Ergonomics: An Implementation & Combination with Digital Product Development

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Abstract: **In the past years, human factor (ergonomics) has assumed a point of crucial importance in engineering, design, development, service and maintenance sectors of industrial products. Nevertheless, in the automotive segment companies are focusing more and more on driver and passengers comfort to cater the expectations of customers, beat the immense competition and reach & extend different market segments. This paper emphasizes the introduction and combination of virtual ergonomics review along with the Digital Mock-Up (DMU) review process followed in automotive industry.**

In this paper, we have reviewed the ergonomic aspects of an automobile digitally during the conceptuation and digital development phases of product cycle. A comparative case study has been conducted at the *Tata Motors Ltd. Lucknow* manufacturing facility to compare the digital and physical ways of reviewing the ergonomic aspects of driver seat, ABC pedal position, GSL position & steering wheel position.

The paper finally concludes the implementation and combination of digital ergonomic review with the digital product development reviews.

***Keywords*: GSL, DMU, ergonomics, digital ergonomic.**

I. INTRODUCTION

Ergonomics is a scientific study of interaction between relative position of instruments with respect to human body to overcome or improve the fatigue, creep & visibility aspects.

Earlier, after the design finalization, physical test were performed for the ergonomic suitability after physical manufacturing of the product which resulted in difficulties related to design change and cost effectiveness. Using 3D ergonomics simulation over a virtual vehicle 3D CAD DMU provides the designer the complete idea of behavior and condition of intended users/customers much earlier during the phase of product development resulting in total cost & time reduction in producing a customer friendly product.

Digital Mock-Up (DMU) review process is of indispensable importance in different phases in product design and development. It is started from product concept design to design review phases (Refer the figure 1), under the consideration of different boundary conditions. DMU process includes the Concept Design, Concept Review, Virtual Validation, Detailed Design & Design Review, all of which are conducted in the context of the customer requirements & marketing analysis.

Comfort, safety and adjustment option in any vehicle plays a key factor among the five most important purchase arguments for customers. In developed countries like US, customers even claim for insurance if they encounter any physical problem due to ergonomically bad considerations, [2].

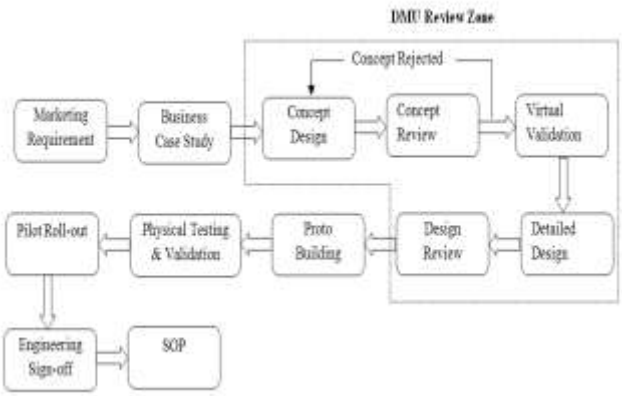


Figure 1 New product design and development phases

II. LITERATURE REVIEW

During the concept development phase for the selection of most suitable concept, the designer need to focus on the ergonomic aspects of the design. Different designers and authors have emphasized the important of ergonomic (man, machine interaction study) and the digital/physical verification of the concept design. This paper tries to explore and innovate the implementation of digital CAD tools into the Product Design for the Ergonomic aspects and requirements, which are presently considered and implemented conventionally through physical methods and tools in the automobile industry, M/S Tata Motors Ltd, Lucknow CVBU in particular. We have done the literature review for the available papers in this regard as follows:

With the use of 3D-CAD environment, the simulation related to access, reach, ingress, regress, etc. are done with varying

manikin sizes resembling to the actual driver populations (Fireman, J., & Lesinski, N. 2009).

The driver's workplace contains basic requirements for an ergonomic and comfortable seating position, which is essential to keep drivers in a good state of health condition. The dim's and mounting positions of driver's seat, accelerator and clutch pedals and steering have to be carefully chosen, considering optimum H-Point position to enable drivers to sit in an ergonomic seating position, i.e. sitting at angles which comply with the given ranges of different comfort position and to allow some variation when seated or as when are required as per regulations (ISO 16121-1, 2, 3& 4)

Ergonomic features are needed for driver comfort, visualization area and ease of access to the controls in line with the regularity requirements as per Indian government, namely the Commercial Motor Vehicle Regulations (CMVR) at product design stage. There is a possibility of addition of lot of ideas and techniques at early design and manufacturing stage of products especially in case of vehicles to make them more ergonomically strong. Maintaining Balance of body while interacting or entrance time with vehicles (e.g. during activity of Ingress/Egress etc.) is one of the key ergonomic issue. Enough gangways are required for the same. Furthermore, this area needs for Center of pressure (COP) trajectory, Center of mass (COM) trajectory, Movement sway etc. Use of digital tools in the ergonomic study of the work location, in particular for the driver station/cab of commercial automobile enables Faster pace leading towards rapid product development (Singh, S., Singh, J., & Kalra, Borner, C. J., Hoormann, H. J., Rizor, H. G., Hütter, G., Kraus, W., Bigalke, S., ... & Küchmeister, G. 2006)

RAMSIS simulation have a unique combination of a sound scientific foundation for ergonomics and design functionality for driver workplace design as well as for passengers setting position design. This explore and innovate the implementation of digital CAD tools into the Product Design for the Ergonomic aspects and requirements (Monacelli, G., & Elasis, S. C. P. 2003, Van der Meulen, P., & Seidl, A. 2007).

III. BACKGROUND

"To succeed in today's tough competitive environment, manufacturing companies need to design more ergonomic products and safer, more productive workplaces" says Dick Slansky, Senior Analyst PLM & Discrete manufacturing for the ARC advisory group. Proven virtual ergonomic solution tools like DELMIA make this easy to digitally analyze human interaction in product design, manufacturing, service & maintenance and training simulation.

Vehicle packaging in design process is categorized into two areas, mechanical package design & occupant package design. While mechanical package design deals with packaging of mechanical components in a vehicle, the occupant package design studies the occupants in spatial environment. In this the location of various occupants is determined while focusing on physical location of various components in a vehicle.

It is critical in vehicle design to study how drivers/passengers interact and move with respect to vehicle packaging. Some of these motions/interactions can be closing and opening of door, how to enter in the vehicle and exit, how to buckle seat belt, accessing various controls of the vehicle, etc. This study concludes how occupant accommodation is affected by vehicle environment & how this can be implemented during initial phase of development.

IV. 3D CAD: HUMAN FACTOR INTEGRATION

As the customer intend to use any new product varies in their physical behavior largely on physique, geography, ethnicity & culture, the designer working on the product development must be aware of all these governing factors from the initial phase of product development throughout different stages towards design finalization and physical product manufacturing.

For new vehicle development, ergonomic aspects are finalized based on the benchmark vehicle, productionised vehicle & industry standards like AIS, IS, ISO, etc. During the earlier phase of product development the designer must focus on:

- Ingress / Egress
- Driver visibility
- Reach availability
- Other comfort constraints

There are a number of CAD tools to analyze the ergonomic behavior of any system like RULA (Rapid Upper Limb Assessment), RAMSIS (Realistic Anthropological Mathematical System for Interior comfort simulation), 3DSSPP^{TM} & SAMMIE CAD. Although, these tools have different methods and steps but the main purpose is to analyze the manikin reaction with the product and surrounding. [5]

Ingress/Egress

Ingress represents first interaction of customer with the vehicle. It represents the entry of intended user inside the vehicle so as to operate it or sit inside it. The opposite term egress refers the exit of customer from the vehicle. Poor ergonomic considerations while freezing the driver/passenger area may result in injury, fatigue and discomfort which results in customer complaints leading to product failure. Maintaining body balance while interacting with vehicle during ingress/egress plays a major ergonomic decisive factor in cab/driver station design & need exploration and methods of body balance assessment. Trajectories of center of pressure (COP) and center of mass (COM) are found to be good quantitative measures of human body balance and postural control, [3].

Driver visibility

In the aspect of driver visibility, vehicle should be designed in such a way that driver may drive the vehicle safely in both day and night. This refers to the vision spectrum of drivers/operators needed for intended product use. Even if the product feature and controls are good, poor visibility may result in driver discomfort leading to customer dissatisfaction which may result in product failure. Following standards are referred to for establishing driver visibility in Indian automobile industry:

Table - 1 List of standards for driver visibility

Standard	Details
AIS 052	Driver's Visibility requirement (Visibility Zone)
AIS 032	Forward Visibility
ECE R 46	Approval of devices for Indirect Vision
AIS 002	Rear View Measurement
ISO 16912 P2	Road vehicles-Ergonomic requirements for the driver's workplace in line-service buses – Part 2:Visibility
AIS012	Lighting & light signaling requirements
AIS002	Rear view mirror

Following reference snap shows the integration of ergonomic verification in freezing driver seat position & accordingly freezing of cab windscreen, lamps and indicators, etc along with DMU review process.

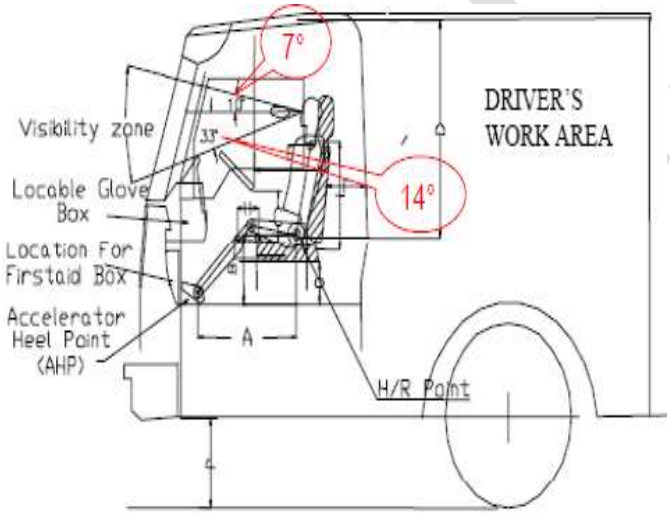


Figure 1 Virtual Ergonomic Verification of Visibility

Critical in vehicle design to study how drivers interact and move with respect to vehicle instrument cluster and mirrors (Front and Rear) have been considered as per ISO 1621 (refer below table)

Table 2 Driver Seat Position as per ISO 1621

Notation	Details	Requirement
A	Distance from Heel Point to "H" Point	600 mm to 640 mm
B	Minimum Distance from floor to "H" Point with the driver's seat in the upper most position	500 mm
C	Thigh Clearance	200 mm to 260 mm
D	Minimum Distance from "H" Point to Roof top	1060 mm
E	Minimum Distance from the lower end of steering to the front of driver's seat back rest	350 mm
F	Minimum Distance of driver's partition from the rear of the driver's seat with the driver's seat in the rear most position	25 mm
-	Upward Visibility Angle	7 Degree
-	Downward Visibility Angle	14 Degree

Reach availability

After finalizing the driver seat, virtual ergonomic verification for the areas & controls inside driver cab and passenger area are established. Indian automobile industry refers the standard AIS046 for hand approach and reach.

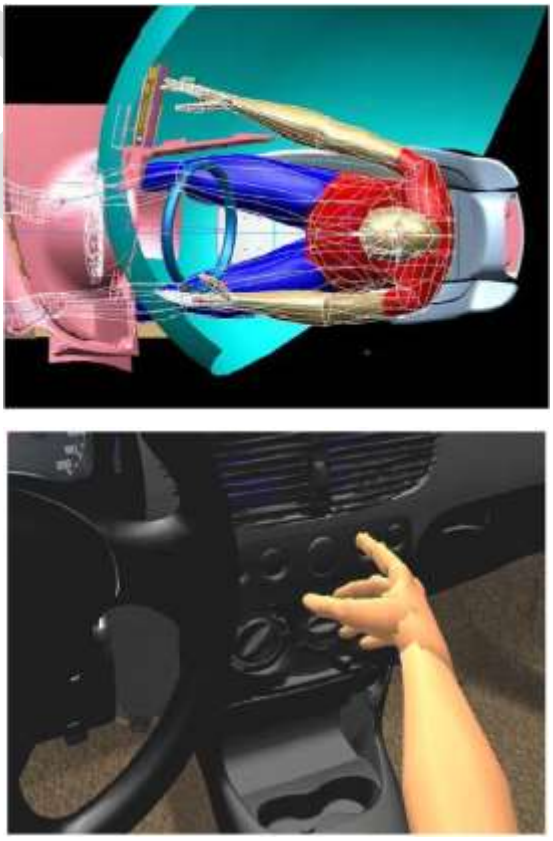


Figure 2 Reachability

(Adopted from: RAMSIS & Monacelli G)

Virtual ergonomic verification is usually done for reach analysis of controls like steering wheel, GSL, ABC pedal position, dashboard switches/knobs, rear view and side mirrors, roof controls, hand brake etc. implementing digital

ergonomic review along with DMU review reduces the chances of operational short comings after physical development.

V. ERGONOMIC: VIRTUAL REVIEW AREAS

These collected data are optimized digitally using 3D CAD tools and physically on cross verification and feedback from operators, designers, engineers and customers. For Indian markets, commercial & passenger vehicles ergonomic requirements are followed from Automotive Industries Standard - AIS in following areas:

- Driver Station
- Front Panel / Instrument Cluster
- Steering Wheel Position
- Gear Shift Lever Position
- Accelerator , Brake & Clutch Pedal Position
- Passenger Seating Posture

All above control positions are established after establishing the driver seat H-Point.

Since the ergonomically suitable position of driver seat H-Point (X, Y, Z) plays the most important role, it is established first by considering:

- Vehicle VCS
- Steering System Hard Points

Vehicle VCS

With respect to the vehicle VCS, H-point X, Y, Z co-ordinate positions are defined based on the feedbacks as discussed earlier.

For this, the most suitable position of driver seat is first established considering the position of CAB, Cowl or Front End Structure (FES) floor, door position, windscreen, side pillars, etc. and their relative positions w.r.t. vehicle VCS. Once this position is freezed, control positions of steering wheel, GSL, ABC pedals, electronic control, etc. are analyzed and freezed for ergonomically suitable design.

The directional orientation of VCS must as given below:

- X – Direction: Starting at front axle plane, positive towards rear of vehicle
- Y- Direction: Starting at vehicle center, positive towards right side of vehicle
- Z- Direction: Starting at long member top, positive towards upward

For proper DMU making, every aggregates assembly must comply to Location & orientation of co-ordinate system of aggregates CAD assembly must be as per VCS & Each AGGREGATES CAD assembly must have references given in below table. For uniformity & easy understanding notations of Planes, Axis & Coordinates systems must be same as that of given in below table

Table 3 VCS Notation

Sr. No.	Notation to be used in Skelton part	Details	Applicable in Groups
1	FACP	Front Axel Centre Plane (Rename 'ASM_YZ Plane as 'FACP')	All Groups
2	LM_TOP_AT_123_From_Ground	Long Member Top At 123 mm from Ground (Rename 'ASM_XY Plane as 'LM_TOP_AT_123')	All Groups
3	VC	Vehicle Centre Plane (Rename 'ASM_XZ' Plane as 'VC')	All Groups
4	RACP	Rear Axle Centre Plane (To be created at 123mm from FACP)	All Groups
5	GROUND	Ground Plane (To be created at 123mm from 'LM_TOP_AT_123_From_Ground)	All Groups
6	WHEEL_CP_AT_123	Wheel Centre Plane (To be created at a height of 123mm from Ground)	All Groups
7	FRONT_WHEEL_CENTER_AXIS	Front Wheel Centre Axis (To be created passing through the centre of front axle wheels)	Frame, Suspension, Tyre & Rear Axle
8	REAR_WHEEL_CENTER_AXIS	Rear Wheel Centre Axis (To be created at intersection of Rear Axle Centre Plane & Wheel Centre Plane)	Frame, Suspension, Tyre & Rear Axle
9	VCS	Vehicle Coordinate System (CSYS_ASM_DEF)	All Groups

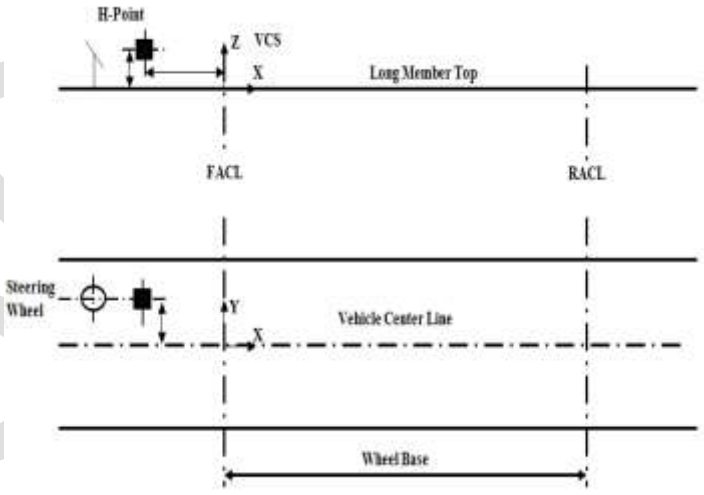


Figure 3 Vehicle hard point position

Steering System Hard Points

With respect to the vehicle steering system hard points, H-point X, Y, Z co-ordinate positions are defined based on the feedbacks as discussed earlier.

For this, Steering system hard points are finalized first by considering vehicle turning center diameter (TCD), steering force requirements and vehicle packaging constraints with respect to drag link, pitman arm, steering arms, steering gear box, steering wheel and linkages positions.

Once the steering wheel position is finalized, seat H-point position is finalized with the help of standards and feedback as discussed earlier. Once this position is freezed, control positions of GSL, ABC pedals, electronic control, etc. are analyzed and freezed for ergonomically suitable design.

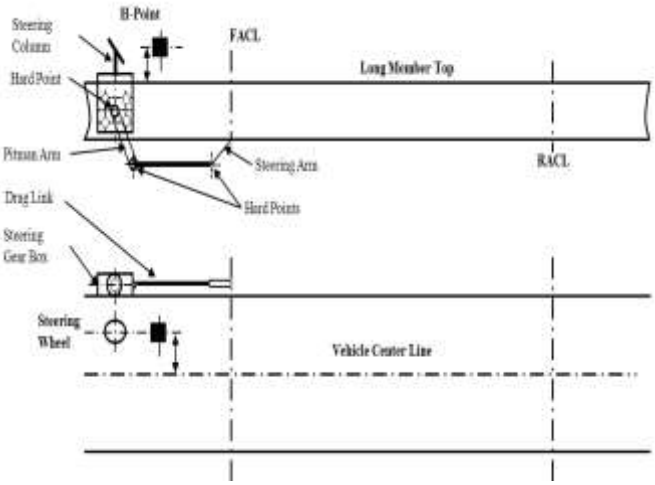


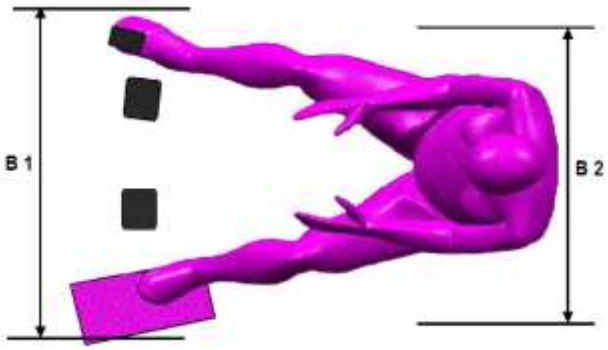
Figure 4 Vehicle hard points

The Y-axis of the H-Point should always be on steering wheel central plane and parallel to vehicle center line.

VI. DIGITAL ERGONOMIC REVIEW

Early consideration in Product development phase to avoid product shortcomings later. Passenger/driver accommodation and ease of access towards different segments like gangway, luggage compartments, overhead controls, etc. Critical in vehicle design to study how drivers/passengers interact and move with respect to vehicle packaging. Needed for motions/system interaction like door closing and opening, vehicle entry and exit, seat belt fastening, accessing various controls of the vehicle, etc

Once the H-point of driver seat is finalized, complete vehicle DMU is assembled and integrated. Now the feasibility and worthiness of each control features as described earlier is reviewed digitally in 3D CAD environment for ergonomic aspects. Based on the digital study and interpretation most optimal positions of all controls are finalized and freezed. As stated earlier this study is strictly based on the benchmark & productionised vehicles and industry standards like AIS, IS, ISO, etc.



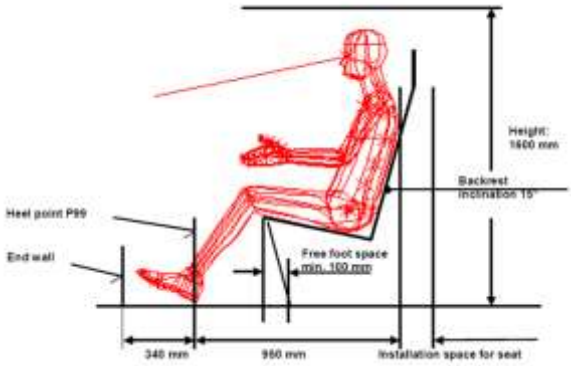


Figure 5 Dimensions of Driver 's Workplace,
(Adopted from: IS16121)

VII. CONCLUSION

This paper deals with the advantages of using digital tools in the ergonomic study of the work location, in particular for the driver station/cab of commercial automobile. The main areas of focus include the driver comfort, visualization area and ease of access to the controls in line with the regularity requirements as per Indian government, namely the Commercial Motor Vehicle Regulations (CMVR). A comparison is made for the time & cost assessment between the conventional and digital approaches of the same to conclude the effectiveness of the former over the later. Use of digital tools into the ergonomic study has reduce the time and cost of the same by reducing requirement of physical manikin and its installation over the driver sheet, hard points determination for controls, manpower, etc. With the use of 3D-CAD environment, the simulation related to access, reach, ingress, regress, etc. are done with varying manikin sizes resembling to the actual driver populations. Further, same approach can be extended to different models and configuration of cab, driver station, vehicle body, passenger seats, gangways, luggage compartments, etc. at a faster pace leading towards better customer satisfaction and achieving the world class quality (WCQ) targets and benchmarks.

VIII. FUTURE SCOPE

- Digital ergonomic approach can be extended to different models and configuration of cab, driver station, vehicle body, passenger seats, gangways, luggage compartments, etc.
- Faster pace leading towards rapid product development
- Better customer satisfaction and achieving the world class quality (WCQ) targets and benchmarks.

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