Design of an Ergonomic Bicycle Seat

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ABSTRACT

Perineum pressure due to riding bicycle with conventional nosed-seats is a well-known problem documented in literature. The problem of perineum pressure due to seating arrangement in bicycle is investigated and detailed analysis is carried out to understand the problems associated. An ergonomic bicycle seat is then designed keeping in mind the specific problems and disadvantages associated with the present designs available in the market. The designed assembly comprises of two rods connected to the bicycle saddle point. Each of the rods are spaced apart from one another, and the rods extend longitudinally from a respective rear end i.e. the saddle point to a respective front end of the rods forming a base portion. The rods are bent at predetermined shape at the front end to form a bent portion, and then extend longitudinally towards the rear end from the bent portion forming a top portion. A damper is provided in between the base portion and the top portion of the rods towards the frontal end of the assembly. This is done to facilitate damping for mitigation of vibration in the seat assembly to increase comfort for the rider. A seating portion consisting of foam material which is provided on top and towards the rear part of the aforementioned assembly. The seat is designed for loading and vibration mitigation using analytical methods and simulation. A user study is carried out with a sample size to understand the effectiveness of the solution.

Keywords – *bicycle seat; ergonomic design; perineum pressure*

1. INTRODUCTION

A bicycle is a sustainable mode of transportation running on human energy. Bicycles are ubiquitous and used for transportation, exercise, and recreation. The bicycle's evolution over time has been a product of necessity, ingenuity, materials, and industrialization [1]. Its efficiency and high maneuverability has always attracted human mind at some point of time. An integral part of the bicycle is its seat or saddle, which is very different in its form and functionality from any other two wheeler vehicle. It is one of the supporting points for carrying weight of the riders, the other two being handlebars and pedals. Thus, comfort in riding a bicycle is much dictated by its seat with ergonomics also having a role to play.

To successfully ride a bicycle in a seated position, a cyclist uses coordinated muscle actions and weight to push and or pull at three different external interfaces that include the pedals, handlebar and seat. Of these three interfaces, the seat appears to be the most difficult to ergonomically design because, in part, it must accommodate the anatomically complex perineum [2]. Numerous investigations and experiments have confirmed the effect of bicycle seat pressure in penile blood flow for males, even leading to impotency and erectile dysfunction in some cases [3-8]. Females are also affected in terms of perineal trauma, numbness and other urological complaints [3]. Women naturally have a pelvis that is wider than men. Because of this extra width, women sitting on a men's bicycle seat place the "sit bones" outside of the area of support. Because of a wider pubic arch and a greater distance between ischial tuberosities in females may increase perineal contact with the seat. This transfers the support from skeletal (pelvic support) to soft tissue which is very uncomfortable. Jeong et al. [4] reported in their research that "…industry-wide modifications in saddle design might be required to completely eliminate a potentially detrimental side effect in the health-promoting sport of cycling."

A poorly designed seat will not distribute body weight or reduce pressure effectively over the perineum and thus increase the risk of seat discomfort or injury, which seems to be a common occurrence among cyclists [5]. From the product design point of view, and particularly from ergonomics, it is a tempting need as it shows a scope of elimination of a negative effect from a common people's product.

This paper aims to describe a solution that is indigenously designed by the authors.

2. METHODOLOGY

Available literature on design, detrimental effects, and contemporary improvements on mechanism of seating are studied. It was decided that the scope of this research points towards the design of seat for common usage bicycles and not specialized ones such as for sports etc.

The areas of concentration in designing are primarily, but not limited to, crotch pressure minimization, suspension for vibration mitigation, stabilization and supporting torso weight on sit bones. Ideation and form exploration of seat is performed keeping in mind the functionality and ergonomic considerations. After selection of a concept, engineering analysis for feasibility of use in terms of dimension and material selection is performed to improve the robustness of the product. Then a prototype is build, iterated, and tested for further improvement. A user survey is conducted to understand user opinion to validate the superiority of the product.

3. LITERATURE SURVEY

Bressel and Larson [6], in their study to determine the influence of anterior cut-out bicycle seats on concluded that a partial cut-out seats may be more comfortable than a standard and complete cut-out seat. Jeong et al. [4], in their study to determine if saddle shapes affects penile blood flow, using a narrow unpadded and another wide unpadded saddle, concluded that the shape of the bicycle saddle clearly affects penile blood flow, where the narrow saddle demonstrates more significant reductions in penile blood flow than the wide saddle. Bressel et al [7] studied the influence of bicycle seat pressure on compression of the perineum using MRI analysis. Since the location of peak compression was not different between subjects, it may be a universal impingement zone that limits blood flow and neural activity to and from the penis, they concluded that this information can be used to optimize seat design and thus reduce perineal injuries. Wilson and Bush [8], in their study of the interface forces on the seat during a cycling, collected vertical and shear loads for the common fit position. The result was that the vertical forces always acted in the downward direction and the friction forces acted in the rearward direction on the cycle. Based on this information, a reduction in the magnitudes of the shear forces at the rider/seat interface could possibly prevent, or delay the onset and decrease the severity of non-traumatic skin injuries at the groin.

Bressel et al [6] adapted a field-based approach to investigate bicycle seat design effects on seat pressure and perceived stability. Three different unisex seat designs with similar rear size dimensions and padding features were tested; the standard sport seat with no cut-out, the sport seat with a partial anterior–medial cut-out, and the sport seat with a complete anterior cut-out; which were used in previous research [9]. Perceived stability of each seat tested was assessed using a continuous visual analogue scale. Mean anterior seat pressure values for the complete cut-out seat were significantly lower than values for the standard and partial cut-out seats. Also the standard and partial cut-out seats' stability scores were greater than the complete cut-out but were not significantly different from each other. Another original finding of this study is that perceived stability of the complete cut-out seat is compromised in comparison to the partial cut-out and standard saddle designs. It suggests that a seat with no protruding nose will minimize pressure to the anterior perineum and may be helpful in reducing some seat injuries such as genital numbness and erectile dysfunction [5]. However, there is a trade off in that a seat with no protruding nose may influence steering performance and or rider confidence if perceived stability is compromised as supported by the results of this study.

4. DESIGN CONSIDERATIONS

There are mainly three types of seat designs in the market. There are variants of each design; though based on the contemporary literature [6, 9] these three are the most generic segregations.

1. Standard Seat
2. Partial-Cutout
3. Complete Cutout

Also, two variants of standard seats are available, wide and narrow. Partial cutout designs are also of two types, Conventional/ Narrow with Cut-outs and

Nose bisected/ modified. These variations are again based on market survey i.e. available designs in the market. Therefore, five specific types of seats can be identified in a further segregation as illustrated below.

Some properties and design parameters of these five variants are also mentioned.

1. Conventional wide saddles which has a wide seat with proper body weight support but poor suspension.
2. Conventional narrow saddles which has evolved from the aesthetic point of view but with no suspension.
3. Conventional and narrow saddles with cut-outs which is basically a design attempt to minimize perineum pressure but with no suspension.
4. Narrow saddles with a bisected nose which is shortened and bifurcated and having a pinching problem.
5. No-nose saddles having the nose cut off completely, leading to a feeling of instability. [9].

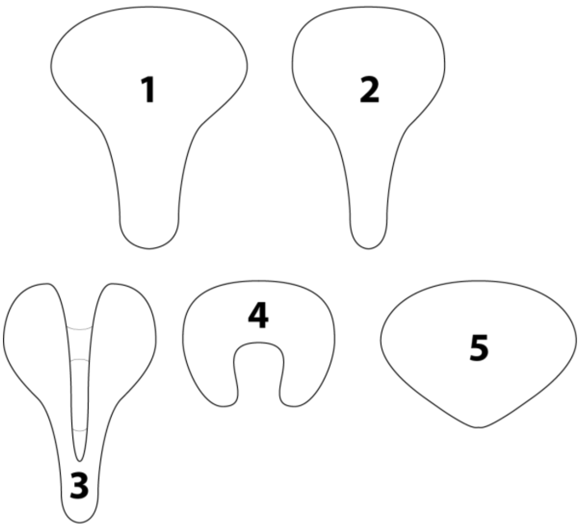

Fig. 1 Types of seats found in market

Numerous ideations were performed to arrive at a solution to all the problems stated above. Using different idea generation and refining methods a final solution was selected on the basis of holistic appropriateness of the same.

This is a plurality of rods connectable to a fork end of the bicycle. Each of the plurality of rods are spaced apart from one another, and rods extend longitudinally from a respective rear end to a respective front end of the plurality of rods forming a base portion. The rods are bent at a predetermined shape at the front end to from a bent portion, and each of the plurality of rods extends longitudinally towards the rear end from the bent portion forming a top portion. The assembly further comprises a damper provided in between the base portion and the top portion of the plurality of rods to facilitate damping in the seat assembly.

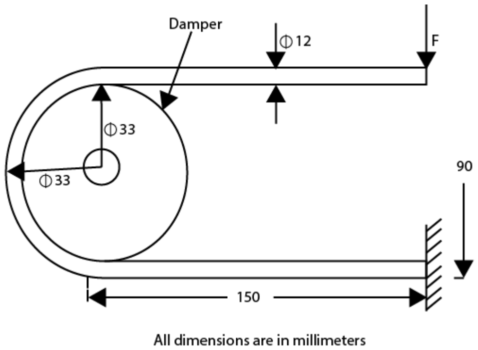

Fig. 2 Major dimensions of the designed seat

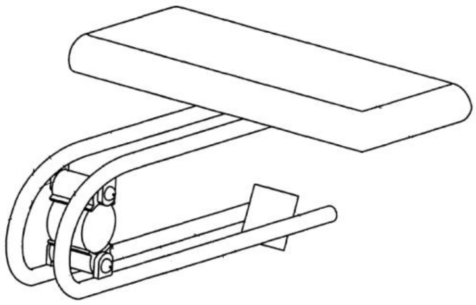

Fig. 3 Isometric view of a representative CAD model of the designed seat

The problem associated with the instability is solved by the nose like structure in front of the seat; which is responsible for stability considerations but at the same time it doesn’t touch the perineum region since the seating arrangement is sufficiently high to keep the perineum from being subjected to pressure.

5. ENGINEERING ANALYSIS

Analysis to determine the appropriateness of the design, concluding arguments on material property of the embodiment design and dynamic arrangements is carried out as follows.

2.1 Damping arrangement of the seat to reduce vibration and discomfort

This section discusses the damping arrangement and engineering justification behind the configuration adopted.

The damper is provided at the frontal portion of the rods so that a parallel spring-damper configuration is achieved. The following diagrams illustrate the configuration and the load paths in the two extremes.

Fig. 4 Line diagram of damper

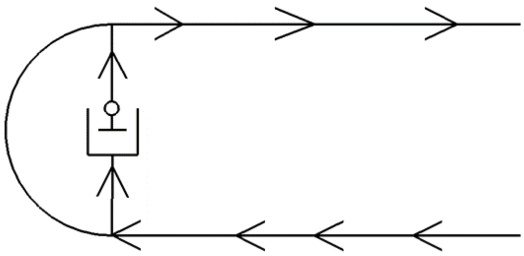

Fig. 5 Load path when the damper is placed in the frontal portion

Fig. 6 Load path when the damper is placed in the rear

The dampers are to be made of a visco-elastic material such as natural rubber, synthetic rubber, neoprene, silicone rubber, butyl rubber, polyacrylic rubber, and polyurethane.

2.2 Calculations for strength

This section discusses the static strength calculation to determine suitable material properties that can withstand dynamic loading. This culminates in the decision to use a particular material for manufacturing the rods. The configuration is constrained by ergonomic and form considerations dictated by its clamping and usage scenarios. After arriving at desired dimensions the material properties are calculated.

The primary ergonomic factor is the comfort of the user from the perspective of maximum deflection of the rear end, which should be less than 10 mm. Also, the maximum stress should be such that the material remain within its elastic limit.

The calculations are based on a static load of 1kN, assuming weight of a user to be 100 kg (1000N) which will be distributed on the two rods and then multiplied by a dynamic scale factor of 2. This results in a material having and elastic modulus greater than 1000 MPa after using curved beam theory for analysis.

Spring steel, which conforms to the above standards, is used for manufacturing the rods in the prototype. Further analysis is to be carried out to explore viable materials other than steel.

6. EXPERIMENT AND USER STUDY

The final prototype is as shown below. This very prototype is used for conducting a user study to understand the usability and effectiveness as compared to a conventional narrow-nose seat.

Fig. 7 Isometric view of the seat prototype

User survey was conducted with 15 male subjects in a 0.5 km pitched road. The designed seat is fitted to a bicycle; another identical bicycle with its default seat is used for comparison. Fifteen people were asked to ride both the bicycles one after another.

Fig. 8 Bicycles used in user study

All subjects are given a demonstration on the design of the seat. The users were asked to compare their perceived stability during riding and turning, comfort of paddling and ease-of-riding in the context of vibration with the designed bicycle seat to the conventional one.

The users expressed overall satisfaction in the design as comparable to the conventional saddle. A slightly below score was reported regarding vibration mitigation.

7. CONCLUSION

The following aspects of the design can be considered.

1. Increasing the flexibility of structure and reducing the weight by using FEM and other analytical tools.
2. Investigate the vibration and damping characteristics of the structure and design the damper accordingly.
3. Improvement in the contour of the seat, in terms of form, functionality and ergonomics.

Stability and fatigue in bicycle riding is dictated by pressure and dynamics of both saddle and handlebar configuration. Both of these aspects are not entirely independent and there is a certain degree of correlation between them. Therefore, a more conclusive study should take into account the effect of handlebar, saddle, and their interaction to suggest improvements in the design.

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