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动车组制动系统具有换代特征的技术进步

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列车制动装置能实现列车的减速运行或停止，从而保证行车的安全。在任何情况下（包括在故障条件下）、在一定的距离内，列车绝对安全地停下来，这称之为安全制动。空气成为列车制动介质可以追溯到百年以前。空气制动从利用列车制动管传递制动指令，发展到在动车组上用微机控制实现阶段制动、阶段缓解，使空气制动的调速精度越来越高，防滑行、状态诊断等智能化的程度也越来越高。长期以来，空气制动已成为列车安全制动的代名词。

动车组的制动系统正酝酿着一场革命。电驱机械制动正成为发展方向。其原理是将电机的旋转运动转换成直线位移，从而产生闸瓦对车轮或制动盘的可控压力以实现摩擦制动。电驱制动系统具有体积小、质量轻、控制精度高、容易实现智能化等优点。

触类旁通。从 20 世纪 80 年代开始，由于飞机的起落架需要更轻的质量、更小的体积、更精确的制动控制，因此在飞机起落架的车轮上开始采用电驱的机械制动；现在这项技术扩展到了汽车制动机上，轨道交通制动系统生产厂家正在研究将这项技术用到轨道交通列车上，并且已取得了工程应用的突破。由于轨道交通列车安全制动受减速度的制约，制动距离长，可靠性、安全完整性要求高，必须通过对列车制动系统安全性能的评估即 SIL4 认证。相对于高速列车，城市轨道交通列车速度较低，更有利于这项技术的推广。

制动系统的功能包括调速制动和紧急制动。由于牵引系统采用了交流传动以及新一代的变流装置，能量可以在列车与电网间可控流动，列车的速度可以通过电气制动调速，直至停车为止。动车组调速制动的功能可以完全由电气制动实现。

紧急制动属于安全制动的范畴，依靠机械制动的安全制动功能无可替代，这就使得具有安全制动功能的电驱机械制动具有广阔的应用前景。要使这一技术革新带来最大的经济效益，需要从系统的角度加以思考。制动系统不用空气作为介质了，那么动力分散动车组可否取消风源系统呢？研究表明，如果解决了空气弹簧的用风问题或者采用其他形式的转向架二次悬挂，动车组就具备了取消风源的条件。取消风源系统可以省去压缩机、空气净化装置、空气管路等一系列装备，一列 6 辆编组的城市轨道交通列车可以减重 3 t 左右！从而可减少维修维护工作量，降低造价。从整个系统角度可以进一步优化控制系统，融合制动控制和牵引控制的功能，实现智能运维和车地一体化的能源控制。

具有换代特征的技术进步带来的变化是不可阻挡的，一场动车组制动系统的变革正在来临，一种采用电驱机械制动、没有风源系统的更智能、绿色、经济的城市轨道交通列车离我们不远了。

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Commentary

EMU Braking System Technological Advancements with Next-generation Features

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Train braking devices can enable train deceleration and stopping operations, thus ensuring operational safety. That a train shall come to a complete and safe stop within specified distance under any conditions (including faults), is termed as safe braking. Using air as train braking medium dates back over a century. Air braking has evolved from using train brake pipes for braking commands transmission to using microcomputers in EMU (electric multiple units) for phased braking and phased release, which gradually increases the precision of air braking speed regulation and the intelligentization level of aspects such as anti-skid and status diagnosis. Over the long term, air braking has become synonymous with train safe braking.

EMU braking systems are currently undergoing a revolution. Electro-mechanical braking is becoming the new developing direction. Its principle involves converting the rotational movement of an electric motor into linear displacement, thereby generating controllable pressure from brake pads onto the wheels or brake discs to achieve friction braking. The electro-mechanical braking system offers advantages such as compact size, light weight, high control precision, and intelligentization accessibility.

Drawing analogies allows for cross-context understanding. From 1980s, when aircraft landing gears required lighter weight, smaller size, and more precise braking control, the application of electro-mechanical braking on aircraft landing gear wheels emerged. This technology has since been extended to automotive brakes, manufacturers of rail transit braking systems are investigating its application to rail transit trains, and breakthroughs have been achieved in engineering applications. Due to the constraints of deceleration, long braking distances, and high requirements for reliability and safety integrity, rail transit train braking systems must undergo safety performance evaluations, SIL4 certification. Compared to high-speed trains, urban rail transit trains operate at lower speeds, more conducive to the promotion of this technology.

Braking system functions include speed regulation braking and emergency braking. With the adoption of AC (alternating current) drive and new-generation converters in traction systems, energy can flow controllably between train and power grid, allowing train speed to be regulated electrically until train stops. The EMU speed regulation braking function can be fully realized by electrical braking.

Emergency braking falls under the category of safe braking, and the safe braking function relying on mechanical braking is irreplaceable. This gives electro-mechanical braking with safe braking function a broad application prospect. To maximize the economic benefits of this technological innovation, it is essential to consider it from a systemic perspective. If the braking system no longer uses air as a medium, can air supply system be removed from power-distributed EMU? Research indicates that if the air supply issue of air springs is resolved or other forms of bogie secondary suspension are adopted, EMU would have sufficient conditions for removing the air supply system. Without air supply system, the need for a series of equipment including compressors, air purification devices, and air pipelines is eliminated, which can consequently reduce the weight of a six-car formation urban rail transit train by approximately 3 tons! In turn, maintenance work is reduced, and costs are lowered. Control system could be further optimized from a holistic systemic perspective, integrating braking and traction control functions, enabling intelligent operation-maintenance and vehicle-wayside integrated energy control.

The changes brought by this next-generation featured technological advancement are unstoppable. A revolution in EMU braking systems is imminent. A new urban rail train featuring electro-mechanical braking, without an air supply system, and offering more intelligence, environmental friendliness, and economic efficiency, is within reach.

(**Translated by ZHANG Liman**)