRP surface. The standard for tightening torque of M5 threads is 5.5Nm, and the dimensions of the standard are similar to those of the ONSERT used. The obtained value of 9Nm is much higher than this. Bollhoff and DELO's ONSERT technology has allowed them to create a safe and efficient hybrid of adhesive technology and loosening screw connections.

Conclusions:

With the aim of lowering mass and enhancing sustainability, this review provides a summary of the opportunities and difficulties facing auto body structure manufacturers in the upcoming years. There are a ton of new ideas for reducing the mass of cars, but they need constant research and financial support to become viable. This question has drawn interest from a number of OEMs and academic institutions, and technological solutions are being developed. However, it is important to note that the development of the next generation of automobiles depends on these analyses. Both theoretical and experimental methods must be used to evaluate the new ideas for reducing vehicle mass. As an automobile's body mass decreases, other components will unavoidably be able to be made lighter. New trends in vehicle design, production, and final assembly will result from this. Engineers are required to assess ever-increasing material specifications as well as the machining and joining techniques employed. In order to realize new concepts for lighter and more efficient vehicles, only tried-and-true methods will be used. For these methods to be successfully implemented in a top-tier manufacturing setting, a thorough evaluation of the business cases is also necessary.

Author Contributions: Shabir Ahmad: Conceptualization, methodology, writing original draft, Wasif ur Rehman: formal analysis, and investigation, Shuangfei Yu: supervision and correction, Writing Review and format sitting.

Conflicts of Interest: The authors declare no conflict of interest.

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