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Recommendations Regarding the Use of High-Strength-to-Weight-Ratio Materials For Trailers and Truck Bodies

Developed by the Technology & Maintenance Council's (TMC)
Future Trailer Productivity Task Force

ABSTRACT

Demands for "lightweighting" trailers and truck bodies will inevitably increase as greenhouse gas reduction, fuel consumption reduction, alternate energy utilization, electric propulsion, and automated vehicle adoption accelerate in coming years. The purpose of this position paper is to discuss technical aspects of how — through development of improved metal alloys, composite, and new metal/composite constructed materials — the goals of lightweighting can be achieved for trailers and truck bodies with high effectiveness. TMC's Future Trailer Productivity Task Force recommends a series of goals and actions which may be undertaken in continuous, collaborative efforts to acheive lightweighting of future transportation equipment.

INTRODUCTION

For many years, the transportation industry has actively sought opportunities to reduce vehicle weight and optimize freight efficiency. Higher freight efficiency:

- increases the amount of freight moved per gallon (tonne-kms/gallon),
- reduces the number of trips,
- increases revenue, and;
- reduces operating costs, pollution and highway congestion.

Vehicles with lower weight that produce less greenhouse impact are one of trucking's and regulators' top goals along with aerodynamic, new energy and automated vehicles. The rush for electric power units will push demand for lower weight trailers and truck bodies as well.

Long-term, radically alternative energy sources and more efficient surface transport systems and/or self-driving vehicles may be a large part of the answer. But these aspects are not the whole solution. In fact, these component

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solutions are still too far away to make a noticeable difference in next several decades. Lightweighting will play a key role in short-to-midterm improvements in fleet energy consumption in step with those solutions requiring long-term infrastructure or organizational changes. Lightweighting will also be an important technology that is likely to be a growing part of the bridging solutions that enable industries to benefit from conventionally constructed, traditionally designed vehicles within a decade.

Lightweighting is a key demand in the transportation industry that affects a huge range of products being designed now and in the near future. It is a trend that is important to fleets, original equipment manufacturers (OEMs), and suppliers including commodity producers.

The goal of this position paper is to foster better understanding of high-strength-to-weight-ratio material requirements with respect to semi-truck trailers and truck body construction, weight reduction, and to determine metrics for structure improvement related to material performance associated with the design of semi-truck trailers and truck bodies. It will attempt to explore technical features of a wide variety of new materials that body builders are focusing on in the effort to meet lightweighting goals.

The intent is to understand the design application and performance requirements of such materials as high-tech fiberglass-reinforced polymer resin composites, ultra-high strength metal alloys, and plastic-metal combined composite materials. Material selection for trailer body structure depends heavily on design optimization. Down-gauging, weight reduction and material strengthening only make sense when structural durability, safety and economic benefits are realized. Material consideration must be based on design criteria and functional purpose of the end products.

TRAILER/TRUCK BODY CONSTRUCTION

Today, trailer and truck bodies use mostly semi-monocoque body designs. Monocoque is a structural system where loads are supported through an object's external skin, similar to an egg shell. A true monocoque carries both tensile and compressive forces within the skin and can be recognized by the absence of a load carrying internal frame. A semi-monocoque is a hybrid combining a tensile-stressed skin and a compressive structure made up of bows, uprights and sub-frames. As a semi-monocoque design, the trailer/truck main body structure consists of walls, doors, a roof, sub-frames and a deck including rails, beams, uprights, sills, bows, crossmembers, floors, and suspension. Lightweighting material options for these members are discussed as follows.

Walls, Roofs, and Doors

The majority of today's trailer/truck body walls, doors and roofs are made of skins such as panels and sheets interconnected with supporting members such as bows, rails, beams and uprights or posts. Panels and sheets can be made of a variety of metal alloys and/or composite materials such as aluminum, stainless and coated carbon steel, fiber-reinforced polymer (FRP) resin composite, and metal/composite combinations.

The most popular wall constructions used today for trailers and truck bodies are sheet and post construction sheet metal skins reinforced by hat, "Z" shape or crown- profiled uprights made of aluminum extrusion or rolled, formed galvanized steel, and composite panels consisting of high-tensile steel skins with polymer cores. For lightweighting and corrosion resistant purposes, high-strength, tempered and non-heat treatable aluminum alloys such as 3000 or 5000 series have been widely used for the skins of conventional sheet and post constructed walls for many years. Tempered 5052, 3003, 3004 and 3105 are the dominant

aluminum alloys often used for trailer roofs and wall skins in the transportation industry. Alloyed with manganese, these aluminum alloys display a combination of good structural strength, durability and corrosion resistance.

In addition, the tempered 6000 and 7000 series ultra-high strength aluminum alloys in thin gauged sheet or coil format are developed and have become available for the sheet and post wall as well as have composite plate wall constructions. These alloys can allow significant weight reduction through down-gauging and improved mechanical properties such as higher ultimate tensile, yield, stiffness and shear strength.

Since cargo carrying capacity heavily depends on durability and wall strength, newly developed aluminum alloys must satisfy the same design criteria to withstand deflection, impact, shear, and fatigue required for monocoque body construction. **Table 1** presents available and potential metal alloys that can be used for the wall application. **Table 2** presents mechanical properties of various aluminum alloys. These properties are provided for reference only and should not be utilized for design purposes.

As more composite materials become readily available, a variety of FRP resin-based composite panel constructions will be employed to build dry-freight trailers and truck body walls. These composites are lightweight, high-strength alternatives to metals. The FRP resin composites offer the ability to create complex shapes to consolidate components, have low thermal expansion, provide good insulation

Table 1: Aluminum And Steel Alloy Usage By Application[1]

Application	Alloy	Key Attributes
Trailer/Truck Body Side Wall And Door Skin	3004-H291, 5052-H291, 6013-T6, 7050-T7451, A653 SS GR80 G90, Type 304 & 201 Stainless steel	Painted, durability
Trailer/Truck Body Roof	3003-H16, 3003-H26, 3103-H	Wide width sheet
Dump Trailer Side/Floor	6061-T6, 5083-H32, 5454-H32	Strength, weldability, fatigue
Tanker Sheet	5454-H32, 5454-O	Strength, weldability, fatigue
Tractor Cab Sheets	6022-T43, 5754-O, 5182-O	Formability

Table 2: Aluminum Alloy Mechanical Property Comparison[1,2]

	Ultimate Tensile (UTS)	Yield Tensile (YTS)	Ultimate Shear (USS)	%Elongation (in 2")
AA3003-H16	26KSI	25KSI	14KSI	8%
AA3004-H291	38KSI	36KSI	18KSI	5%
AA5052-H291	42KSI	37KSI	20KSI	7%
AA6013-T6	55KSI	52KSI	32KSI	8%
AA7050-T7451	76KSI	68KSI	47KSI	11%

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properties and very good corrosion resistance. Engineering load cases are used to determine the proper fiber reinforcement, resin system and manufacturing process to meet the requirements at a competitive cost. The three key factors to select a composite system are:

- mechanical performance,
- weight target, and;
- cost.

Changes can be made to any one of these factors and have an impact on either or both of the other two. For example, consider using both fiberglass and carbon fiber reinforcement in the same composite to meet the mechanical performance with a slightly higher part weight and lower cost. The walls of trailers and truck bodies can be constructed with FRP sheets or panels consisting of these high-performance fiber reinforcements and multi-layer thermoset or thermoplastic resin systems.

Thermoset resins are liquid at room temperature and are cured by a chemical reaction or by applying heat in an oven. (Examples of thermosets are: epoxy resins and hardeners such as vinyl esters, polyesters and polyurethanes. Some of the positive aspects of thermoset resins are good thermal stability, good rigidity and stiffness, resistance to creep, remaining in a solid state once cured, and ease of manufacturing. Some of the negative aspects are they cannot be melted and reshaped once cured, are difficult to recycle, a long curing time, and a typically higher cost than thermoplastics.

Thermoplastic resins are usually stored in pellet form and once heated become moldable above a specific temperature and then injected into a mold to solidify upon cooling. (Examples of thermoplastics are nylon, ABS, polycarbonate and polypropylene.) Some of the positive aspects of rhermoplastic are shorter manufacturing cycle times, reshapeability by applying heat, recyclability,and a typically lower cost and higher puncture strength than thermosets. Some of the negative aspects are inconsistent thermal stability based upon the properties of the resin system, lower resistance to creep, and lower stiffness strength than thermosets. Resin system selection must strike a balance of mechanical performance, manufacturing process and cost.

The reinforcing fibers selections can vary depending on strength-to-weight ratio. For trailer/truck body applications, fiberglass, carbon fiber, aramids and natural fibers can be utilized.

- ***Fiberglass roving (yarn)*** is made up of many very fine glass fiber filaments. This roving can be woven into fabrics, mats, knitted, braided or chopped. There are many grades of fiberglass for different applications. The different grades provide a wide range of performance characteristics. Fiberglass reinforcements provide a good balance of strength and cost.
- ***Carbon fiber tow (yarn)*** is made up of many very fine carbon filaments. Carbon fiber tow size is described in the number of thousand (k) filaments- example 3k = 3,000 filaments. Carbon fiber is generally manufactured in 1k, 3k, 6k, 12k and 24k tow sizes. Traditionally the more expensive smaller tow (1k-6k) is used for aerospace applications and the less expensive large tow (12k-24k) is used for industrial applications. Carbon fiber is manufactured in many different grades that provide a wide range of performance characteristics and cost. Carbon fiber reinforcements provide very high strength and light composite parts at a cost that is justified by the performance gains.
- ***Aramid fiber yarn*** is made up of many very fine, man-made polyamide filaments. Aramid fiber yarn size is described in linear density (dtex). Different dtex yarns are used for different applications and the dtex of the yarn will impact fabric performance and appearance. Aramid fibers are manufactured in different grades that provide a wide range of performance characteristics and costs.

Aramid fiber reinforcements provide an abrasion resistant, low flammability and a high-strength composite at a cost that is justified by the end use requirements.

- Different ***natural fibers*** can be used in structural composite applications. Fibers such as cotton, banana and palm leaf fibers, jute and flax have been used in different applications. These fibers are low-cost, moderately strong and renewable. However, natural fibers have a greater variability in properties and absorb moisture which results in the fiber swelling. Natural fiber reinforcements provide for a low-cost, environmentally friendly and moderate strength composite. Engineering load cases and failure modes must be well understood when working with these types of fiber reinforcements.

High-performance fibers can be woven into fabrics, chopped to produce a random mat, milled to be used in injection molding compounds, resin transfer molding (RTM), sheet molding compound (SMC), or as unidirectional fiber for pultrusion and unidirectional prepreg. Fiber reinforcement choice is based upon balancing mechanical performance, desired final part weight, manufacturing process and cost (see **Table 3**).

Another popular form of composite material for trailer/truck wall systems is the structure sandwich panel consisting of high-yield strength galvanized steel or aluminum alloy skins with homogenous polymer based core such as high density polyethylene (PE), or polyvinyl chloride (PVC). These panels are employed for lighter and high-cubic capacity plate wall trailer and truck body construction. In general, the composite walls weigh less than the sheet and post constructed walls. The typical 7.5 mm thick composite panel wall with 0.016" thick steel skin and high-density (40pcf) PE core weighs 2.2 lb./ ft^2. Whereas aluminum sheet and post wall construction with plywood lining weighs 2.6lb./ ft^2. This weight difference translates to approximately 350 pounds on 53' trailer. The skin material of the composite panel is predominantly made of 80 KSI yield galvanized or galvalume coated steel. However, as advanced high strength steel (AHSS) with yield strength more than 100 KSI and tempered 7000 series high-tensile aluminum alloy with 70 KSI plus yield strength become available, the weight saving potentials using various lightweight core and skin materials made of these high-strength metals with optimized geometries are even greater. Potentially, the lighter core will allow thicker panel construction which will provide higher stiffness.

In particular, sandwich-materials consisting of two face sheets with a lightweight center core material, are widely used (see **Figure 1**). When separating the face sheets by increasing the

Table 3: High-Performance, Fiber-Reinforced Composite Material Strength-to-Weight Comparison[3]

NOTE: The properties shown are provided for reference only and should not be utilized for design purposes.

Strength	Fiberglass fabric composite	Carbon fiber fabric composite	AA6013-T6 Aluminum Alloy	High-Strength Steel	A36 Mild Steel
Tensile (Mpa)	300	840	350	550	400
Modulus (Gpa)	250	700	150	207	200
Specific Gravity	1.7	1.6	2.7	7.7	7.8

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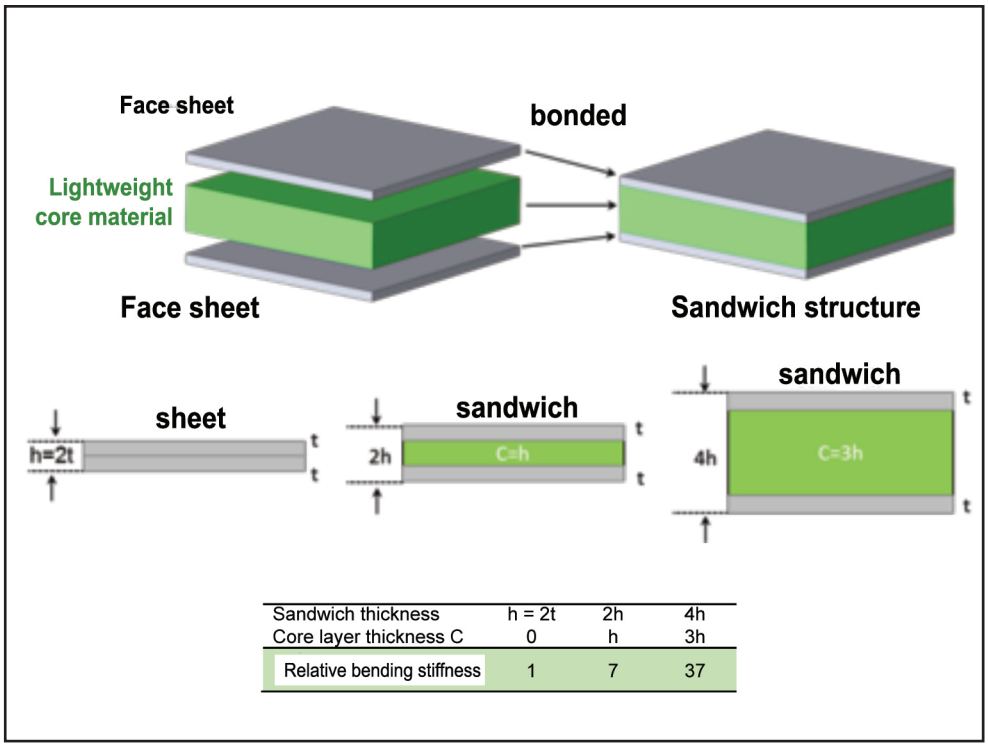

Sandwich thickness	h = 2t	2h	4h
Core layer thickness C	0	h	3h
Relative bending stiffness	1	7	37

Figure 1: Sandwich Material – Bending Stiffness[4]

core layer thickness "*C*," the bending stiffness grows proportionally, with "*t"* denoting the face sheet thickness.

The bending behavior of a sandwich panel can be compared to an I-beam, where the face sheets and flange are bearing the normal in-plane loads, while the out of plane load (i.e., transverse shear) is introduced into the core layer and web, respectively. The sandwich panels used in the trailer/truck body side walls are mainly under a bending load, whereas the sheet and post construction walls used in semi-trailers (classic example of a "Wagner" beam) need to resist a significant in-plan shear load. As trailer body construction design and technique advances, these panels need to be thinner and lighter and maintain the structure integrity.

Many different sandwich panels with multilayer constructions using advanced lightweight metal or composite skins with varying density non-homogeneous cores such as honeycomb and honeycomb derivative cores can be employed

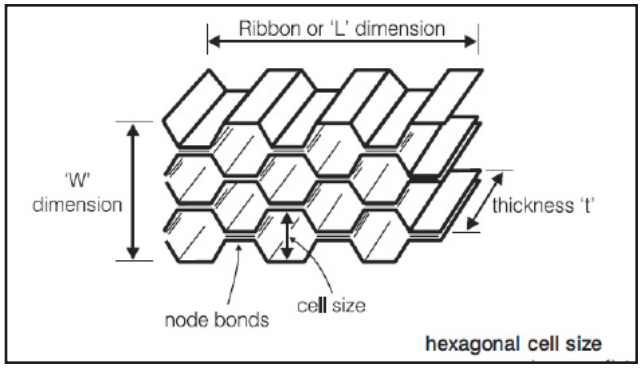

Figure 2: Honeycomb Structure[4]

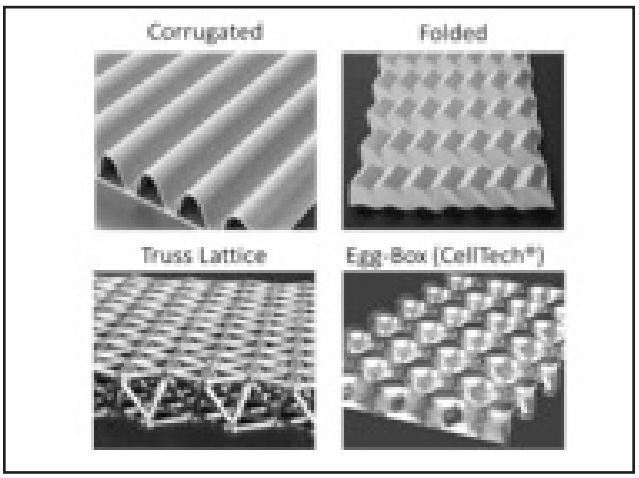

Fig. 3: Derivative Honeycomb Structure[4]

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for even further weight savings. As shown in **Figures 2 and 3**, some of the possible core construction and material are polypropylene (PP) hexagonal honeycomb, truss lattice, metal corrugated and folded sheet and egg shell formation. The honeycomb structures are well known for popular usage in less price sensitive industries, such as the packaging industry. The hexagonal-shaped cell core thin walls feature relative high surface plane compression and shear properties despite of its low density. Depending on its application, a variety of core materials can be used such as; aluminum, Nomex, impregnated kraft paper, polypropylene or polycarbonate.

A newly developed process of slitting and folding sheet material has led to a cost-efficient, continuous, producible honeycomb product. However, today's process only supports plastic films where performance can significantly affected by heat. Furthermore, structural elements and longevity can be reduced due to material creeping. Besides the honeycomb structures, there exists a broad variety of derivative honeycomb structures which can be categorized as corrugated, folded (i.e., chevron), truss lattice or egg-box structures. These periodical cellular core structures can be tailored for optimal performance specific to load conditions through continuous folding, stamping and/or embossing, while maintaining low manufactured cost.

In addition to plastic sheets, a wide selection of sheet metal (e.g., low-carbon steel, aluminum alloys) can be used, which enables their usage in higher temperature applications. Although the panels with a low-density core structure feature a high bending stiffness to weight ratio, they can deliver inferior local compression strength as shown in **Figure 4**. Incidental damages and reparability and cost must be taken into consideration. The diminished dent and puncture resistance can also challenge traditional mechanical fastening for joining methods. The latter can be solved either by

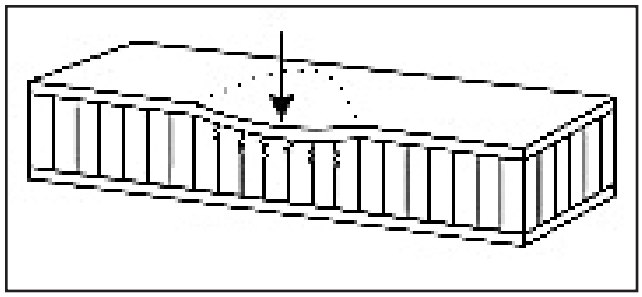

Figure 4. Local Indentation[4]

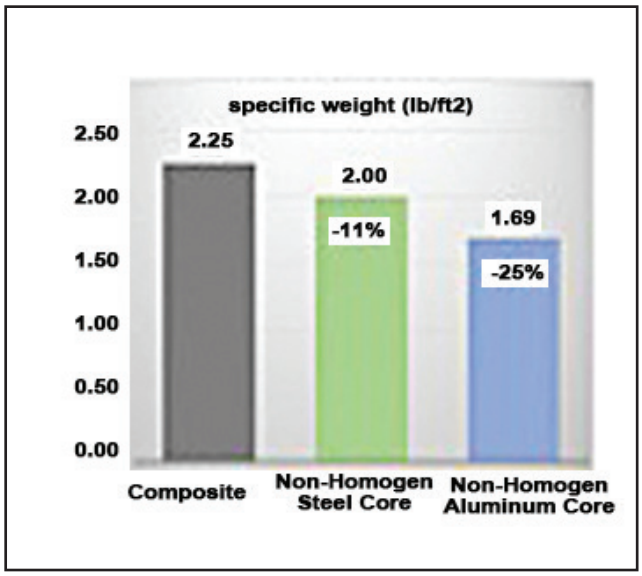

Figure 5. Comparison of Sandwich Panels[4]

using; advanced bonding techniques, building local reinforcements into to core structure (i.e., rigid foam) or embedding load component features (i.e., insert). **Figure 5** shows a comparison of homogenous core verses hollow core construction sandwich panels; each consists of two 0.016" thick steel face sheets (standard dry van wall configuration). All three panels feature a similar bending stiffness, due to negligible contribution of the core on a large panel. While the polyethelene core with steel skin composite panel weighs 2.25 lb./ft^2, the egg shell shape steel core with steel skin panel weighs 2.00 lb./ft^2 (11 percent less) and 1.69 lb./ft^2 (25 percent less) with aluminum core — creating estimated 500 pounds weight savings on a 53-foot trailer. Although the hollow-core

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sandwich panel displays higher weight-to-bending-strength ratio, since the derivative honeycomb structures are more porous, they can have other failure concerns compared to a solid-core sandwich material. Therefore, it is very important that each sandwich panel is engineered and optimized for the specific application.

Depending on the composite panel construction, the weight differential can be even bigger. However, the weight saving potential with composite panels must be coupled with structural integrity improvement.

Some of the possible sandwich panel constructions are:

- Metal skin (galvanized steel or aluminum) + high-density polyethylene core + metal skin
- Metal skin + metal core (non-homogeneous) + metal skin
- FRP skin + honeycomb (PP) + FRP skin
- FRP skin + metal core (honeycomb derivatives) + FRP skin
- Metal skin + honeycomb (PP) + metal skin
- FRP thermoplastic/thermoset multi-layer sandwich panels
- Carbon fiber-reinforced thermoplastic/ thermoset multi-layer sandwich panels

The panels with these multi-layer sandwich constructions must satisfy trailer/ truck body wall design criteria for the semi-monocoque body construction. Specifically the shear, bending and fatigue stress, tension, compression and impinging impact force acting on the panels must be overcome by the main structure members such as skin, core, reinforcements and assisting stiffeners acting as a single unit providing structure integrity.

Frames, Decks, and Suspension

Trailer/truck body frames, decks, and suspension systems are considered to be the main supporting members of semi-monocoque construction. They are the members which interconnect and join body members together to help carry loads imposed by cargo. They are important functional members contributing to rated cargo carrying capacity of a trailer and truck body. Typically, they are the rear and door frames, deck frames, front and side wall stiffeners or frames, suspension components and frames, temperature control unit (TCU) mounting frame, upper coupler for fifth wheel coupling frame, under ride guards and floors. These members are constructed with rails, bows, cross members, sills, uprights or posts, beams and floor boards. There are significant lightweighting potential with these members using high strength-to-weight-ratio metals such as AHSS, high-strength aluminum and magnesium alloys and composite material.

Traditionally, trailer body structures have been manufactured from conventional steel grade such as Grade 50 (50 KSI yield strength steel), — thick gauges designed with regard to static load carrying capacity and stiffness. This results in heavy vehicles that are often oversized in regard to fatigue and stability. Currently, many trailer producers are manufacturing lightweight vehicles from Grade 100 (100 KSI min. yield strength) or similar steel grades. By reducing plate thickness of the consisting parts, working stress levels will increase and, if no other measures are taken, this will lead to reduced fatigue life.

The stiffness and weldability in down gaging must be addressed as well. However, by improving details of design and geometry and implementing high quality manufacturing techniques, the fatigue, stiffness, weldability and stability can be managed to utilize these higher strength steel grades in trailer applications. The commonly used steel alloys such as high-strength low alloy (HSLA) and structure Steel (SS) for frame components today can be replaced by ultra-high tensile steel (UHTS) or AHSS with yield strength above 100 KSI and high ductility. The AHSS typically ranges from

130 KSI to 200 KSI which is 50 to 70 percent stronger than the HSLA or SS. Down-gauging is very possible with these steel alloys since they have high ductility to form very complex shaped parts such as frame header, rails, sills, and posts.

Alloy	UTS Mpa (Ksi)	TYS Mpa (Ksi)	Total Elong (%)
5052-O	193 (28)	90 (13)	30
5052-H32	228 (33)	193 (28)	12
5083-O	290 (42)	145 (21)	25
5083-H32	317 (46)	228 (33)	16
5182-O	276 (40)	135 (20)	27
5454-O	248 (36)	119 (17)	25
5454-H32	276 (40)	207 (30)	18
5754-O	233 (34)	122 (18)	25
6022-T43	235 (34)	126 (18)	27
6022-T43 PB	300 (44)	238 (35)	24
6111-T4	273 (40)	163 (24)	26
6111-T6	327 (47)	300 (44)	12
6013-T6	406 (59)	372 (54)	9
6061-T6	310 (45)	276 (40)	12
6055-T6	385 (56)	376 (55)	12

Table 4: Mechanical Properties of Common Aluminum Alloys[1]

Application	Alloy	Key Attributes
Trailer Frames	6061-T6, 6013-T6, 6055-T6	Strength, fatigue
Dump Trailer Side/Floor	6061-T6, 5083-H32, 5454-H32	Strength, weldability, fatigue
Fuel and Air Tanks	5052-O, 5052-H32	Impact resistance
Dry van and Reefer Floor	6061-T6	Strength, fatigue
Wheels	6061-T6 (other proprietary alloy such as Arconic Magna Force™)	Fatigue, surface, wear
Bumpers	6061-T6, 6013-T6, 5000	Surface, strength
Trim	Various 3000, 5000	Good surface
Accessories, Tread plate, scuff band.	3003-H22, 6061-T6, 5036-H32, 5082- H34	Formability, appearance

Table 5: Possible Trailer Application Areas For Aluminum Alloys[1]

Another lightweighting option is to convert from a higher density material (normally steel) to a lower density material such as tempered aluminum alloys (6000 and 7000 series), magnesium alloy, or titanium. Aluminum alloys 6013 and 6055 are two of the strongest 6000 series alloys available, capable of reaching strength levels nearly 50 KSI for 6013 and 55 KSI for 6055 with a treatment of two percent stretch plus 400°F for 60 minutes. The 6013 alloy was originally developed as a sheet alloy for automotive bumpers. It has good formability in the T4 temper, and has been evaluated extensively for aerospace sheet, automotive sheet, and drawn tube applications. The 6013 alloy is an excellent candidate for trailer/truck body frames. The 6055 alloy was originally developed for fuselage skin sheet applications. The alloy provides roughly a 10 percent strength advantage over 6013 and is the strongest 6000 series alloy available. Additionally, 6055 has improved corrosion performance (ASTMG110) over 6013 and improved fatigue performance. Alloy 6055 is currently being evaluated for applications requiring high strength in a number of different application areas. Some of the possible applications for these aluminum alloys include rails, beams, crossmember, bumper tubes, rear frame, TCU mounting frame, Landing gear, Upper coupler, wheels and floors. Aluminum cast alloys such as 385 and crash alloy such as 6053 can be

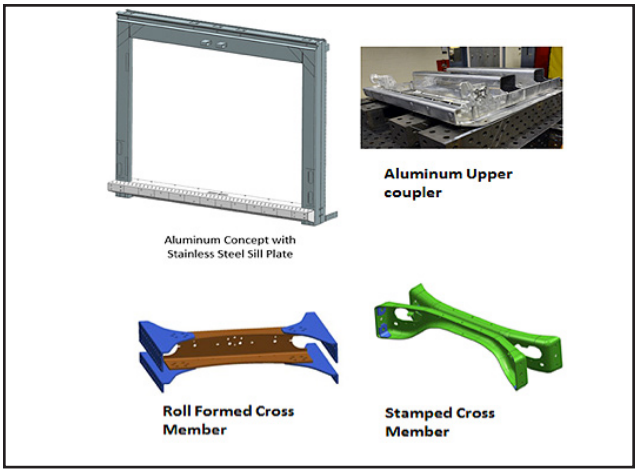

Figure 6: Examples of Aluminum Alloy Component Applications[4]

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used for the bumper tube, corner caps, and suspension components as well.

Some of the popular floors available today are high-tensile aluminum extrusion and composite floor boards. The aluminum extrusions or roll formed sections made of 6061, 6063, 6051, and 6015 alloys are used for the floors of trailers and truck bodies for light weighting. These aluminum alloys are excellent candidates because of their excellent mechanical properties. **Table 4** shows typical mechanical properties of common aluminum alloys. **Table 5** provides possible trailer applications for different alloys, with examples of components illustrated in These properties are provided for reference only and should not be utilized for design purposes.

High-performance composite materials such as high-performance fiber reinforced polymers previously mentioned in the **Walls, Roofs and Doors** section with various composite manufacturing processes can produce high strength-to-weight ratio composite materials for the frame members. Some of the popular manufacturing processes to produce these materials are injection molding, RTM, SMC and pultrusion.

Injection molding with fiber reinforcement is the process of mixing chopped or milled fiber with molten thermoplastic to make pellets that will be later melted and injected into a mold to make a part. The injection molding process and tooling allows for single surfaces as well as ribs and features for attachment and strengthening. Typical thermoplastic resins with fiber reinforcement include various types of nylon, polypropylene and ABS. The injection-molded composite material can be used for suspension mechanical spring, suspension level arm, cross members, bows, and front and rear frame header, post and corner cap.

Resin transfer molding (RTM) is the process of infusing resin into a dry fabric to mold a part. The fabric is cut or formed to a pattern and laid into the molding press. The press is closed and thermoset resin is infused throughout the fabric pattern and cured using a predetermined heat and pressure cycle. RTM processed composite can be used for parts requiring complex shapes such as bumper tubes and guards, suspension hangers and level arms and rails.

Pultrusions are manufactured by pulling resin soaked fiber and/or fabric through a heated die (approximately one meter long) to cure the resin. The finished product is similar to an extrusion as the profile is constant. Thermoset resins such as vinyl ester and polyester are used. It is common to manufacture pultrusions at a rate of several feet per minute. As it is a continuous manufacturing process, the cost of liner foot production is relatively low. Carbon fiber and fiberglass can be used independently or together to develop a product that meets performance, weight and cost targets. Pultrusions can be used for rails, posts, sills, headers, floor boards, suspension frame and load beams and cross members. The figure 6 shows strength to weight ratio comparison for different composite material and metal alloys.

Sheet molding compound (SMC) is the process of placing a fiber reinforced thick sheet (blanket thickness) of thermoset resin into a mold and then compressing and heating it to form a finished part. This type of manufacturing technique works well for large components such as pickup truck boxes and vehicle body panels. SMC has a very low density and excellent class A surface properties. SMC is typically reinforced with fiberglass, but carbon fiber reinforced SMC is now on the market. SMC can be used for corner caps, scuff band, lining, vents, and covers. The composite floors consist of laminated hardwood with layer of fiber glass reinforced resin bonded to bottom face of the hardwood are popular for light weighting and strength improvement for the trailer floor and deck systems. The various combinations of FRP resin composite with different fiber reinforcement introduced in the previous section

can be used for further weight reduction and performance improvements.

GOALS AND ACTIONS

Whether the walls, frames or decks are constructed using FRP resin composite, high-tensile metal alloys or sandwich panels as the high-strength-to-weight-ratio material, lightweighting is possible when the goals of structure durability, strength superiority, product safety and economics are achieved. TMC recommends following goals and actions regarding the use of high-strength-to-weight ratio materials used in trailers and truck bodies :

Goals

- Improve ultimate tensile and yield strength with adequate ductility and formability.
- Improve puncture resistance to withstand impact damages.
- Improve fatigue life with endurance limit.
- Improve bending stiffness.
- Improve stiffness modulus.
- Improve skin and core shear strength in sandwich panel construction
- Improve tensile peel strength between skin and core material in Sandwich panel and multilayer FRP resin panel construction.
- Improve core dent resistance in non-homogeneous core construction.
- Improve Thermal conductivity resistance.
- Improve Non-Flammability.
- Improve Surface energy for bonding.
- Improve Water permutation resistance.
- Improve Tear resistance.
- Improve Surface cleanability and anti-microbial capability.
- Improve Environment (UV) resistance.
- Improve Corrosion resistance.
- Improve repairability of non-metallic material.
- Improve weldability of thin high strength metals

Actions

- Develop high-strength aluminum and steel alloys in sheet or coil format that can be used for wall skins or sandwich panel skin that are higher in bending stiffness, shear strength, peel strength, and puncture strength and fatigue strength for wall application. It is imperative that side wall of trailer or truck body must endure high bending moment exerted by bulk load such as carpet and tires and produce minimum displacement such as bulging.
- Develop aluminum and steel alloys that can be in extrusion or roll formed sections with higher fatigue and yield strength and ductility for deck, frame, and floor application.
- Develop steel or aluminum alloys that are superior in mechanical strength, fatigue strength and corrosion resistant than the current existing alloys for suspension frame and component application.
- Develop more economical FRP resin composite material made of high performance fibers such as carbon fibers for frame and wall application.
- Develop more economical and higher strength multilayer thermoplastic or thermoset sheet and panels that can be used for wall systems.
- Develop more economical and manufacturing friendly high-strength-to-weight-ratio sandwich panel constructions that can be used as panels for wall system.
- Develop dent and crush resistant non-homogenous core, such as honeycomb or honeycomb derivatives, for sandwich panel core material made of high strength to weight composite material or metal alloys for wall system.
- Develop high-strength-to-weight-ratio FRP resin composite for suspension components.
- Develop repair methods for non-metallic material.

SUMMARY

Many opportunities exist for lightweighting

of heavy-duty commercial vehicles through employment of high-strength-to-weight-ratio material and through design optimization discussed in this paper. The demands for lightweighting will inevitably increase as greenhouse gas reduction, fuel consumption reduction, alternate energy utilization, and automated vehicle usage accelerate in coming years. The increase in all-electric power vehicle utilization especially will force trailer and truck bodies to become lighter. Through development of improved metal alloys, composite, and new metal/composite constructed materials, the goals of lightweighting can be achieved for trailers and truck bodies with high effectiveness.

Today various steel and aluminum alloys are being studied and developed to improve durability and corrosion resistance in various high tech industry sectors. More economical and higher strength FRP resin composite materials are being introduced to replace metal alloys for light weighting in the advanced technology industries such as aerospace sectors. Future trailer and truck bodies will need to be constructed using the advanced high-strength-to-weight-ratio material in order to be in step with the other advancing technologies.

The wall systems, whether in sheet and post or plate wall designs, can be constructed with ultra-high strength steel or aluminum alloy or high-performance FRP resin composite skins with stiffening members or core material made of composite, ultra-high strength metal alloys and/or combinations of both materials. The frames and their members can be made of high-performance FRP resin composite replacing heavy metal alloys or down-gauged metal alloys with improved fatigue and mechanical strength. The material employment for lightweighting trailer and truck body can vary depending on the design needs to satisfy functional requirements. It is important to emphasize lightweighting only makes sense when structural, total cost of ownership and safety requirements are met. Continuous and collaborated efforts are needed more than ever for light weighting of the future transportation equipment.

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