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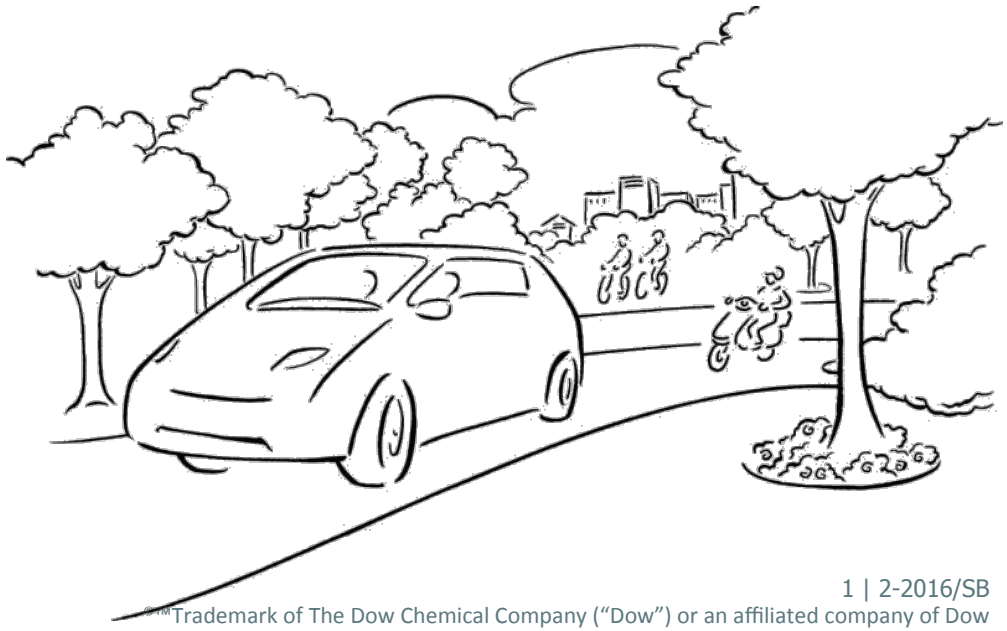
Adhesive Solutions: Lightweighting Technologies

Dow Automotive Systems
Selamawit Belli

March 17, 2016



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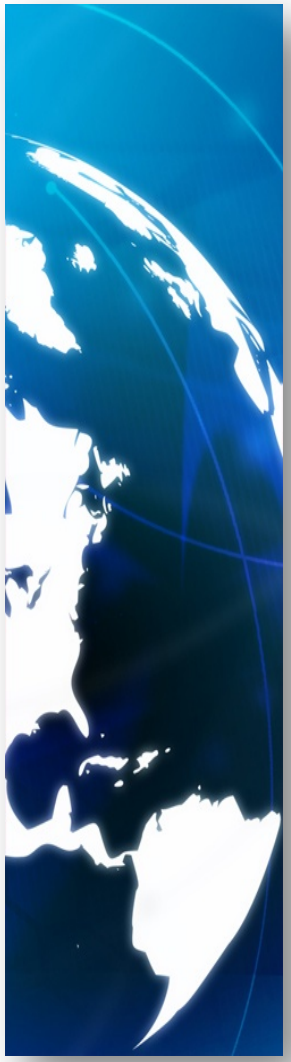
Sustainability and Emerging Regions



- In the US and the European Union, aggressive new fuel efficiency and GHG emission standards are being implemented, with more aggressive targets committed for 2020 to 2025.
- Major emerging markets (China, Brazil, India, and Russia) are also pressed by the air quality challenges in megacities and the fastest motorization growth rate in history.
- Consumer behavior is changing the marketplace. With energy price concerns, customers are purchasing more fuel-efficient vehicles.
- Vehicle OEMs are drastically reducing fuel consumption to address a growing and valuable segment of customers who prefer large vehicles (full size pickups and SUVs).
- **There is a need for an evolution of lightweight, fuel-efficient vehicles.**

Sustainability requires making every decision with the future in mind.

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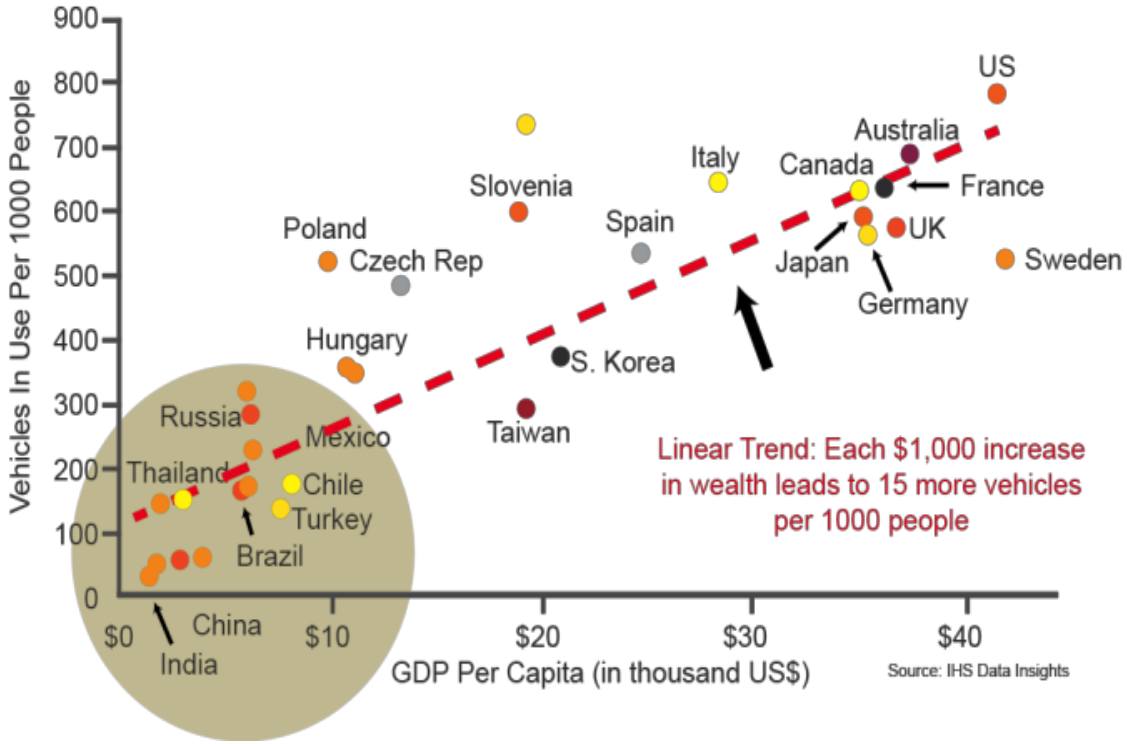
Impact Potential of Emerging Markets

- Considering demographics, disposable incomes and individual, as well as freight mobility needs, **the global transportation industry will shift towards emerging countries.**
- Structural adhesives will make a **significant impact on the lives of hundreds of millions of new consumers.**
- They will contribute to the **progress of safer, more fuel efficient vehicles.**



Structural adhesives are enabling technology to meet the needs of industry trends.

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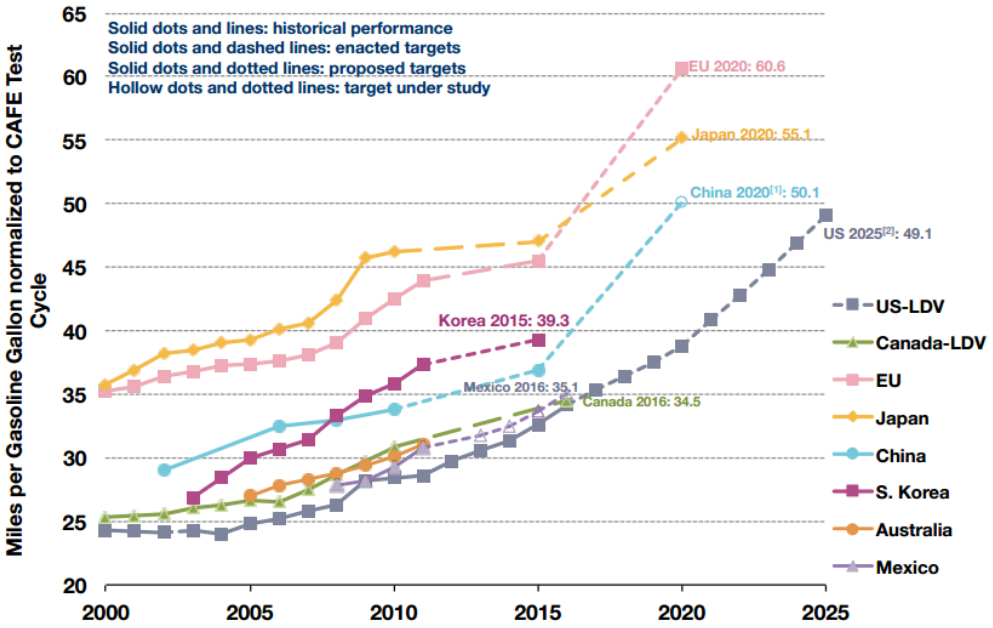
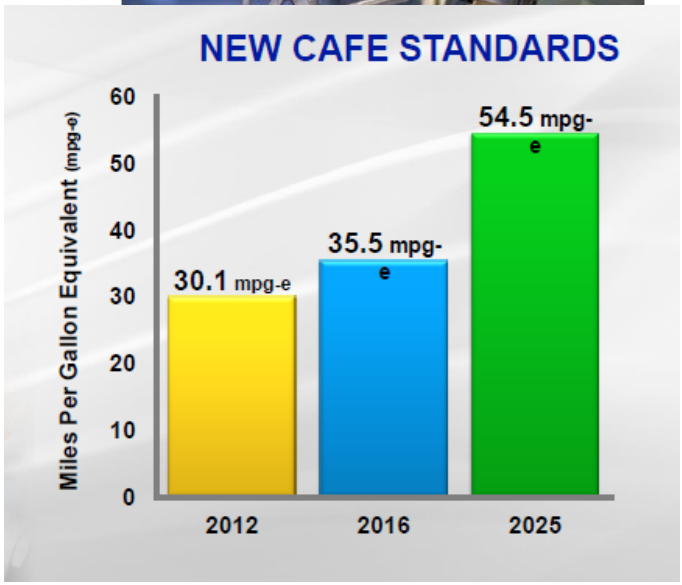
Vehicle Lightweighting

New CAFÉ & CO_2 Requirement

The **Corporate Average Fuel Economy** (**CAFE**) regulations are intended to improve the average fuel economy of cars and light trucks (trucks, vans and sport utility vehicles) sold in the United States.



[1] China's target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
[2] US , Canada, and Mexico light-duty vehicles include light-commercial vehicles.



MPG equivalent, MPGe, *is a measure of the average distance traveled per unit of energy consumed*

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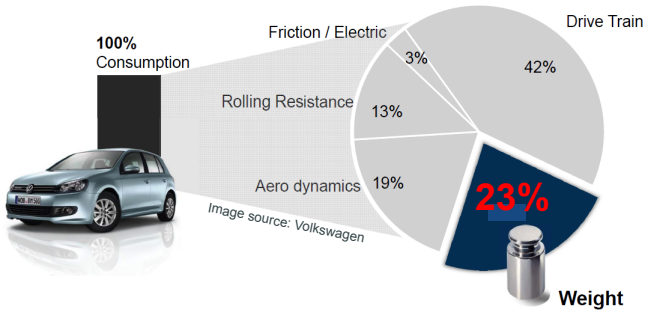
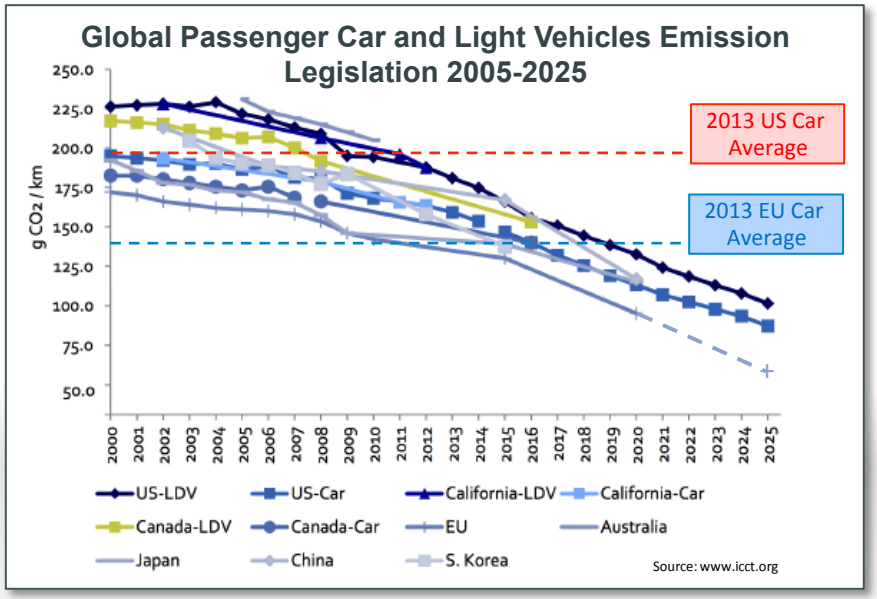
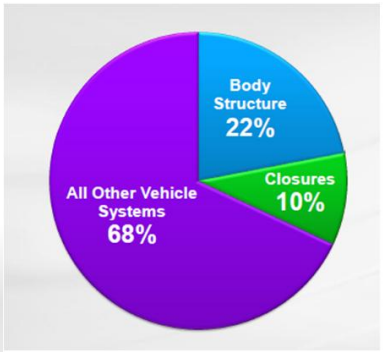
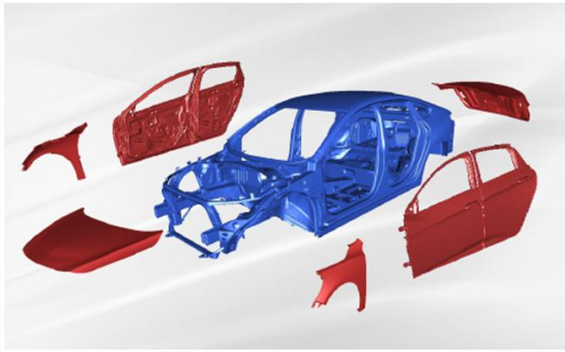
Mass Reduction + Legislation = Innovation

Mass reduction is vital for car makers to avoid fuel efficiency or legislated emissions penalties.









Body is ~1/3 of the Vehicle Curb Mass

10% mass reduction = + 6-8% fuel efficiency including secondary mass (and cost) reduction of powertrain/chassis.

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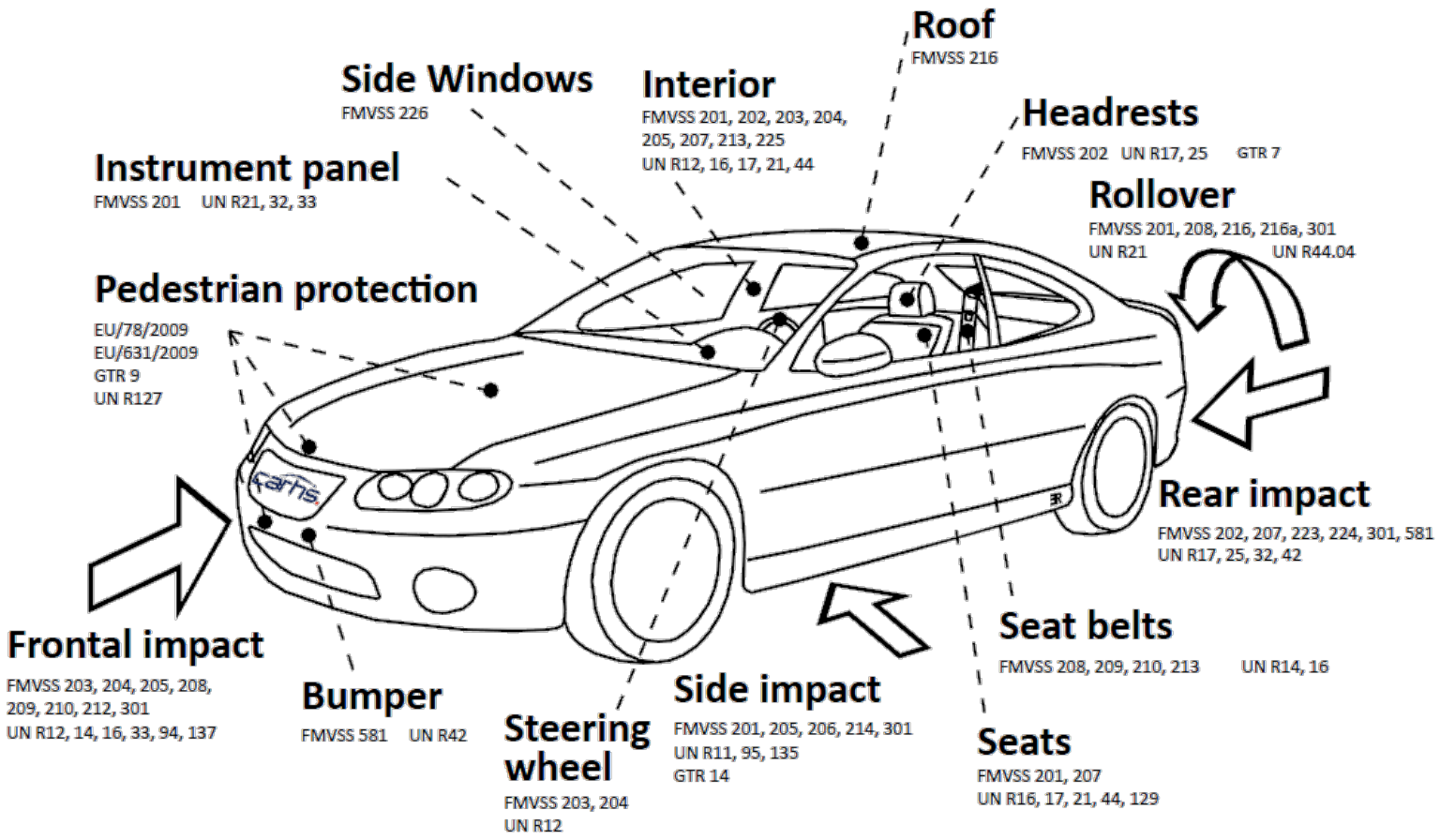
Safety: Top Priority and Major Challenge

Crash Regulations, US, Europe, and United Nations



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Dow Automotive Systems

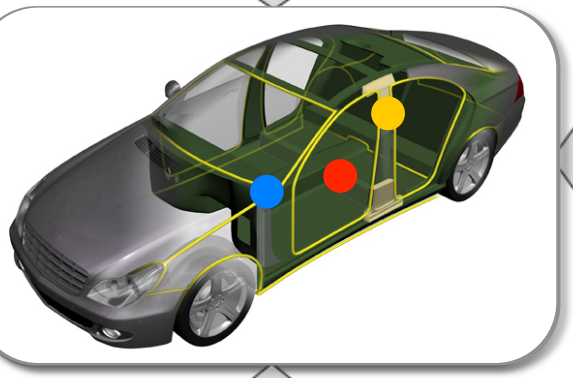
Why Dow Automotive Systems?

VORAFORCE™
resin matrix systems

- Tailored substrate surface chemistry for optimal performance
- Materials design and joint engineering to manage interrelationship between different substrates
- Down-engineering of composite components by leveraging adhesive joint
- Solutions for body shop or trim shop assembly

BETAMATE™ and BETAFORCE™
structural adhesives

- Optimization of interface between carbon fiber and resin
- Ability to create carbon fiber systems tailored for automotive composite applications



- Adhesive bonding of cavity sections reinforced with structural foam
- Continuous bond-line contains structural foam within the cavity

DowAksa AKSACA™
carbon fiber and derivatives

- Potential to reduce level of carbon fiber in the composite by leveraging reinforcement contribution of structural foam
- Acoustical contribution of foam in composite body

BETAFOAM™
structural foam

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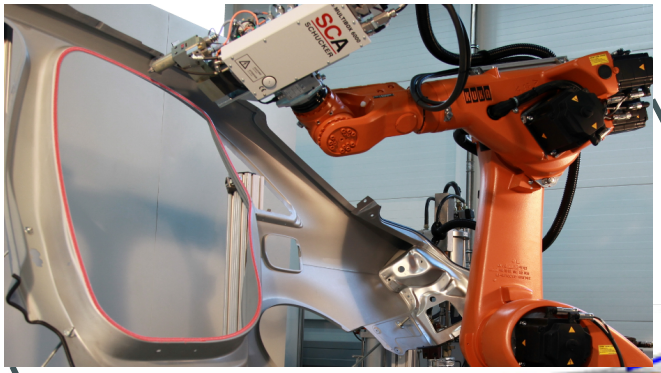
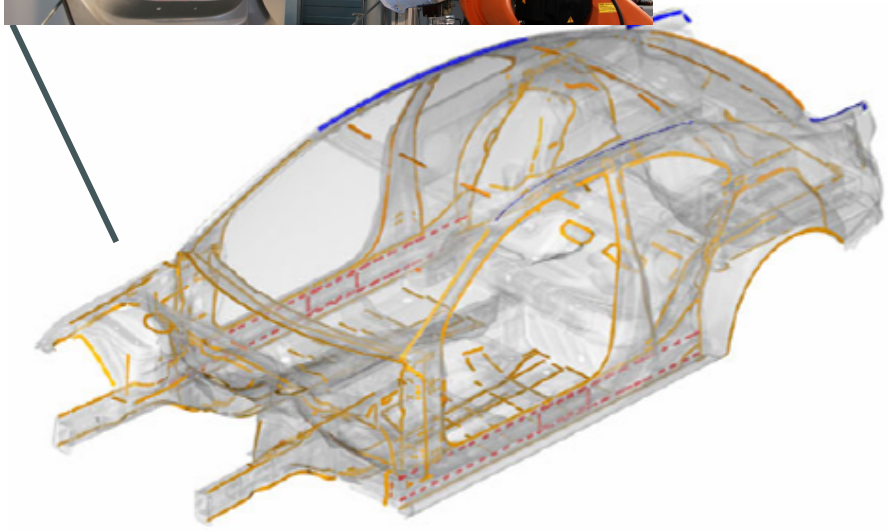
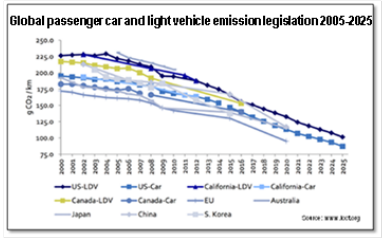
Why Adhesives?

Structural adhesives enable improved crash safety, durability, ride-handling, comfort and sustainability targets.





Fuel efficiency



CO_2 compliance

Sustainability targets

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Market Drivers and Benefits

Structural Adhesives Benefits

Increased static stiffness to 20%

Durability & Driving Comfort

Increased dynamic stiffness: 2-3Hz

Acoustic Comfort

Increased energy management capability

Safety

Weight reduction
- High strength steel usage
- Panel thickness reduction
- Multi material design

Environment

Cost down capabilities
- Weld spot reduction up to 50%
- Metal content reduction up to 10kg/vehicle
- Process speed improvement of between 50 & 100%

Savings

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Lightweight Material Comparison (Multiple Sources)

Why adhesives?

Alternative, lighter weight materials of construction will be required

Adhesives are an enabler for joining dissimilar materials

Decreasing Density of Materials

Coefficient of Linear Expansion α of Substrates at 20°C, µm/m/°C	
Steel	11-13
Aluminum	21-23
Magnesium	26
Continuous CFC	0
CFC Molding Compound (CLTE influenced by fiber content, fiber length and orientation)	5-20

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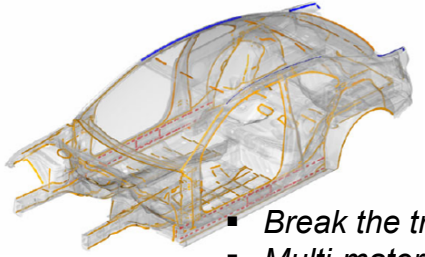
Challenges for Vehicle Lightweighting

- **A challenge** for lightweight material implementation in vehicles is **effective joining technologies especially for dissimilar, lightweight substrates** such as high strength steel, aluminum, magnesium and composites.

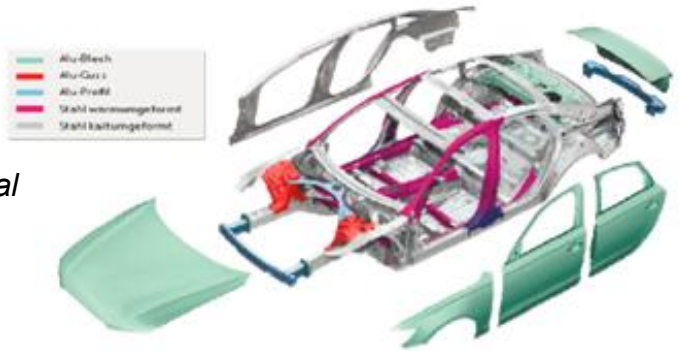


Structural adhesive bondline in yellow

- *Break the trend of increasing body weight*
- *Multi-material use in body shop*
- *Bonding full aluminium vehicles*

- **Epoxy and polyurethane structural adhesives** are an **enabling technology for dissimilar material assembly,** where traditional joining techniques such as welding and riveting are limited in their applicability.

Multi-material use



- Other benefits of structural adhesives:
  - **Increased load-bearing capability, static and dynamic stiffness.**
  - Leads **to improved safety and crash behavior; reduced vibrations and noise; optimized ride, driving and handling characteristics; and extending the vehicle life expectancy** and long-term value via higher durability.

- The value of lightweight is even more pronounced **in electric vehicles** as a way to offset the additional battery load (up to 900 lbs) and to extend the vehicle range.

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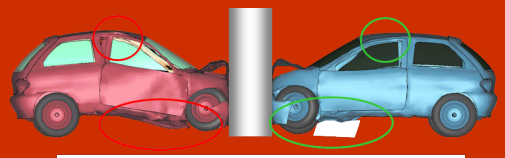
Challenges of Joining Dissimilar Materials

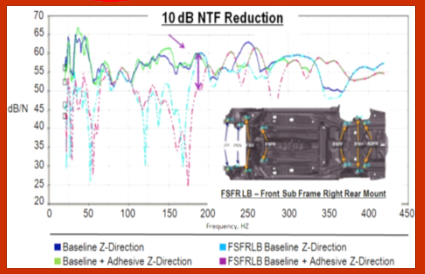
Joining

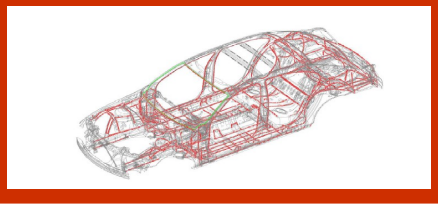
- Thinner substrates
- Dissimilar materials
- Earlier in manufacturing process
- Challenges:
  - Coefficient of linear expansion differences
  - Residual stresses
  - Component distortion due to thermal and mechanical loads
  - Impact of residual stresses on adhesion performance
- Strength, fatigue/durability, and corrosion
- Galvanic corrosion
- Hybrid joining (secondary attachment)

Performance

- Safety
- NVH performance
- Ride and handling comfort
- Fuel economy







Current and next generation adhesives facilitate solutions

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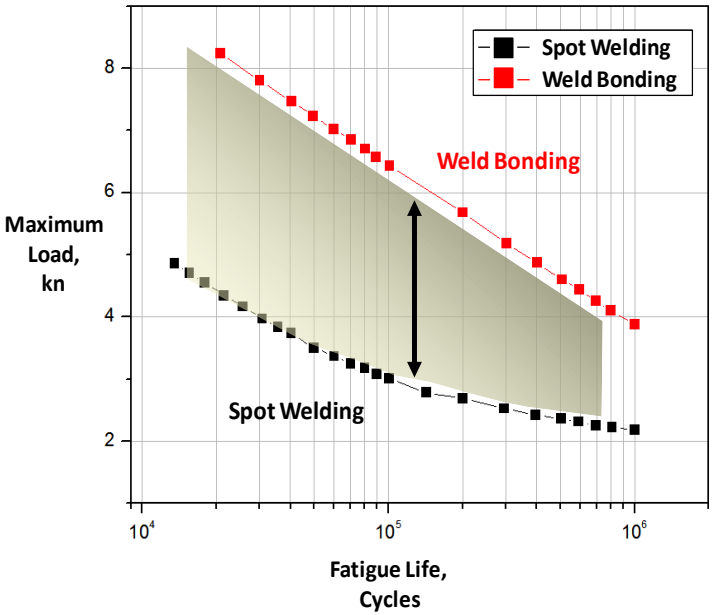
Structural Adhesives Make a Difference

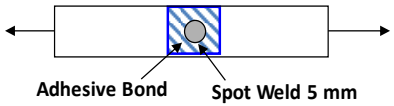
In applications of structural adhesives where designers are optimizing for weight reduction, evidence suggests that **0.6 to 1.1 kg of mass can be reduced for every meter of structural adhesive applied**.

Why are Structural Adhesives Effective?

- Reduce stresses in bonded joints, which improves vehicle durability
- Enables down gauging of steel, which reduces weight
- Higher loads can be sustained, which improves crash and safety performance



- **Spot Welding**: Standard joining technique
- **Weld Bonding:** Adhesive bonding with welding secondary attachment



- Increased load-carrying capability allows down gauged substrate for weight reduction

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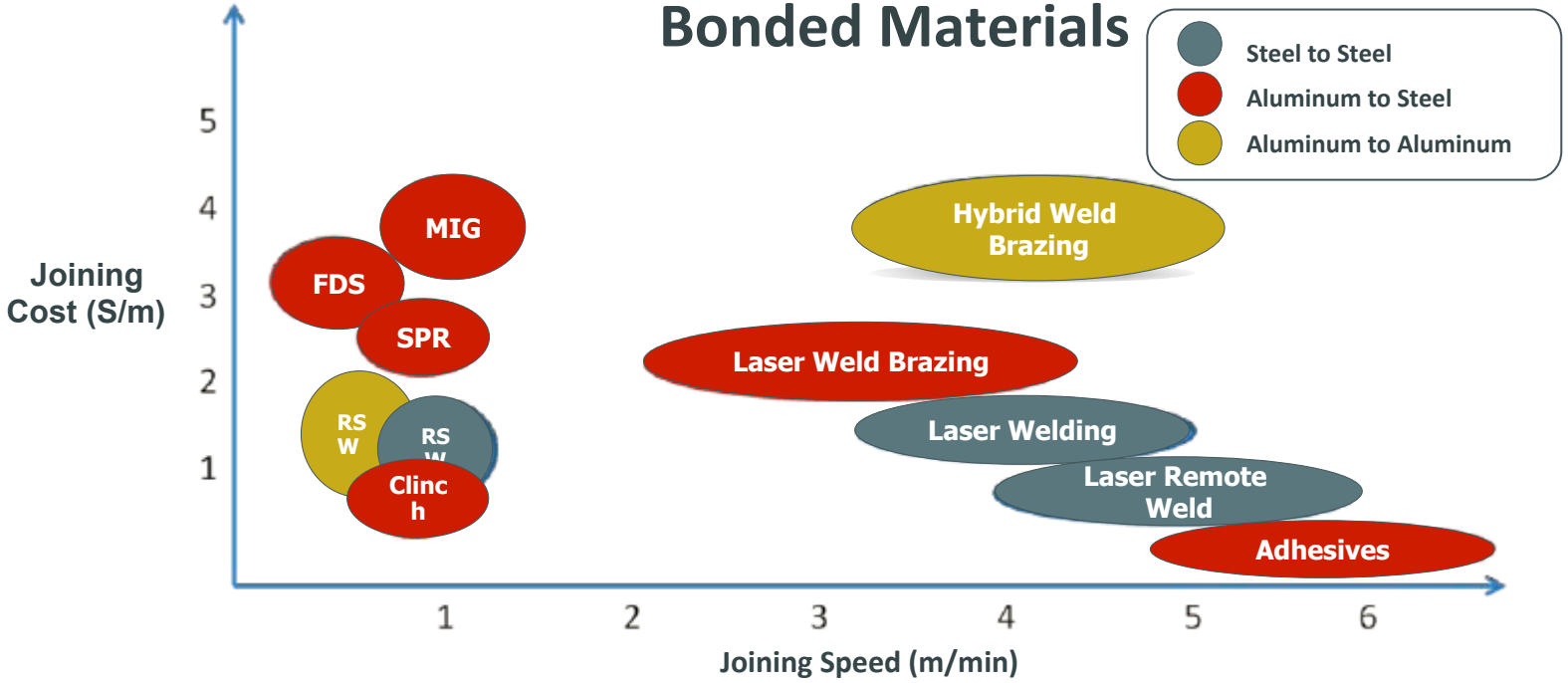
Dow Automotive Systems – Why Adhesives?

Tradeoffs and Benefits of New Joining Methods Required for Mixed Materials

Cost and Speed of Joining Technology with Consideration to Bonded Materials



FDS: Flow Drill Screw, MIG: Metal Inert Gas, SPR: Self Piercing Rivet, FSW: Friction Stir Welding, RSW: Resistance Spot Welding

Source: Dr. Ing. Bernard Criqui, "Robust Joining Processes for Series Production Today and Tomorrow." Innovative Developments for Light Weight Vehicle Structures. Wolfsburg: Volkswagen, 2009. 190.

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Dow Automotive Systems – Why Adhesives?

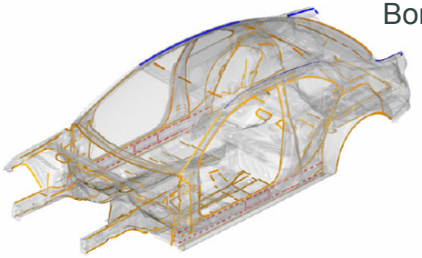
Process Adapted Structural Adhesives

Body Shop → 180° C, 30′ → Paint → 80-160° C, 30′ → Trim Shop → 25° C, → Repair

Heat Cured and Room Temperature Cured Epoxy Technology

Room Temperature Cured PU Technology

BETAMATE™
Bond Line in Yellow



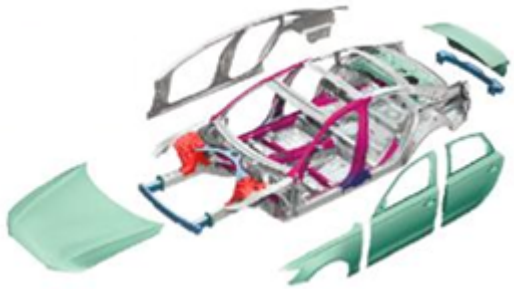
- Break the trend of increasing body weight
- Multi-material use in body sho
- Bonding full aluminium vehicle

Can be used for OEM, tier or field repair.

Full Body Bonding

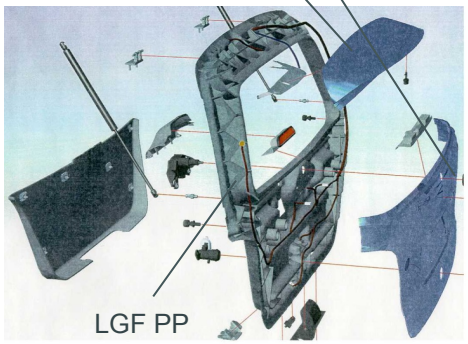
BETAFORCE
CFRP
Structure

Module Bonding



- Aluminium Sheet
- Cast Aluminum
- Aluminum Profiles
- Warm Stamped Steel
- Cold Stamped Steel

Multi-Material Use



Light Weight Closures

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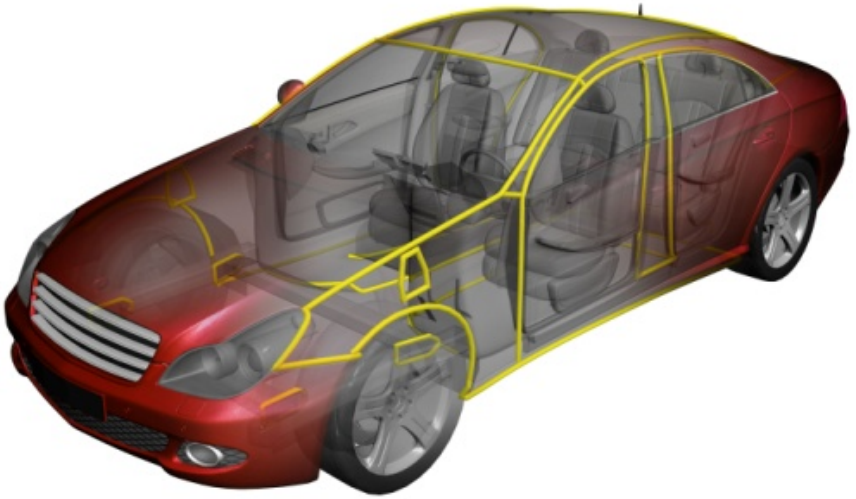
Conclusions

- **Structural adhesives** enable vehicle lightweight strategies by:
  - Bonding **dissimilar materials** including **carbon fiber-reinforced composite materials** to many lightweight substrates
  - Managing **thermal expansion differences** with dissimilar materials
  - **Facilitating down-gauging** and/or **down-grading** of steel for **cost and weight reduction**
- The continuous bond line provides **improved load transfer** between sheet metal parts, resulting in **improved stress distributions**
- Adhesives **enable dissimilar material joining** when traditional joining methods cannot be used and **addresses galvanic corrosion** concerns

BETAMATE™ and BETAFORCE™ structural adhesives enable lightweight benefits, including:

- ***Significant CO2 emission avoidance***
- ***Billions of gallons of gasoline saved***
- ***Improved safety performance***
- ***Existing and emerging world transportation sector***



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Thank you
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