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Design implementation and analysis of a universal lumbosacral support device to prevent low back pain in motorized two-wheeler riders

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Introduction

According to National Institute of Neurological Disorders and Stroke (NINDS), a division of National Institutes of Health (NIH), about 80% adults suffer from low back pain at some point in time and about 2 out of 10 people who are affected by acute low back pain develop chronic low back pain with persistent symptoms at one year [1]. Though in some cases, treatment does relieve chronic low back pain, but in other cases, pain persists despite treatment. Mostly, the lower back pain is of mechanical nature, i.e., disruption in the way the components of the back (the spine, muscle, intervertebral discs, and nerves) fit together and move. The causes of lower back pain can be imputed to various conditions such as sprains and strains, osteoarthritis, herniated discs, whiplash, compression fracture, scoliosis, stenosis, inflammation of joints, osteoporosis. It not only causes pain, but also severs the economy of a nation. It is a major contributor to missed workdays [1]. Research indicates that the total indirect costs due to back pain accrue to more than $100 billion annually [2]. Not many people can afford traveling by car or taxi to office, especially in developing countries and in cities with high traffic, where people prefer to travel by two-wheelers for their access to work and other amenities. However, people with lumbar problems are recommended not to use two-wheelers as the movement of the body on uneven roads or while braking/accelerating may increase the pain and discomfort. This reduces the productivity of not only the individual and the firm but also the productivity of the country as a whole.

Significance of the device

The support device is suggested for universal use in two-wheelers, even the ones designed for differentially abled. It is proposed for people with diffuse muscular issues and inconsistent spine and not for people who experience pain following deformities as in scoliosis or stenosis. As it uses only structural steel and polyethylene, the device would be inexpensive and affordable. There is no other device that is commercially available to cater the need of low back pain in this aspect [3,4]. With this device, a person idle at home would be able to go to work or meet other people, which would help in increasing the productivity of an individual and the nation as well.

Design feature

The device mainly has two parts, fixture part, and backrest part. The latter is designed to fit the contour of the human back. The design constraint is to retain the normal kyphotic and lordotic angles of the spine, even when a forward and backward movement is expected at the hip during the ride. The pressure was calculated by considering a person of 100 kg under maximum acceleration. This acceleration is calculated by considering the time taken to accelerate from 0m/s to 60 m/s.

$$a = \frac{v-u}{t} \quad a = \frac{60-0}{6.5}$$

Where,
a = acceleration of vehicle; v = final velocity = 60 m/s
u= initial velocity = 0 m/s; t = time taken for the vehicle (which is shown in fig.1.a) to reach 0m/s to 60 m/s = 6.5s [5]

$$a = 9.23 m/s^2$$

Then force (F) is calculated as

$$F = m \times a$$

Where m = mass of the person = 100 kgs

$$F = 100 \times 9.23$$
$$F = 923\, N$$

And the pressure (P) applied on the seat is found out as

$$P = \frac{F}{area}$$

Where area = 0.038609m^2

$$P = \frac{923}{0.038609}; \quad P = 23906.34\, Pa$$

Yield strength of polyethylene = 2.5 E7 Pa
Yield strength of structural steel = 2.5 E8 Pa
Since most stress is observed only on the steel braces (Fig.5, Fig.7), yield strength of structural steel is taken for calculation of Factor of Safety

$$Factor\ of\ safety = \frac{Maximum\ Yield\ stress}{Working\ stress}$$

Taking factor of safety as 2,

$$2 = \frac{2.5\ \text{E8}}{Working\ stress}$$
$$Working\ stress = 1.25\ \text{E8 Pa}$$

Hence working stress should not exceed 1.25 E8 Pa.

Fig. 1 – Different views of the support device

Analysis of settings

The horizontal braces are considered as fixed support. Pressure is applied on the area (Fig. 2) of impact normal to the surface. Area of impact is taken by considering the curve of the seat that bulges most and hence most pressure will be applied there. The analysis is done without considering foam to provide results with worst-case scenario. The pressure acts due to the inertial force of the person seated while acceleration or deceleration. The resultant equivalent stresses and strain are noted using ANSYS Structural. Though the entire mass of a person will not exert the inertial force, to simulate the worst case scenario it is considered so. However, jerks, vibrations and fatigue analysis of materials are disregarded for ease of calculations. The factor of safety was taken as 2 as a standard value. Fine mesh is selected.

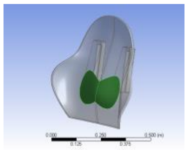


Fig. 2 – Green represents the area where majority of force will be applied

Fig. 3 – Cross Section of support overlaid by sagittal spinal view

Discussion of result

Von mises stress and deformation analyses were done on the model with various loading. Maximum stress is found in the proximity of joints between the vertical and the inclined pipes due to the concentration of the stress (Fig. 4). Maximum deformation is observed at the lowest part of back support because that area of the part has the least support from the steel pipes (Fig. 5(a) and 5(b)).

On performing stress analysis iterations for different weights, it was found that the support could bear a person weighing a maximum of 400 kg for this particular setup (Fig.5). Depending on the model of the two wheeler and the dimensions of the braces used in the development of the device, the maximum bearable weight would vary. Table 1 shows the different values of von-Mises stress and deformation for varying loads.

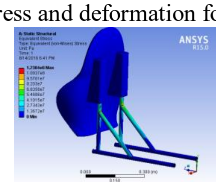
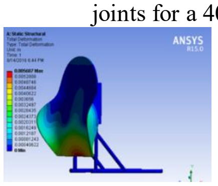


Fig. 4 – Result of Von Mises Stress analysis for steel joints for a 400 kg person



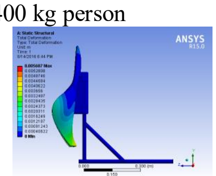


Fig. 5(a) and 5(b) – Total deformation results in two different views for a 400 kg person

Implementation of the support device

In order to get a better understanding on how this device can be mounted to provide back support, the design was implemented on a few two wheeler designs that were commonly used by the riders. This is also shown in Figs 7(a) and 7(b). The two-wheeler used by the differently abled is similar to the one shown in Fig.6(b). Therefore, this design can universally be used on any two wheelers, which has to seat as demonstrated below.

The design of the back support was done, considering the natural curvatures of the spine (Fig. 3) to provide maximum comfort and support. The material used for the back support is polyethylene which is low-cost yet strong. The back support can further be padded by foam of appropriate thickness which cushions the impact of sudden accelerating or braking. Seatbelts with a limited range of forward motion can also be provided for constriction of motion of the passenger.

Table 1 – The von-Mises stress and total deformation for varying loads for an acceleration of 9.23 m/s^2(in kgs)

The weight of the person	Maximum deformation (mm)	Maximum Von Mises stress ($1*10^7$ Pa)
50	0.71	1.538
100	1.42	3.076
200	2.84	6.152
300	4.26	9.228
400	5.68	12.304#

#Maximum stress for a factor of safety 2 is $12.5*10^7$ Pa, at which the structure could fail.

Fig. 6 (a) – Moped

Fig.6 (b) – Moped after installation of the support device

Fig. 7(a) and 7(b) – Installation demonstrated on other vehicles with a few modifications in fixture clamp

This arrangement is attached to the moped using steel braces welded on the chassis (Fig.8.b) of the scooter.

Conclusion

This research is to ideate, design and structurally analyze an orthotic support device that can be mounted universally on a two-wheeler by people with low back pain for commuting to work and other amenities. The analysis was done on the system and it was found to be safe for a person weighing up to 400kgs (which is majorly higher than normal) such that load above 400 kgs would lead to failure for an acceleration of 9.23 m/s^2 with a factor of safety as 2.

The authors declare no conflict of interest for this work.

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