

The Basic Design of Korean High Speed Train System

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ABSTRACT

This paper summarize the basic design of the Korean High Speed Train System (KHST) and shows its sub components which were already manufactured. KITECH(Korea Institute of Industrial Technology) who is being strongly cooperated with KRRI (Korea Railway Research Institute) developed a new design of high speed train and several companies are involved and manufacturing so as to manufacture it in order to acquire key technologies and lead a high speed railway project in the future.

First, three types of train configuration were introduced according to a way to install traction system and couple each car in a train set. Three types of the train configuration have been developed and validated against a variety of variables, such as energy consumption, passenger capacity and axle load and so on.

Through numeral simulation, three train configurations were compared to each other, and an articulated high speed train with distributed traction showed better than the power car with articulated bogie and the distributed power train with conventional bogie. A distributed underfloor power train having a 15% more space for the seats need less number of bogies, reduced mass, lower running resistance and noise& vibration than the concentrated power train in case of an articulated trainset.

However, the discrepancy between goal and the real state of affairs in Korea, a concept of the power car was selected, that is different from the simulation results.

Keyword : Train configuration, Prototyped test train, Concentrated power train system, Distributed power train system, Conceptual design, Basic design, Power car, Motorized car, Trailer car

1. INTRODUCTION

The high speed line between Seoul and Pusan is being built now and will be operated for commercial service in the beginning of 2004 in Korea. The train system will be supplied by EUKORAIL consortium, so called KTX(Korea Train Express) whose maximum service speed is 300km/h and passenger capacity 935persons. The KTX is now being tested on test section of the high speed line in Korea.

Six years ago, KITECH suggested a proposal of R&D project for developing a new high speed train system and acquiring related key technologies including train system engineering technology. Major objective of this R&D project is to design and manufacture train system and key subsystems, such as carbody shell, propulsion system, pantograph, etc. for future domestic market of high speed railway.

A prototyped test train, which include all the key components and have two power cars, two motorized trailers, and three trailers. The key components, such as carbody shell, traction motor, pantograph, etc. were already designed and manufactured. During last five years, several companies in Europe supported Korean engineers to improve and decide the final design of key components. The prototyped test train

will be manufactured and tested in 2002[1].

Through the R&D project also can promote industrial engineers and make them have their own capability to collaborate with the other company for a new high speed railway project in the world.

This R&D project is now being led by KRRI(Korean Railway Research Institute) and KITECH(Korea Institute of Industrial Technology), and several Korean companies and universities are joined. KITECH is fully in charge of train system and its components, where as KRRI handles system integration, such as signaling system, infrastructure and power supply system, etc.

This paper summarizes some of results in the area of basic design of a prototype test train in this project. The prototype test train was designed by many engineers for institutes, industries and universities. Each engineering group has their own workscope and collaborated with each other based on related issues.

2. CONCEPTUAL DESIGN OF A HIGH SPEED TRAIN SYSTEM

In the development of a new train system, a prospect of business, function and performance specifications about high speed train system have to be investigated thoroughly and defined to minimize a risk bearing of failure, utilize the limited resources, and make the project success in the end.

The investigation, analysis and feedback procedures have to need to regulate this process properly. Also, the system integration problem such as propulsion and braking, interaction between train system and track, signal and control, dynamics between pantograph and catenary line have to analyzed before detailed design of each sub-system. In the development procedure, it is necessary that every detail specifications are managed and adjusted a viewpoint of system engineering before manufacturing components and sub-systems.

The most difficult problem in the development of train system is system engineering that it requires each system to be mutually coincided, each component to be integrated and function of completed train system to be verified as intended. The whole system has to understood sufficiently to check the priority of, and it have to be known that modification of a specific part each components lead to what kind of results the whole system generate.

2.1 DETERMINATION OF TRAIN SYSTEM CONFIGURATION

According to 'Operational requirements of train system', a new Korean high speed train system has a maximum operating speed of 350km/h and can be operated together with Seoul-Pusan high speed train system in the high speed line that will be constructed between Seoul to Pusan and can satisfy the following specifications[1].

- Reduce travel time between Seoul and Pusan within 100 minutes
- Keep energy consumption, ride quality and track damage etc. to be a level of Seoul-Pusan high speed train system
- Prevent an additive bad reaction to surrounding environment
- Secure a transport capacity more than one thousand passengers per train set
- Secure flexibility appropriate to coming expert market as well as domestic
- Secure equivalent reliability, durability and safety etc to Seoul-Pusan high speed train system
- The whole length of train system is less than 400m.

To determine a train configuration that can satisfy the given design target, some sketches of train system configuration is proposed and qualitative and quantitative evaluation of each train system configuration were done.

The reviewed contents to propose and evaluate the train configuration are shown in Table 1. Specially, relative comparative analysis of concentrated power train system and distributed power train system, articulated train configuration and independent train configuration were performed.

The train configurations were proposed by considering also a domestic situation at that time, a tendency of the advanced country and a possibility of technology development. Three type's train configurations were proposed based the transferred technology of Seoul-Pusan high speed train system, the advanced technology of Germany and the future oriented next-generation technology which were not verified at that time.

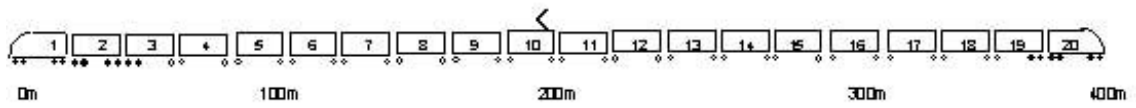
Table 1: Reviewed items for proposing a train configuration

Design target	Related issues
Maximum speed (350Km/h)	Propulsive force, Aerodynamic resistance, Braking, Coefficient of adhesion, Weight of train system
Travel time (within 100 minutes)	Tilting train, Passenger flow in the station
Ride quality (Same level with TGV-K)	Track quality, wheel/rail, Wheel maintenance, Suspension system design, Bogie type, Passenger environment
Track damage (Same level with TGV-K)	Static axle load, Unsprung mass, Track quality, Propulsion/Braking control, Wheel/rail damage and abrasion, Bogie stability
Energy consumption (Same level with TGV-K)	Aerodynamic resistance, mechanical Resistance, Efficiency of propulsion system, Acceleration, Regenerative braking, Train weight, Additive load
Environmental effect (Same level with TGV-K)	Exterior/Interior noise, Ground vibration, Waste of train system
Passenger (more than 1000 persons)	Size and configuration, Seat arrangement, Gang way
Adaptability of train configuration (Train system adaptable to international market in future)	Coupling device, Pantograph, Power distribution, Bogie type, train system design
RAMS	RAMS plan, RAMS management, Maintenance, Verification of sub-system
Costs	Life cycle cost, Initial costs, Costs management

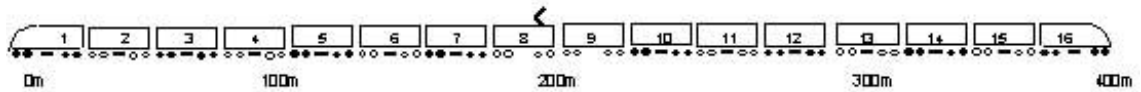
The evaluation procedure is shown in Figure 1. The train configuration was basically derived from the verified technologies, that is, a technology transferred from Seoul-Pusan high speed train system and ICE3 technology of Germany. The case of concentrated power train system increases the number of motorized car and the case of distributed power train system increases main motor power of 10 %. Also, for complementing a disadvantage that follows the conventional technology, the train configuration quoted a part of development concept ('ICE21') of next generation train system was considered[2,3,4].

To acquire the validity of comparison of each configuration, specifications that are not included in the technical characteristics concerned were assumed identically. The axle load and unsprung mass etc. significantly influenced on weight of train system, the number of passenger, consumption rate of energy, available adhesion coefficient were handled very importantly and are shown in Table 2. Figure 2 compares three configurations schematically.

1. Concentrated Power Systems & Articulated Bogies(2P+1B+2M+15T, 17,920kW)



2. Distributed Power Systems & Conventional Bogies(2End car+6Transformer car+6Conv car+2T, 17600kW, 16M Bogies+ 16 T Bogies)



3. Distributed Power Systems & Articulated Bogies(2End car+2Middle Car+16Converter car+1 Trail car 17,600kW, 16 Mab+ 3 Ab + 4Tb)

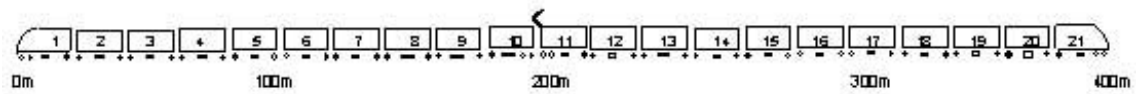


Figure 2.: Evaluated train system configurations (Train length 400m)

Table 2: Significant characteristics of each train configuration

Configuration	Concentrated power type	Distributed power type	Future oriented type
Background of technology	· Application of technology transferred from KTX	· Application of Germany ICE technology	· Future oriented technology applied future oriented train system concept of Germany
Characteristics	· Concentrated power train configuration · Introduction of Motorizes car concept · Articulated train configuration · Convenient application of technology transferred from KTX	· Concentrated power train configuration · Module type train concept · Necessity of Germany company cooperation	· Distributed power train configuration · Articulated train configuration · Module type train concept · Acquirement of future oriented technology · Risk assignment of technology development
Consumption rate of energy per passenger	Average	Disadvantage	Advantage
Number of passenger per configuration	Low	High	Middle
Train weight	Average	Disadvantage	Average
Axle load/Unsprung mass	Disadvantage	Advantage	Average

To compare significant characteristics of each train configuration, train weight, the number of passenger per configuration, energy consumption per passenger, travel time, axle load/unsprung mass and available adhesion coefficient were compared in detail and the summary are shown table 3.

Table 3: Summary of evaluation of each train configuration

Reviewed specification	CPT	DPT	HSR
Train weight	2	3	1
Number of passenger per configuration	3	1	2
Energy consumption per passenger	3	1	2
Travel time	3	2	1
Axle load/Unsprung mass	2	3	1
Applicative level of adhesion coefficient	3	1 or 2	

* Ranking(1-advantage, 3-disadvantage)

* CPT: Concentrated power train system, DTP: Distributed power train system, HSR: Future oriented train system

From reviewing each train configuration, It was checked that the concentrated power train system is easy to apply the transferred technology from KTX and has the highest possibility of success with the limited budget and manpower. But it was expected that the application of a new technology would be more competitive than other country, so the development of future oriented train configuration was proposed by engineering group at that time. The status of art of domestic companies could not be neglected, however, and then, CPT(concentrated power train system, train length 400m) type was selected finally as a basic train configuration of the R&D project[3] .

To complement disadvantage which basic specifications of train system are generally determined with technology transferred from KTX, a minimum research work about HSR 21(distributed type, future oriented train system of articulated train configuration) was also proposed.

2.2 BASIC TRAIN CONFIGURATION OF KOREAN HIGH SPEED TRAIN SYSTEM (KHST 20)

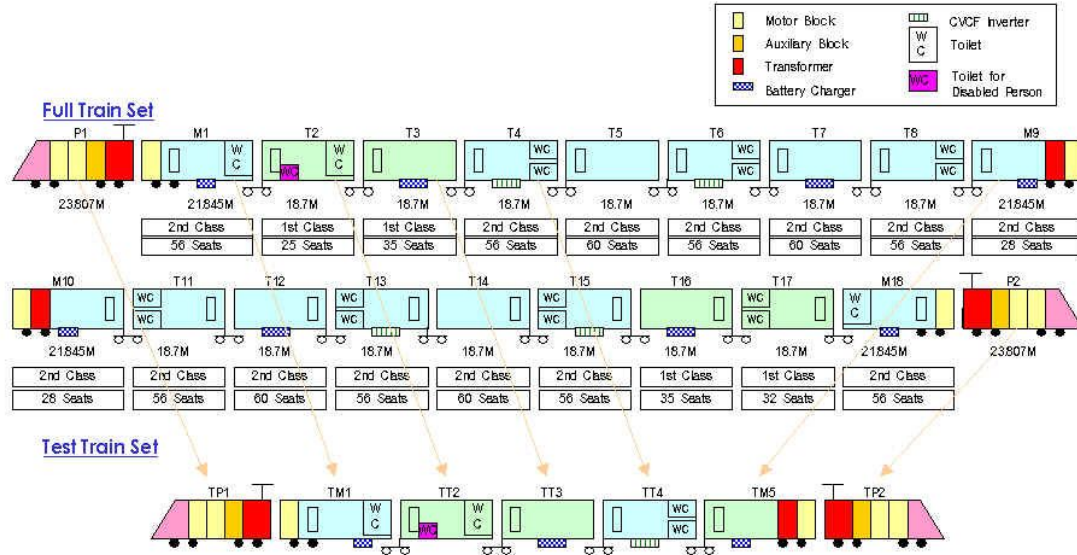


Figure 3: Basic train configuration of Korean high speed train system (KHST20) and prototyped test train

The basic configuration of KHST20 consists of 2P + 4M + 14T (P: Power car, M: Motorized car, T: Trailer car) from figure 3, in order to, the 20car trainset was symmetrical arrangement from motorized car (M9) to power car (P1). In the configuration of 11 car trainset (KHST11), it consists of 2P + 2M + 7T and a power car is placed at the rear position instead of middle motorized car (M10) of the configuration of KHST 20 to become half-train configuration.

In the train configuration, main transformer is placed at power car (capacity of 3 motor block) and middle motorized car (capacity of 1 motor block) and to secure first class seat over 15% of the total seats, a passenger car (T2, T3, T16, T17) is configured as first class salon cars. The toilet for a handicapped person and the depository of a wheelchair are installed in T2 passenger car. And, to reduce the number of differently designed car, every train is configured symmetrically around middle motorized car (M9 and M10) [4,5].

2.3 PROTOTYPED TEST TRAIN

In the R&D project, we don't need to product the full train configuration, so that only seven cars were selected and designed [5,6,9]. Figure 4 shows the prototyped test train configuration from KHST20, which included all the key components of KHST20, and have two power cars, two motorized trailers and three trailers.

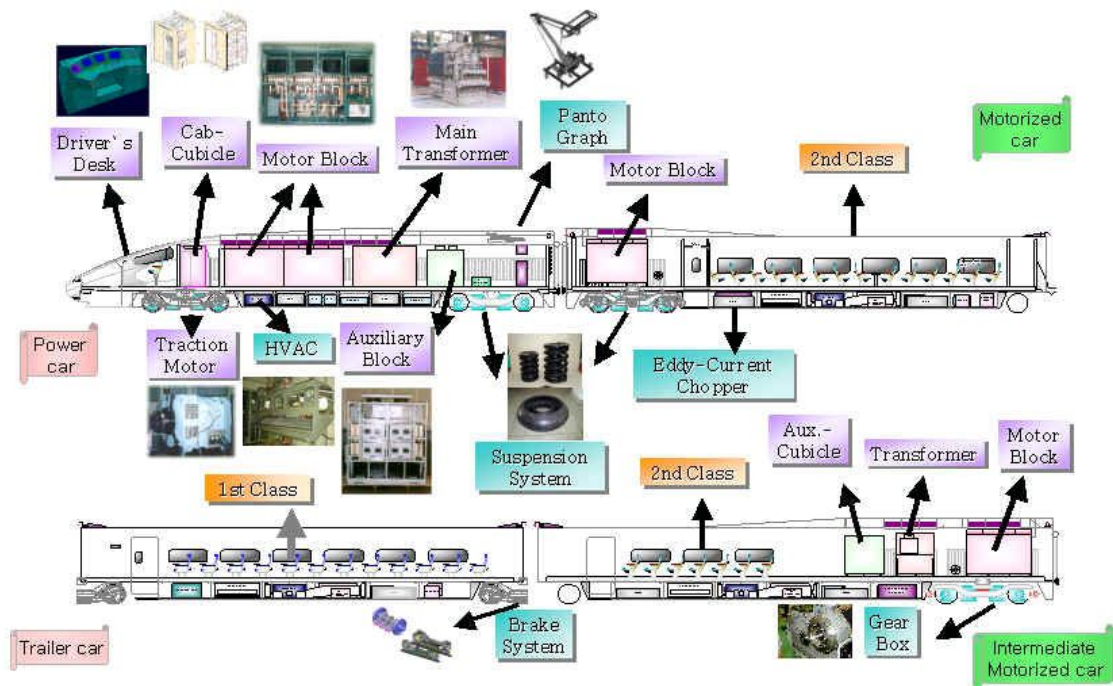


Figure 4: General layout and composition of components in main car

3. BASIC DESIGN OF A PROTOTYPED TEST TRAIN

This section shows several examples designed or manufactured prototype of train components for the prototype test train.

The power car, motorized car and passenger car are being developed in the R&D project for Korean high speed train. In order to reduce the weight, a bodyshell of the motorized car and passenger car is manufactured with Aluminum extruded profile. Figure 5 shows a manufacturing area of a trailer car in Korea. Figure 6 and 7 present a test laboratory for static load test of power car and trailer car respectively.



Figure 5: Manufacturing field of a trailer car



Figure 6: Load test of a power car



Figure 7: Load test of a trailer car

A newly developed pantograph is a single arm typed one and renders lower noise and good performance of lifting force in high speed of interest. A new high speed pantograph was also designed and already tested in the laboratory. Figure 8 shows pantograph installed in high speed and low noise wind tunnel for testing its performance.

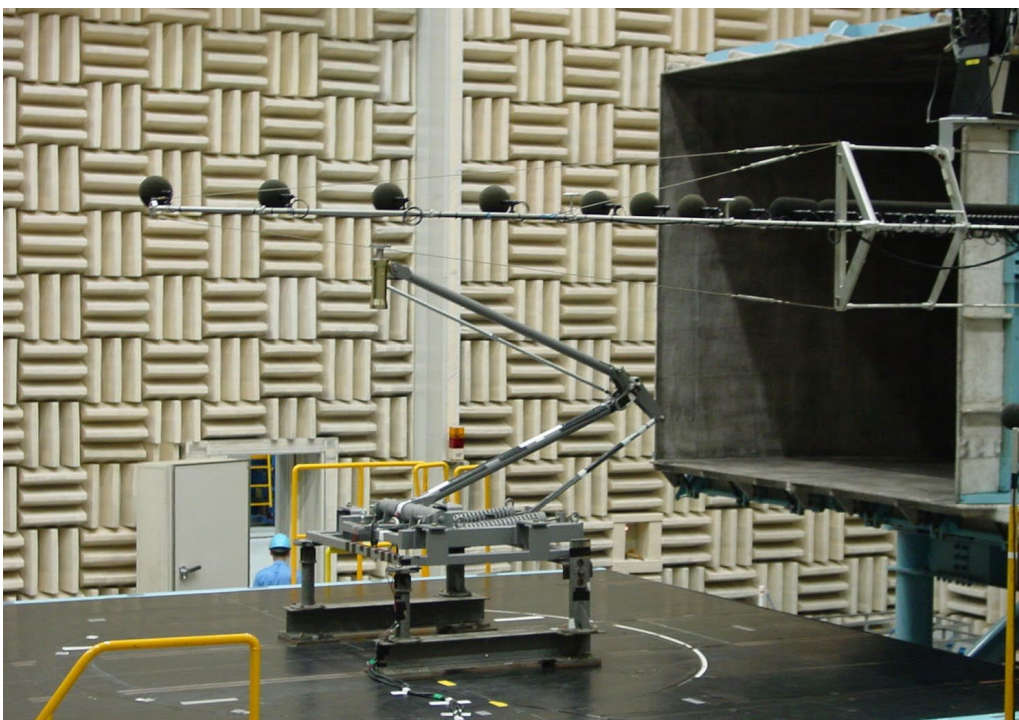


Figure 8: Wind tunnel test of pantograph



Figure 9: Traction motor

Figure 9. shows a traction motor: The type of traction motor is frameless 3-phase asynchronous type traction force, maximum rpm and weight is 1,100kW, 4300rpm and 1525kg, respectively.

The front and exterior design of power car is shown in Figure 10, and the interior design of trailer car are shown in Figure 11.

The exterior of a power car was designed by applying concept of "unification of color design" which was matched for interior color and selected a suitable color for function of each part and running condition.



Figure 10: Front and exterior design of power car

The interior of KHST was designed by considering user interface through behavior analysis of passengers. Additionally, the interior design concept of the advanced high speed train system of foreign countries was also investigated, analyzed and referred. These design concepts made great contributions to optimizing of passenger's room, explicit the information and sign system, color of interior parts[8].

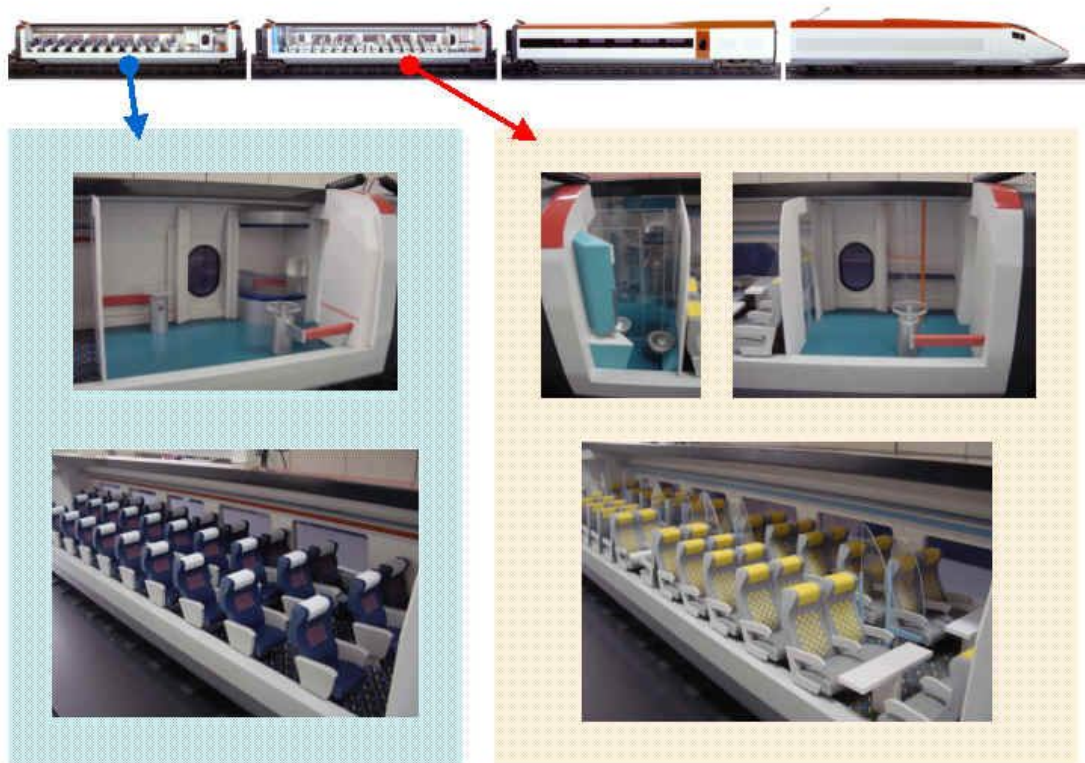


Figure 11: Interior design of a trailer car

For HSR21 train, a general layout of key equipments, basic design of carbody shell and coupling were finished and will be used in the future according to demand of operator. The new motorized bogie for HSR21 train was also designed for future application[7,10]. The motor is installed on the bogie frame as can be seen in Figure 12.

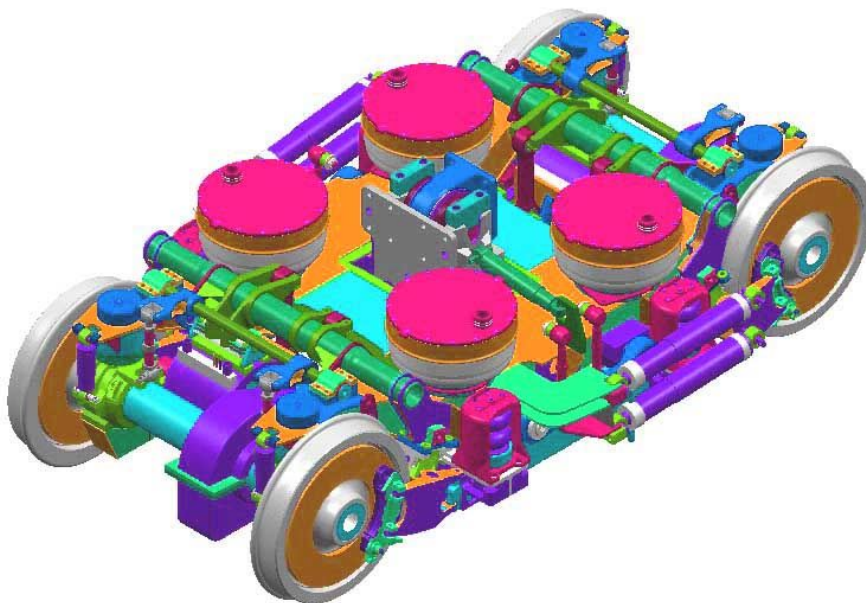


Figure 12: New motorized high speed bogie for HSR21

4. CONCLUDING REMARKS

The Korean engineers involved in the R&D project, even though they have not enough experience about high speed railway, worked very hard to meet the target in each field during the previous five years.

The Korean engineers have very tough schedule and have to develop and integrate various key components of train all together. They had a lot of trouble during last five years, but they attached the problems step by step and found a solution finally.

The prototype test train will be manufactured until the beginning of 2002 in Korea and will be tested. During design and manufacturing the subsystems, such as Al carbody and pantograph, several experts from outside of Korea supported us by reviewing drawings and making recommendations for improving design. The collaboration with several companies in Europe and Japan will be continued in the next year.

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