时　评

打造性能更优新一代 CR450 高速动车组 助推中国高铁事业“十四五”更大发展

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20 世纪 90 年代至今，中国高速动车组经历了自主探索、引进消化吸收、自主创新、全面创新四个发展阶段，成功实现了从追赶到领跑的历史性跨越。特别是 2012 年起，为贯彻落实习近平总书记的重要指示精神，中国高速动车组技术进入全面创新阶段。在中国国家铁路集团有限公司、中国中车股份有限公司等组织下，中车长春轨道客车股份有限公司联合国内外科研院所和全产业链供应商，加大自主创新力度，以中国标准为主导，按照正向设计思路，以自主化、简统化、互联互通互换、技术先进为目标，成功研制出具有完全自主知识产权的时速 160 km、250 km、350 km 系列化“复兴号”动车组，创造了时速 420 km 列车交会试验的世界记录，实现了全球首个时速 350 km 商业运营，“复兴号”动车组成功奔驰在祖国广袤的大地上。

2021 年 1 月，习近平总书记乘坐京张高铁赴张家口赛区考察北京冬奥会筹办工作时指出，我国自主创新的一个成功范例就是高铁，从无到有，从引进、消化、吸收再创新到自主创新，现在已经领跑世界。要总结经验，继续努力，争取在“十四五”期间有更大发展。截至目前，我国已建成设计时速 350 km 的高铁线路 1.5 万 km，在建设计时速 350 km 线路 8 800 km。基于时速 350 km 高铁基础设施条件，通过动车组技术水平的全面提升，实现时速 400 km 商业运营，促进我国产业转型升级和经济高质量发展已势在必行。

CR450 动车组定位于新一代更高速度、更加安全、更加环保、更加节能、更加智能、更加自主、更可持续、系统更优的“复兴号”动车组新产品。遵循先进、可靠、成熟、经济、必须的原则，引领动车组向标准化、系列化、模块化、智能化发展。

更高速度　基于既有高铁线路运用边界，建立“车辆-线路-环境”大系统耦合模型，深入研究轮轨、弓网、流固及其相互的耦合影响关系；持续开展气动减阻、整车轻量化、制动能力提升等方面技术研究，突破速度和能效提升技术瓶颈，实现运营速度达到时速 400 km，试验速度达到时速 450 km 以上，极限试验速度力争突破时速 600 km。

更加安全　深入开展整车轻量化和制动系统能力提升，以及主被动防护、灾难预警、卫生防疫和智能化安全状态管理等技术研究，实现时速 400 km 紧急制动距离 6 500 m。在已有安全体系基础上，围绕新能源、信息技术融合应用等技术进行研究，提升安全保障能力。通过车-车互联、实时通信、自主驾驶、自我管理，提升运行安全性、智能性。深入开展列车防火、耐碰撞、恶劣环境适应性技术研究，提升应急保障、故障救援能力。

更加环保　深入开展新能源（氢能源、电池储能等）、新材料（高可靠性超导材料等）、新工艺（激光熔覆、增材制造等）、新技术（噪声主动控制、绿色制冷等）等方面的技术研究，进一步提升环保性能指标。

更加节能　开展基于“质量-阻力-动力”的多目标均衡综合节能技术研究，实现时速 400 km 运行时能耗 22 kWh/km。重点开展“新型材料-拓扑结构-先进工艺”一体化技术研究，提升轻量化水平。采用整车平顺化、细部结构优化、流场主动控制等手段，降低运行阻力。研制基于永磁牵引电机和高功率器件（SiC）的牵引系统，提升牵引链效率。开展辅助驾驶和自动驾驶融合技术研究，实现进一步节能的目标。

更加智能　深入开展智能化技术研究及应用，广泛应用人工智能、智能传感、无线传输、大数据、云计算、物联网等新技术，通过全方位态势感知、故障预测与健康管理等手段，使动车组由“智能型”向“智慧型”转变，具备自感知、自决策、自排故三大能力，实现车辆的智能制造、智能行车、智能服务和智能运维，提高旅客界面、司乘界面、运维界面智能化水平。

更加自主　通过研发 CR450 高速动车组，全面掌握时速 400 km 高速动车组系统集成、承载、走行、驱动、控制等关键核心技术，建立相关的设计、制造、试验、评估、运用、检修维护等技术标准体系，构建完

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全自主可控的高速动车组技术平台,实现高铁基础理论、关键技术、装备研制、标准体系的全面创新。

更可持续 从市场需求、技术研究、产品研发、试验验证、应用示范等全链条推进高水平自立自强。基于 CR450 高速动车组技术平台,引领世界高速列车发展,形成谱系化产品,提升我国高铁移动装备技术水平和竞争力。

系统更优 CR450 动车组的运营速度、制动距离、能耗、噪声等关键技术指标世界领先,动车组单位公里寿命周期成本与 CR400"复兴号"动车组相当。通过高速动车组系统集成技术的科技创新,实现动车组安全性、先进性、可靠性、经济性、可维护五个方面的全面提升。

综上所述,CR450 动车组作为"复兴号"动车组家族的新成员,其运营速度和综合能效水平更高,能大幅提升我国高铁科技创新水平和自立自强能力,以及巩固扩大技术领先优势,将在中国高铁事业"十四五"更大发展中担当主力,并为推进"一带一路"倡议和交通强国建设、实现"双碳"战略目标提供技术和装备支撑。

Commentary

Creating a New Generation of CR450 High-Speed EMUs with Better Performance Promoting Greater Advances of CHSR during the 14th Five-Year Plan Period

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Since the 1990s, China's high-speed EMU have undergone four development stages: autonomous exploration, introduction and absorption, independent innovation, and comprehensive innovation, thus successfully making a historic breakthrough from struggling from chasing to taking the leading position. Especially since 2012, China's high-speed EMU technology has entered a comprehensive innovation stage to implement the spirit of the important instructions of Secretary General Xi Jinping. Organized by China Railway, CRRC Corporation Limited, etc., and guided by Chinese standards, CRRC Changchun Railway Vehicles Co., Ltd. cooperated with domestic and foreign research institutes and suppliers of the whole industry chain to strengthen the independent innovation and successfully developed a series of "Fuxing" EMU with completely independent intellectual property rights (IIPR) at different speeds of 160 km/h, 250 km/h, and 350 km/h for the purpose of achieving autonomy, simplification, interconnection and interchange, and advanced technology in accordance with forward designs. Consequently, a world record for the train passing test at a speed of 420 km/h was made, and the world's first commercial operation at a speed of 350 km/h was realized. The "Fuxing" EMU successfully operate on the vast land of China.

In January 2021, Secretary General Xi Jinping took the Beijing-Zhangjiakou high-speed train to inspect the preparations for the Beijing Winter Olympics in Zhangjiakou Division and pointed out that high-speed railways mark successful examples of China's independent innovation, which has played a leading from scratch in this field around the world through a process of introduction, absorption and re-innovation, and independent innovation. We should summarize experience, keep working hard, and strive for greater progress during the 14th Five-Year Plan period. By now, China's high-speed trains with a design speed of 350 km/h have run on 15 000 km rail lines, and the 8 800 km rail lines for high-speed trains with a design speed of 350 km/h are under construction. Considering the infrastructure conditions of high-speed trains with a speed of 350 km/h, it is imperative to make overall progress in EMU technology andrealize the commercial operation of EMU with a speed of 400 km/h, thus promoting China's industrial transformation and upgrading and high-quality economic development.

CR450 EMU is a new generation of "Fuxing" EMU that is faster, safer, more environmentally friendly, more energy-saving, more intelligent, more autonomous, more sustainable, and more system-optimized. Besides, it pursues standardization, serialization, modularization, and intelligence of EMU in accordance with principles of advance, reliability, maturity, economy, and necessity.

Faster A large-scale system coupling model of "vehicle-line-environment" wasset up based on the operation boundary of the existing high-speed rail lines, and in-depth studies on wheel-rail, pantograph-catenary, fluid-solid, and their mutual coupling influ-

ence were conducted. Technical research on pneumatic drag reduction, vehicle lightweight, braking capacity improvement, etc., was continuously carried out and the technical bottleneck of speed and energy efficiency was broken through. As a result, an operating speed of 400 km/h, a test speed of over 450 km/h, and an ultimate test speed of 600 km/h were realized.

Safer In-depth technical research on vehicle lightweight, braking system capability improvement, active and passive protection, disaster early warning, health and epidemic prevention, and intelligent safety status management were conducted to obtain an emergency braking distance of 6 500 m at a speed of 400 km/h. Given the present security system, studies on technologies such as new energy and information technology (IT) integration and application were carried out to enhance the safetyassurance ability. In addition, the operation safety and intelligence were improved through vehicle-to-vehicle interconnection, real-time communication, autonomous driving, and self-management. And in-depth technical studies on fire prevention, collision resistance, and harsh environment adaptability of those trains were conducted to enhance emergency support and breakdown rescue capabilities.

More environmentally friendly In-depth technical research on new energy (hydrogen energy, battery energy storage, etc.), new materials (high-reliability superconducting materials, etc.), new processes (laser cladding, additive manufacturing, etc.), and new technologies (active noise control, green refrigeration, etc.) were carried out so as to further improve the environmental performance indicators.

More energy-saving Technical studies on multi-objective balanced comprehensive energy-saving technology based on "weight-resistance-power" were conducted, and the energy consumption of 22 kWh/km was realized at an operating speed of 400 km/h. Meanwhile, technical research on the integration of "new materials-topological structures-advanced technologies" was focused on to enhance the lightweight level. The operation resistance was undermined by virtue of vehicle smoothness, detail structure optimization, and active flow field control. Besides, a traction system based on the permanent magnet traction motor and high power device (SiC) was established for improving the efficiency of the traction chain. And technical research on the integration of assisted driving and automatic driving was conducted for more efficient energy saving.

More intelligent In-depth research and application of intelligent technology were concentrated on, new technologies such as artificial intelligence (AI), intelligent sensing, wireless transmission, big data, cloud computing, and Internet of Things (IoT) werein wide application. EMU have transformed from "intelligent" ones to "smart" ones with three capabilities of self-perception, self-decision, and self-trouble shooting through omni-directional situational awareness, failure prediction, health management, etc. For this reason,the intelligent manufacturing, intelligent driving, intelligent service, and intelligent operation and maintenance of vehicles were realized, and the intelligent level of passenger interface, steward-passenger interface, and operation and maintenance interface was enhanced.

More autonomous The research and development of CR450 high-speed EMU contributed to the full grasp of the key core technologies such as system integration, bearing, operation, driving, and control of the high-speed EMU with a speed of 400 km/h, the establishment of relevant technical standard systems concerning design, manufacturing, test, evaluation, application, overhaul, and maintenance, and the completion of a fully independent and controllable high-speed EMU technical platform, thereby realizingthe comprehensive innovation of high-speed rail basic theories, key technologies, equipment development, and standard system.

More sustainable High-level self-reliance was promoted from the whole chain of market demands, technology research, product research and development, test verification, and application demonstration. The CR450 high-speed EMU technology platform helped China take a leading role in the development of high-speed trains in the world. Consequently, pedigree products were made, and the technical level and competitiveness of CHSR mobile equipment were improved.

More system-optimized Key technical indicators such as operating speed, braking distance, energy consumption, and noise of CR450 EMU stake a leading role in the world, and the life cycle cost per kilometer of the EMU is equivalent to that of CR400 "Fuxing" EMU. The safety, advancement, reliability, economy, and maintainability of EMU were comprehensively enhanced via scientific and technological innovation of high-speed EMU system integration technology.

In conclusion, CR450 EMU, as a new member of the "Fuxing" EMU family, enjoys a high operation speed and a comprehensive energy efficiency level, which significantly enhances the scientific and technological innovation level and self-reliance ability of CHSR, consolidates and expands our technological leading advantages, and plays a major role in the greater progress of CHSR during the 14th Five-Year Plan period. Furthermore, it will provide technical and equipment support for boosting the Belt and Road, building China into a transportation power, and realizing the strategic goal of "carbon peaking and carbon neutrality".