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Adhesives in Transportation Series

Part I: Adhesives and Joining Methods in Land Transportation

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Part I: Adhesives and Joining Methods in Land Transportation

Executive summary

Adhesives have a long history of use in land transportation. Passenger cars, heavy duty trucks, and buses have used adhesives to address joining challenges in the body structure and interior. Adhesives are commonly used to create invisible, permanent bonds, that are strong and fatigue resistant. Changes taking place in the regulatory environment for cars, trucks, and busses, notably the need for more fuel efficient and environmentally friendly vehicles, are creating challenges for the industry for which adhesives offer solutions.

Recent regulatory changes, in particular proposed increases to fuel economy, are requiring manufacturers to aggressively reduce vehicle weigh in many segments of the ground transportation industry. This requires the use of mixed material structures and the introduction of new metals, plastics, and composites, for which adhesive bonding is a preferred solution. As a result, adhesive consumption is expected to exceed market growth over the next four years, as manufactures more frequently look to adhesives to meet their material joining challenges.

Vehicle manufacturers have a variety of joining techniques at their disposal, and considerable experience with the design, processing, and inspection of welds and rivets. Because metals are the most common material of construction, these are the most common joining methods used on light vehicles, trucks, and busses today.

Common Joining Methods in Land Transportation

When it comes to selection of joining methods, the primary considerations are the materials to be joined and the physical and environmental demands on the joint in service. In land transportation, the load requirements can vary greatly, but often include the ability to withstand frequent repetition of high loads over a lifespan of 12-15 years of operation in temperatures ranging from well below freezing to the heat of the desert sun.

Materials	Method 1	Method 2	Method 3
Steel	WELD	MECHANICAL	ADHESIVES
Aluminum	RIVETS	ADHESIVES	WELD / MECHANICAL
Composites	ADHESIVES	RIVETS	MECHANICAL
Dissimilar Materials	ADHESIVES	RIVETS	MECHANICAL

WELD	RIVETING	ADHESIVES	OTHER MECHANICAL
			

Source: Ducker Worldwide, ASC Growth Program Research, 2015

Welding is known to be efficient, reliable, and economical joining process in vehicle manufacturing. Because steel has a long history of use in land transportation a great deal of infrastructure and research has been conducted on welding, making it a low risk option for manufacturers. Spot welding, in particular, lends itself to the short cycle times required for light vehicles, and simple visual and mechanical testing can be used to verify weld quality. Aluminum can be spot welded, although not as efficiently as steel, and mass production spot welding of aluminum has been conducted by a variety of manufacturers. However, welding is not well suited for joining dissimilar materials or when parts must be easily removable for maintenance or repair. In these cases, other

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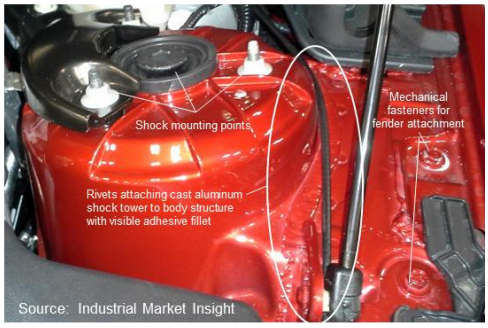
joining methods are used. Other concerns with welding are that the size and spacing of welds can create stress concentrations that can lead to fatigue failures, and the processing heat can degrade properties of the metal in and adjacent to welds. From an aesthetic standpoint, spot welds are not acceptable on exterior surfaces, and care must be taken in the design process to locate welds out of sight.

Riveting has long been a preferred method for joining aluminum, and as the light vehicle segment increases consumption of aluminum, the use of rivets is becoming more commonplace. Ford uses riveting and rivet-bonding to construct the aluminum cab of the F-150, and has experience manufacturing with aluminum through prior relationship with Jaguar / Land Rover, longtime users of the light metal. Much like spot welds, rivets are known to create a reliable bond that can easily be visually or mechanically inspected. However, because of their relatively small size, rivets can create local stresses that lead to fatigue issues. Rivets are more costly than spot welds, due to both fixed costs of equipment investment and the variable cost of the fasteners themselves. From an aesthetic standpoint, it is normally desired to keep unsightly rivet heads off of exposed, finished surfaces, although they are sometimes present on exterior surfaces of medium and heavy duty trucks to create an "industrial" aesthetic.

Ford F-150 aluminum pillars, showing spot welds and rivets

Adhesive bonding is favored when joining composites, plastics, and when dissimilar materials need to be joined. The overall cost associated with adhesive bonding is often less due to the simplicity of dispensing equipment relative to welding and riveting. Adhesives generally create a larger bonded area than other joining methods, which serves to reduce stress concentrations and create stiffer, stronger, and more fatigue resistant joints. Adhesives can also create aesthetically pleasing bond lines that are invisible to the consumer, which can create new styling and design options to differentiate manufacturers. The primary downside of adhesive is the time and/or temperature required for them to build strength, which can make it difficult to achieve short cycle times required for high volume production. However, it is becoming commonplace to find adhesives used in conjunction with spot welds and rivets. In these applications, the adhesive serves to create a strong, fatigue resistant bond, and the structure is mechanically locked in place with weld or rivet so that processing can continue prior to the adhesive's full cure.

Aluminum shock tower joined to steel body rail with rivets and adhesives



Adhesives and sealants on firewall and floor of steel pickup truck cab

Other mechanical fasteners, such as screws and bolts, are used primarily on parts that are likely to require removal for maintenance or repair. These include parts such as suspensions, sub frames, bumper beams, and fenders. The convenience of removal comes at a price, due to both the variable cost of the fasteners and the labor intensive installation process.

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The North American Land Transportation Market

Segment	2015 NA Production (thousands)	Annual Market Growth 2015 – '19	Adhesive Growth	Adhesive Growth Drivers	Applications driving growth
Light Vehicle	17,400	2%	Above market	Fuel efficiency creating the need for lighter vehicles. Lighter vehicles achieved with mixed materials, which require adhesives to join.	Stiffening and reinforcing steel and aluminum body structures. Joining aluminum and multi-material structures.
Heavy Truck	285	-1%	Above market	Fuel efficiency achieved through improved aerodynamics, which is made possible with plastics and composites. Weight reduction allows for Increased cargo carrying capability.	Use of composites and aluminum in cabs and fairings. Reduce number and cost of mechanical fasteners.
Specialty Truck	168	4%	Above market		
Bus	36	4%	With market	Passenger capacity increased with vehicle weight reduction	Potential to join aluminum as a replacement or in conjunction with rivets.

Sources: Ducker, IHS, Industrial Market Insight

Although the need to improve fuel economy is consistent across all segments, each segment has a unique set of drivers stemming from different customers, regulations, and manufacturing constraints. The result is a very different selection criteria for materials of construction and joining methods. For example, there are three orders of magnitude separating the largest segment, light vehicle, from the smallest, which is bus.

Customer: Light vehicles are generally a consumer purchase, while specialty and heavy trucks and busses are an industrial asset. Therefore, the purchase decision criteria are very different. Light vehicles are purchased based on consumer preference for styling, features, performance, and safety. The importance of fuel economy will vary greatly depending upon the buyer, their budget, and the cost of gasoline at any point in time. Conversely, specialty trucks, heavy trucks, and buses are assets that are purchased with a profit motive. Therefore, the purchase decision tends to be more rational and may include metrics such as return on investment. Because improvements in fuel economy will increase return on investment, it may be a more important consideration to buyers of commercial vehicles.

Regulatory: Requirements for light vehicles, heavy trucks and busses differ greatly. Although proposed fuel economy standards are increasing across the board, the increases in light vehicle are much greater than in other segments, creating more urgency for change. Furthermore, safety regulations are dramatically different in each segment, and have significant influence on vehicle architecture and design, which in turn influences material selection and methods of construction. For state safety inspectors with authority over buses, welds are a familiar joining method that are easy to inspect.

Manufacturing: The vast differences in the volume of vehicles produced in each segment result in different material choices and methods of production. North American production of light vehicles are orders of magnitude higher than trucks and buses. Therefore, they are the most sensitive to variable material costs and cycle time. Steel has long been the material of choice for light vehicles, as it relatively inexpensive, and can be joined quickly and inexpensively with spot welds. Adhesives are often used in conjunction with other joining methods when structural bonding is required in order to permit swift assembly while adhesive curing takes place. Specialty and heavy trucks are produced in far lower quantities. While still produced on an assembly line, production rates are much lower, making composites a more viable material choice, and friendlier of longer cycle times associated with adhesives compared to spot welding.

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	Light Vehicle	Med/Heavy Truck & Bus
Production Volume	High >60,000	Low ~10,000
Customer	Consumer	Industrial Asset
Materials of construction	Body: Steel	Cab: Composite, Al Frame: Steel

Source: Industrial Market Insight, Creative Commons

Summary

Despite the differences listed above, the forces driving each segment are pushing manufacturers to reduce vehicle weight by using new combinations of materials, such as high strength steel, aluminum, and composites. Multi-material assemblies are best joined by adhesives or rivets, or a combination of the two, so adhesive consumption is expected to outpace market growth over the next several years. Due to the significant differences in each segment, material selection criteria and joining methods employed can differ greatly in each segment. For that reason, the trends, opportunities, and outlook for materials and adhesives are best examined separately.

Related Documents

Part I: Adhesives and Joining Methods in Land Transportation

Part II: Adhesive Opportunities & Outlook in Light Vehicles

Part III: Adhesive Opportunities & Outlook in Heavy Duty Trucks & Busses

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