Development of Lightweight Technology & its Application in Automobiles

by ZHANG Ning

in Chongqing, on November 17, 2015
I. Why has it to be lightweight?

II. Current Lightweight Level and Efforts in China

III. Lightweight Technology in the US, Germany and Japan

IV. How to make Chinese vehicles even lighter

V. Conclusion
Main approaches to energy saving and emission reduction

<table>
<thead>
<tr>
<th>New energy vehicles</th>
<th>EV, PHEV, FCV</th>
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<tbody>
<tr>
<td>Energy-saving vehicles</td>
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<tr>
<td>Hybrid power technology</td>
<td>Structural design optimization</td>
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<td>Advanced power system</td>
<td>Lower friction</td>
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<tr>
<td>Lightweight</td>
<td>Electronic control</td>
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<tr>
<td>Alternative energy vehicles</td>
<td></td>
</tr>
<tr>
<td>CNG, LNG, alcohol, methanol...</td>
<td></td>
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</tbody>
</table>

- Improvement in automotive technology
- Improvement in traffic & roads
- Good driving habits
- Smart transportation
- Driving habits
- Reasonable use
- ...
Curb weight vs. fuel consumption of PV worldwide

\[ y = 0.0055x - 0.213 \]

Source: Auto Catalog 2010-2013
Trend and forecast for average curb weight of PV worldwide

Higher standards and functions lead to higher curb weight

Energy saving and emission reduction leads to lower curb weight

(kg/vehicle)

Source: Lightweight Vehicles and their Development in China - Strategy and Roadmap, SAE-China
Every 100 kg in vehicle mass reduction leads to a reduction of 0.3-0.5 L fuel consumption per Km and a reduction of 8-11 g CO₂ emission per Km.

Lower mass leads to better acceleration and maneuverability, better response and shorter braking distance.

With lighter vehicles, we can choose engines with a lower volume that provides meets the performance requirements and lead to further reduction in fuel consumption.
Average fuel consumption of PV manufacturers: China

Average fuel consumption of Chinese passenger vehicles (L/100km)

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<th>Year</th>
<th>Current actual value</th>
<th>Future: Should be better</th>
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<td>2013</td>
<td>7.12</td>
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<tr>
<td>2014</td>
<td>6.9</td>
<td></td>
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<tr>
<td>2015</td>
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<td>2016</td>
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<tr>
<td>2017</td>
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<td>2018</td>
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</table>

Average whole curb weight (kg) | Average corporate fuel consumption ≤6.9 L/100km
---|---|---
2013 | 1327 | 23 | 27.46%
2014 | 1340 | 25 | 34.55%

Source: Average Fuel Consumption Calculation and Publication for Passenger Vehicle Manufacturers in China, MIIT and other four departments; Energy Saving and New Energy Vehicle Sector Development Program (2012-2020), State Council
Top 10 passenger vehicle manufacturers in 2014, which accounted for 54.88% of the total sales, among which: the average fuel consumption of Chongqing Chang’an, Dongfeng Motor and Shanghai VW ≤6.9 L/100km. No vehicles can reach ≤5.9 L/100km, which is the standard for an energy saving passenger vehicle.

Source: *Average Fuel Consumption Calculation and Publication for Passenger Vehicle Manufacturers in China*, MIIT and other four departments.
Purpose:

- Collaboration and cooperation
- Driving Innovation
- Co-win and co-prosperity

Position:

- Do what cannot be done by single companies or by single sectors
- Focus on the industry chain and create an innovation chain, and promote lightweight technology, and improve the competitiveness of the automotive industry of China.

Alliance of Automotive Lightweight Technology Innovation and Strategy

Date of incorporation: Dec 2007

Members: 17 + 43 = 60 (companies/organizations)

- 80% of Chinese automotive production
- 11 of Global 500
- All backbone Chinese steel users are now its members
Practice of Lightweight Alliance: Main activities

- To build a common technical platform
- To formulate Alliance standards (for product design, materials selection, and evaluation)
- To build databases (for components, materials, patents and literatures)
Practice of Lightweight Alliance: Main achievements

For more than 8 years since its incorporation, the Alliance has worked effectively to instill lightweight-related ideas into people, seen that the technologies it promotes have been successfully applied in its members as whole-body manufacturers, improve the competitiveness of original Chinese brands, helped a number of companies that supply lightweight components, and drive related industrial sectors in product and structural readjustment.

The Alliance has successfully implemented the Development of Key Automotive Lightweight Technology and Its Application in the Whole Body (which is one of projects under the technical support program in the 12th Five-Year Plan), achieved breakthroughs in a number of core lightweight technology project, fill in a few gaps of the Chinese automotive industry in technology and performance, and broken up the monopoly of foreign companies in relevant areas.

The Alliance has created a working mechanism of “Joint work + knowledge transfer + sharing of results,” explored and build up an operational mechanism of “collative innovation; combined production, learning, research and use; and the group development of Chinese original brands,” to provide valuable examples for the independent and innovative growth of the automotive industry.

The Alliance has built up a common technical platform, as well as standards and databases, to provide strong support to R&D companies. The formation of enterprise groups and experts groups has lead to the effective spreading of the research results of the Alliance.
Practice of Lightweight Alliance: Collaborative innovative platform

- Knowledge sharing platform
- Lightweight Research Institute (under construction)
- Major laboratories (10)
- Innovative bases

- 17 shareholders
- 3 universities + 8 car manufacturers + 4 steelmakers + SAE + AERI
- Baosteel, Ansteel, WISCO, Masteel, Northeastern University

- Support to the building of a national lightweight lab
- Platform for common technology research, technical services and the spreading of technologies
- Central lab + 5 subcenters
- Central institute for far-reaching researches
- An essential element in building up a common platform.

- Support platform for the innovative tasks of the state
- Base for technology development, incubation and industrialization
- Base for talent training

- R&D strategy
- Research on tech routes
- Compilation of tech std
- Databases
- Discussions
- Communications
- Training
Practice of Lightweight Alliance: On-going work

- Compiling the lightweight development guide for the Natural Science Foundation and the Combined Automotive Fund
- Guiding positive product development, corporate decision-making evaluation methods and research, and key data collection and preparation:
  - Study on the relationship between the curb weight of loaded vehicles and fuel consumption;
  - Study on the relationship between the weight of revolving parts and fuel consumption;
  - Collection of welding data (spot welding) of automotive steels.
- Conducting pre-study for tackling key technological issues, to lay the basis for national scientific and technological research projects:
  - 12 open subjects from Lightweight Research Institute
  - 21 independently developed subjects from the Innovation Base of the Alliance
  - Application of lightweight design and evaluation: 9
    - Application of lightweight technology in new energy vehicles: 5
    - AHSS application: 10
    - Application of aluminum-magnesium alloys: 7
    - Application of composite materials: 5
    - Forming processes and linking technology: 5

Hope to accelerate the process with the governmental support.
### BIW materials for PV: Materials selection in China

<table>
<thead>
<tr>
<th></th>
<th>Time to market</th>
<th>Proposed materials (total = 100%)</th>
<th>Steel</th>
<th>Al alloys</th>
<th>Mg alloys</th>
<th>Non-metal materials</th>
<th>Others</th>
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<td>0.00%</td>
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<td>0.00%</td>
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<tr>
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<td>85.00%</td>
<td>0.00%</td>
<td>11.00%</td>
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### BIW materials for PV: Steel grades in China

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<th></th>
<th>Mild steel</th>
<th>Traditional HSS</th>
<th>AHSS</th>
<th>Stainless steel</th>
<th>UHSS</th>
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<td>8.50%</td>
<td>—</td>
<td>3.00%</td>
<td>2.10%</td>
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Total = 100% / “—” = 0.00%

BIW steels for PV: foreign countries

<table>
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<tr>
<th>钢材</th>
<th>车型</th>
<th>BMW i8</th>
<th>Mercedes-Benz C-Class</th>
<th>Chevrolet Corvette Z06</th>
<th>Audi TT</th>
<th>Volvo XC90</th>
<th>Jaguar F-TYPE</th>
<th>Peugeot 308</th>
<th>Renault Twingo</th>
<th>Subaru WRX</th>
<th>Mazda 2</th>
<th>FIAT 500X</th>
<th>Ford Mustang</th>
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</table>

Source:  Automotive Circle International, EuroCarBody 2014
Technological routes and trends for lightweight car body globally
Lightweight requires collaboration across the value chain

- Complete vehicle optimization
- Design of components & parts
- Equipment, Processes, Molds
- Materials
- Use & maintenance
- Recovery & reuse

- Can be disassembled
- Maximize the recovery and reuse of materials

- Performance level (fuel consumption, safety, NVH...)
- Market positioning
- Cost control
- ...

Reusable components
Useless components
Views on lightweight cars globally

Lightweight means to integrate and apply the structural lightweight technologies, the lightweight materials and the lightweight manufacturing processes to achieve the weight reduction, provided that the needs for car use, safety and cost control are satisfied.

Lightweight must not be achieved at the expense of safety or NVH, but must be restrained by the proposed target for whole weight reduction, the target for whole body cost control, the safety target and the required NVH level.

Internationally recognized principles for materials selection

Use the right material at the right place; use the right technology at the right place
Lightweight in national S&T strategies: US

Key R&D researches and investments in the *EV Everywhere Grand Challenge Blueprint*:

- Battery;
- Electric power system;
- Lightweight vehicles;
- Weather control.

**Development target for lightweight technology**

By 2022, the mass of PEV will be reduced by around 30%, where

- Body weight will be 35% less
- Interior decoration weight will be 5% less
- Chassis/ suspension will be 25% less
## Lightweight in national S&T strategies: Germany

### National EV development plan

<table>
<thead>
<tr>
<th>Battery</th>
<th>€986 m</th>
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<tbody>
<tr>
<td>Drivetrain technology</td>
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<tr>
<td>ICT and infrastructure</td>
<td>€753 m</td>
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<tr>
<td>Recycling</td>
<td>€90 m</td>
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#### Light weighting

- Development of lightweight materials
- Optimization and development of components
- Development of lightweight EV structures
- Resource-efficient manufacturing processes suitable for mass production

#### Vehicle integration

- BEV²
- REEV³/PHEV⁴ vehicle
- PHEV commercial vehicle

#### Total level of project funding - €3.967 bn

Source: *Second Report of the National Platform for Electromobility, NPE Germany*
Technological routes for the application of lightweight materials: US

- **HSS**
  - Tensile strength 1500-2000MPa
  - Density lowered by 5%
  - Modulus up by 10%
- **Ti alloy**
  - Overly high cost
  - 4 times the cost of stainless steel
- **Ni alloy**
  - 2 times the cost of stainless steel
- **Al**
  - Non-recycling for high-performing Al alloys
  - Cost reduced by 25%
  - Recycling of high-performing Al alloy is 50%
  - 2 times the cost of Al
- **Mg**
  - Less corrosion resistance, joining and compatibility
  - Alloy usability improved by 2 times
  - Electro-chemical corrosion from dissimilar materials is eliminated
  - At the same cost of Al
- **Composites**
  - Carbon fiber is 5% of vehicle weight
  - Carbon fiber costs $12/pound
  - Glass fiber’s rigidity improved by 30%
  - SMC $1-2/pound
  - Carbon fiber has its 25% recyclable, and the carbon footprint reduced by 25%
  - SMC costs the same as Al
  - 4 times the cost of stainless steel
  - 2 times the cost of stainless steel
  - Carbon fiber costs $2.5/pound
  - Glass fiber is as rigid as Al
  - Carbon fiber has its 50% recyclable, and the carbon footprint reduced by 75%
  - SMC costs the same as Al

- **2010**
  - Overly high cost
  - Cost reduced by 50%
  - Cost lowered to the level of Al-Mg
  - Alloy usability improved by 2 times
  - Common one-step pre-treatment

- **2025**
  - Overly high cost
  - Cost reduced by 50%
  - Cost lowered to the level of Al-Mg
  - Alloy usability improved by 2 times
  - Common one-step pre-treatment

- **2050**
  - Overly high cost
  - Cost reduced by 50%
  - Cost lowered to the level of Al-Mg
  - Alloy usability improved by 2 times
  - Common one-step pre-treatment
Technological routes for the application of lightweight materials: Japan

- **Steel**
  - Basic research:
    - Rigid steels
    - Nanofiber steels
  - Root study:
    - Honeycomb structure materials
  - Breakthrough study:
    - High tensile, high strength anisotropic stamped steels
  - Practicability:
    - High strength, high tenacity, non-quenched or tempered steels

- **Nonferrous metal (Mg)**
  - Basic research:
    - Design of high-strength, cold-formed sheet alloys
    - High-speed extrusion of high-performing sections
  - Root study:
    - Micronization of the organization of cast materials
  - Breakthrough study:
    - Treatment of high-performing surface of heavy sections
  - Practicability:
    - Production innovation of cast materials

- **Nonferrous metal (Al)**
  - Basic research:
    - High-strength, high-tenacity Al alloys
  - Root study:
    - High-rigidity treatment of Al alloys
  - Breakthrough study:
    - Porous Al composites, aluminized wires
  - Practicability:
    - Improvement in stamping technology; application of special-shape materials

- **Resin/composites**
  - Basic research:
    - Transparent DLC, SP treated nanoparticle synthesis
  - Root study:
    - SP treated nanoparticle surface modification
  - Breakthrough study:
    - Treatment of high-performing surface of heavy sections
  - Practicability:
    - Production innovation of cast materials

- **Processing**
  - Basic research:
    - Use of servo press, sheet forging
  - Root study:
    - Clean forming, smart hot stamping
  - Breakthrough study:
    - CFRP forming, Mg cold-forming
  - Practicability:
    - Forming of hollow materials

- **Joining of different materials**
  - Basic research:
    - Identifying the principles for the joining of metals, high polymer and C-FRP
  - Root & breakthrough study:
    - Innovative 2D connector between metals
  - Practicability:
    - Innovative 3D connector between metal, high polymer and C-FRP

**Weight-reduction target set for major vehicle types**
- 15% of weight loss for vehicles after 2015
- Average 5-10% weight loss for all vehicles in 2015
- Average 10% weight loss for vehicles after 2010
- 100 kg weight loss for launched vehicles
- A further 100 kg reduction for all vehicles after 2016

**Lightweight research direction of Japan**
## Driving forces to lightweight vehicles: Government

<table>
<thead>
<tr>
<th>Main actions</th>
<th>Country/region</th>
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<tr>
<td><strong>Technical standard</strong></td>
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<td>Fuel economy standard</td>
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<td>Technical requirements and targets</td>
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<td>Common key technology R&amp;D project</td>
<td>US, Japan, EU</td>
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<tr>
<td>Encouraging and supporting cross-sectoral cooperation</td>
<td>USCAR, EUCAR</td>
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</table>
Driving forces to lightweight vehicles: Collaboration

Companies + Universities + Research institutes

Lightweight technology
- Design
- Evaluation
- ...

Key technology

Common key technology

- Materials
- Processes
- Equipment
- Molds
- Joining
- ...

Quality, cost control
- Production consistency
- ...

Supported by government
Coordinated by social organizations
Manufacturers, universities and research institutes working together
Made in China 2025: key areas

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<td>1</td>
<td>New-generation info and comm technology</td>
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</table>

To continue to support the development of electric cars and fuel-cell cars, control the core technologies in carbon reduction, informationization, and intelligent operation, improve the engineering and industrialization capacity in power cell, drive motor, high-performing internal combustion engine, advanced gearbox, lightweight materials, and intelligent control, form a complete industrial innovation system from key components to the whole vehicle, and drive national brands and new-energy vehicles to reach the international advanced level.
Urgent issues: How is it related to materials

Lightweight ≠ another material or materials; the sole change to another material will lead to many issues:

- Without the optimization of the whole vehicle and components, it leads to inferior NVH, inferior passive safety and many other issues;

- Without the testing standard and evaluation method for components made of a different material, it leads to problems with the reliability and durability of vehicles;

- Without the optimization and overall plan of the complete vehicle and without the coordination with processes, molds and equipment, it leads to higher production cost of the complete vehicle.

Conclusion

The realization of lightweight must depend on the whole vehicle design and evaluation technology, the component design and evaluation technology and the new material development forming technology; otherwise, it must lead to inferior performance and quality and high costs.
Urgent issues: Systemic technology

Samples: Basic theory, Development Tech, Engineering Tech, Quality control, Cost control, ... Maintenance Tech, Disassemblable Tech, Remanufacturing Tech, ...

Products: Product development, Product manufacturing, Use & Maintenance, Recycle & reuse

Goods: Test equipment, Databases, Manufacturing equipment, Raw materials, Maintenance equipment, Fuel, lubricant, Related equipment, Recycling system
Urgent issues: Component basis

- Companies do no focus on materials, but on whether the materials can meet their needs in components forming, control of cost and quality, reliability and production consistency, and how they affect the production organization.

- The national industrial basis of components determines how well new materials can be used and the value of lightweight materials in application.

- The national industrial basis and the comprehensive S&T strength determine how companies select and use their materials (such as, the HF materials in Europe and the composites in Japan).
Urgent issues: How it relates to other technologies

Which technology is more important?

- Lightweight
- Engine starting and stopping
- New energy vehicle
- ...

Which parameter is more important?

- Safety, NVH, emission
- Reliability, durability
- Cost, price
- ...

Conclusion

- The lightweight technology is not against any other technology in energy-saving or emission reduction.
- Lightweight is one of the core and basic technologies that involve all the vehicles. It is one of the major future directions for the automotive industry globally.
- The industrialization of new energy vehicles is further highlighted.
What troubles the related industrial sectors:
- We have developed so many good technologies and so many good products. But why don’t you use them?

What troubles automotive manufactures?
- The coordination with their market positioning, performance targets and development cost;
- Sources of new investments and the returns on them;
- Cost control and quality control;
- Processes, equipment, cycles, accuracy and consistency;
- Components supply system;
- Coordination with other products on the same platform;
- Recycle and reuse;
- Callback, and guarantee of repair, replacement and refund of substandard products;
Urgent issues: Supply chain adjustment solution

For any complete vehicle manufacturer, it has to be extremely cautious to change the supplier of raw materials.

How many vehicles will be affected; the life cycle of vehicles using new components; the recertification and the cost; how will it affect the product performance, market positioning, cost, reliability, production consistency and production organization...

Materials supplier
Equipment supplier
Molds supplier
## Suggestion: appropriate lightweight approach route

### Basic principles: use materials according to their strong points and characteristics

### Suggestion in the near-to-medium term:

- **For low-priced cars (<100,000 RMB), mainly steel + glass fiber-reinforced plastic;**
- **For medium-priced cars (100,000 ~ 200,000 RMB), mainly steel + a small amount of aluminum + glass fiber-reinforced plastic;**
- **For high-priced cars (200,000 ~ 350,000 RMB), mainly steel + more aluminum + glass fiber-reinforced plastic;**
- **For brand cars (>350,000 RMB), mainly aluminum + steel and plastic (or) carbon fiber-reinforced plastic + aluminum**

### Vehicle type | Focus
--- | ---
Level-A passenger vehicle (A00/A0/A/Small SUV) | Cost, performance, fuel consumption
Levels B&C passenger vehicle | Configuration, brand, performance, fuel consumption
Lux passenger vehicle | Brand, comfort
Med to large-sized SUV, etc. | Cross-country driving, brand, fuel consumption
MPV, etc. | Cost, comfort, fuel consumption, brand
Suggestion: Accelerate the building of a lightweight value chain

Prove that the idea is realizable.

Mass production is possible under a particular quality standard.

Stable production is possible with high quality, high production consistency and low cost.
Suggestion: Create a good industrial ecological environment

- Formulate programs and publish policies to promote lightweight vehicles
- Conduct lightweight technology research and promote the application of lightweight materials in automobiles
- Focus on long-term strategic needs and align the research efforts involving basic technology, engineering technology and product technology
- Focus on the development of component sectors, to build a lightweight component supply system as suitable for the automotive industry and support a number of key component suppliers
- Focus on the collection of basic data and use it in the decision-making process of the country, industries and companies
- Build a common technology platform and lead the industrial technological advancement
- Give full play to the Alliance, to work together as a group and promote cross-sectoral collaboration and development
Suggestion: Key development points in the near-to-medium term in automotive steels:

- Application of high-elongation (20%) AHSS of 1,200MPa in the bumper
- Application of HF steels of 1,500MPa (galvanized), 18,00MPa and 2,200MPa in the pillar A/B
- Application of third-generation HF steels of 1,500MPa in the safety components
- Application of RF steels of 1,300MPa and 1,500MPa in door sills
- Application of AHSS of 1,000MPa in car seat rails
- Application of QP980/TWIP980 AHSS in the bumper
- Design and development of 5%-10% low-density HSS
- Application of anti-fatigue and anti-tamper spring steel of 2,000MPa in the coil spring
- Application of customized forged components of 600-1,000MPa in the connecting rod of the engine
- Application of DP steels of 80MPa in the suspension/torsion-beam
Suggestion: Key development areas in the near to medium term for other materials:

- Application of high-quality aluminum alloy panels in automobile closures
- Application of cast aluminum alloys in the shock-absorption tower, steering knuckle and sub-frame
- Application of forged aluminum alloys in the swing arm
- Application of magnesium alloys in the car seat frame and the dashboard beam
- Application of high-performing PP-modified or reinforced materials in the interior/exterior panels, bumpers and new-energy battery packet
- Application of CFRTP in the intake manifold of a naturally aspirated gas engine of 1.6L or below
- Development of large-tow automobile carbon fiber and its application in the car body
Conclusion:

To build lightweight vehicles is an important way to realize the targets set in the *Industrial Development Program for Energy-saving and New-energy Vehicles 2012~2020* and the *Made in China 2025*. It is also one of the feasible and essential technological routes under the current resource conditions and policy environment of China. Steels cannot be substituted by any other materials in lightweight applications.

No lightweight technologies can be evaluated as good or bad. Companies should determine which technology it uses in light of the market positioning, the performance target to be achieved, the cost control target, and the lightweight level of the competition.

The total curb weight cannot be used as the single indicator of the lightweight or not of a vehicle. The lightweight should be pre-conditioned on the performance and cost control, with systemic consideration to various factors.

It is a systemic work to build lightweight vehicles, which depends on deep-rooted collaboration across industrial sectors and disciplines and between manufacturers, universities and research institutes. For the lightweight vehicles of China, it is the only way to grow through collaborated innovation and development groups. The strong government support will help accelerate the process.

To look into the future, we need to be more confident, patient and persistent. The Society of Automotive Engineers of China (SAE) and the Lightweight Alliance would like to work with everybody and contribute to the target *in the Made in China 2025*. 
Thank you for your attention