A Study on the Safety Assessment for Driver-machine Interfaces in the Railway Driving Cab by the VE Simulation Verification

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In this paper, a study on ergonomics safety assessment for driver-machine interfaces of driving cabs will be presented. Considering train driver's physical dimensions, skeleton model of train driver was developed and an ergonomic guideline for driver's cab is drawn. Using the guideline, 8200-class locomotive using virtual engineering was evaluated and the need to conduct further examination on the more appropriate limit of the field of vision was found. Finally, a virtual engineering simulator for the driver-machine interface was developed to verify the driving cab's design and operate the train with ergonomic assessment. Those results can be applied to ergonomic evaluation for the next MMIS design of locomotive cabs.

I. INTRODUCTION

The railway system is a typical means of transportation in which human factors should be emphasized and human features are applied to almost all categories from the operation of the train to monitoring and planning processes. In other words, from the manufacture of a train to its operation and from passenger transport to their safety, human factor must be considered from beginning to end wherever humans are involved. As such important aspect, the management of human factors must not be overlooked for the safety and the efficiency of railway, yet research on humans -- the subject of operation -- has been relatively disregarded compared to other means of transportation (airplane, road vehicle, ship, etc.). This is primarily because the railway has not yet experienced any major accident that could bring the importance of human factor to the fore. In addition, as the existing railway is in operation without a sufficient systemic ergonomic evaluation, the potential causal factor of human errors lurks. Given the potential of causal factor of human errors and the rate of accident caused by the human error intervention, we can understand the research on human factor is indeed also important in the railway.

FRA (Federal Railroad Administration) suggests ergonomic design guidelines by realizing that work environment affects safety and productivity. UIC 651 provides train drivers' minimum and maximum physical dimensions for designing the locomotive cab and basic space requirements in numerical values. The Technical Specifications for Interoperability (TSI) provides that the same criteria as those of UIC 651 should be followed. AAR (Association of American Railroads) S-504 emphasizes the need of ergonomic design for driver's seat in the driving cab. Massachusetts Institute of Technology conducted ergonomic research into display of driving cabs of high-speed railway vehicles. Sweden's high-speed train X2000, Japan's high-speed railway Shinkansen and France's TGV and German high-speed train ICE (Inter City Express) used ergonomic designs for the interior and instruments of driver's cabs. U.S. Department of Defense MIL-STD-1472E suggested ergonomic design criteria for military system and equipment. NASA (the National Aeronautics and Space Administration) suggested system engineering designs for driving cabs of aircraft and spaceships for managing human fatigue. DOT (Department Of Transportation) conducted ergonomic evaluation after developing locomotive cabs. In the nuclear industry's case, it requires that an ergonomic evaluation be conducted in designing a main control room which corresponds to a driving cab of railway vehicle.

Drivers' physical and mental conditions while operating trains may be closely related to human errors. For example, in case seat height or angle is not suitable, or noise exceeds the limit or the visibility is significantly low, they will adversely affect drivers' physical and mental conditions. The factors affecting drivers' physical and mental conditions include the environment of driver's cab (noise, vibration and air quality etc.), layout (accessability, visibility and seat etc.) and workstation design (display, equipment etc.). Evaluation and improvement for the above factors are required. For preventing drivers' errors, evaluation and improvement for work environment including the environment of driver's cab, layout and workstation design are required in addition to current competency system and training. At present, Korea lacks evaluation by standardized ergonomic checklists when developing locomotive cabs. Consequently, it is needed to develop ergonomic evaluation technology for work environment of locomotive cabs (e.g. diesel locomotive, electric locomotive).

In this paper, a study on ergonomics safety assessment for driver-machine interfaces of driving cabs will be presented. Considering train driver’s physical dimensions, skeleton model of train driver was developed and an ergonomic guideline for driver’s cab is drawn. Using the guideline, 8200-class locomotive using virtual engineering was evaluated and the need to conduct further examination on the more appropriate limit of the field of vision was found. Finally, a virtual engineering simulator for the driver-machine interface was developed to verify the driving cab’s design and operate the train with ergonomic assessment. Those results can be applied to ergonomic evaluation for the next MMIS design of locomotive cabs.

II. SKELETON MODEL OF KOREAN TRAIN DRIVERS

It is considered convenient to use CAD system especially for checking the human-machine interface. Therefore, we have specified the skeleton model for the male 95th percentile and female 5th percentile (refer to Table 1 and Fig. 1) of human body modeling based on the measurement data of human body size.

Table 1. Physical dimensions of train driver (mm)

Measurement Items	Male train driver		Female train driver	
	5th	95th	5th	95th
Stature	1616	1796	1495	1659
Knee Height, Sitting	471	546	440	506
Arm Length + Hand Length	707	816	653	754
Sitting Height	872	972	813	902
Shoulder Height, Sitting	552	641	519	595
Buttock-Knee Length	530	610	503	580
Biacromial Breadth	361	431	332	388
Hand Length	172	199	162	188

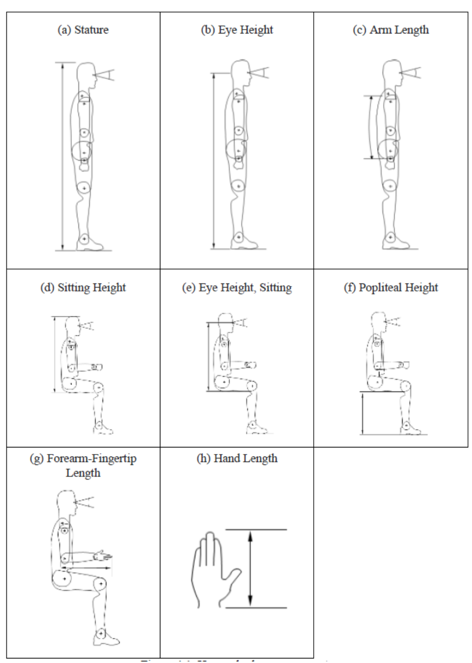


Fig 1. Human body measurements

The skeleton model is convenient for the rough check of human-machine interface, but we expressed it as in Fig. 2 to distinguish the size clearly by contrasting it with human body measurements.

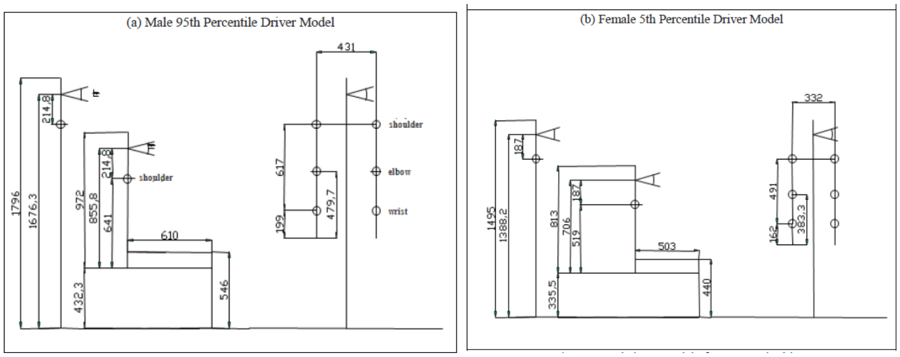


Fig 2. Skeleton model of Korean train driver

Table 2. Comparison of the major body sizes of Korean male and female with those of UIC 651 (ISO/TR 7250-2)

Stature (body height)*		
Eye height*		
Sitting height (erect)		
Eye height, sitting		
Lower leg length (popliteal height)*		
Thigh clearance		
Knee height*		
Buttock-popliteal length (seat depth)		
Buttock-knee length		

* Black line: UIC 651, Blue line: Korean male population, Red line: Korean female population. The heights here change when the driver wore shoes and 30mm were generally used as the shoe size.

UIC 651 provides train drivers' minimum and maximum physical dimensions for designing the locomotive cab and basic space requirements in numerical values. From the developed skeleton model for train drivers, the several requirements of the current UIC 651 code were effected. In this context, since 2011, Korea Railroad Research Institute has tried with studies on ergonomic design considering domestic drivers' physical characteristics. With the same reason, KRRI conducted the project on the layout of drivers' cab in rail vehicles with the support of UIC from 2013 to 2015. From the project, the guideline to define the requirements for driver's cabs has been created to define the effected requirements.

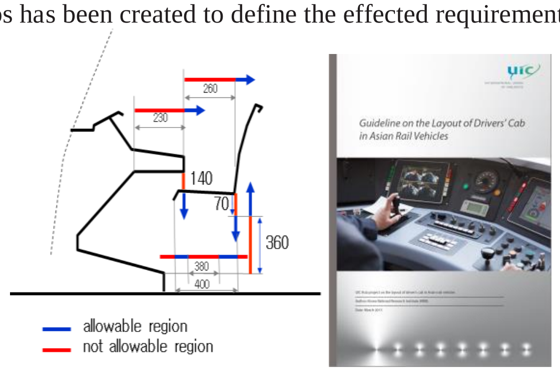


Fig 3. Guideline on the Layout of Drivers ' Cab in Asian Rail Vehicles

III. Application to the 8200-class locomotive

Ergonomic design factors can be evaluated in the design stage, reflecting the working space, field of view, and body size. The evaluation has been applied to 8200-class locomotive which is operating in Korea main line.

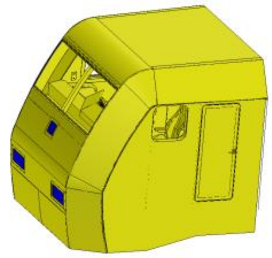
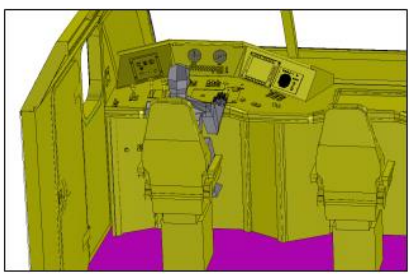
Actual Locomotive	Result of Modeling
	
	

Fig. 4. Virtual Modeling of the 8200-class locomotive

(a) Male driver 95th percentile



(b) Female driver 5th percentile

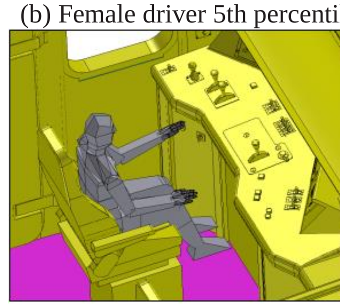
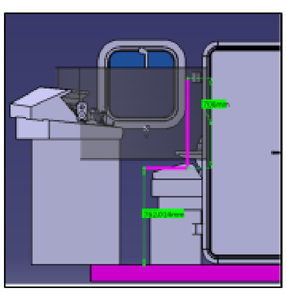
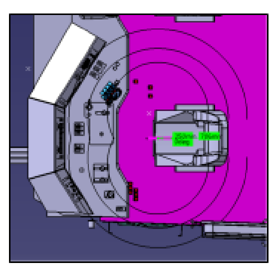


Fig. 5. Virtual scene of potential male driver 95th percentile (8200-class locomotive)

As a result of evaluating the suitability of working space using the driver model, the arrangement heights of working space and driver's seat, etc. were not appropriate in the case of the female 5th percentile. In particular, with a high control desk, we can presume the inconvenience experienced by many drivers.



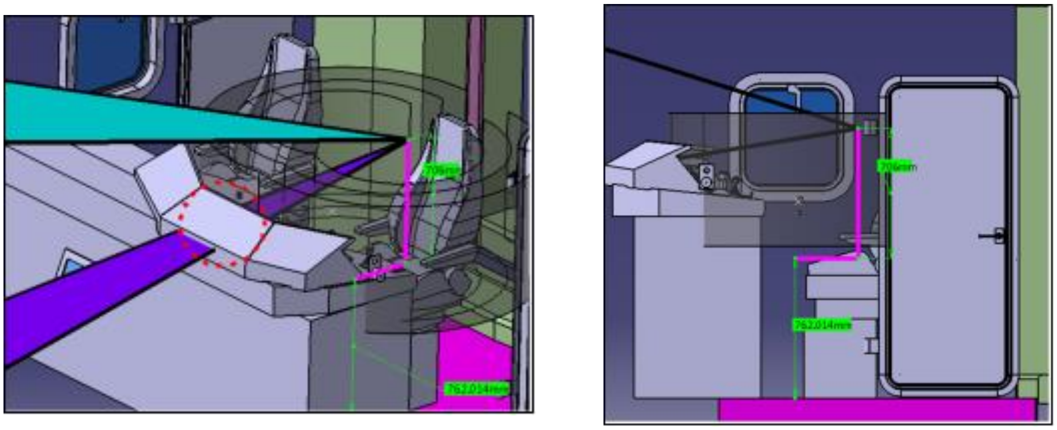


(a) Working Condition of Potential Female Driver 5th Percentile (inappropriate height)

(b) Driving Range of Potential Female Driver 5th Percentile

Fig. 6. Working space test of potential female driver 5th percentile (8200-class locomotive)

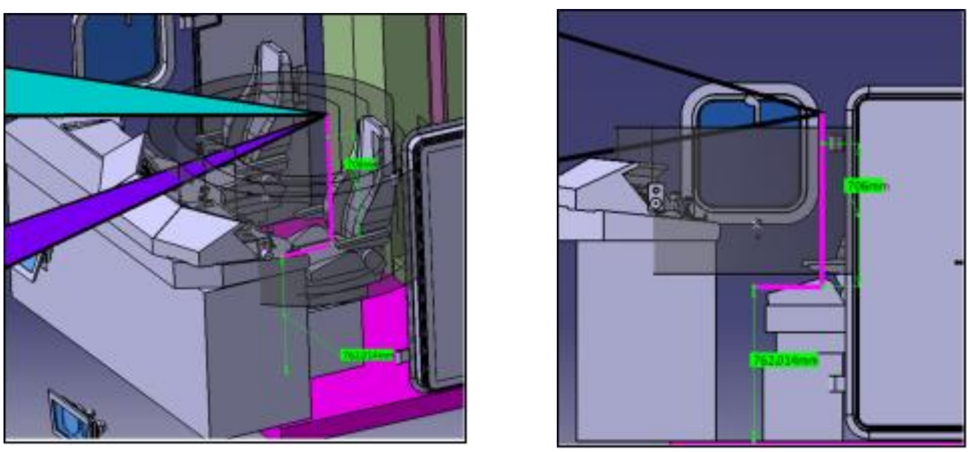
Meanwhile, we can see that the signal devices and driving range are all appropriate as shown in the potential male driver 95th percentile; in the case of the potential female driver 5th percentile, however, the driver cannot check the lower signal in sitting state, being affected by the arrangement of devices. Therefore, we can assume that the 8200-class locomotive was designed to be suitable for the physical condition of Westerners rather than Asians.



(a) Lower Signal Checking of Potential Female Driver 5th Percentile

(b) Lower Signal Checking of Potential Female Driver 5th Percentile

Fig. 1. Visibility of potential female driver 5th percentile (8200-class locomotive)



(a) Lower Signal Checking of Potential Male Driver 95th Percentile

(b) Lower Signal Checking of Potential Male Driver 95th Percentile

Fig. 2. Visibility of potential male driver 95th percentile (8200-class locomotive)

For signal standard, the standard was based on the fact that the driver should catch the lower signal in the height of the rail 15m ahead and the upper signal in the 6.3m height 10m ahead, as proposed in UIC 651. Nonetheless, we see the need to conduct further examination on the more appropriate limit of the field of vision.

IV. Virtual engineering simulator for the driver-machine interface

As shown in 8200-class locomotive case, design change the design of the cab when the DMI problem occurs after the design completion is not easy. Therefore, a technique for evaluating the DMI and experience in a virtual space is required from the design phase. This study develops a simulator that can evaluate the design conformity of DMI in the cab and be operated by variably changing the cab design.

Fig. 9. Virtual engineering simulator for the driver-machine interface

II. CONCLUSIONS

This is the Korea`s first research into ergonomic evaluation and improvement of locomotive cabs, comprehensively considering man-machine interface system (MMIS) in locomotive cabs. Considering train driver's physical dimensions, skeleton model of train driver was developed and an ergonomic guideline for driver's cab is drawn. Using the guideline, 8200-class locomotive using virtual engineering was evaluated and the need to conduct further examination on the more appropriate limit of the field of vision was found. Finally, a virtual engineering simulator for the driver-machine interface was developed to verify the driving cab's design and operate the train with ergonomic assessment. Those results can be applied to ergonomic evaluation for the next MMIS design of locomotive cabs.

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