Developing A Korean Standard Metro Car

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ABSTRACT

표준전동차는 1995 년 9 월부터 2001 년 12 월까지 수행된 도시철도차량 표준화 · 국산화사업의 일환으로 도시철도차량 표준화와 차량핵심장치의 국산화를 위해 개발되었으며, 한국의 표준이 되는 전동차이다. 도시철도차량의 표준사양, 성능시험기준, 품질인증기준, 안전기준, 정밀진단기준 등 제반 표준화기준에 의거하여 표준전동차가 설계, 제작되었으며, 수입에 의존하던 추진장치와 차량제어장치를 국산화하여 장착하였다. 제작된 핵심장치 및 표준전동차에 대해 구성품시험, 완성차시험, 본선시운전시험, 실용화를 위한 10 만 Km 내구도주행시험 등 각종 성능시험이 수행되었으며, 전동차 국산화율이 60%에서 95%로 향상되었다.

본 논문은 표준전동차의 개발경위, 핵심장치 국산화 내용, 각종 시험결과 등 전반적인 개발내용을 기술하고 있다.

1. Introduction

Since the first introduction of the subway in Seoul in August 1974, subways in Seoul have been in service on No. 1 to No. 4 line in the first phase and No. 5 to No. 8 in the second phase, which total length is 278Km in 2001. Some subway lines have been being completed and further lines are planed in such local metropolitan areas as Pusan, Daegu, Incheon, Daejeon, and Kwangju. Furthermore, light railway transits not in service yet in Korea are going to be constructed by lots of local governments. The share of Seoul urban railway system in ground transportation is still 36.8% in 2001, and shall be increased to over 50% in the future. Also it is expected that the total volume of urban rail vehicles shall be increased from 6,136 cars in 2001 to more than 10,000 cars in coming ten years.

Even in despite of an increasing quantity of the urban rapid rail transit vehicles, Korea has not had a standard specification for them, therefore different parts or equipments have been introduced whenever a new line has been constructed. In addition, Korea has imported lots of core parts such as inverter, traction motor, and train control system from foreign manufacturers due to the lack of core technology. This has resulted in the low maintenance efficiency due to the lack of exchangeability of parts, and also difficulties in identifying accident causes, which has in turn required a certain urgent need in the standardization and localization of core parts.

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With a view to improving the maintainability and safety of the vehicles, Korea government (Ministry of Construction and Transportation) has invested 20 million dollars in the project which is called "the standardization and development of the urban rail vehicle" motivated by the Urban Transit Law revised in 1995.

This project has been performed by Korea Railroad Research Institute in cooperation with lots of related authorities and companies from 1995 to 2000. Figure 1 shows the project execution system. KMCT (Korea Ministry of Construction and Transportation) plays the role of policy decision and supplying the research fund. , and KRRI is responsible for the project management,

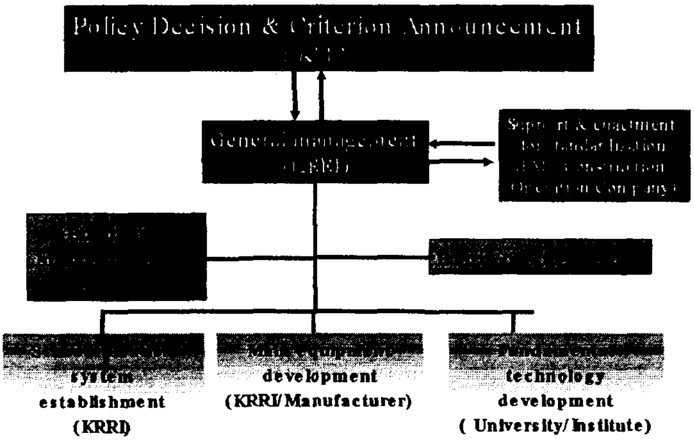

Fig. 1. Project execution system

standardization establishment, conducting research with universities and government institutes.. Operation authorities are in charge of enacting the standardization system. Manufacturing companies play the main role of developing the core parts and Korean standard urban rail vehicle. All of standardized documents are to make public after reviewing processes by a board of standardization affairs. A board of project operation examines the research planning and evaluates the results.

Two major objectives of the project are the establishment of the standardization system for urban rail vehicle, and localization of core parts such as aluminum carbody, inverter, traction motor, train control system, and finally Korean standard urban rail vehicle(K-EMU).

2. Carbody

Carbody of K-EMU was designed towards low weight, low noise level, minimum running resistance in the tunnel, and outstanding appearance. Aluminum alloy A6005A was adopted as a material of carbody in order to reduce the weight.. Hollow type large size extrusion aluminum plate was manufactured in order to satisfy the required strength and to reduce indoor noise level. Also streamline shape was applied, which minimizes the running resistance in the tunnel and looks good. The front part of the control car was made of FRP. Korea Rolling Stock Corp. played the main role in developing the carbody which prototype is shown as figure 2. Aluminum carbody resulted in reducing the structure weight by 30%. Structure analysis was performed using NASTRAN. And after manufacturing, static load test was executed., which result is shown as Table 1.

Fig. 2. Carbody structure

Table 1. Static load test result of carbody structure

Test item	Requirements	Test Result	Remark
Vertical load test (Stress)	12.4Kg/mm^2	8.97Kg/mm^2	
Vertical load test (Strain)	13.8mm (between bolsters)	10.6mm	
Compression test (Stress)	12.4Kg/mm^2	5.49Kg/mm^2	
Torsional load test (Stress)	8.7 Kg/mm^2	0.45 Kg/mm^2	
Natural vibration test (Bending mode)	More than 10 Hz	16.75 Hz	

3. Bogie

Bogie of K-EMU is a bolsterless type ,which was designed towards low running noise and low comfortability index(less than 2.5 in UIC index). Dynamic analysis program for rolling stock was developed by Korea Railroad Research Institute for the purpose of designing the bogie system. Using this program, all parameters of bogie system such as spring constant, damping coefficient, and unsprung mass, were optimized. Figure 3 shows the dynamic analysis model and its result.

After manufacturing the bogie system, completion car test was executed. Table 2 shows the specification and test result of bogie system.

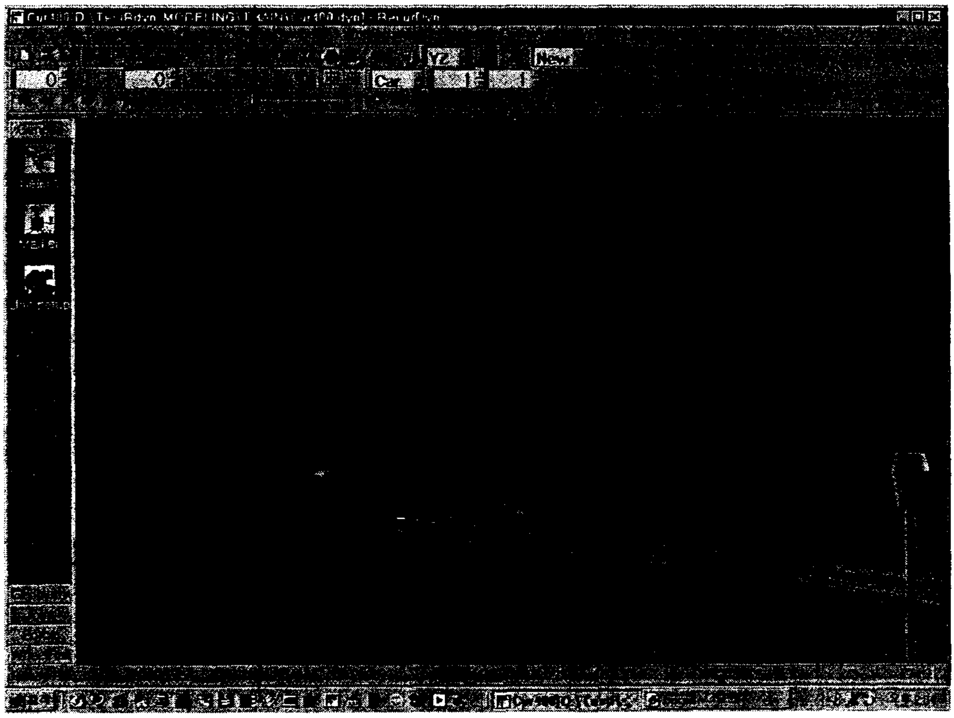

Fig. 3. Dynamic analysis of rolling stock

Table 2 Test result of bogie system

Item	Requirements	Test Result	Remark
Critical Speed	More than 120Km/h	157Km/h	using new wheel
Static wheel unloading test	Less than 60%	50%	at 80Km/h
Derailment	Less than 0.8	0.7	
Wheel lateral force	Less than 5.3 ton	4.5 ton	
Length between wheel axles	2100mm (reference)	2100mm	

4. Inverter

The inverter of K-EMU was designed towards driving under high speed switching and low power voltage control, which was VVVF(Variable Voltage Variable Frequency) control. It adopted natural cooling type and IGBT as a control element. One inverter controls 4 motors, i.e., 1C4M type. The pulse width modulation is selected as a controlling method based on the DSP so as to improve its reliability and maintenance efficiency. Table 3 gives the specification of the inverter.

Transient phenomena and adhesive control occurring in the 1C4M type is examined. WOOJIN Industrial Systems Co. Ltd. manufactured prototype of inverter, shown as Figure 4. After manufacturing, characteristics test was executed using inertial load simulator, which result satisfied the required specification.

Table 3. The specification of inverter

Item	Specification	Remark
Input voltage	1500V, DC (1000 to 1800V)	
Output power (Continuous)	More than 1100KVA	
Control capacity	More than 800KW	
Output Voltage	1170V, AC	
Control voltage	100V, DC (70 to 110V)	

Figure 4. Prototype of inverter

5. Traction Motor

The traction motor of K-EMU is a 3 phase 4 pole squirrel cage type induction motor having its own excellent maintenance feature. It adopted natural cooling method, and has technical specification as Table 4. The analysis such as slot assembly, high frequency environment, cooling and insulation characteristics, and mechanical dynamics, was performed from a concept design stage. Also optimization studies on the high speed switching, electro-magnetics, cooling and insulation linked to IGBT inverter interfaces were done.

HYOSUNG Corporation played the main role in developing the traction motor, which prototype is shown as Figure 5. Performance test for the prototype was performed using motor test facility, which result is shown as Table 4.

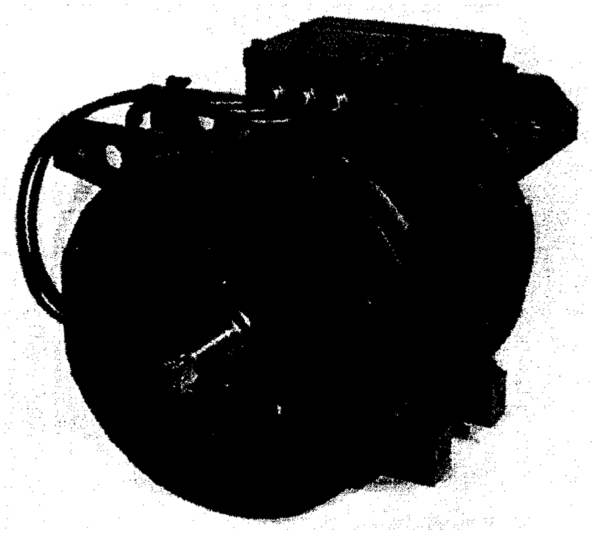

Figure 5. Prototype of traction motor

Table 4. Specification and test result of traction motor

Item	Specification	Test result	Remark
Load characteristics	Current : less than 125A Efficiency : more than 92% Power factor : more than 88%	Current : 121A Efficiency : 92.5% Power factor : 89.1%	
Temperature increase	Less than 160K	118K	
Noise	Less than115dB at 4800rpm	105.8dB	
Vibration	Less than 5.25mm/sec	2.54mm/sec	
Maximum speed	5800rpm, 2 Min.	OK	
Insulation	More than 20MΩ	2000MΩ	
Endurance for high voltage	4500V, I Min.	OK	

6. Train Control & Monitoring System (TCMS)

TCMS plays a central role in monitoring and controlling main equipments such as propulsion system, brake system, passenger service, and so on. It also interfaces among equipments, and manages the whole information of vehicle. It is composed of car computer(CC), train computer(TC), and communication equipments with ground signaling system. It includes ATO(automatic Train Operation) which controls vehicle velocity for the precision stop at the station platform.

Based on domestic available protocol standard, all of software and hardware were developed according to the required train function. WOOJIN Industrial Systems Co. Ltd. manufactured prototype of TCMS shown as Figure 6. After manufacturing, functional test was performed using TCMS simulator, which result satisfied the required specification.

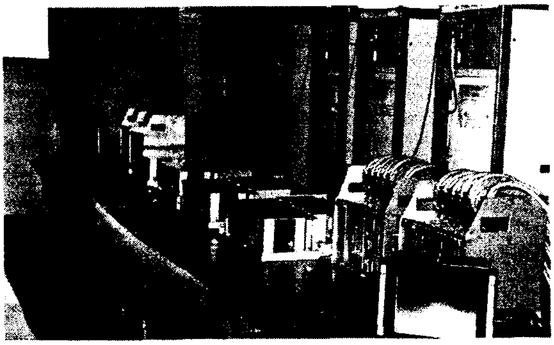

Figure 6. Prototype of TCMS tested in simulator

7. Korean Standard EMU(K-EMU)

According to the above mentioned standard criteria, Korean standard electrical multiple units(K-EMU) were designed, which is the reason why it is called as the K-EMU. There are two purposes in developing K-EMU. One is for completion car test of homemade core equipments., another for making proof of technical validity for the standard criteria. K-EMU contains advanced core equipments such as traction motor, VVVF inverter, and TCMS(Train Control & Monitoring System) which had been manufactured in Korea. It comprises four cars which are two motor and two trailer cars. Its carbody is made of aluminum alloy.

Korea Rolling Stock Corp. manufactured the K-EMU in 1999. It was tested and evaluated by the performance and safety test criteria on the 7^{th} line of Seoul subway in 2000. It has run 100,000Km on the test line for the purpose of reliability assurance in 2001. Figure 7 shows the K-EMU being tested on the commissioning line. Its specification and test result is shown as Table 5.

Figure 7. K-EMU tested on commission line

Table 5. Specification and test result of K_EMU

Item		Specification	Test Result	Remark
Power Supply		DC 1,500V	the same as left	
Rolling Stock	length width height	19,500mm 3,120mm less than 3,600mm	the same as left	
No. of passengers		Tc car : 148 (48 seats) M/T car : 160 (54 seats)	the same as left	
Perfor-mance	Speed. Acc. Decel.	More than 100km/h More than 3.0km/h/s More than 3.5km/h/s	110km/h 3.2km/h/s 4.08km/h/s	
Speed control		VVVF inverter blended with regenerative braking	the same as left	
Ride comfort		Less than UIC 2.5	2.4	
Noise level		Less than 80dB(A)	79dB(A)	

8. Conclusion

Due to the development of Korean standard urban rail vehicle, the homemade production ratio of subway rail vehicle is increased from 60% to 95% on the basis of procurement price. And it is expected that over 10 percent of total maintenance expense for vehicles should be reduced. Also eventually the RAMS (reliability, availability, maintainability and safety) of the vehicles shall be enhanced.

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