International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 01 | Jan 2026 www.irjet.net p-ISSN: 2395-0072

Pedal ergonomics through mathematical modelling

Ashutosh Eknath Satpute[1], Saikrishna Buddaram[2], Ashish Deshpande[3], Harshal Bhamare[4]

[1]*Assistant Design engineer, Tata Technologies Pvt. Ltd., Pune.*
[2]*Design Engineer, Tata Technologies Pvt. Ltd., Pune.*
[3]*Manager, Tata Technologies Pvt. Ltd., Pune.*
[4]*Design Engineer, Tata Technologies Pvt. Ltd., Pune.*

---***---

Abstract - *Clutch control/clutch actuation system plays an important role in disengaging gearbox from engine while shifting gears in manual clutch transmission systems. In designing clutch actuation systems, it is necessary to consider vehicle type, route, and frequency of clutch actuation. Driver should not get a jerky feeling while engaging the clutch and it should not be a fatigue inducing job for the driver in case of frequent clutch operation. Therefore, it is necessary to maintain good pedal ergonomics and lower pedal effort for driving comfort. This in turn increases clutch life and eliminates gearbox failures. A unique mathematical model has been developed to arrive at good pedal ergonomics for a particular percentile population and for a given seat location. Based on this model and benchmark study, we arrive at alternative designs that can meet the requirements with their advantages and disadvantages. Based on comparative analysis, design is finalized. This paper discusses the arriving good ergonomic position of pedal using this model.*

***Key Words*: Ergonomics, pedal, ergo, mathematical, driver, clutch, control, anthropometry**

1. INTRODUCTION

Ergonomics is broadly defined as, "How comfortable a system has been defined and / or created for a user to work with it." In simple words, it is the science of designing 'the job to fit' for the worker, not forcing the worker to 'fit the job'. Ergonomics demands the human machine interaction to be smooth i.e. free from ergonomic injuries. It is also described as 'Human Factor Engineering'. It plays a major role for its acceptance within the user base and making the product successful.

Accelerator, Brake and Clutch Pedal plays a vital role in automotive ergonomics, as driver remains in constant interaction with pedals while driving. Thus, pedal position, orientation and its associated effort have a profound effect on driving comfort of the driver. The major constraint in designing the pedals with design intended position is vehicle packaging. Packaging of other aggregates, especially in commercial vehicles in same space leads to deviation from ideal position of pedals. This deviation causes the deterioration of pedal ergonomics of the vehicle, and quantifying the amount of debilitation is a problem. Simulation software's have been designed to give the reports based on the complete vehicular ergonomics, and does not allow designer to further subjugate comfort factor for the improvement solely in the pedal position. So, a high discomfort value can also be caused by improper position of steering wheel or difficulty in accessibility of gear shifter or improper pedal positions or insufficient seat travel.

SAE paper (2017-26-0252) consists of mathematical model through which designer can run multiple iterations and finalize best possible pedal positions based upon packaging constraints.

2. TERMINOLOGY

Hip Breadth-The measured distance between the two human hip centres, marked with abbreviations H1 and H2, in figure 2

Thigh Length-The length corresponding to the human thigh, in figure 3.

Lower Leg Length-The length corresponding to the lower leg of the leg, in figure 3.

Foot Length-The length corresponding to human foot, in figure 3.

Pedal Foot Length-The distance between heel point and BOF, in figure 3.

Torso angle-The angle measured between the vertical line through H-point and the torso line, in figure 3.

Thigh Angle-The angle measured between the thigh centreline and the horizontal line through H-point, in figure 3.

Hip Angle-The angle measured between the torso centreline and the thigh centreline, in figure 3.

Knee Angle-The angle measured between thigh centreline and the leg centreline, in figure 3.

Ankle Angle-The angle measured between the lower leg centreline and the foot, in figure 3.

Shoe Plane Angle-The angle measured between the floor of the vehicle (with carpet) and the foot base, in figure 3.

Leg Spread Angle-The angle measured between the thigh centreline and the vertical line from Hip points, as represented in figure 2.

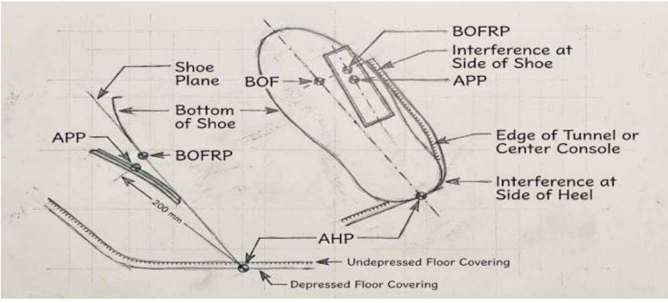

Fig.1: Depiction of the ergonomic terminology at the foot of the driver while operating the pedals.

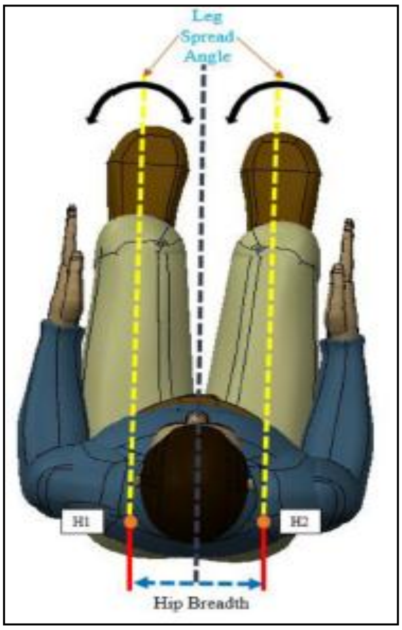

Fig.2: Depiction of the ergonomic terminology in top view of the driver seated.

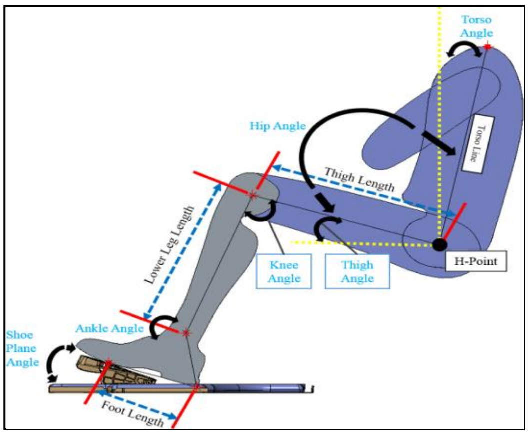

Fig.3: Depiction of the ergonomic terminology in side view of the driver operating the pedals.

3. INPUTS FOR PROCESS

- Effective value of H30: The height of the H-Point from the floor i.e. the H30 value as specified in SAE J1100 [1], value to be entered after subtracting the carpet thickness from it. For example, the H30 value in a vehicle is 430 mm, and the thickness of the carpet is 15 mm, then the effective value of the H30 will be, 430-15 is equal to 415 mm.
- For suspended type pedals, with pedal travel towards firewall, following details are required,
- Pedal plate angle
- Pedal lever angle
- Pedal lever length, to be calculated as indicated in figure 5 below;
- The human anthropometric data with respect to legs i.e. lower leg length, thigh length, hip breadth and foot length. For the desired targeted percentile population.
- Clutch and accelerator pedal plate angle.
- Seat travel, the distance by which the seat can be pulled forward from its rearmost resting point.
- Torso angle, minimum and maximum value of torso angle is to be set in the model for the driver comfort, keeping in view the driving visibility constraints.

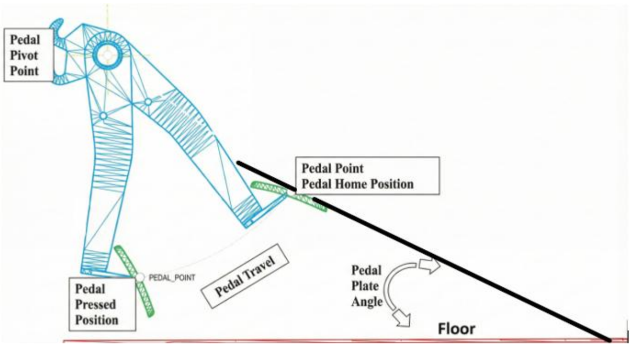

Fig. 4: Key parameters for pedal ergonomics.

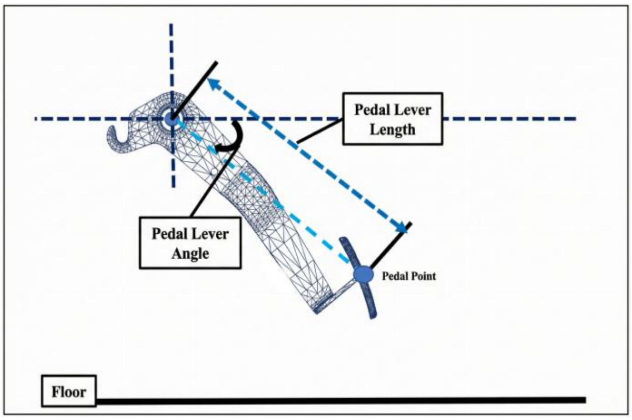

Fig. 5: More key parameters for pedal ergonomics

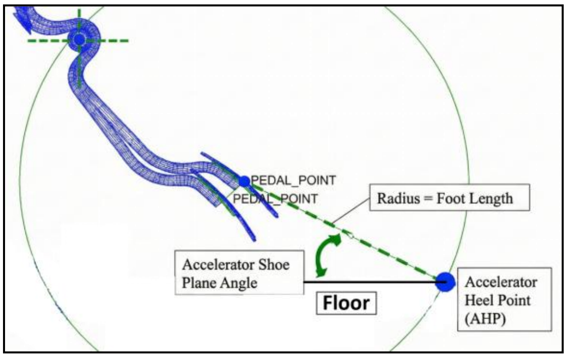

Fig. 6: Key parameters for pedal ergonomics with respect to the accelerator pedal.

4. LIMITS FOR RESULTS

Below are leg comfort angles which are considered as limits for giving results.

- Manual measurement doesn't give the flexibility of iterations for optimization.
- Subjective jury analysis, the subjective analysis is based on hints thereby, cannot be standardized.
- Limitation of Simulation software is that it doesn't steers the users towards the optimized values.

Table 1: Leg comfort angles.

Unacceptable limit	Unacceptable limit	Max limit	Min limit	Unacceptable limit
Leg spread angle	>17	16	7	<4
Thigh angle	>20	16	-10	<-20
Knee angle	>140	137	98	<95
Ankle angle	>115	115	90	<85

5. WORKING OF THE MODEL

Refer below flow chart for working of model. Different iterations can be done in model to arrive at the final pedal positions. It reduces time of making CAD model and ergonomic analysis in Simulation software.

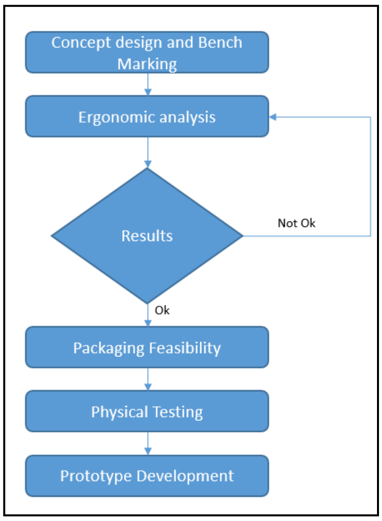

Fig. 7: Workflow for the model

6. FINAL RESULTS

This model gives comfort angles for legs for various percentile population for accelerator, brake and clutch pedal after multiple iterations.

Fig. 8: Depiction of sample output using the model.

Acceptable results

Below are a sample of acceptable results

Characteristic	X	Y	Z
Accelerator Pedal	-830	158.298	-300.2

Characteristic	X	Y	Z
Clutch Pedal	-850	-130	-276.627
Seat Track Length	160	—	—
Accelerator Actuation Angle	—	—	19
H30	—	—	430
Clutch Shoe Plane Angle	42.687	—	—
Back Angle Variation	Minimum: 10	Maximum: 25	—

Knowledge Based Engineering (KBE) approach

Knowledge engineering primarily deals with knowledge acquisition, representation, validation, inferencing, explanation, and maintenance. The Knowledge Engineering Process gets completed in five major tasks:

7. 1. KNOWLEDGE ACQUISITION

Knowledge acquisition includes the process of acquiring knowledge, be it from human experts, books, documents, or any other relevant source of necessary expertise.

7.2. KNOWLEDGE VALIDATION

In this step, the knowledge acquired from various sources is validated and verified, usually by way of test cases, until deemed acceptable.

7.3. KNOWLEDGE REPRESENTATION

After determining validation, knowledge gets organized into a knowledge representation. This task subsumes the preparation of a knowledge map and encoding the understanding in the knowledge base.

7.4. INFERENCING

Once the knowledge representation gets established, businesses need to design the software to enable inferences based on that knowledge. Then, the system provides advice to a non-expert user.

7.5. EXPLANATION AND JUSTIFICATION

This task involves designing and programming an explanation capability to answer specific questions, such as why there is a need for a particular piece of information or how one came to a specific conclusion.

8. WORKING MODEL

This model is more effective and accurate as compare to regular model and increases the productivity

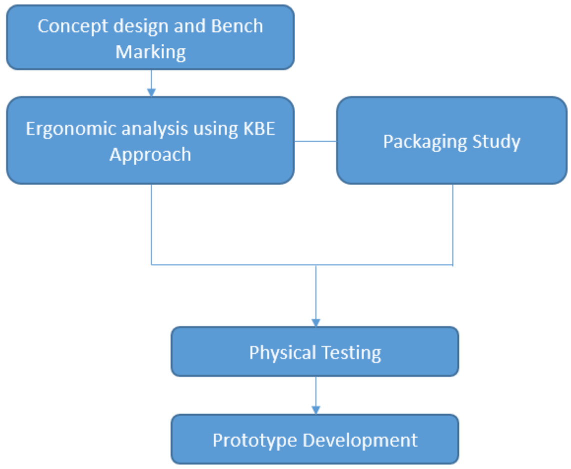

Fig. 9: Modified workflow with KBE approach, of the model.

9. BENEFITS OF KBE

- It helps to increase the productivity of design engineer.
- Re-uses the captured knowledge so that any novice person can generate the results
- Reduces the design cycle time by faster computation of results.

10. CONCLUSIONS

Now a days automotive Original Equipment Manufacturers are paying more attention on providing comfortable ergonomics positions of pedals but it is difficult meet the requirement of each and every (all percentile populations) person because of packaging/ manufacturing/ costing constraint so here adjustable clutch pedal assembly provides the unique solutions to meet the drivers comfort requirement with low cost and less development time.

References

[1] Survival Space for the Protection of the Occupants of the Cab of a Commercial Vehicle AIS-029 / 2004

[2] SAE paper- 2017-26-0252- Analysis of Automotive Control Pedals Ergonomics through Mathematical Modelling Based on Human Anthropometry. Authors- Garg, S., Bhide, S., and Gupta, S.

[3] SAE International Surface Vehicle Recommended Practice, "Accommodation Tool Reference Point for Class B Vehicles," SAE Standard J1516, Rev. Oct. 2011.

[4] SAE International Surface Vehicle Recommended Practice, "Driver Selected Seat Position for Class B Vehicles - Seat Track Length and SgRP," SAE Standard J1517, Rev. Oct. 2011.