Design and Analysis of Two Wheeler for Armless Differently-Abled Persons by using ANSYS

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Abstract
Transportation has become an integral part of people's day to day life. At certain times, in large countries like India, people are forced to travel long distance from their work place to their place of residence. There are many ways to make transportation easier for the people with disabilities who may wish to drive by themselves as others on the road. People with disabilities in limbs have difficulties in travelling and cannot travel long distances. They use devices such as wheel chair, crutches and artificial limbs for mobility. These however cannot be used for long distance outdoor transportation Therefore, the aim of this project is to design and fabricate „Foot operated system" for armless people. The Foot Operated Steering mechanism is a mechanism controlled by foot or both the feet in order to steer the vehicle in the desired direction. This system consists of a steering which can control brake along with steering. The main objective of the project is to design a foot operated system for handicapped people.

1. Introduction

Motorcycle dynamics is the science of the motion of and motorcycles and their components, due to the forces acting on them. The places of interest in bikes include steering, braking, accelerating, balancing, suspension activation, and vibration. There are two types of forces acting on the motorcycle – Internal forces and External forces with both being inertial forces. The internal forces are caused by the rider and by interaction between components due to friction. The forces caused by rider includes but not limited to the torques the rider can apply between the steering mechanism (handlebars, front fork, front wheel, etc.) and rear frame, and between the rider and the rear frame. Some bikes come with steering dampeners to dissipate undesirable kinetic energy while steering. Some bikes have suspensions which also add to the internal forces caused within the bike. In addition to that, brakes contribute to internal forces due to the friction it creates between the rotating vehicle and the non-rotating frame. There always exist friction between any parts that move against each other.

External forces are those forces affecting the motorcycle and caused by externally occurring factors like wind, gravity, etc. Gravity pulls the rider and all the bike components toward the earth. At contact point of each tire there are ground reaction forces with both horizontal and vertical components. The vertical components mostly counteract the force of gravity, but also vary with braking and accelerating. The horizontal components are in response to propulsive forces, braking forces, and turning forces. These horizontal forces are the result of friction between the wheels and the ground, including rolling resistance. Aerodynamic forces are a majorcontributor to the external forces of a bike. They are due to the wind are occur mostly in the form of drag, but can also be from crosswinds. At normal speeds on flat ground, aerodynamic drag is the largest force resisting forward motion. At faster speed, aerodynamic drag becomes the largest force resisting forward motion.

Turning forces are another contributor to external inertial force and are generated during manoeuvres for balancing in addition to just changing direction of travel. Gyroscopic forces acting on rotating parts such as engine,transmission, wheels, etc., are also due to the inertia of those rotating parts.

Tatyaso A.Garande et al, This paper discussed the various modes of transport available and suitable for physically handicapped persons for long and short distance travel. The modes are classified as per the maneuverability, ease, automationand comfort. Various machines used for travelling of disabled persons include wheelchair, automatic wheelchair, Smart wheelchair, retrofitted vehicles, tricycles, modified cars. Systematic comparison of all these vehicles is carried out in this paper. Rashmi Urdhwareshe et al, Establishing National Approval Scheme for modifications to Vehicles Driven by Physically Challenged. Po Er Hsu et al, Mobility Assistance Design of the Intelligent Robotic Wheelchair. Leishman et al, This paper described the implementation of assistance to the driving of a smart wheelchair through a deictic approach. Initially, a state of the art of mobility assistance, interfaces and types of commands for smart wheelchairs is presented. The deictic concept and more particularly, the approach used for the design of interface are examined. Then the two functionalities carried out to implement this type of interface, as well as methodology used to control wheelchair are illustrated.

Ethirajan Bhaskaran, The primary objective of this project was to develop a vehicle for Disabled Persons especially for people without legs. Here, handle bar is used with accelerator and brake incorporated. The Permanent Magnet Direct Circuit (PMDC) Motor is used in the brake drum driven by battery. Current since this is a vehicle primarily designed for Disabled Persons, the vehicle is designed considering their disability in mind and much importance is given regarding the safety of the passenger after. Hence driverergonomics plays a key role in the designing of vehicle for legless persons.Handle bar designed to suit both manual steering and electric steering. Chassis design and center of Gravity is calculated and the Brake is kept in the Handle Bar. Loi, K The authors of this paper discussed the new standards of tourism development on critical issues such as quality, sustainability, image, innovation and accessibility. Brahim Rekiek et.al, the objective of this paper is to implement Grouping

Genetic Algorithm to find optimal routes for transporting handicapped people in terms of service quality and number of used vehicles. S S Tachakra, The paper discussed the psychological benefits of riding vehicle for persons with disabilities. Also, the author describes the various modifications and driving aids that can be done to existing cars. The author also discusses the various types of disabilities and the impact they could have on the livelihood of the persons. Arun Raju.C et al, This study aimed at designing and fabricating a 3-wheeler with dual steering system for people with locomotive disabilities and armless people.A greater steering effort is required in the case of a four-wheeler compared to a three-wheeler.

2. Lateral Dynamics

Lateral dynamics deals with the Motion that is out of the central plane of symmetry. They include balancing, leaning, steering, and turning.

Balance

There are three factors that determine how well the motorcycle balance can be achieved – stability, self-stability and controllability. Stability is the ability of a system to remain in mechanical equilibrium i.e., a state where the net forces acting on the system is zero. In a perfectly balanced motorcycle, the net force on each of its individual parts is zero. Self-stability is defined as rider-controlled stability of motorcycles. The inputs that the rider gives to the motorcycle contribute to the self- stability of the vehicle. Controllability is also a defining factor for self- reliability. A bike remains upright when it is steered so that the ground reaction forces exactly balance all the other internal and external forces it

experiences, such as gravitational if leaning, inertial or centrifugal if in a turn, gyroscopic if being steered, and aerodynamic if in a crosswind. Steering may be supplied by a rider or, sometimes, by the bike itself. This self-stability is generated by a combination of several effects that depend onthe geometry, mass distribution, and forward speed of the bike. Tires, suspension, steering damping, and frame flexibility can also influence it in motorcycles. Controllability is an important property of a motorcycle, and the controllability property plays a crucial role in many control problems, suchas stabilization by feedback, or optimal control.

Forward speed

The rider applies torque to the handlebars in order to turn the front wheel and to control lean and maintain balance. At low speeds, larger steering angles are required to quickly move the ground contact points laterally, however at high speeds; small steering angles can achieve the sameresults in the same amount of time. Due to this, it is usually easier to maintain balance at high speeds. As self-stability typically occurs at speedsabove a certain threshold, going faster increases the chances that a bike is contributing to its own stability.

3. Center of mass location

The closer the center of mass of the combined bike and rider is to thefront wheel, the less the front wheel has to move laterally in order to maintain balance. Conversely, the closer the center of mass is located to the rear wheel, the more front wheel lateral movement or bike forward motion is required to regain balance. Mass over the rear wheel can be more easily controlled if it is lower than mass over the front wheeling.

A bike can be treated like an inverted pendulum. A tall bike with a high center of mass can be easily to balanced when riding than a bike with low center of mass because the tall bike's lean rate (rate at which its angle of lean increases as it begins to fall over) will be slower. However, when the bike is stationary the opposite becomes true. A top-heavy bike requires more effort to keep upright, when stopped in traffic for example, than a bike which is just as tall but with a lower center of mass. A small force at the seat or handlebars at the top of the bike easily moves a large mass if the mass is closer to the ground.

Trail

Trail is the distance that the front wheel ground contact point trails behind the steering axis ground contact point. The steering axis is the axis about which the entire steering mechanism pivots. In traditional bike designs, with a steering axis tilted back from the vertical, positive trail tends to steer the front wheel into the direction of a lean. In a lean, gravity provides this force. Trail can be increased by increasing the wheel size, decreasing the head angle, or decreasing the fork rake. The more trail a bike has, the more stable it feels, but too much trail can make a bike feel difficult to steer.

Wheelbase

Wheelbase is the horizontal distance between the ground contact points of the front and rear wheels. The radius of curvature for a given steer angle and lean angle is proportional to the wheelbase. The wheelbaseincreases when the bike is leaned and steered.

Gyroscopic effects

The role of the gyroscopic effect in bike designs is to help steer the front wheel into the direction of a lean. This phenomenon is called precession and the rate at which an object to its rate of spin. The slower a front wheel spins, the faster it will process when the bike leans, and vice versa. The rear wheel is prevented from precessing as the front wheel does by friction of the tires on the ground, and so continues to lean as though it were not spinning at all. Therefore, gyroscopic forces do not provide any resistance to tipping.

Longitudinal Dynamics

In order for a bike to make a turn the front wheel must aim in the desired direction. Friction between the wheels and the ground generates the centripetal acceleration necessary to alter the course from straight ahead as a combination of cornering force and camber thrust. Bikes must also lean during a turn to balance the relevant forces: gravitational, inertial, frictional, and ground support.

Counter steering

In order to initiate a turn and lean in the direction of that turn, a bike must steer in the opposite direction for a short time. This is called counter steering. While counter steering, with the front wheel at a finite angleto the direction of motion, a lateral force is developed at the contact patch of the tire. This force creates a torque around the longitudinal (roll) axis of the bike, and this torque causes the bike to lean away from the initially steered direction and toward the direction of the desired turn.

Steady-State Turning

When a turn is established, the torque must be applied to the steeringmechanism in order to maintain a constant radius at a constant forward speed. At low speeds, the self-stability of the bike will cause it to tend to steer into the turn, righting itself and exiting the turn, unless a torque is applied in the opposite direction of the turn. At high speeds however, the instability will cause it to tend to steer out of the turn, increasing the lean, unless a torque is applied in the direction of the turn.

Steering Angle

Steering angle is the angle at which the front assembly is rotated about the steering axis, necessary to maintain a steady-state turn. Steering angle is affected by several effects like the lean of the bike, slip angles, camber thrust, etc.

Gyroscopic Effects

One of the effects of turning the front wheel is a roll moment caused by gyroscopic precession. The magnitude of this moment is proportional tothe moment of inertia of the front wheel, its spin rate, the rate at which the rider turns the front wheel by applying a torque to the handlebars and the angle between the steering axis and the vertical.

Tires

Tires have a large influence over motorcycle handling. Tires influencebike dynamics in two ways: finite crown radius and force generation. Increase in the crown radius of the front tire decreases the size or eliminateself-stability. Increasing the crown radius of the rear tire has the opposite effect, but to a lesser degree. Tires generate the lateral forces necessary for steering and balance through a combination of cornering force and camber thrust. A tire inflation pressure also plays a major role in the behavior of a motorcycle at high speeds.

High Side

A high side is a type of bike motion which is caused by a rear wheel gaining traction when it is not facing in the direction of travel, usually after slipping sideways in a curve. This can occur under heavy braking, acceleration, a varying road surface, or suspension activation, especially dueto interaction with the drive train.

4. PROCEDURE

Ansys R17 version was used for analyzing the individual components of the steering hub. The components were loaded and the total deformation and equivalent (Von – Mises) stresses were analyzed. The analysis was done in the Static Structural tab of Ansys Workbench.

SHAFT

The shaft is loaded axially with a load of 200N and the deformation and stress distribution are analyzed in Ansys. The fixed supportwas given at the third step in the shaft from the right as shown below in the figure 1. This is the part that fixes to the base hub. The fixed support is given on both the axial surface and along the curved surface.

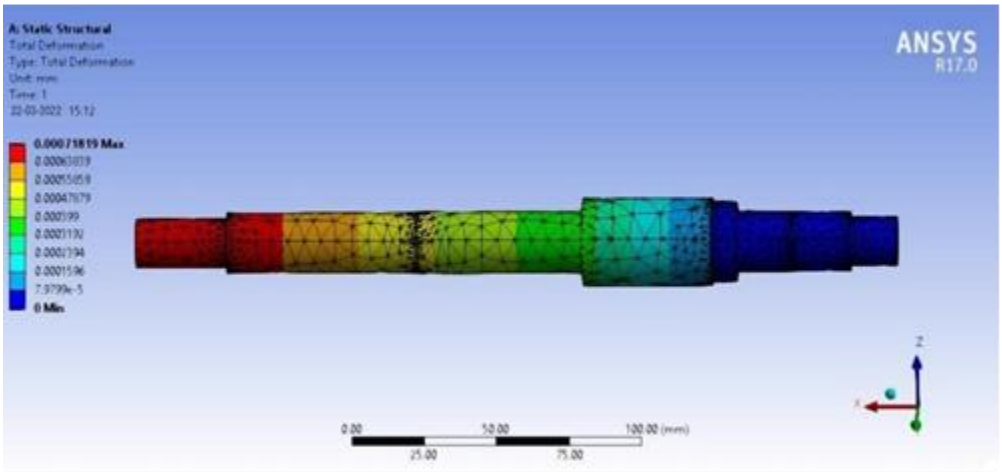

Figure 1 Deformation analysis of stepped shaft due to axial loading

The deformation curve shows that the maximum deformation (0.007mm) occurs at the upper region of the shaft where it connects to the steering plate as shown below in the figure 2

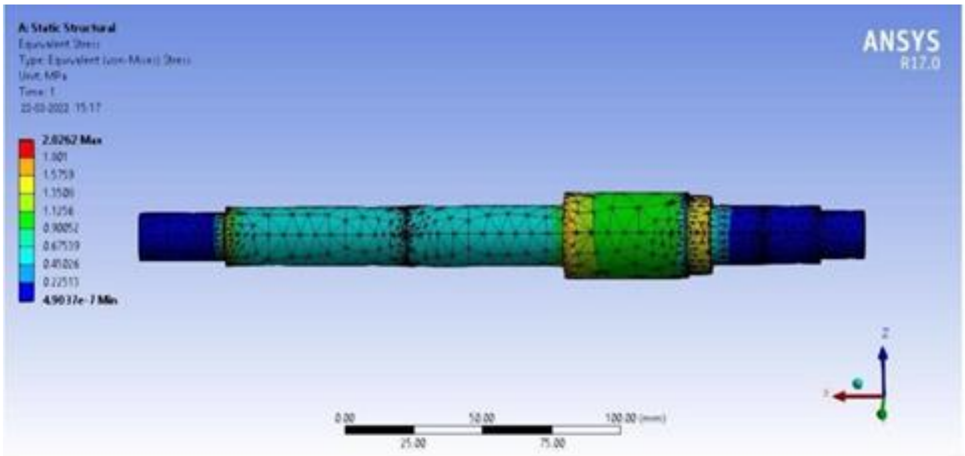

Figure 2 Von-Mises Stress analysis of Shaft under Axial Load

The Stress analysis shows the regions where the highest stresscould occur. The maximum stress is 2.02MPa and the high stress regions are the region where the Steering Plate sits, the region where the Steering Sprocket sits, the region where the shaft fixes to the hub. The top most part and the bottom part experience no stress. Steering Hub Deformation with Load on Footrest The footrest is assembled and a load of 100N is applied along the negative X component on both the footrests. The fixed support is given at the part where the shaft connects to the steering hub as shown below in the figure 3

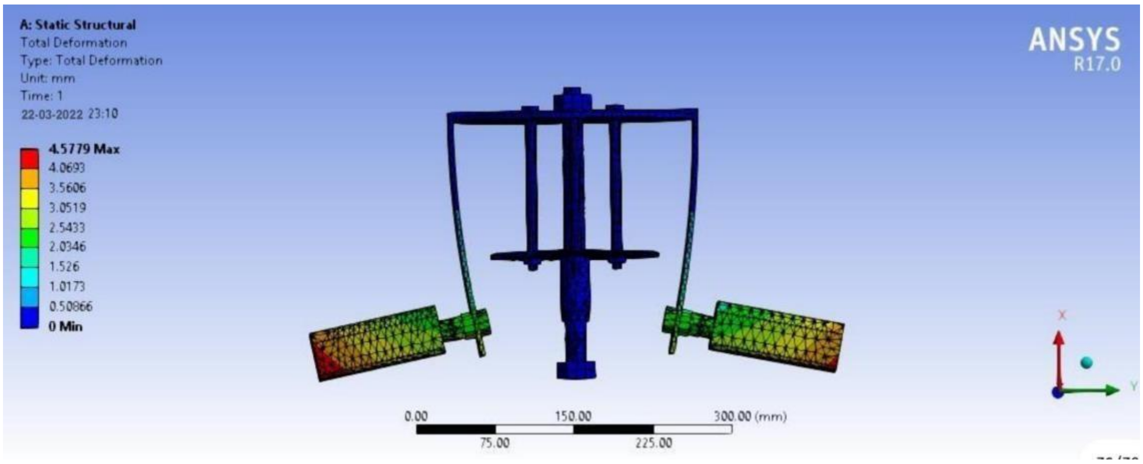

Figure 3 Total Deformation analyses on foot rest

The maximum deformation occurs at the footrests and a little deformation occurs at the extension plate. From this we can infer that the footrest is the critical part of failure i.e., when excessive loads are applied, the footrest will be the first to deform and break.

Steering Hub Assembly

In this analysis the footrest is not included since from our previous analysis we could infer that the footrest would be the point of failure when excessive load is applied. So, in this analysis, we excluded the footrest and applied load directly to the bolt holes in the extension plate to see the deformation in the rest of the steering hub.

Axial Load

The steering hub assembly is loaded axially with a load of 100N on each side of the extension plate at the bolt holes in the negative X- component as shown below in the figure 4

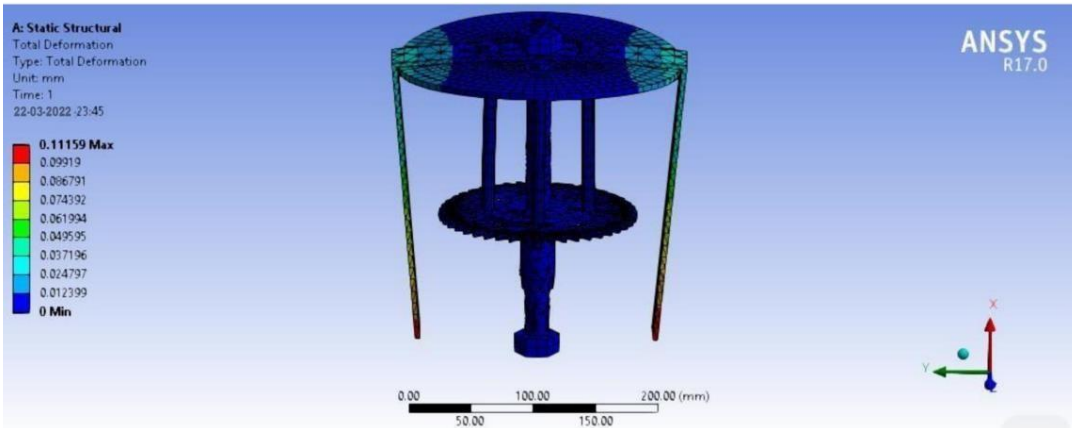

Figure 4 Total Deformation analyses on steering hub due to axial loading

The maximum deformation occurs at the ends of the extension plate. The steering plate also undergoes a small deformation

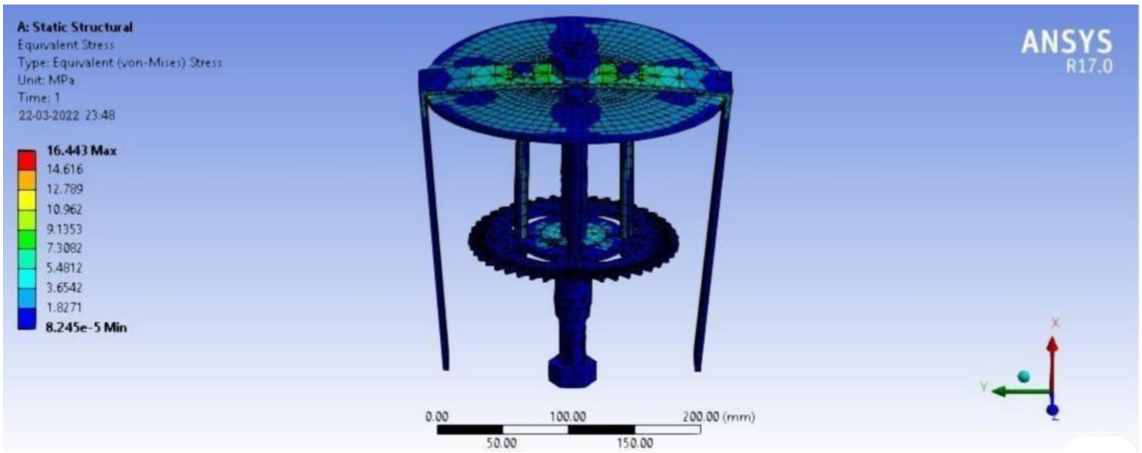

Figure 5 Von-Mises Stress analysis of steering hub under axial load

The stress analysis shows that the maximum stress intensity is on the extension plate and the steering plate at the regions where the bolts are provided. Also, stresses occur on the sprocket around the region where it is bolted and at the region where it connects to the shaft. The supporting pipesalso experience stress as shown below in the figure 5

STEERING LOAD

The steering hub assembly is loaded with 50N on each side of the extension plate at the bolt holes in the negative X-component and 100N in the Z-component. This is to simulate actual steering effort where the foot's weight pushes down on the footrest whereas the steering effort pushes the footrest radially creating a torque as shown below in the figure 6.

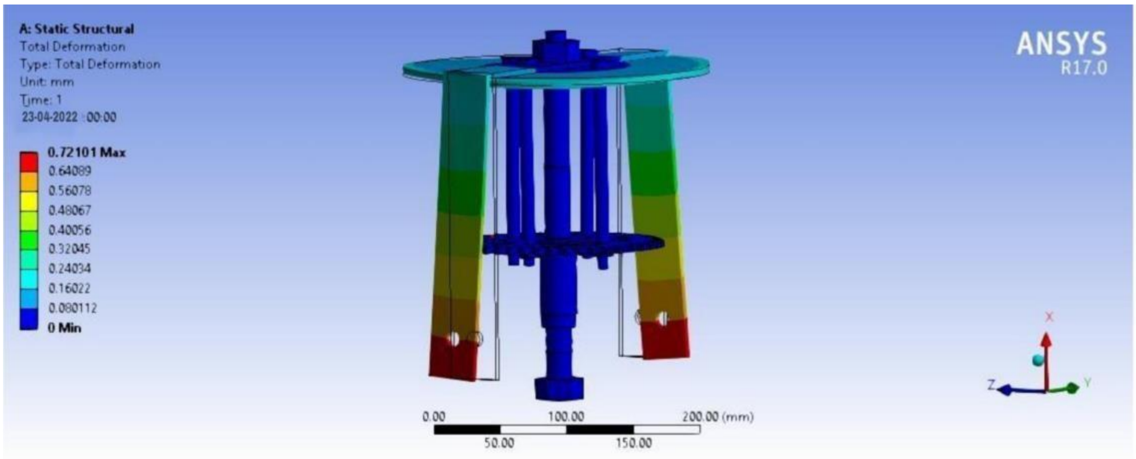

Figure 6 Total Deformation analysis of steering hub while operating

The total deformation is maximum at the ends of the extension plate. Minimal deformation occurs in the steering plate but the other regionsare void of any deformation.

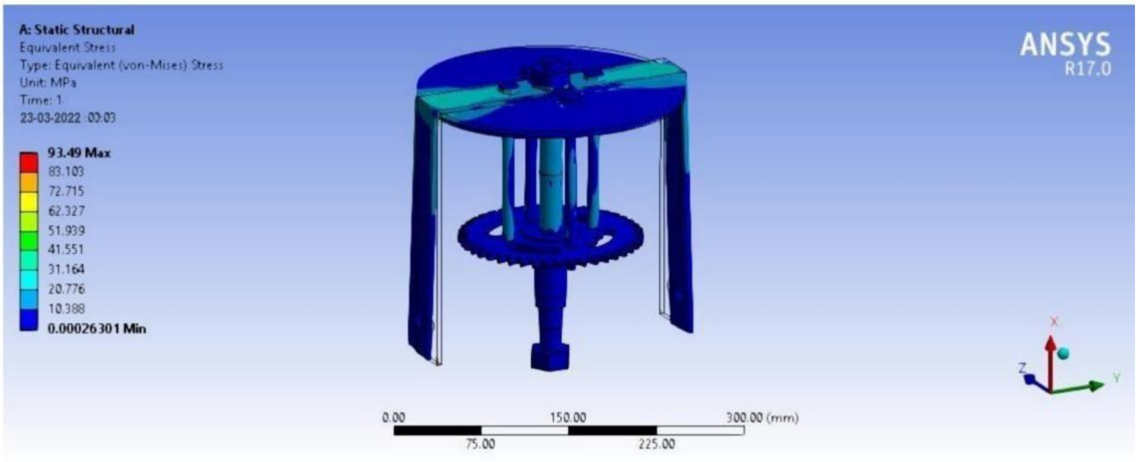

Figure 7 Von-Mises stress analysis of steering hub while operating

When steering, the maximum stress occurs on the extension plate in the region where it connects to the steering plate. The region of shaft between the steering plate and the steering sprocket also experience stress. Stress occurs in the bolts and the supporting pipes as well as shown below in the figure 7

SPROCKET

The sprocket is fixed at the bolt holes to mimic the resistance given to the sprocket by the steering action. Pressure of 0.02 MPa is applied on almost half of the sprocket teeth to mimic the action of chain. Since only half of sprocket is in mesh with the chain, the pressure is applied only to half of the teeth. In the 45 teeth driving sprocket the pressureis applied only on 22 teeth.

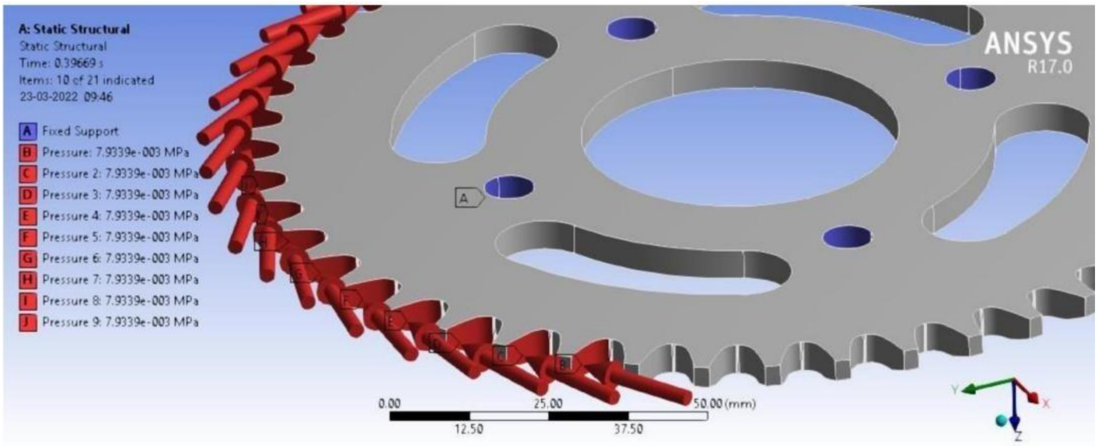

Figure 8 Application of Pressure on Sprocket teeth

The reason for applying pressure instead of force is that in Ansys force can act only in one direction i.e., when deformation occurs in the material the force will not change its direction with respect to the deforming surface. But in case of pressure, the direction changes with respect to the deforming surface. From the Figure 8 The blue regions (A) are fixed andpressure (B, C, D) are applied to the teeth surface.

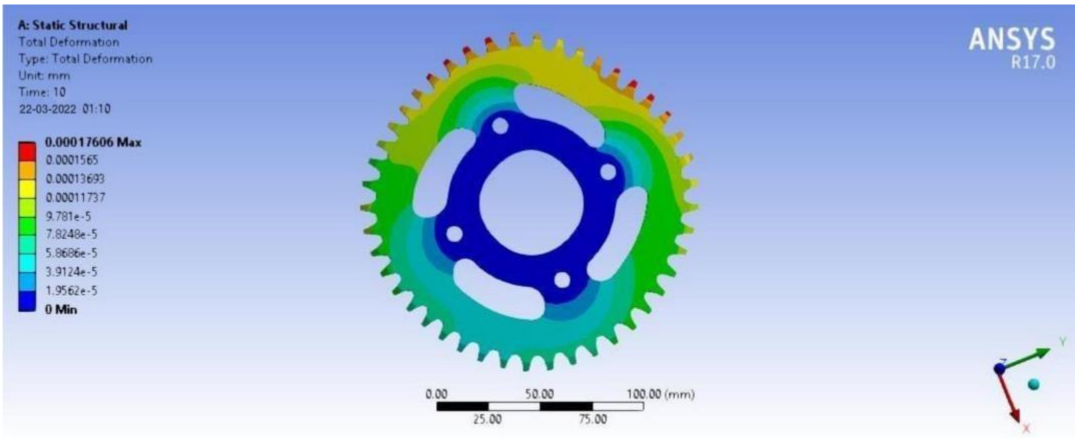

Figure 9 Total Deformation analyses on sprocket under load

The maximum deformation (0.00017mm) occurs at the teeth thatare in mesh with the chain. The region near the meshed teeth also deforms. Minimal deformation occurs at the other half of the sprocket but no deformation occurs at the region where the bolts are connected and near thebore. The regions of maximum stress are around the bolt holes and at the regions around the elliptical cut as shown below in the figure 9

5. CONCLUSION

In this venture we have considered the problems faced by the handicapped people with no arms and executed a foot operating steering system in an E-kart framework. This foot operating steering in E-kart system is going to help a lot of handicapped individuals in their day to day journeys.We hope that our work would help the differently abled persons to not only ride a bike without anybody's help but also break free of the unhealthy psychological effects born out of the feeling of inability toperform activities like an ordinary person.

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