HUMAN FACTORS BASED
REDESIGN OF PILLION RIDER FOOT PEGS

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PROBEM STATEMENT

Majority of the population in India have two wheeler motor vehicles as their major mode of transport. But as we know not many of the two wheelers are not from any native manufacturer. There are only a few Indian players in this sector. An average Indian might not be comparable to others in terms of anthropometric details of the native country people. These reasons might cause problems from human factors point of view and usability perspective. So problems pertaining foot peg design is discussed here.

Foot pegs: The foot pegs and the floor board are the most common supports found in any motor vehicle. Foot pegs are essential accessories for a motor vehicle to rest the foot against them. They maintain the balance of the pillion rider. They provide support to the pillion riders while travelling. They also include the ones for a driver to which clutch and brake can be fixed. They are simple metallic protrusions with a rubber cover cantilevered from the body of the vehicle. It is attached through a simple revolute joint to open and close according to use. They vary largely depending on the model of the vehicle and the its specific function. For example, a passenger bike like an Activa has a simple rod like structure but whereas for much performance intense applications may demand much robust and secure foot pegs. Shown below are the major types of foot pegs.

Figure 1. Normal foot pegs

Problems faced due to the wrong foot pegs (stresses and disease):

A lot of care must be taken during the design and assembly of two wheeler foot pegs. This is mainly because of two reasons, foot peg location dictates the posture of the pillion rider subsequently his grip and safety and the other reason is the transfer of continuous vibration to the pillion rider through the foot pegs.

Figure 2. Dirt bike foot pegs

A posture may lead may translate to a leg ache during travelling, back pain, neck ache etc. It may lead to fidgeting of the pillion rider which may cause imbalance to the vehicle. The rate of fidgeting can be used as a parameter to study the discomfort pillion riders face with the foot pegs.

Whereas improper dampening of the vibrations may be exposed to a Whole Body Vibration (WBV). This poses serious life threats through a long term usage.

People may also suffer from muscular-skeletal disorders if the design is not ergonomic and if the human interacts it with a large time continuously, which is the case for people in India who prefer two wheelers for urban traffic.

It should also be noted that the manufacturers often tend to concentrate on the ergonomics and the comfort of the driver rather than a pillion rider since generally a driver is the consumer of the product.

SURVEY:

Details about the survey are as shown:

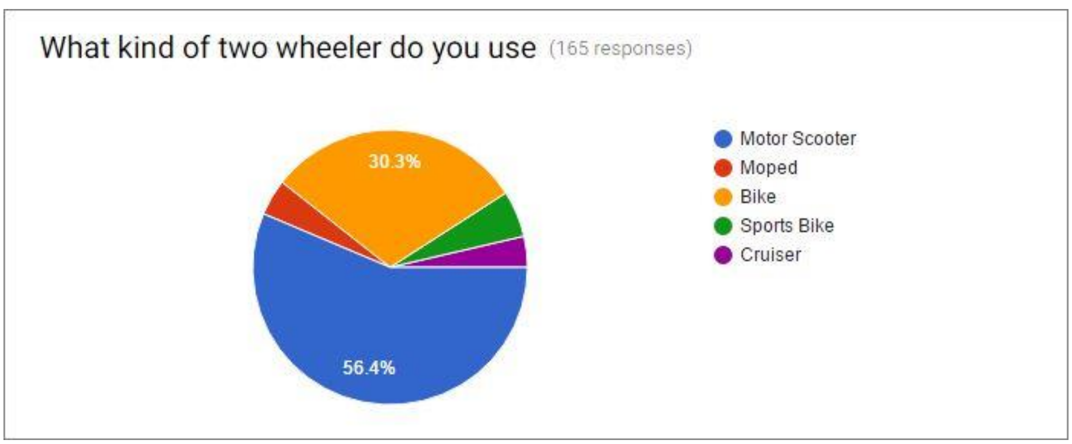
A survey is conducted in the institute through both descriptive and interview bases. The responses of the survey show the following facts and assumptions of the survey.

Population	Margin of Error			Confidence Level		
	10%	5%	1%	90%	95%	99%
100	50	80	99	74	80	88
500	81	218	476	176	218	286
1,000	88	278	906	215	278	400
10,000	96	370	4,900	264	370	623
100,000	96	383	8,763	270	383	660
1,000,000+	97	384	9,513	271	384	664

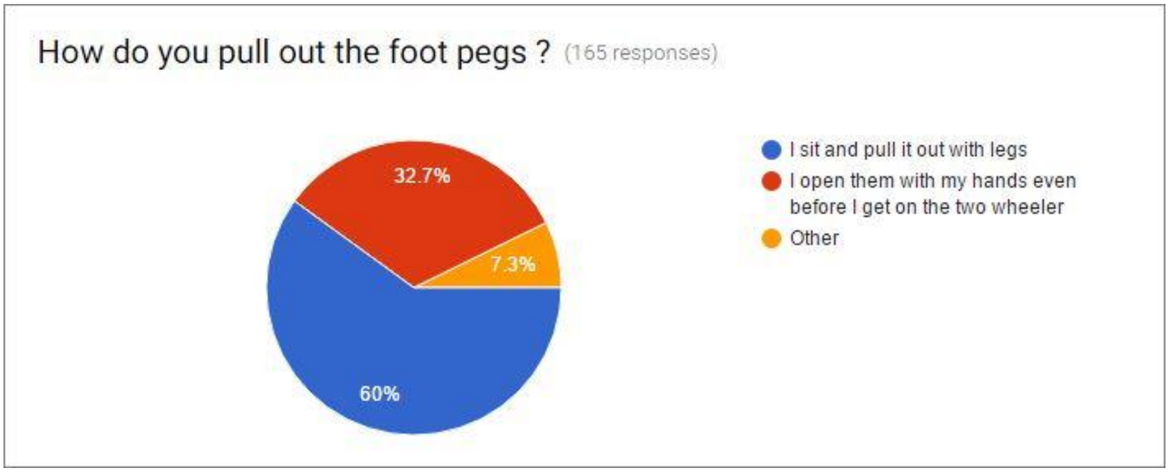
Note: These are intended as rough guidelines only. Also, for populations of more than 1 million you might want to round up slightly to the nearest hundred.

Since all the people who have filled the form are completely random (But majority might be student body) we can assume it to be a random sampling. Also the sample size of the number of people using two wheeler motor vehicles is definitely more than 1,000,000. We have also assumed that the margin of error is 5%, which is of a typical order of magnitude in general. So we need at least 384 responses as we can see from the above chart. But we have only about 168 responses till now.

Most of the people who filled the survey use a motor scooter (Class to which Activa, duo, access etc. belong)



Also we can see that many of them use their hands to open the foot pegs before even mounting the bike as they are inaccessible. Foot pegs are generally designed to be opened by just kicking them in the sideways.



DETAILS OF A TYPICAL HONDA ACTIVA:

A typical foot peg design calls for the dimensions of 10 x 5 x 5 cm approximately and a weight of around 100-300 grams.

Fig. Activa and its dimensions

There for the foot pegs are 165 mm from the ground, the pillion rider will be at 765 mm from the ground. So there is a vertical displacement room for the legs to be placed between them i.e. the pillion rider has 600 mm of free space in any knee angle configuration.

Activa is aimed at an average user and the dimensions are obtained by physically measuring it from various models of Activa available in the institute. For all the further analysis and considerations, it is assumed that the comparison is being done between classes of vehicles like Activa, Duo etc.

ANTHROPOMETRIC ANALYSIS

AVERAGE INDIAN DIMENSIONS:

The following is the chart showing body parameters for an average Indian.

Table 1: Descriptive statistics for measured anthropometric dimensions in the study

Parameters	N	Mean	SD	Range	Percentile		Shapiro-Wilk	
					5	95	Statistic	Sig.
Weight (kg)	195	60.0	10.5	38-94	44.0	78.3	.988	.271
Stature	187	1647	62	1460-1861	1551	1754	.979	.034
Eye height	168	1539	60	1404-1714	1452	1643	.987	.206
Acromial height	168	1372	50	1267-1538	1293	1463	.983	.091
Iliocristale height	167	963	48	680-1104	896	1048	.920	.000
Trochanteric height	167	844	41	704-945	779	919	.983	.091
Metacarpal-III height	167	704	39	632-987	647	763	.834	.000
Knee height	167	468	30	248-544	431	510	.831	.000
Elbow height	168	1046	39	959-1149	978	1118	.990	.432
Scapula to waist back length	166	542	37	450-660	482	600	.991	.516
Waist breadth	165	275	31	187-366	233	329	.994	.788
Inter scye breadth	165	336	28	251-402	289	379	.993	.725
Chest circumference	196	886	70	715-1090	770	1006	.990	.454
Waist circumference	196	800	103	575-1100	654	1000	.986	.185
Hip circumference	181	881	71	710-1120	756	995	.989	.385
Calf circumference	196	320	32	165-440	269	375	.988	.259
Wrist circumference	188	156	9	135-185	140	173	.963	.001
Chest depth	164	223	21	164-283	192	258	.991	.476
Biceps skinfold thickness	186	4.5	2.2	2-22.2	2.4	8.5	.832	.000
Triceps skinfold thickness	186	9.1	4.2	3-20.6	3.8	18.0	.938	.000
Subscapular skinfold thickness	186	12.1	4.9	4.8-27.2	5.9	22.8	.949	.000
Supra iliac skinfold thickness	186	8.6	4.7	2.8-28.8	3.4	18.6	.876	.000
Abdominal skinfold thickness	194	12.6	6.5	3.2-28.4	4.2	24.9	.952	.000
Chest skinfold thickness	193	9.4	4.5	3-26.5	3.8	17.4	.955	.000
Midaxillary skinfold thickness	193	9.2	4.8	2-30	4.0	19.1	.882	.000
Thigh skinfold thickness	193	12.6	5.3	3.6-26.4	5.1	22.3	.971	.005
Calf skinfold thickness	192	12.0	5.8	2.6-29	4.3	23.1	.967	.002

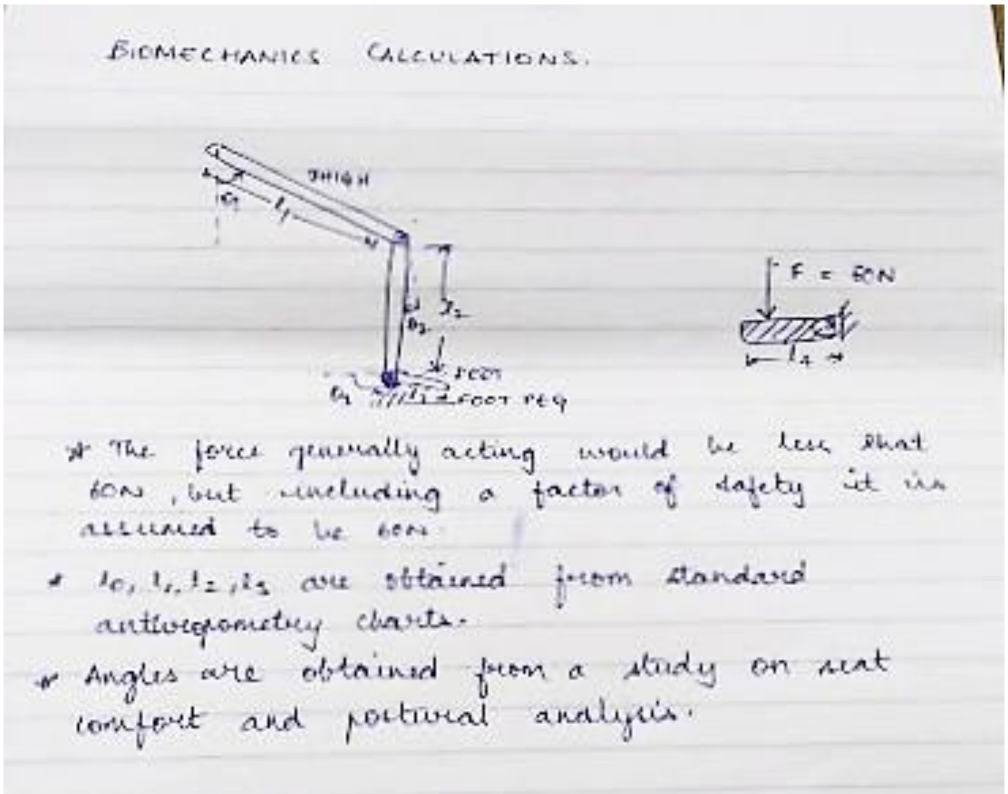
Note: All values in mm, unless otherwise mentioned.
* Lower bound value of true significance.

Here a 95th percentile value says that 95% of the time data points to the values below the indicated value and 5% of the times they are above that value. Based on these and other studies the anthropometric dimensions of an average male and female have been listed below.

- Gluteal furrow- 841 and 807
- Trochanter – 705 and 681
- Mid patella 517-479
- Lateral malleolus – 70 and 65
- Maximum body breadth – 619 and 599
- For a male and female respectively. Also guidelines have been laid down for the ideal seating posture of a certain human. Based on the constraints, anthropometric data and the seating posture a best fit dimensions are decided. Calculations regarding the same are as shown.

BIOMECHANICAL ANALYSIS:

A brief biomechanics study has been done to find out various stressed parts according to the present design so that insights could be drawn for the redesigned component. The idealization for the study can be seen in the following picture. This is the model used for finding the forces and later verified with standard bearable forces by a human.



DESIGN CONSIDERATIONS:

Anthropometric Details of Activa: as an example we take Honda Activa one of the most sort motor vehicle in India the placement of the foot pegs are as shown previously.

Most of the passenger foot pegs are made of aluminium. The body is machined from an aluminium billet initially and then is given a thick rubber covering to dampen the vibration and prevents it from passing on to the user.

According to a study legs can tolerate 2Hz with legs flexing to over 20Hz in rigid posture and spinal column in axial mode in 10-12 Hz. So it is advisable to design a foot peg which dampens these vibrations before inducing them in the user to an acceptable range.

We can clearly see that these do not satisfy the comfort region of an average Indian user. Also in the next figure you can see the side rails obstructing the foot pegs and the pegs punched in to an inaccessible bend fitting into the chassis. Foot peg design (Material chassis placement and manufacturing and foldable mechanism): The foot pegs are placed there because of many reasons, like ease of manufacturing and assembly etc. so keeping even those points in mind a new design is proposed, which meets the Indian market requirements.

GUIDELINES FOR IDEAL POSITION

The ideal guidelines are derived from an ideal seating posture rather than any other considerations. The ideal seating posture shows the angles and the other constraints to be as shown below:

1. Ideal sitting posture demands the person to maintain his/her back perpendicular to their torso.
2. The angle that is to be maintained between the knees is around 10-15 degrees from the normal.
3. Also the heel position and angle are as present in Activa. Care should be taken that the curve of the heel should rest on the pegs but not the front toe.

Based on calculations of the above constraints the placement is preferred to be at 498 mm from the top.

CONCEPT GENERATION AND SELECTION

Calculations based on the anthropometric details of Indian user has been done and is found out that the present location of foot pegs is almost close to the ideal position with a small offset of 4 cm diagonally. Based on calculations of the above constraints the placement is preferred to be at 498 mm from the top. Also the heel position and angle are as present in Activa. Care should be taken that the curve of the heel should rest on the pegs but not the front toe. So now the design demands for an adaptable solution which is deployed in the same place but, should be easily actuated and should accommodate the drivers leg movement and prevent it from touching the pillion riders' legs.

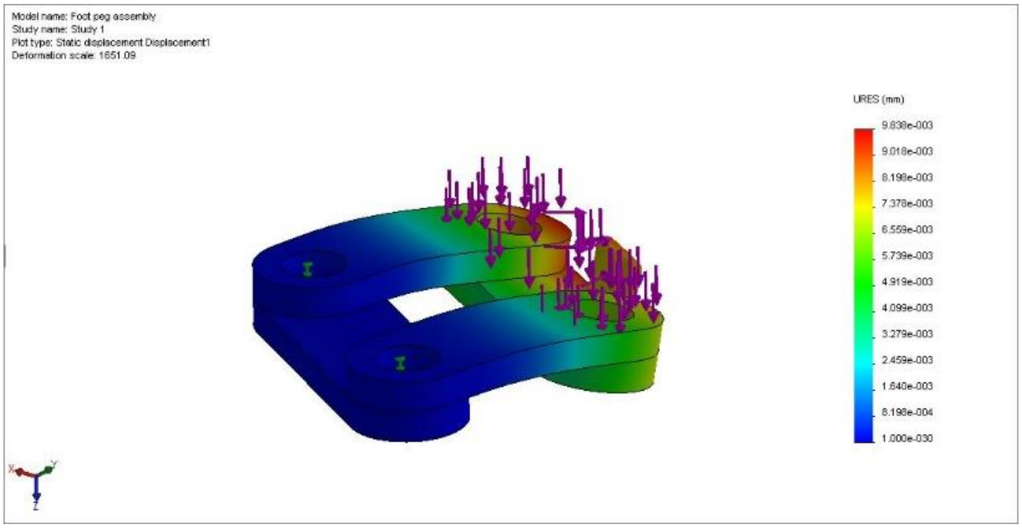
So we'll need to have some kind of retractable mechanism for reorienting the foot peg position based in the driving situation and also to adjust according to pillion rider comfort. And also for ease of implementation the fixtures used on the present vehicles shouldn't be modified very much for the implementation of the design. Based on these a conclusion has been drawn to design a rotary joint based mechanically actuatable modular mechanism, which can be easily manufactured and implemented.

A lot of concepts have been designed keeping in mid the pillion rider's usability point of view. Some of the concepts includes the use of a telescopic sliding mechanism which can be easily pushed by the used with his legs, but such a mechanism would cause instability to the vehicle as the natural motion of the leg is a circular or a spherical motion as the leg is kind of pivoted at the seat.

Keeping in mind all the design and cost constraints a four bar mechanism has been synthesized in such a way that the mechanism satisfies the space given to it. To easily actuate the mechanism an ergonomic extrusion is made which complements the heel curve with which the user pushes it and gives a smooth opening. The proposed concept is then tested for failure and the results are as below.

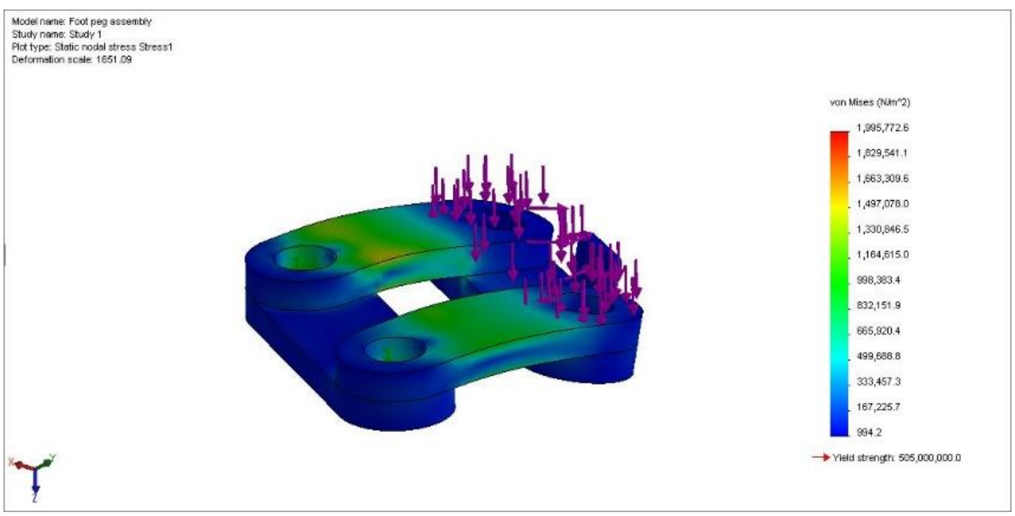
ANALYSIS

We can clearly see that under the operating conditions the maximum stress that is observed is 50.6 MPa, which gives a factor of safety of at least 5. This also gives room for further decrease in mass and size of the mechanism.



DISPLACEMENT OR DEFLECTION ANALYSIS

During the working cycle the displacements are also in the orders of mm which is fair and would not interfere into the vehicle components.



VON-MISES STRESS ANALYSIS

CONCLUSION

The work is done keeping the concepts of usability and human factors in perspective. On the other hand, care is taken that the design is compatible with present fixture and other manufacturing constraints in mind. Guidelines are laid on the position and orientation of the foot pegs for safe operation of both the driver and the pillion rider. A survey has been conducted to validate the points and provide a proof for the arguments. The data is consolidated and analysed. Design outline is laid based on the conclusions of the survey. Based on these set of constraints concept generation and concept evaluation has been done and a suitable, yet easy to assemble concept is chosen. A Finite Element Analysis has been done on the selected concept. The results of the finite element analysis also support the usability and ease of use of the user. The forces required for actuation are within human limit and the analysis is run based on the biomechanical model approximated between the leg and the foot peg of the user.

FUTURE WORK

The design is done considering normal two motor vehicles like Honda Active and not for extreme sports or bikes in consideration. So it is compatible with all such two wheelers fixtures only. A future work would be designing a universal plugging adapter which would go into any foot peg fixture. The model generated is designed for an average Indian user and may not be compatible with all of the users as it is designed for a 50^{th} percentile user.

An appropriate material like aluminium is chosen due to its low weight but an exhaustive study should be done for its implementation. Rubber coating has also been chosen to dampen the vibrations but the parametric study of thickness vs allowable vibration study is to be further done.

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