Development of the Integrated Design Environment for K-AGT

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ABSTRACT

Concurrent engineering technologies have been broadly used in the field of design, testing and manufacturing to reduce product development cycle time and costs. Virtual engineering technologies regard as a key technology to integrate the computer-aided technologies and to build collaborating environment.
In this research, we developed an integrated design environment for the K-AGT(Korea Automated Guideway Transit) as a basic study for building a concurrent engineering environment of rolling stock. For this purpose, knowledge from structural analyses results on the body of trailer car was parameterized to develop an automatic design module. An empirical dynamic model corresponds to the physical test equipment was developed to analyze dynamic behavior of a bogie. A driving simulator was developed based on physical test line built in Kyungsan to generate immersive driving environment. It is expected to give better understand to customers on the driving scenery of the K-AGT. We expect to reduce the time and costs of newly developed rolling stock using the integrated design environment developed in the research.

Keywords: Virtual Reality, Integrated Design Environment, Modeling & Simulation, Product Data Management

1. INTRODUCTION

Modeling and simulation technology is regarded as powerful tool in engineering problem solving. It can be defined as the method to use computer-based, interactive, distributed simulation technologies. It becomes an indispensable element in the industrial operation and is called a catalyst for human comprehension enabling humans to understand the kinetics and complexity of system environment. Currently, the use of modeling and simulation technology at an early stage plays an important role in a modern development process. We must combine the benefits of the modeling and simulation methods with the physical testing methods in order to shorten the product development cycle time, to minimize costs and to improve quality [1].
Engineering design process is a relatively abstract process, so it is difficult to develop proper model. It is considered as a "problem solving" process which is an expression for a desire to be satisfied by the outcome of the process. Such initial communication of need is neither discrete nor final. Customers are neither clear nor precise in defining their requirements. With the increasing complexity and multi-disciplinary nature of technical research and modern product development, there is a growing need for interactive, collaborative experimentation unlimited by physical location [6].
Bombardier [2], one of the biggest railroad companies in the world, applied knowledge based conceptual design technology to build digital prototype at initial design stage. They can make a digital prototype which is satisfying customer's requirements by changing several parameters from the master train model in real time. With the prototype, they could check the interference between rolling stock and platform, tunnel, railway et al. Owing to the technology, they can stabilize the design faster and reduce the number of design change. Recently, SNCF [3] decided to build a concept train that is similar to what the car industry has been doing for a long time with concept car. They expect to better communication on the future of train transportation and to demonstrate to their customer that innovation and technology feed the railway company's efficiency. They built the virtual mock-up of concept train and rendered with high quality rendering software to get realistic images. Central Japan Railway Company [5] developed vehicle dynamics simulator to evaluate train ride comfort of the high speed Tokaido Shinkansen. They built vehicle dynamic simulator with six-degree of freedom motion system, sound and visual system. They could generate real vehicle

motion and they expect to better understand the mechanism of ride comfort and to improve train ride comfort through the various ways of evaluation

Development of the integrated design environment to support the designing, analyzing, testing and manufacturing works is essential for the reduction of product development cycle time and cost with the fulfillment of customer's various requirements. In this paper, we suggested the structure of integrated design environment for the newly developed rolling stock. For this purpose, we did research on core technologies such as parametric design technology, virtual testing technology, virtual reality technology and product data management technology.

2. ROLLING STOCK DESIGN PROCESS

Typical rolling stock design process is repeated works for stabilizing an initial design as shown in Fig. 1. Currently, joint efforts have to be made because the product development cycle time has to be shorter. Designer receives the product specification from marketing and styling departments and he has to take various production aspects into account. Intensive exchange of information among all the steps through conceptual design, detailed design, analysis and evaluation steps are important. The details and specified designs are calculated and checked by appropriate measurements in test laboratory. Proving ground driving tests are used to verify the stability and reliability. The transition from the test track to the test laboratory represents a huge gain in time. Since increasingly more variants of a new product design are being defined from the start, it is still necessary to make a selection of which variant to test. Performing all tests on all variants is no longer feasible within the given time, so the development process has to be adjusted [6][7].

The computer-aided engineering (CAE) tools like CAD, digital mock-up and simulation software for structural analysis, aerodynamic analysis, fatigue life and crash analysis et al. are of crucial significance for successful product development. By comparison with conventional methods, computer models are relatively easy to change and the possibility of making computer simulations and calculations, which allows alternatives to be compared at an early stage, without the need to make expensive and time-consuming prototype is high. If we apply CAE successfully, we could have identical or compatible systems and obtain access to the engineering database for data exchange.

New railroad technology development is a huge and complicate project, because railroad signal system, electrical system and railway system as well as rolling stock system should be developed in one project. Usually a consortium is organized at the initial stage and strong cooperation among the industries, universities and research institutes was maintained. Closer co-operation between designer, analyst and tester is necessary, and right from the start of the engineering phase the railroad system has to be simulated by performing complex calculations and analyses using advanced hardware and software. To be able to develop a railroad system faster and better, it is essential to know the interactions of the vehicle characteristics at an early stage of development. If a design has to be changed for the reason that requirements are not achieved, it is possible to investigate the impact of this on all other characteristics without delay. For this reason, virtual and collaboration environment is highly recommended to coordinate and integrate through the system interface engineering to reduce the number of design change and to avoid the overlapped works and to concentrate all research efforts on core technology developments.

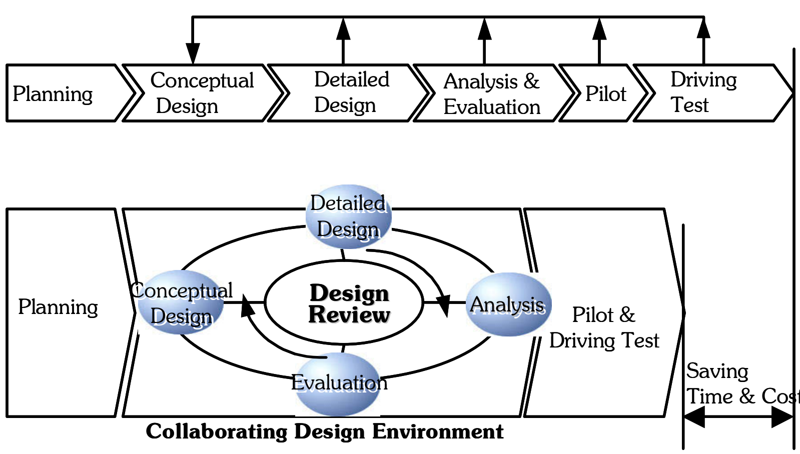


Fig. 1. Comparison of product development process between procedural and concurrent method

3. PRACTICAL APPLICATION: DESIGN OF K-AGT

It is very important to concretize conceptual ideas to visualized models at an early design stage. By visualizing the conceptual idea, engineers can share ideas, check the customer's requirements and find better solutions. Stabilizing the idea at en early design stage can reduce the number of design change and the development cost can be saved. The integrated design system is thought of as a design environment that provides support for a collaboration work in the product development stages. In order to coordinate such activity, a mechanism for coordination of processes in a distributed working environment is required. Rolling stock design is undertaken in a collaborative work by distributed design teams that may be on multiple sites. The computing environments also needs a collaboration implemented by distribution, with computers connected in networks that allow them to communicate with other machines all over the world. Processes have to be executed on one computer under control of another computer, allowing different modeling, analysis and simulation components to be collaborated over a network with heterogeneity of computer platforms and languages, and to be executed as desired to achieve design automation by automatic invoking processes in an appropriate order. For this reason, rolling stock design work related to the product development life cycle is moving to collaborative design work.

In this research, we developed the integrated design environment to support collaborative work based on the virtual engineering technologies as shown in Fig. 2. Our research consists of 5 topics; parametric design, digital mock-up, virtual testing, virtual reality and network based PDM. We expect to visualize an idea by creating conceptual design model using parametric design method and make it expand to the detailed design in the digital mock-up module. The design can be evaluated in the virtual testing module and can be visualized in the virtual reality module. The PDM module supports all the data necessary. In this paper, we will explain the concepts and processes to build the integrated design environment.

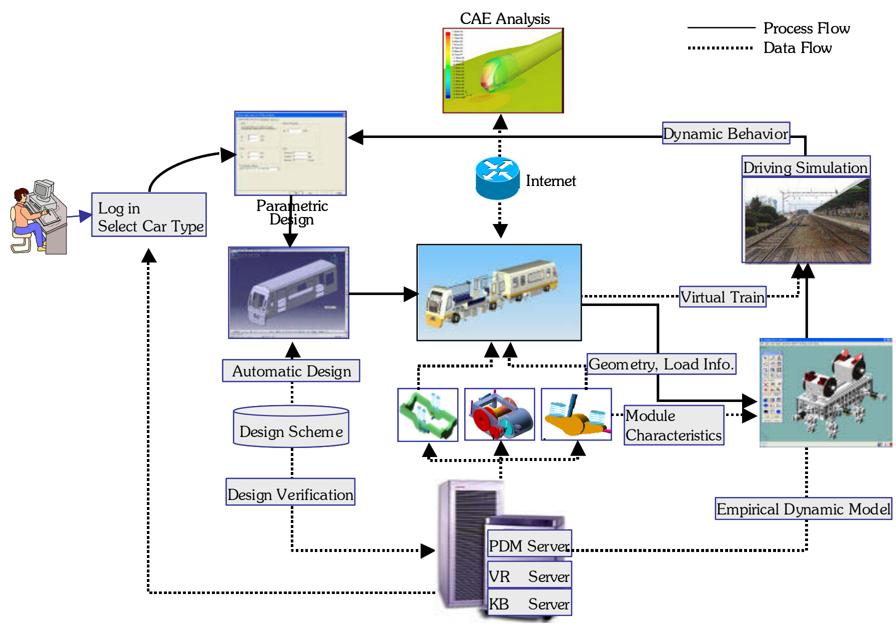
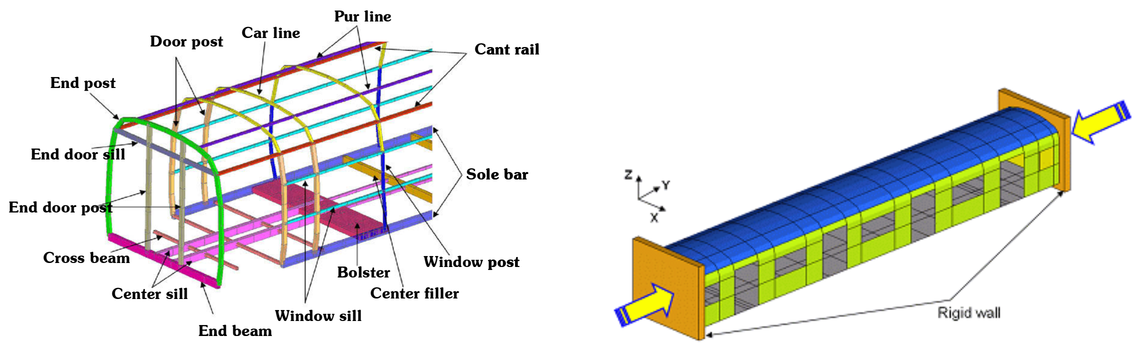


Fig. 2. Structure of the integrated design environment for rolling stock

3.1 Parametric Structure Design

Achieving design automation involves an integration of the information processing required by the various disciplines involved at the different stages of the design process. For well-established designs, it may be possible to model the flow of information between different disciplines and stages, and to use these models to assist in the automation of the design process. However considerable human input is needed to set up geometric models or parametric models and then to use these models in the preparation of analysis models for the activities. A major effort in reducing the human effort required for information processing in design is the use of model representations. Parametric modeling is regarded as a key technology in this respect. Computer-aided design with feature representation may be used to define and maintain product design information for analysis and simulation of products from the early stage of the product

development cycle. By using a parametric description of engineering parts, the automation of such processes as optimization design may be assisted. The human input required in the modeling of the geometry and then in the preparation of the analysis model may be simultaneous reduced.
We are developing automatic design methodology for the design of a rolling stock. Structures of conventional trailer car consist of post, sill, beam and filler parts. We classified the structure in 3 groups as vertical part, horizontal part and post part according to their functions. We did structural analyses on the car body applying compressive load to the end of car body supposing train collision to find out which parts are weak compared to other parts.



(a) Typical structure of trailer car (b) Loading condition
Fig. 3. The structural analysis model of conventional trailer car

Based on structural analyses results, we made design scheme of car body and develop parametric design module using the CATIA V5, well-known 3D CAD software. Although the module is not practical yet, we can easily visualize the idea with 3D CAD model and we check the the fulfillment of customer's requirements.

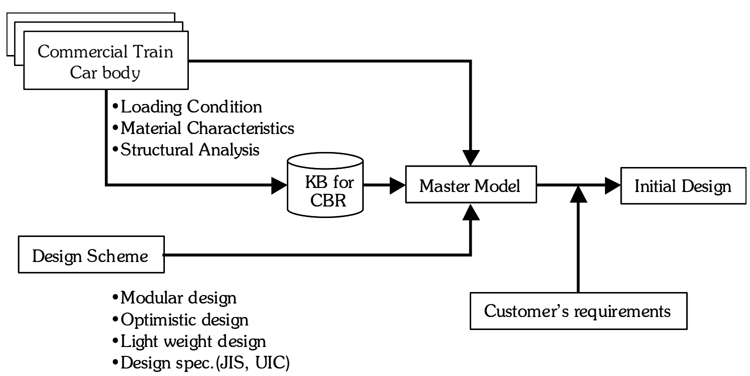


Fig. 4. The schematic diagram for parametric design technology

3.2 Digital Mock-up

The objective of the building digital mock-up is to increase the interaction between designers and developed products. Designer can create and modify their designs in real time, seeing the effects of their modifications immediately. Connecting the DMU technology to the immersive virtual environments could support many phases of design, including interactive visualization of physics based simulations, real time simulations of manufacturing and assembly process, creation of virtual prototypes that can be manipulated in real time and checking parts for fit and interference before building the physical prototypes.
In this research, a virtual prototype of rolling stock can be assembled with the standard parts like wheel, shaft, motor block and inverter et al. The standard parts stored in the PDM module and the designer can load the feature-based models with their engineering characteristics. The designer can easily modify the digital mock-up with CAD interface and can get information about the rolling stock before they make a physical prototype. He can estimate the weight and check the interference with each part. The digital mock-up of the K-AGT is shown in Fig. 5.

Fig. 5. The digital mock-up of the K-AGT

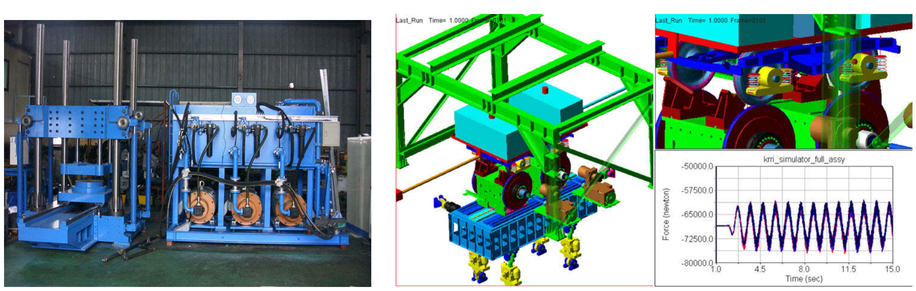
3.3 Virtual Testing

In order to be of value for engineering and design applications, the systems behavior should appear realistic and it must be in accordance with the laws of physics and should respond in real-time to operator control. The virtual test laboratory is the virtual reproduction of physical test stand with all its hardware and software components. The virtual testing method has many advantages as followings;

- The design can be evaluated before an expensive prototype is built.
- A test can be simulated before the test equipment is available.
- The simulation can provide information regarding the type of test equipment needed.
- Proper load and boundary conditions can be defined and investigated.
- Virtual tests can be conducted faster, easier and at lower cost than physical tests.
- Additional information can be obtained from a virtual model that is not readily available from a physical test.
- A number of design alternatives can be rapidly evaluated in “what if” studies. This allows optimized design with respect to cost, weight, durability, etc.

It assures that the analytical tests are directly linked to the physical tests and therefore allows one to correlate and ultimately lead to a validation of the analytical models. This allows the user to work with models of higher confidence [3]. In this paper, two research topics were introduced, one for the development of computer simulation model for dynamic analysis of a bogie and one for the development of empirical equation which define the relation between loss of contact ratio and running speed of a power collector.

Proving ground test in a test line is the final procedure to prove the stability and reliability of newly developed rolling stock. Dynamic behavior of rolling stock can be tested with driving in a test line or commercial line. Usually over 100,000 km driving records are necessary to prove the stability of rolling stock. But construction of test line requires too much cost. In Korea, it costs about $40 million/km. Therefore it is almost impossible to build test line only for the test of newly developed rolling stock. In addition to it is not easy to test in commercial line because there are always chances to accidents happen. For this reason, substitution from physical test to virtual test is highly recommended. We developed an empirical dynamics model of the bogie to estimate the dynamic behavior of rolling stock. To make the realistic dynamics model, we made the physical test equipment as shown in Fig. 6(a) and we made the computer simulation model as shown in Fig. 6(b). Although, we are still studying on the correlation between test and simulation model by calibrating the results from physical test equipment and computer simulation model, we can predict the behavior of physical test equipment.



(a) Physical test equipment (b) Computer simulation model

Fig. 6. The virtual test model for the simulation driving stability

A power collector is important part in electrical equipments. Electricity necessary for driving rolling stock can be charged through the power collector from conductor rail. So it is important to maintain the contact during the driving. Loss of contact means uncharged condition. A power collector was designed and manufactured to drive the correlation between the running speed of rolling stock and power collection capacity as shown in Fig. 7. The initial contact force between power collector and conductor rail was set to 90N based on the dynamic behavior of contact force variation.

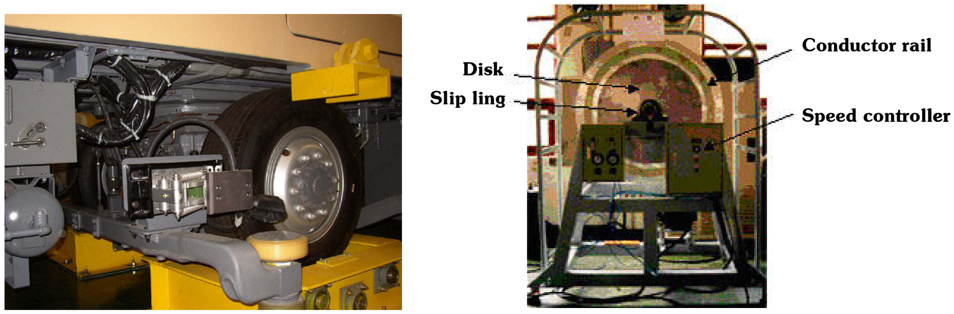


Fig. 7. The figure of power collector installed at the K-AGT and equivalent testing equipment

Physical tests were performed and de-wiring time was measured. The loss of contact ratio calculated by the Eqn. (1).

$$\alpha = \frac{\sum t_i}{t_m} \times 100[\%] \quad (1)$$

where,
α : loss of contact ratio [%]
t_i : de-wiring time [sec]
t_m: total measurement time [sec]

Fig. 8 shows the relation between the loss of contact ratio and running speed of power collector. Loss of contact is not visible range from 0 km/h to 20 km/h and slightly increase from 20 km/h to 50 km/h. It records 2.8% at the maximum commercial operating speed, 60km/h of the K-AGT and it proves the stability of power collector.

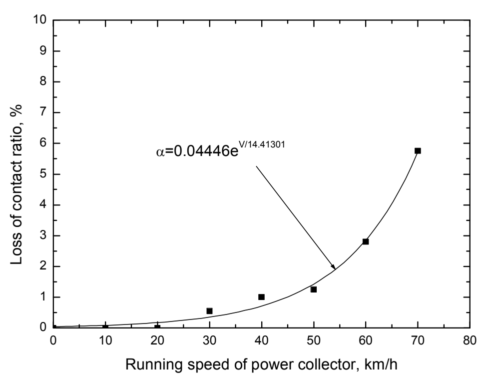


Fig. 8. The loss of contact ratio as running speed of power collector

Now, we can drive the empirical equation between the loss of contact ratio and the running speed of power collector as shown in Eqn. (2). by fitting the graph in the Fig. 8. We can predict the power capacity collected through the power collector with the Eqn. (2). We can use the equation to decide the speed of newly built rail network without loosing power.

$$\alpha = 0.04446e^{V/14.41301} \quad (2)$$

where, V : running speed of power collector [km/h]

3.4 Virtual Reality

Computer generated images mean the 3D graphic image that calculated with a computer from a virtual model. These images may be calculated in real time as in a virtual reality application. A real time application must calculate images in a very short time. So it needs 3D accelerated graphic cards and high quality rendering software. A graphic card is a hardware component in charge of displaying data on the screen. Usually it has a 3D hardware acceleration to compute perspective projection of 3D models onto the screen space. OpenGL is an open language specification used to describe the communication between the computer and its graphic card.

We built a driving simulation environment as shown in the Fig. 9. It consisted of 4 PC; main control computer, instrument control computer, 3D image generation computer and dynamics analysis computer. The main control computer had a function to integrate the 4 computers and analyze the digital signals from user interface. The instrument control computer had a function to control the instruments installed in the rolling stock cabin. The driving simulation computer had a function to generate 3D images and the dynamics analysis computer had a function to calculate the dynamic behavior of rolling stock according to the variation of driving speed. They are connected with 100Mbps Ethernet cable.

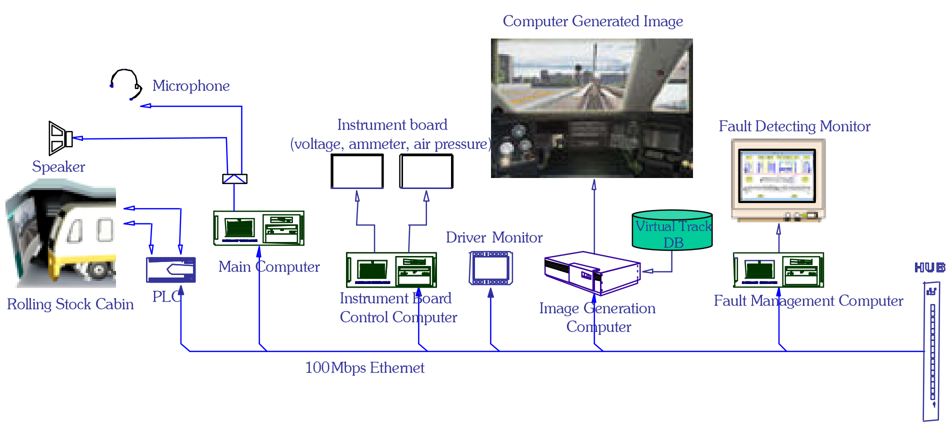
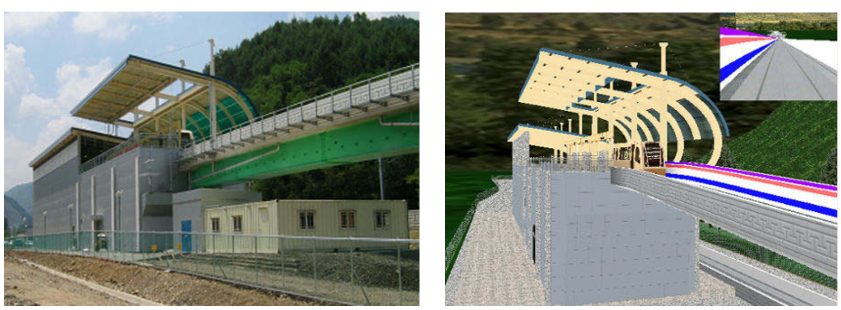


Fig. 9. Schematic diagram of the driving simulator

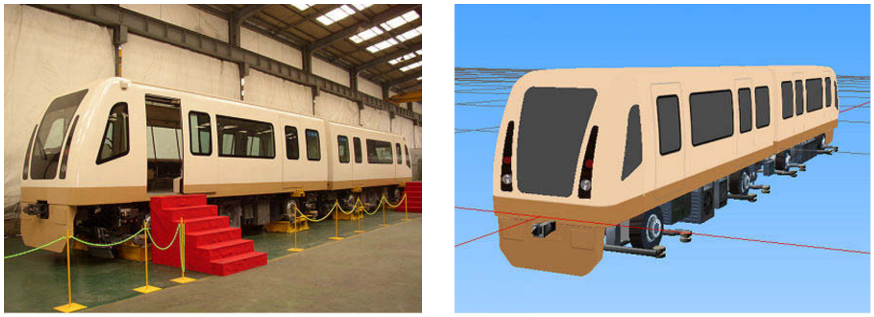
Fig. 10. shows the comparison between the physical test line and the computer generated virtual test line. The virtual test line modeled with the Multigen Creator v.2.6 developed by Multigen Paradigm and rendered with the Vega Prime v.1.2.



(a) Physical test track (b) Virtual test track

Fig. 10. Development of the virtual test track based on the physical test track

Fig. 11. shows the comparison between the physical K-AGT and the virtual K-AGT model. We developed the virtual K-AGT model by converting 3D CATIA CAD model to stl model and reduce the number of polygons to running in real time.



(a) Physical train model (b) Virtual train model

Fig. 11. Development of the virtual test track based on the physical test track

3.5 Product Data Management

The growing complexity of models and analyses, which are based on huge quantities of different types of data, generates many difficulties. The product data management (PDM) technology provides a solution by tracking data and ensuring that the right information is available for the right person at the right time and in the right form throughout the company. The PDM regards as efficiency tools for managing all the data related to the product including parts data, product specification, documents, CAD and CAE data. Also it can manage all the process related definition and management including approval and distribution.

In this research, we developed the PDM system to support engineering activities in the designing newly built rolling stock. The PDM module has a repository for storing product data of rolling stock and a method to capture and record the product data during the product development process. Also it supports process control to restrict and distribute the flow of information between processes for management.

4. CONCLUSION

In this research, we developed the integrated design system to support the design process of newly developed rolling stock. The system consists of parametric design, digital mock-up, virtual testing, virtual reality and PDM module. We applied the system in developing the K-AGT project to stabilizing the system and prove its usefulness. Although, the system was not fully developed yet, we could make rolling stock driving environment visible to give better understand and we could share the ideas and find better solutions.

5. ACKNOWLEDGEMENT

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