High-speed, Efficient, Intelligent and Green

— FUTURE METRO “CETROVO”
Part I Listen to the Market

1 Remarkable achievements

After more than 50 years of hard work on the basis of long term exploration, through technical introduction, digestion and independent innovation, generations of various type of products have been developed, remarkable achievements have been made in China urban rail transportation, which contributes significantly to the modern urbanization process.
Part I Listen to the Market

One of largest in world — 165 lines plunged in 34 cities, mileage 5033km, fleet 4871 sets. 685 for Beijing, 732 Shanghai.

Another 8900km will be built by 2020, fleet will up to 10,383 sets.

Getting stronger — Traffic volume increase continuously, account up to 53% of urban transportation. Industrial revenue from less than a million up to over trillion. Boosts city development & industry upgrading.

Improving obviously — Comprehensive performance such as safety, reliability, comfort, energy saving & eco-friendly are getting better.

Upgrading yearly — From 1st generation of low speed & efficiency train to 2nd generation featuring high speed & efficiency. Finish localization.

Serial platforms developed — Incl. regional, metro, tram, monorail vehicles. Capable for diversified requirements based on TQC.

Speed range cover 120km/h, comp. 2-8 cars, passenger capacity 360-3440 per train.

Running speed keep raising — $V_{max.}: 75-120\text{km/h}; \text{min. headway } 17.5-2\text{min}; V_e: 25-90\text{ km/h}, 3 \text{times higher} ; \text{starting and brake ability improving accordingly}$

Greatly improved — Adapt to different climatic, line conditions, mileage, passenger flow characteristics, operation modes & cost requirements.

Increasing continuously — Passenger flows blowout. With network operation, larger composition and higher speed, capacity soaring continuously. Eg. Beijing daily delivery is 10.35 million, 456 times higher.
World-leading operational scale

By the end of 2017, there are 34 cities in China mainland who have opened totally 165 urban rail lines with total 5033 km operational mileage and 4871 trainsets, among which there are 3883 km metro mileage, accounting for 77.2%. The other rail systems accounting for 1149km. Among all operational mileage, Beijing owns 685km, Shanghai 732km, and Guangzhou 365km. The operational mileage and number of operational trainsets rank the first in the world. According to national plan, another 8900km will be built by 2020, with10,383 trainsets.
Product family tree has been initially formed

Three major types of trains covering regional vehicles, metro vehicles, trams, suspended and straddling vehicles, etc. The speed ranges from 75km/h to 120km/h. Composition changes from 2-car to 8-car. Passenger capacity ranges from 360 to 3440 people/train. They are adaptable to different conditions and operational demands. Differentiated customization can be realized on basis of TQC.

<table>
<thead>
<tr>
<th>Project</th>
<th>Urban rail it</th>
<th>Type-A metro</th>
<th>Type-B metro</th>
<th>Type-L metro</th>
<th>Tram</th>
<th>Suspended</th>
<th>Straddling train</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car width m</td>
<td>Wenzhou S1</td>
<td>Beijing 14</td>
<td>Chengdu 1</td>
<td>Guangzhou 4</td>
<td>Chengyang 1</td>
<td>Hancheng</td>
<td>Chongqing 3</td>
</tr>
<tr>
<td>Car length m</td>
<td>3.3</td>
<td>3.0</td>
<td>2.8</td>
<td>2.6</td>
<td>2.65</td>
<td>2.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Composition</td>
<td>22.8</td>
<td>21.8</td>
<td>19</td>
<td>17</td>
<td>35.3</td>
<td>33.45</td>
<td>13.9</td>
</tr>
<tr>
<td>Capacity</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Speed km/h</td>
<td>240</td>
<td>310</td>
<td>240</td>
<td>242</td>
<td>180</td>
<td>168</td>
<td>170</td>
</tr>
<tr>
<td>Acc. m/s²</td>
<td>140-160</td>
<td>80~120</td>
<td>80~120</td>
<td>90</td>
<td>60</td>
<td>55</td>
<td>80</td>
</tr>
<tr>
<td>Dec. m/s²</td>
<td>140</td>
<td>80~120</td>
<td>80~120</td>
<td>90</td>
<td>60</td>
<td>55</td>
<td>80</td>
</tr>
<tr>
<td>Power supply</td>
<td>Catenary</td>
<td>Catenary</td>
<td>Catenary</td>
<td>Catenary</td>
<td>Catenary</td>
<td>Catenary</td>
<td>Catenary</td>
</tr>
<tr>
<td>Applicable</td>
<td>Regional / intercity</td>
<td>Urban rail transit</td>
<td>Urban rail transit</td>
<td>Urban rail transit</td>
<td>Brach line</td>
<td>Tourism, branch line</td>
<td>Tourism, branch line</td>
</tr>
</tbody>
</table>
Higher operation speed

In order to enhance passenger capacity, operation speed and headway are progressively improved. The maximum operation speed is increased from 75 km/h of Beijing Line 1 to 120 km/h of Guangzhou Line. The minimum headway is increased from 17.5 min of Beijing Line 1 to 2 min of Guangzhou Line 3. The mean traveling speed is increased from 25 km/h to 50~90 km/h (80 km/h of Shanghai Line 16, 87 km/h of Nanjing S9 line). Speed is enhanced by more than 300%. Accordingly, the acceleration and deceleration performance is continuously improved. Acceleration from 0 km/h to 40 km/h is improved from 0.83 m/s² (Tianjin line 3) to 1.0 m/s². Deceleration of emergency brake is increased from 1.2 m/s² (Tianjin line 3, etc.) to 1.4 m/s² (Hong Kong urban line).

Speed of Beijing metro
Speed of Shanghai metro
Speed of Guangzhou metro
Part I  Listen to the Market

Increased transport capacity

With the rapid development of economy and urbanization, the urban rail transit network is changing everyday. The composition and speed of vehicles are progressively improved. Transport capacity and passenger flow are soaring. For example, in 1971 Beijing, the number of trips taken is 8.28 million and number of daily trips is 2.8 ten thousand. In 2017 it is 37.8 hundred million and number of daily trips is 10.35 million. The number is increased by 456 time. Metro vehicles, as the main force, accounts for 81.7% of total fleets, and bears the most transport capacity.

Analysis of Chinese urban rail transit
Part I  Listen to the Market

- Increasing scale effect

The proportion of urban rail transit in public transportation is continuously increasing, which is 53.2% in Beijing and 50.7% in Shanghai, playing a very important role in it. It features cutting-edge technologies, long industrial chain, and strong spurring capability, which significantly speed up the development of cities and upgrading of industries. In recent years, the mileage of urban rail transit is further expanded and network has progressively taken shape. Scale effect is becoming more prominent. The industrial scale is developed from less than a million in 1970s to trillions at present. Its investment benefits, investment spurring rate and the promoting effect to such urbanization-related industries as real estate, commerce, and service sector are continuously increasing.
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2 Technical challenges

With urbanization process is just in full swing, aroused comprehensive demands on URT are growing as well, leaving us with various new urgent and complicated challenges, which need systematic and creative solutions.

Climatic, geographical, line conditions, operation modes —
Higher temp. humidity & altitude, strong wind & sand & ultraviolet, small curve, large gradient, tunnel effect, power supply modes, suit for interoperation

Complex issues fours on —
Structural strength, passive safety
PHM, fire alarm & protection etc.

Develop human factors engineering
Improve stability & comfort, air quality & temp., pressure fluctuation control, lighting and noise performances.

Develop new concepts — Auto. driving, Intelligent O&M, & smart service

Insufficient transport capacity —
higher speed, rapid starting & stopping, larger composition, shorter headway

Passenger flow density is higher to 25,000 p/km.d. Lead to long-time overloading. Low speed is bottleneck of 3-D door-door transportation of airlines + high speed rail + urban rail.

Network operation, tidal passenger flow, regional difference — flexi composition

Higher requirement —
optimization lightweight, aerodynamic, system efficiency, energy management & feedback

Higher requirement — vibration & noise reduction, EMC manage
Transport capacity gaps

In recent years, the passenger flow density of each major metro line is increasing to more than 25,000 times/km per day. The transport pressure is still very large despite composition increase and headway reduce. Lines are in long-term overloading state. The overloading rate is up to 100%. The lack of transport capacity is getting more prominent, which must be solved by further composition increase, better acceleration and deceleration capabilities, and smaller headway.

Beijing Metro Line 1: in 1971, headway of type B 2-car train is 17.5 minutes, daily passenger flow 28,000 man-time. In 2013, headway of 6-car train is 3 minutes, daily passenger flow 1.0341 million man-time. In 2018, headway of type-B 6-car train is 2 minutes, daily passenger flow 10.35 million.
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Bottleneck of speed

As the comprehensive development of airlines, high speed rail, and urban rail transit, multi-network integrated and multilevel transport pattern has been progressively optimized. The door-to-door passenger transit service demand is becoming more prominent. The limit on existing operation speed is getting more and more outstanding, which holds back the bonus of high speed of medium and long distance traveling.

According to statistics, in ideal line conditions, with the maximum operation speed of trains increased from 80km/h to 140km/h, the actual traveling speed can be enhanced from 35km/h to 70km/h.

Analysis of mean traveling speed

<table>
<thead>
<tr>
<th>System</th>
<th>Distance km</th>
<th>Station distance km</th>
<th>Number of stations</th>
<th>Station dwell s</th>
<th>Acceleration m/s²</th>
<th>Deceleration m/s²</th>
<th>Max. speed km/h</th>
<th>Mean speed km/h</th>
<th>Auxiliary time h</th>
<th>Traveling time h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airlines</td>
<td>1300</td>
<td>1300</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>800</td>
<td>800</td>
<td>2.5</td>
<td>4.1</td>
</tr>
<tr>
<td>HSR</td>
<td>1300</td>
<td>300</td>
<td>4</td>
<td>120</td>
<td>0.3-0.4</td>
<td>1.0</td>
<td>350</td>
<td>230</td>
<td>1.5</td>
<td>7.2</td>
</tr>
<tr>
<td>Regional</td>
<td>300</td>
<td>50</td>
<td>5</td>
<td>60</td>
<td>0.4-0.8</td>
<td>1.0</td>
<td>160-200</td>
<td>120</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>Metro</td>
<td>60</td>
<td>2</td>
<td>20</td>
<td>30</td>
<td>0.8-1.0</td>
<td>1.0</td>
<td>80-120</td>
<td>35-54</td>
<td>0.5</td>
<td>1.6-2.2</td>
</tr>
</tbody>
</table>
Part I  Listen to the Market

**Flexible composition**

With the continuous development of lines and network scale, networking transportation shall definitely take shape. In addition, considering the tidal characteristic of metro passenger flow and unbalanced development among urban areas, flexible composition technology must be developed to enable automatic interoperation and networking operation, thus to enhance the transport capacity in peak hours and utilization efficiency of lines.
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Adaptability

Different solutions are generated from different climatic conditions, line conditions, operational modes, and various economic and technical demands from customer, which propose higher requirements on platforming, modularization, standardization, and better adaptability.

- **Ambient temperature** high temperature and extreme coldness, ambient humidity, windy and sandy weather
- **Altitude** insulation and voltage withstand, anti-ultraviolet, temperature rising and heating
- **Vehicle clearance limit** Operational speed, running resistance, platform gaps, vibration and noise
- **Maximum gradient** Adaptable area, adhesion utilization, motor performance, failure restart
- **Minimum curve** Adaptable area, negotiation capability
- **Power supply system** Type of traction, energy feedback, energy storing, selection of battery
- **Operational speed** Running resistance, traction power, in&exterior noise, tunnel pressure, airtightness, riding quality
- **Headway** Acceleration and deceleration performance, mean speed, energy consumption per capita
- **Type of composition** Passenger flow, full load rate, network composition, flexible composition, interoperation
Part I Listen to the Market

- Energy saving and eco-friendly

Energy conservation and environmental protection are contestant targets of rail transit. With the continuous development of operation speed and headway, energy consumption, noise & vibration, and radiation problems are becoming more severe. Comprehensive and systematic optimization solutions are becoming much more urgent on such aspects as traction and brake efficiency, energy feedback and management, lightweight design, vibration reduction, vibration and noise insulation, and EMC, etc.
Comfort and convenience

In a long term, metro transport is just fours on resolve the problem of urban passenger transportation with comparatively low service quality, left with very large space that can be greatly improved in terms of air quality, air pressure fluctuation, temperature control, vibration noise, information service, lighting, color, and space experience.
The existing train control and monitoring system (TCMS) is composed of WTB and MVB. Transmission rate of WTB is 1Mbps, and that of MVB is 1.5Mbps. The integration level of traction, brake and auxiliary system, especially that of door, HVAC, lighting, PIS, and various monitoring system into TCMS is not high. The functions are repeated, with low real-time level, and consistency. High level of integration is urgently necessary. Automatic Train Operation is beginning. Intelligent operation and maintenance is still under-developing. Intelligent service concept requires more optimization. The train self inspection, self identification and self diagnose capabilities urgently need to be improved.
Part I  Listen to the Market

Safety

Facing so many technical issues, the general protection requirements must be broken down into whole structure, each sub-system and components. Analysis shall be done to each process of design, simulation, test, so as to make safe, effective, and comprehensive optimization solutions. Attention shall be focused on passive safety and online diagnose.

- **Tracing and collision**— Operation control failure: overspeed, overrun, blocking failure, Train failure: early-alarm failure, train slide, sliding over limit
- Anti-collision failure: Deformation and torsion, lifting and climbing
- **Dynamics**— Derailment, load reduction, wheel-rail force, critical unstable
- **Overspeed protection**— Overspeed in curve, train control failure, self inspection failure
- **Pneumatic safety**— Rear car lifting force, lateral torque, lateral wind performance
- **Modal matching**— Car-bogie, car-line, carbody-equipment, pantograph-catenary resonance
- **Structural design**— Strength breakage, fatigue breakage, corrosion breakage, overheated axle and sinking axle, loosening and fall-off, derailment protection
- **Earthquake early-alarm**— Train ground communication, decision-making mechanism
- **Electromagnetic interference**— Human health car, car train control, car control, safety-protection circuit.
- **Electromagnetic sensitivity**— Monitoring system, car train control, car control, safety-protection circuit.
- **Circuit design**— Bad isolation, grounding failure, gap discharge, electric leakage and breakdown

- **Impact damage**— Collision and impact, secondary collision, crossing-brake impact, curve centrifugation, equipment fall-off, train wind
- **Extrusion damage**— Collision and compression, train-platform gap, door and mechanism
- **Abrasion damage**— Vehicle clearance limit interference, foreign matter interference, pantograph damage and fall of from catenary
- **Electrical sparks**— Bad contact, overload, short-circuit, electric breakdown, arc discharge, touch between stator and rotor
- **Equipment burned**— Thunder, maze, switch-surge, circulation, breakdown, short-circuit
- **Material property**— Fire protection, toxicity and smoke protection.
- **Fire protection design**— Matching between structure and material, smoke and fire leakage, spreading path, fire extinguishing measures, evacuation path
- **Equipment explosion**— Overloaded high temperature impact-battery, capacitor, insulator, high pressure impact-high pressure pipeline, pressure vessel, glass
- **Splash damage**— Glass fragments, etc.
- **Terrorism explosion**— Explosion protection capability, disaster foresee, evacuation strategy
Part I: Listen to the Market
Part II: R&D CETROVO Prototype
Part III: Lightweight Solution
Part IV: Future Exploration
Part II  R&D of CETROVO Prototype

Reflecting on domestic market requirements and up-to-date technologies, CRRC initiated to R&D a new type of metro — the CETROVO prototype will bring our customer with:

*High speed, high efficiency, intelligence, green, high adaptability*
## Part II  R&D of CETROVO Prototype

### 1  Stronger adaptability

It is adaptive to vast areas of China and overseas with various condition as well as different line conditions and operation modes.

<table>
<thead>
<tr>
<th>Climate conditions</th>
<th>Line conditions</th>
<th>Operation mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment temperature: -25~45, considering -40°C</td>
<td>Loading gauge: Type A Metro</td>
<td>Organizing mode: Flexible composition + interoperation</td>
</tr>
<tr>
<td>Relative humidity: ≤95%</td>
<td>Standard track gauge: 1435mm</td>
<td>Headway: 90s</td>
</tr>
<tr>
<td>Altitude: 2500m</td>
<td>Min. curve radius: R80</td>
<td>Driving mode: Automatic drive + return</td>
</tr>
<tr>
<td>Max. wind speed: 38m/s</td>
<td>Max. gradient: 50‰</td>
<td></td>
</tr>
<tr>
<td>Radiation intensity: 140Kcal/cm²</td>
<td>Platform: 1080mm/140m</td>
<td></td>
</tr>
</tbody>
</table>

**Power supply**

- Mode: Catenaries/Energy storage
- Voltage: DC1500/750V
- Energy feedback: Rheostat / regenerative brake
Part II  R&D of CETROVO Prototype

2 Excellent performance

140km/h with excellent general performance of traction, brake, control, flexibility, passenger capacity, efficiency, intelligence, safety, energy saving and eco-friendly, convenient and comfort for passengers.

- Running speed ........................................Max.140km/h
- Composition........................................4M2T flexible
- Tare weight ..............................................195t
- Max. axle load...........................................16t
- Capacity...........Seated 48/ nominal 310/ overload 432
- Transmission...........................................DC-AC+PMSM
- Propulsion power.................................3730kW
- Starting acceleration .............................≥1.0 m/s²
- Average deceleration......................≥1.4 m/s² (emergency)
- APS..................High frequency +parallel network
- Carbody Strength.........................Comp. 120/ Ten. 96t
- Bogie frame strength........................UIC615/UIC515
- Airtight strength..............................................±4 kPa
- Running safety.........Derailment ≤0.8 / offloading rate≤0.6
- Fire safety..............................................EN45545/CJ/T416
- Crashworthiness..................................EN15227-C-II
- Passenger comfort........Stability W < 2.5/ comfort N < 2
- Standstill noise.................................Saloon 65dBA
- Running noise...........................................Saloon 68dBA
- Exterior noise........................................76dBA
- Energy consumption..............................< 0.03kWh/t·km
- Network bandwidth..................100Mbps / vehicle 1Gbps
- Pre-warning..............................Correct ≥92%, delay < 500ms
- Vehicle dimensions.............................22x3x3.842m
All subsystems are designed on the principle of functionalization, modularity and lightweight. Air conditioner and mono-arm pantograph are mounted on the roof. Modern passenger interface and control facilities are provided in the saloon. Traction, auxiliaries and brake systems are suspended in the equipment bay under the floor.
Part II  R&D of CETROVO Prototype

4 Flexible composition

Designed with independent propulsion, brake, APS and control unit, self-adaptive control network, rapid coupling & decoupling devices, as well as on-line de&re-coupling technologies, it can realize flexible composition of 2-12 cars, and take just about 5 minutes for re-composition.

Flexible formation

Self-adaptive Network

Power & brake unit

Automatic coupling

Rapid diaphragm

2 end car as a basic unit, flexible for add or remove M or T.

Formation changes

ETBN power on Initial running

ETBN exchanges information to obtain vehicle information

ETBN obtains information of the train

ECN address resolution

ECN address mapping

Independent traction & brake configuration, flexible & redundancy

Auto- mechanical, pneumatic and electrical coupling

Rapid uncoupling & coupling
5 Up-to-date propulsion & APS — main circuit

Propulsion is fed from DC1500V catenary via mono-arm pantograph+VVVF circuit, in addition to a DC750V circuit fed by onboard energy storage unit. 1T+ 2M as a basic unit is accommodated with a individual double-mode power unit with axle-controlled state-of-the-art SIC traction inverters and PMSM. Advantages: Powerful — support running at 140km/h with big starting acc.; Lightweight — 15% weight reduction; Higher efficiency — improved by 5%; ESU could ensure 15km powerless operation, support no-catenary-fed, self-powered return and crossover operations.

Part II  R&D of CETROVO Prototype
Part II  R&D of CETROVO Prototype

5 Up-to-date propulsion & APS — APS

Auxiliary power supplied by 2 grid-connected high frequency APS each consisting of 2 SIVs + 1 battery via AP bus bar. With HFL design, resonant soft switching and cross-phase control technologies, SiC inverter, lithium titanate battery and CFRP housing, it boasts of light weight, low noise and high redundancy.

VLC

Composition APS

Main circuit

Parameters | Auxiliary inverter | lithium titanate battery
---|---|---
Capacity | 125kVA | 40Ah
Efficiency | 92% | -
Voltage | DC110/AC380/ DC700V | DC110V
Weight | 730kg | 160kg

High frequency soft switch DC/DC

IGBT Module

SIC inverter

SiC schematics

Main technical parameters

CFRP Housing

Lithium Battery

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Part II  R&D of CETROVO Prototype

5 Up-to-date propulsion & APS — APS of hydrogen fuel cell

Taking advantages of clean, eco-friendly, high energy intensity and uninterruptible feeding capability, hydrogen fuel cell power is developed to feed HVAC, to ensure peak traction power requirement during train starting and charge on-board ESU — tram car with HFC propulsion has already been developed, while intercity train with HFC propulsion is under developing.

- Output power…………….≥ 30kW/set
- Output voltage…………..250~560V
- Output current…………….0~200A
- Starting mode…………….cold-start
- Pressure……………………..35MPa
- Capacity…………………….9.6kg
- Hydrogen tank……..CFRP winding
- Continuous supply…………..4 hours
6 Advanced brake system

In order to simplify the system, to reduce time delay and to improve brake accuracy, new type of electro-mechanical brake system is developed the same time to replace the existing electric-pneumatic brake. For this system, brake piping has been removed and response time could be ≤ 0.5s, brake force error could be ≤ 5%.
Part II  R&D of CETROVO Prototype

7 Self-adaptive lightweight bogie

Blending advanced technologies such as CFRP bogie frame together with various lightweight components with high performance, active steering device, active lateral damper, and intelligent detecting& diagnosis system etc., active steering bogie, CFRP bogie and PMSM direct driving bogie are developed, all with same interface and interchangeable with each other. Bogies boast with high speed, light weight, low wheel-rail effort, low noise, strong adaptability, superior dynamics and ride quality. The max. running speed is 140km/h, max. axle load is 16t and min. curve radius negotiable is 80m.

Active steering bogie  CFRP bogie  PMSM direct driving bogie
Part II  R&D of CETROVO Prototype

9 Highly integrated control network

New type of Train Control and Monitoring System is developed based on control Ethernet and control technologies. It consists of Ethernet Train Backbone and Ethernet Consist Network with transmission speed up to 100Mbps/1Gbps. Train control network integrates subsystems such as TCMS, PIS, CCTV and signaling. Service network integrates intelligent operation & maintenance and entertainment systems. Multi-network integration is to simplify system and improve conformity, safety and real-time performance, ensure high bandwidth data transmission for intelligent operation & maintenance system.

Network architecture
Multi-network integration

<table>
<thead>
<tr>
<th>Network parameters</th>
<th>Comprehensive display</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETB 100Mbps</td>
<td>Information integration</td>
</tr>
<tr>
<td>ECN 1Gbps</td>
<td>Redundant display of key information</td>
</tr>
<tr>
<td>Flexible formation,</td>
<td>High picture quality</td>
</tr>
<tr>
<td>self-adaptive</td>
<td></td>
</tr>
<tr>
<td>Virtual network</td>
<td></td>
</tr>
<tr>
<td>isolation, data</td>
<td></td>
</tr>
<tr>
<td>classification</td>
<td></td>
</tr>
<tr>
<td>Simple and efficient</td>
<td></td>
</tr>
<tr>
<td>network</td>
<td></td>
</tr>
</tbody>
</table>

Main parameter

17.3 inch screen

TCMS display
PIS display
Signaling display
Integrated display
Effort has also been made in green and eco-friendly technologies to develop a new type of energy storage air conditioner. With energy storage technology of liquid-solid phase transition adopted to utilize spared cooling capacity, 20% energy is saved.

Main parameters

<table>
<thead>
<tr>
<th>Main parameters</th>
<th>Indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cop (Nominal)</td>
<td>2.61 (increase 15%)</td>
</tr>
<tr>
<td>PMV</td>
<td>0 (high comfort)</td>
</tr>
<tr>
<td>SPL noise</td>
<td>69dB (A)</td>
</tr>
<tr>
<td>Collection coefficient (&gt;PM2.5)</td>
<td>96%</td>
</tr>
</tbody>
</table>

Main performance

Oval tube heat exchangers

Electrostatic precipitators

Phase change energy storage air conditioner

Temp. curve during charging & discharging

Variable frequency air conditioner

Smartsensory comfort PMV control principle

Principle of phase-change energy storage device
## Part II  R&D of CETROVO Prototype

### 11 Superior aerodynamics

Excellent aerodynamic design with streamline body shape and smoothness surface is to solve crucial problems such as resistance, noise, pressure wave of trains crossing and micro-pressure wave at 140km/h in 21m² tunnels.

#### Aerodynamic Cases

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Head optimization</th>
<th>Pantograph</th>
<th>Aerodynamic noise</th>
<th>Wind tunnel test</th>
<th>Moving model test</th>
</tr>
</thead>
</table>

#### Technical indices

- Aerodynamic drag coefficient reduce 35%
- Aerodynamic lateral force with cross wind reduce 3%
- Pressure wave reduce in-tunnel 3–5%
Part II  R&D of CETROVO Prototype

12 Intelligent passenger interface

New technologies such as modern industrial design, up-to-date facilities, PIS, OLED, WIFI, HAVC and lighting have been integrated to passenger interface for the prototype — to develop new concept of passenger priority and offering more service beyond expectations.
Part II  R&D of CETROVO Prototype

13 Modern intelligent technologies

Modern network, information communication & sensor technologies are deeply integrated into train control system to fully improve self-sensing, self-identifying, self-decision and self-learning ability, realizing automatic drive, intelligent O&M and intelligent service for higher efficiency and safety.

Intelligent Service
Modern PIS, virtual scene, intelligent lighting & HVAC

Automatic Drive
Automatic control, train-ground interaction, safety mechanism

Intelligent Operation & Maintenance
Real-time monitoring, intelligent pre-warning, remote maintenance

Passenger service
- Conventional PIDS service system
- Modern information system
- Local enquiry
- On-line service
- Broadcast system
- Multimedia
- Touch screen
- LED curved screen
- CCTV
- 360° area view

Conventional PIDS
Modern information system
Local enquiry
On-line service
Broadcast system
Multimedia
Touch screen
LED curved screen
CCTV
360° area view

Intelligent lighting

 Intelligent air con.
PMV/PPD adjusting

Local enquiry
On-line service
Virtual scene

Health monitoring

Intelligent pre-warning

Remote O & M control center
monitoring, decision, guiding
maintenance plan, spare parts
organizing, continuous tracing

Big data center
Part II  R&D of CETROVO Prototype

14 Effective noise control

Acoustic insulation and reduction principle has evolved from acoustic insulating materials to integrating materials with structures, focusing on overall effect and integration of structural. Technologies of airtightness carbody, quasi-vacuum & nanometer materials, damping wheels and superior aerodynamics design have been adopted. Breakthrough has been made in noise control on CFRP carbody. Interior / exterior noises at 140km/h are to be under 75/88dB(A), nearly equivalent to that of conventional metro at 80km/h.
Running resistance is reduced through superior aerodynamics and lightweight design; Systematic optimization for traction, brake, air conditioner and lighting system is to improve system efficiency; On-board energy management is to optimize starting and operation sequence and status.—result in overall improvement on train efficiency.

Streamline shape
Equipment bay
Smoothness surf
Aero-drag
reduce
>30%

Dissipation strategy
running
Fan semi-speed
stop
Fan full speed

Dissipation strategy
Starting
Running
Braking
Energy storage +
catenaries

Lightweight design
reduce running
resistance
>6%

Aerodynamic optimization
Streamline shape
Optimization section

Lightweight design
reduce running
resistance
>6%

Various components
dissipation &
energy consumption
strategy;
Dual power supply
management—further
energy consumption,
overall efficiency >15%

Systematical
optimize traction &
auxiliary systems to reduce
energy consumption,
improve overall efficiency >15%

Various components
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energy consumption,
improve overall efficiency >15%

CFRP cab
Light strip
CFRP carbody

CFRP bogie
frame + aluminum parts
Carbon-ceramic
brake disc
CFRP equipment bay

CFRP carbody
Light strip
CFRP carbody

CFRP bogie
frame + aluminum parts
Carbon-ceramic
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brake disc
CFRP equipment bay
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Future Exploration
Part III Breakthrough in Lightweight

1 Optimization scheme

Contradictions between light weight and various performance such as strength, stiffness, fatigue, corrosion, noise and fire protection shall be solved in a balance way, approach includes structure optimization, material improvement and integration optimization of them.

**Lightweight**

- **Strength**
  - Improved
- **Rigidity**
- **Fatigue resistance**
- **Anti-corrosion**

**Contradictions between light weight and performance such as strength, stiffness, fatigue, corrosion, noise and fire protection shall be solved in a balance way, approach includes structure optimization, material improvement and integration optimization of them.**

**Structure optimization**

Light weight shall be taken as basis to improve strength, optimize vibration and noise and manage EMC.

**Material optimization**

Searching for lighter, stronger, more stable and weather-endurance materials, processes and structures.
Part III Breakthrough in Lightweight

Environment impacts

In terms of materials light weight approach, as high speed metro vehicles need to withstand complex interactions, geographic and climate conditions as well as different operating scenarios, which lead to strong fluid-structure-electrical-magnetic coupling, there are great challenges on strength, rigidity, vibration and electro-magnetic requirements for materials.
Part III Breakthrough in Lightweight

Technical demands
For future high-speed metro car, an efficient, reliable, eco-friendly, energy-conserving solution is to adopt new materials with excellent comprehensive performance that can break technical constraints of traditional metal materials.

Fiber reinforced composites such as carbon fiber, glass fiber and aramid fiber become the best solutions to lightweight problem because of their excellent comprehensive performance such as light weight, high strength and high weather resistance as well as proven applications in aviation, aerospace, shipbuilding, automobile, sports, medical care and other fields.
Part III Breakthrough in Lightweight

2 Application status — learn from relevant fields

With years of proven application and continuous technical development, problems existing in materials, structural design, manufacturing technique, service performance and maintenance technology have been solved, which can be used for reference.
2 Application status — pay attention to our counterparts

CFRP has been widely used on railway vehicles. Attempts of various extents have been made on rolling stock parts and components, such as interiors, head cover, energy absorbing elements, coupler adapter, pantograph, as well as major parts such as cab, carbody and bogie. At present, all applications are at exploration stage.
Part III Breakthrough in Lightweight

2 Application status — work on domestic foundation

Main applications: interiors and light load structures such as head cover, equipment bay and carbody of low-speed trains. Extensive attempts have been made in R&D steps and experience has been accumulated, which lays a foundation for further R&D.
Part III Breakthrough in Lightweight

3 R&D strategy

- **Material replacement**
  - Function realization

- **Operation verification**
  - Structure optimization

- **Proven application**
  - Batch production

### R&D Scheme

#### Beijing-Xiongan HST 2019
- HST integral cab for high-speed assessment; small batch application

#### High-speed Maglev Train 2020
- To develop main structures for high-speed maglev, and explore technical features and solutions for high-speed scenarios

#### Application promotion—2025
- Realize HST main structure and series parts batch application based on TQC; Optimization & create industrial chain

#### Equipment bay of Fuxing EMU 2016
- Attempt to develop large structural parts of high-speed EMU, to realize running assessment and to study service performance and verify feasibility

#### CETROVO prototype 2018
- To develop main supporting structures of carbody, cab and bogie, to perform low-speed running assessment and to make breakthrough in R&D technologies and build R&D platform
4 Fuxing HST equipment bay

Modular structure is adopted to enable piece-by-piece, module-by-module or integral assembly and disassembly. Drawer-type bottom plate and hinged skirt plate are adopted in fail-safety design. Compared with aluminium alloy structure, weight is reduced by 35%. It can withstand vibration, ground effect as well as impact, high temperature, high humidity, wind, sand, rain and snow erosion.

The first attempt of large CFRP components in HST. Various type tests and 600 000 km climate and geographical online assessment has been finished, with max. running speed of 420km/h.
5 CFRP exploration on CETROVO

It takes three years to develop carbody, cab, bogie frame, equipment bay and other crucial parts, to explore large and complex train components design and engineering techniques. During which, various design, curing, inspection and test validation technologies are developed. 140km/h running assessment is planned in this year.
5.1 CFRP Cab
With idea of integration of material-design-process, and integration of structure & bearing function of shell, interiors, underframe and console as a monoblock, it boasts light weight, crashworthiness, integration and commercialization. In which, various OOA technology for large complex structures have been successfully developed. With just only 5 modules, which are bonded together after curing, it greatly reduce parts number. With fitting-out process separately, cab can be installed onto the vehicle after completion, to improve manufacture process. Weight reduction is $> 30\%$. 
5.2 CFRP Carbody

Its self-supporting structure with bearing and mounting structures integrated, with completely CFRP modulars (except bolster) bonding+riveting together after curing. Pultrusion, winding, braiding and integral processes such as co-curing, co-bonding are explored for large-heavy-load components. Result in flexible and high-efficient & precision molding and quality control technologies, suitable for mass production. Features light-weight, robust and air-tightness: weight reduction by 30% while complying with strength requirement of EN12663, airtightness strength is up to ± 3500Pa.
5.3 CFRP bogie frame

Its of H-shaped modular structure, simple, efficient, economical and easy to maintain. High modulus CFRP and advanced technologies such as weaving + HPRTM and dry/wet winding + high temperature curing etc. are adopted for side sill, cross beam and air cylinder, mechanically connection and bonding are adopted for assembly. Its suitable for automatic manufacturing of large heavy dynamic load CFRP structure with thick wall, crossing cavity and variable sections, boasting high efficiency and quality. Weight reduction is > 40%.
Part III Breakthrough in Lightweight

5.4 CFRP equipment bay
The equipment bay follows modular concept of Fuxing EMU, which can be assembled in pieces, in modules or as an integral part. Material system, structural design and molding process are optimized. A series of advanced curing technologies such as pultrusion and VARI are adopted to improve technical performance, quality and production efficiency, reducing weight by 30%.

- Side sill
- Cross beam
- Skirt plate
- Carline
- End plate
- Bottom plate
Part III Breakthrough in Lightweight

5.5 Carbon ceramic brake disc

Lightweight, fire resistant, and high-adaptability carbon ceramic brake disc is developed for technologies reservation of high speed train. It is now under line test of 140km/h. Weight is saved by 60% compared with steel disc.

- **Technical features**
  - Lightweight: 1t lighter per car
  - Good performance: 50 MJ/disc
  - Fire-resistant: 1600°C
  - Suitable to: all environment, wind, snow, sand, and rain.

- **Critical issues**
  - Structural design of friction pair
  - Development and processing of material
  - Matching and selection of friction pair.

- **Project progress**
  Stand test of sample has been finished. Its performance complies with UIC standard. It is to be mounted in CETROVO prototype for operation validation.
Part III Breakthrough in Lightweight

5.6 C/C composite sliding plate
Lightweight and wear-resistant C/C pantograph contact was developed, which will be initially installed on exported EMU and CETROVO prototype for operation assessment at 140km/h. After completion, it is expected to be promoted to HST.

- **Technical features**
  With carbon fiber prefabrication as reinforcement, carbon slide is molded by chemical vapor deposition process, improving mechanical property by 2-3 times and expanding life span by 1 time.

- **Critical issues**
  Design of 2.5D carbon fiber prefabrication, graphitization treatment process.

- **Project progress**
  Bench tests of impact energy and 300km/h friction abrasion have been finished. It is planned to carried out operation assessment in 2018.
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Part IV Future Exploration

During CETROVO platform R&D, tens of modern and advanced design concepts and new materials, structures, systems and processes have been developed. Some of them have been transferred to market products to improve its technical performance, some of them is still under developing, subjected to further test and running assessment before mass application.

- **SiC converter**: to R&D and optimize full SiC convertor with high power element
- **PMSM**: to R&D much more compact, lightweight and large torque products
- **Electro-mechanical braking**: finish running assessment and improve reliability
- **Multi-network integration**: to integrate control of main facilitates such as door, HVAC and monitoring system etc. into TCM.
- **Intelligent technologies**: to further develop automatic driving, intelligent O&M and intelligent service based on big data cloud platform.
Part IV Future Exploration

**CFRP application**

R&D carbody, cab, skirt plate, chasis and other parts of 600km/h maglev.

R&D main components such as integral-cab, carbody and bogie frame for HST.

Develop typical components that is favorable for GCFRP, such as metro integral-cab, HST pantograph mounting seat, equipment bay etc. for batch application.

Develop low-cost and high efficiency CFRP design-process technology for application of HST decoration, sub-bearing structures and main bearing structures.
With continuous hard work, crucial technologies and systems will become more and more proven, the prototype will lead to popularized the new generation metro and play a leading role in the nearest future.
Thank you!