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# ACCESSIBILITY ADAPTATIONS TO ASSIST MOTORCYCLISTS WITH LOWER LIMBS DISABILITY

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***Abstract***: Motorcyclists with lower limbs limitations require customised adaptations to ride motorcycles. Gearshifting and rear brake actuation must be adapted to be performed by the upper limbs of the motorcyclist. Also, motorcyclists with lower limbs disability need assistance from others to be able to get on the motorcycle and maintain equilibrium until reaching a minimum necessary speed. Thus, this work presents accessibility adaptations to assist motorcyclists with lower limbs disability, including the development of a structural support modeled on CAD platform and analyzed by the Finite Element Method. Convergences of solutions were carried out to assure results with good reliability. All adaptations proposed in this work were elaborated aiming ease of manufacturing, mounting and installing, as well as, low cost and minimum maintenance. All the work was developed considering the Honda CBR1000RR. Nevertheless, all ideas and concepts presented in this work can be expanded and adapted to practically all existing motorcycles.

***Keywords:*** Structural Support; Adapted Motorcycles; Disabled Motorcyclists; Finite Element Method; Accessibility; Lower Limbs Disability.

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## Introduction

Motorcyclists with lower limbs limitations, including paraplegia and amputation, require customized adaptations to ride motorcycles. Gear shifting and rear brake actuation must be adapted to be performed by the upper limbs of the motorcyclist. Also, motorcyclists with lower limbs disability need assistance from others to be able to get on the motorcycle and maintain equilibrium until reaching a minimum necessary speed. Therefore, this work aims to serve motorcyclists with lower limbs disability in order to provide them with the opportunity to ride motorcycles again, overcoming the physical limitations by the construction of low cost and efficient accessibility adaptations. The vast majority of existing adaptations change the character of the motorcycle's structure to a tricycle, which does not provide the same sense of freedom and ergonomics that a two-wheeled motorcycle does. Thus, a structural support was developed in this work to be used in a Honda CBR1000RR motorcycle in order to provide equilibrium at standstill and low speeds until the motorcyclist can have autonomy of conduction. Although the work has been developed considering the Honda CBR1000RR motorcycle, all the ideas and concepts presented in this work can be adapted to practically all existing motorcycles. The structural support was modelled on the SolidWorks CAD platform, and analyses with the Finite Element Method were conducted to avoid failures using the Ansys software. The boundary conditions were estimated considering a reasonable scenario for the application. Convergence evaluations of the solutions were carried out to ensure reliable results. Thus, we expect that this work can provide resources to favor motorcyclists with lower limbs disability in order to enable them to ride motorcycles again.

### Review on Accidents Involving Motorcycles

Toma, Njilie, Ghajari and Galvanetto (2010) performed computational simulations with the finite element method related to structural integrity determination of helmets in typical motorcycle crash scenarios. Chen and Liu

(2012) conducted studies to determine the impact of the law that obliges motorcyclist to use helmet while riding a motorcycle in terms of injury and medical costs reductions. They concluded that medical cost fell by 11.5% and the number of skull injuries fell by 18.6%. Chen et al. (2015) performed a study on the number of motorcyclists that advance red light while waiting for the green light of pedestrians to go out. Based on this study, they highlighted standard behaviors that contributed to give rise to severe accidents. Carvalho et al. (2016) accounted for percentages related to accidents involving motorcyclists. They proved that there is a significant influence of some illicit substance, not only alcohol, in accidents involving motorcyclists. French and Gumus (2018) examined whether state-specific texting/handheld bans significantly influence motorcyclist fatalities in the USA. Their findings indicate that motorcyclists are at elevated risk of being a victim of distracted riding and thus could greatly benefit from the implementation of texting/handheld device laws and other traffic policies. Xiao, Huang, Peng and Wang (2018) analyzed motorcyclist head injury based on epidemiological statistical analysis and car-motorcycle accident reconstruction using real-world accident data to obtain a comprehensive understanding about safety effects of helmets on motorcyclists head injury.

## Review on Motorcycle Adaptations

Tong and Jwo (2007) developed an electric motorcycle project featuring high engine power, outstanding performance and good autonomy. Agostoni, Cheli, Leo and Pezzola (2012) opted for a project aiming at riding comfort. They reduced vibrations transmitted to the motorcyclist taking into account the modal response of the motorcycle frame. Murakami, Nishimura and Zhu (2012) performed simulations with the intention of stabilizing a motorcycle during braking when a sharp deviation on the front wheel occurs. They used a steering assistance control system that can be applied in various situations to prevent motorcycle's loss of control increasing safety. Hong (2012) presented in his work an adapted motorcycle for people with lower limbs disability, once himself got polio when a young man, a disease that made his lower limbs significantly weak. Jolly, Krzywinski, Rao and Gupta (2019) conducted a kinematic analysis of a motorcycle rider to identify typical body postures obtained by the motorcyclist while mounting and riding a motorcycle. The identification of typical body postures of motorcyclists was used for the generation of ergonomic garment patterns. Singhania, Kageyama and Karanam (2019) studied the low-speed stability of a motorcycle using a theoretical and experimental approach to identify the parameters that can reduce the rider's effort. Their findings provide parameters to control the motorcycle to achieve low-speed stability.

## Review on Technical Analyses Involving Motorcycles

Kostopoulos, Markopoulos, Giannopoulos and Vlachos (2001) evaluated the energy absorption by a helmet during an impact. They used DYNA3D code to analyze the composite shell that surrounds the motorcyclist's head. Sheng, Xu and Li (2015) made an assessment in measured and predicted traffic noise levels. In another study, Seedam et al. (2017) analyzed driving data to categorize motorcyclists by fuel consumption and riding behavior. Road driving parameters that influence fuel consumption and emissions were then determined. The results revealed that the proportion of idle time significantly influences the fuel consumption and motorcycle emissions. Uberti, Copeta, Baronio and Motyl (2018) propose an approach for the design and development of a new concept of off-road motorcycle to meet the requirements of low environmental impact and lightweight of the vehicle, while maintaining the pleasure of riding in nature. Atahan, Hiekmann, Himpe and Marra (2018) presented a study with development details of a new and versatile motorcycle barrier coupled with an existing vehicle barrier in order to safely redirect motorcyclists during a collision event.

## Review on Motorcycles and Safety

French, Gumus and Homer (2009) conducted a study that provided a comprehensive investigation on fatal and nonfatal injuries, considering data from 1990 to 2005, analyzed from the perspective of determining how various state policies can affect motorcyclists' safety. The results consistently showed that helmet has the most significant effect on fatal and nonfatal injuries. Compulsory motorcyclist education programs and speed limits on rural roads have significantly reduced the severity of accidents. Erdogan et al. (2013) evaluated the effectiveness of the protective clothing in relation to injuries caused by accidents with motorcyclists. Silva et al. (2011) presented a study to identify factors associated with couriers' accidents in two medium-sized cities in southern Brazil. The results revealed the lack of strategies to reduce accidents and the need for better working conditions for these motorcyclists. Vasconcellos (2012) considering the Brazilian scenario analyzed the fact that deaths in traffic associated with motorcyclists increased exponentially, from 725 in 2006 to 10,143 in 2010. He tried to address the involved issues, like public policies, changes in traffic regulations and economic/social reasons. Teoh and Campbell (2010) analyzed fatal crash data to highlight differences in associated motorcycle types and motorcyclists' behaviors. Truong, Nguyen and De Gruyter (2018) explored risky behaviors while riding a motorcycle with data obtained from a survey of university students in Vietnam. Mobile phone use while riding was associated with multiple risky riding behaviors. They suggested a coordinated approach to reduce multiple risky behaviors. Gil, Savino, Piantini and Pierini (2018) studied a camera-based sensor for the application of preventive safety in tilting vehicles.

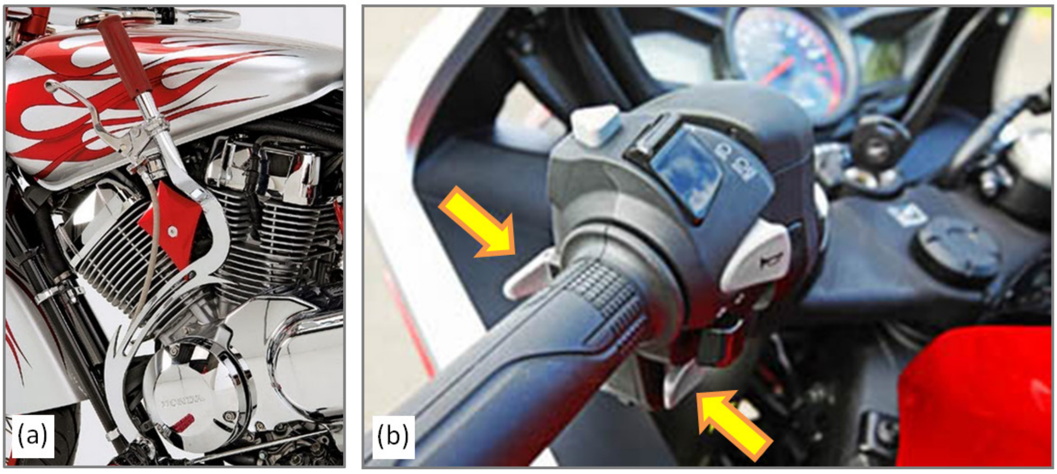
## Accessibility Adaptations

In order to meet the main objective of this work, gearshifting and rear brake actuation must be adapted according to motorcyclist's needs. It is assumed that motorcyclist has a reduction or lack of movements in lower limbs. Thus, gearshifting and rear brake actuation must be adapted to be performed in a manual way. In addition, the motorcyclist with lower limbs disability needs assistance from others to be able to get on the motorcycle and maintain equilibrium until reaching a minimum necessary speed. Thus, a structural support mechanism is also necessary.

## Gearshifting Actuation

Adaptations that enable gearshifting can be made by mechanical or electromechanical means. In general, the mechanical method requires manual actuation for gearshifting. The lever location is normally near to the handlebar and it works with the aid of steel wires, as shown by Figure 1(a). This mechanism is popularly known as suicide lever. The electromechanical method occurs by means of small electric circuits that can be activated on the handlebar, along with a small motor that will be responsible for sequential or automatically gearshifting, Figure 1(b). Considering the automatic mode, it is simply necessary for the motorcyclist to select the riding mode and gearshifting will occur automatically.

*Figure 1. Accessibility adaptations for gearshifting: (a) Mechanical suicide lever; (b) Honda VFR 1200F electromechanical automatic gearshifting.*




## Rear Brake Actuation

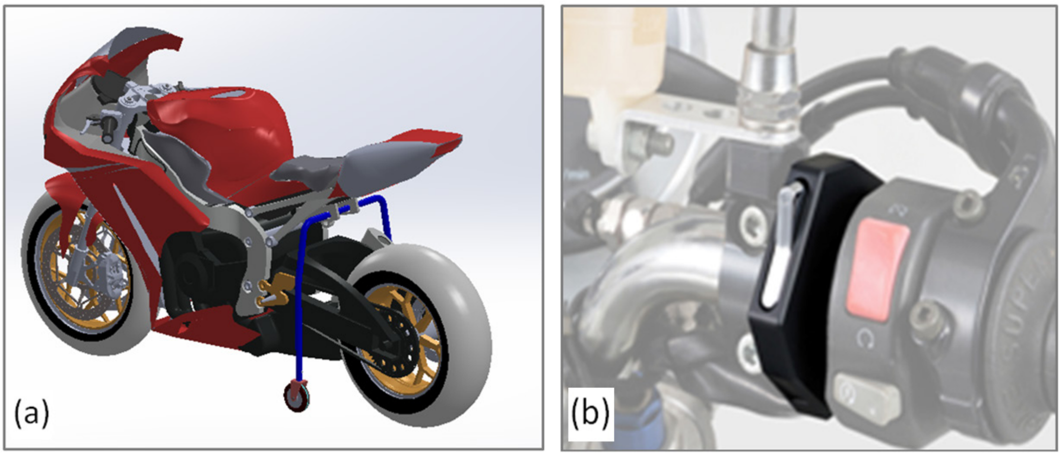
Traditionally, the rear brake is actuated by the use of a pedal located on the right side of the motorcycle. Considering the existence of lower limbs disability, rear brake actuation must be done by hands. Some adaptations can be made, from the rudest and cheapest but functional to the most refined and technological at higher costs. An alternative is to use a larger flex known as Aerokip with an oil reservoir for brake fluid attachment. This adaptation allows the use of two maniples, one for front brake actuation and one for the rear brake actuation, as shown by Figure 2. For a better adaptation, it is suggested the use of disc brakes, which can be very well fitted to this system and, also, to practically all existing motorcycles.

*Figure 2. Accessibility adaptation for rear brake actuation.*

## Structural Support Actuation

The developed structural support must be capable of being operated according to motorcyclist's wish by using a switch attached to the handlebar. Figure 3(a) shows Honda CBR1000RR motorcycle with the developed structural support in a position that allows motorcycle resting or running at low speeds. Once a minimum speed is reached, allowing riding autonomy, the same switch can be operated again to rotate the structural support to a partly horizontal position giving complete freedom to the motorcyclist. Figure 3(b) shows an example of the switch that can be used to activate/deactivate the structural support mechanism.

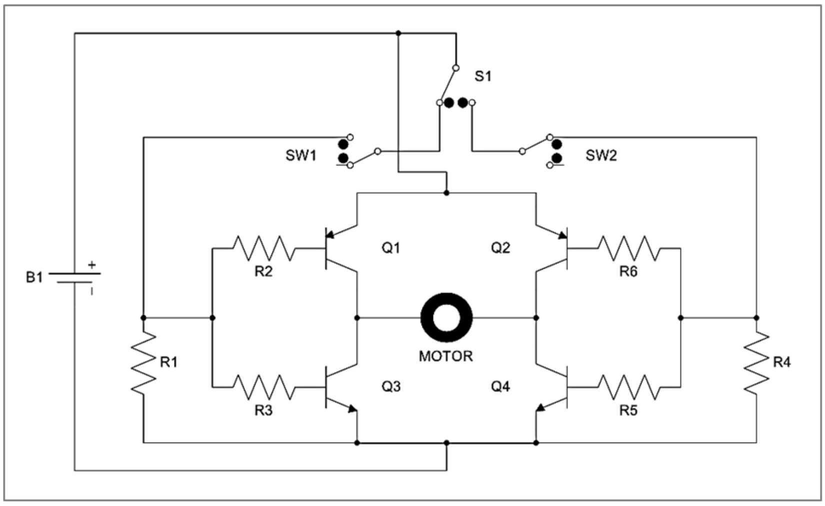
*Figure 3. (a) Honda CBR1000RR with structural support attached; (b) Switch that can be used to activate/deactivate the structural support mechanism.*




By means of a small electronic circuit, as shown by Figure 4, a 12V DC electric motor starts and keeps activated for a few seconds until the limit switch is activated, being enough for the support to rotate to a partly horizontal position or, in an inverse operation, to a partly vertical position. The components used in this circuit are listed below:

- Q1 and Q2: TIP32 - PNP Power Transistors;
- Q3 and Q4: TIP31 - NPN Power Transistors;
- R1 and R4: 200Ω Resistors;
- R2, R3, R5 and R6: 250Ω Resistors;
- S1: 2-Position Selector Switch (Switch);
- SW1: Normally Closed Limit Switch (NC) - Lower Limit Switch;
- SW2: Normally Closed Limit Switch (NC) - Upper Limit Switch;
- B1: 12V DC battery.

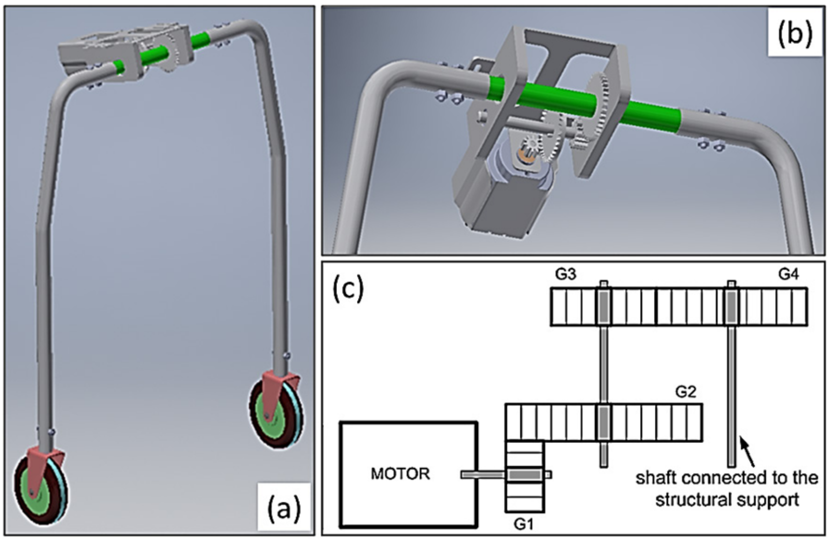
*Figure 4. Electronic circuit used to activate/deactivate the support.*




## Transmission System of the Structural Support

Figure 5(a) shows the structural support developed in this work. It is possible to see its main constructive details, including the fixation part to the motorcycle. Figure 5(b) shows the gear set that gives rise to the transmission system of the structural support and is responsible together with the electrical motor for the forward and backward movement of the rods and casters. The gear transmission system is shown schematically in Figure 5(c).

*Figure 5. (a) Perspective view of the developed structural support with its rods and casters; (b) Detailing of the gear transmission system and electric motor; (c) Schematic diagram of the gear transmission system.*



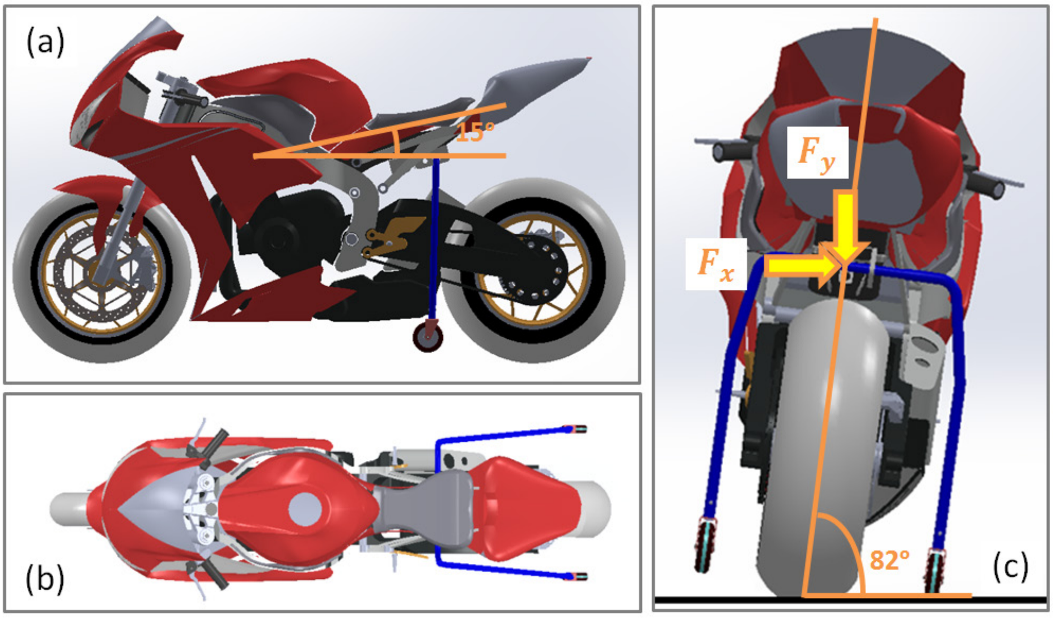
A speed-torque ratio has been defined for the developed structural support in order to achieve satisfactory results. Considering the four gears G1, G2, G3 and G4, they respectively have 10, 40, 14 and 36 teeth. This will provide a final gear ratio of approximately 10 times. Thus, it will be necessary for gear G1 to rotate 10 times in order that gear G4 rotates 1 time. Therefore, the movement speed of the structural support will be reduced by 10 times from the engine speed. On the other hand, with respect to the transmitted torque, there will be a 10 times increasing from engine torque to G4 gear, making it easier for the structural support to leave the state of inertia and/or face some kind of resistance.

## Finite Element Analyses

In order to obtain satisfactory results, some boundary conditions were adopted according to the motorcycle and motorcyclist weights, so that the rods and casters of the structural support do not suffer damages or failures. Figure 6 shows three views of the structural support with the Honda CBR1000RR motorcycle. Figure 6(a) shows the inclination of the electric motor in relation to the ground. Figure 6(b) shows the top view of the motorcycle with the developed structural support in the partly horizontal position. Figure 6(c) shows the inclination of the motorcycle in relation to the ground when in resting condition. Thus, it is possible to estimate the forces acting on the rods and casters of the structural support with respect to the $x$ (horizontal) and $y$ (vertical) components. Taking into account some reasonable factors associated with the application, it is considered for Honda CBR1000RR with ABS brakes a weight of approximately 190 kg (1900 N) and for the motorcyclist a weight of approximately 120 kg (1200 N). At the critical moment when the motorcyclist climbs the motorcycle in resting condition, it is considered a load of 60% of the motorcycle’s weight and a load of 80% of the motorcyclist’s weight transmitted to the structural support, as it is understood that a great part of the motorcycle's weight will be supported by the ground. Similarly, the motorcyclist's weight will not be fully transmitted at once to the structural support since in many cases the motorcyclist does not have one or both full legs, and, on the way up, the motorcyclist will put his legs under the motorcycle seat, and then pull his trunk or vice-versa. Thus, the following boundary conditions were used for the computer simulations:

- Motorcycle's weight: 1900 N × 60% = 1140 N;
- Motorcyclist's weight: 1200 N × 80% = 960 N;
- $F_x$= 2100 N x cos (82°) = 292 N;
- $F_y$= 2100 N × sin (82°) = 2080 N.

*Figure 6. (a) Inclination of the DC electric motor in relation to the ground; (b) Top view of motorcycle with structural support in the partly horizontal position; (c) Inclination of the motorcycle in relation to the ground.*




Computer simulations were conducted taken into account Aluminum 6351-T6 alloy and AISI 1060 Steel normalized at 900°C. The finite element analyses were performed based on the acting stresses and deformations values, with the respective calculation of safety factor for each case. The main mechanical properties (Young's modulus, *E*; Poisson's ratio, *v*; and, Yield stress, $\sigma_y$;) used in the computer simulations for Aluminum 6351-T6 alloy and AISI 1060 Steel normalized at 900ºC are, respectively,

$$E_{Al6351\text{-}T6} = 71 \text{ GPa};\ \nu_{Al6351\text{-}T6} = 0.33;\ \sigma_{y\_Al6351\text{-}T6} = 283 \text{ MPa};$$
$$E_{AISI\_1060\_Steel} = 200 \text{ GPa};\ \nu_{AISI\_1060\_Steel} = 0.285;\ \sigma_{y\_AISI\_1060\_Steel} = 420 \text{ MPa}.$$

The meshes used to discretize the problem geometries are of hexadominant type. A hexadominant mesh is composed mainly of hexahedral elements and their respective variations. In Ansys, a hexadominant solid mesh is formed by Solid186 elements. Solid186 is a higher order 3D 20-node solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal *x*, *y*, and *z* directions. The element supports plasticity, hyperelasticity, creep, stress stiffening, large deflection, and extensive strain capabilities. It also has mixed formulation capability for simulating deformations of nearly incompressible elastoplastic materials, and fully incompressible hyperelastic materials. The geometry, node locations, and the coordinate element system for this element are shown in Figure 7. A prism-shaped element may be formed by defining the same node numbers for nodes K, L, and S; nodes A and B; and nodes O, P, and W. Similarly, pyramidal- and tetrahedral-shaped elements may also be formed as shown. Their respective shape functions and integration points can be found in Zienkiewicz (1997). Convergence analyses of the solutions were performed using adaptive mesh refinements on the places of more significant interest in order to obtain more reliable results, Leme et al. (2019). In Figure 8, it can be seen the created initial mesh for the rod. In Figure 9, it can be seen the created initial mesh for the caster bracelet. The applied boundary conditions for the rod analyses can be seen in Figure 10(a). The applied boundary conditions for the caster bracelet can be seen in Figure 10(b). In both cases, the red color indicates the applied static loading and the blue color indicates the fixed condition.

*Figure 7. Solid186 element in Ansys and its variations.*

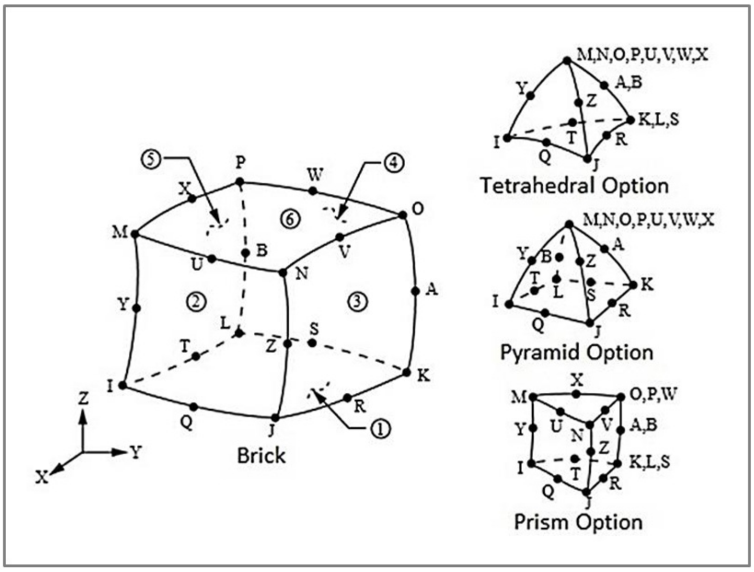



*Figure 8. Views of the initial mesh of the rod of the structural support.*

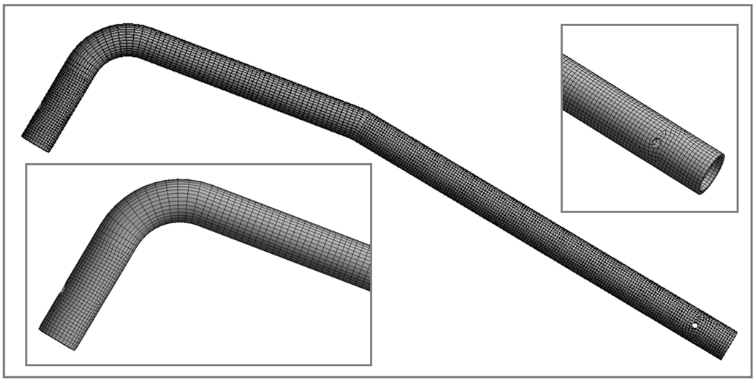


*Figure 9. Views of the initial mesh of the caster bracelet.*

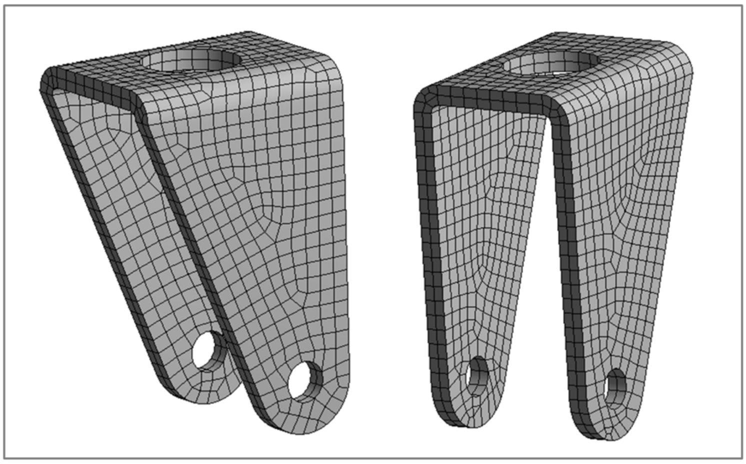
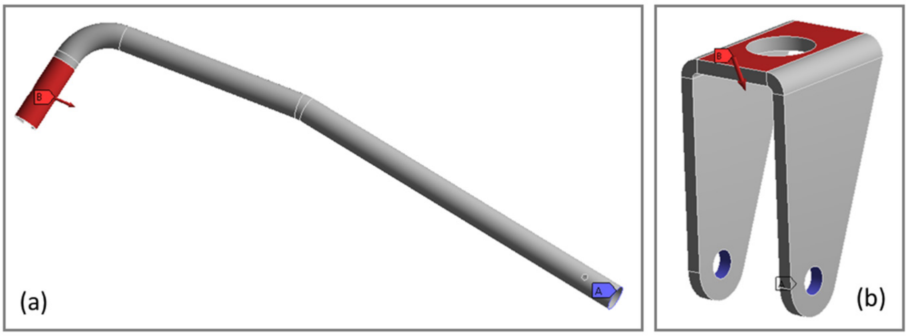


*Figure 10. (a) Applied boundary conditions for the structural support rod; (b) Applied boundary conditions for the caster bracelet.*




## Results and Discussions

Solution maps for total deformations and equivalent von Mises stresses were calculated considering the structural support rod and caster bracelet. Figure 11 shows a total deformations map for the rod. This total deformations map is similar for both steel and aluminum alloys and for the various rod thicknesses taken into account. Figure 12 shows a von Mises equivalent stresses map for the rod. This von Mises equivalent stresses map is also similar for both steel and aluminum alloys and for the various rod thicknesses taken into account. The maximum calculated solution values for the rod are shown in Table 1, considering each thickness analyzed. In both cases, for total deformations and for von Mises equivalent stresses, the red regions show the highest solution values and the blue regions show the lowest solution values.

*Figure 11. Total deformations map for the structural support rod.*

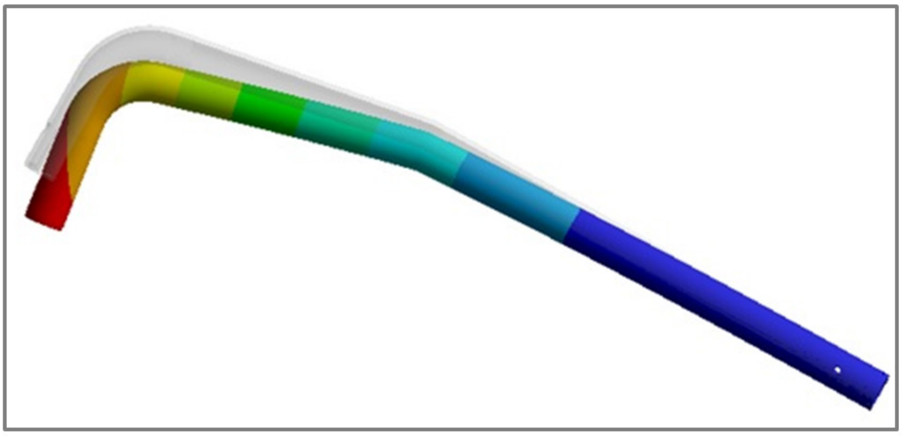
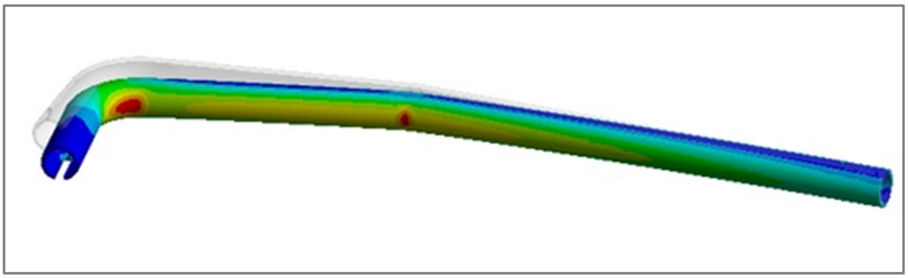


*Figure 12. Von Mises equivalent stresses map for the structural support rod.*

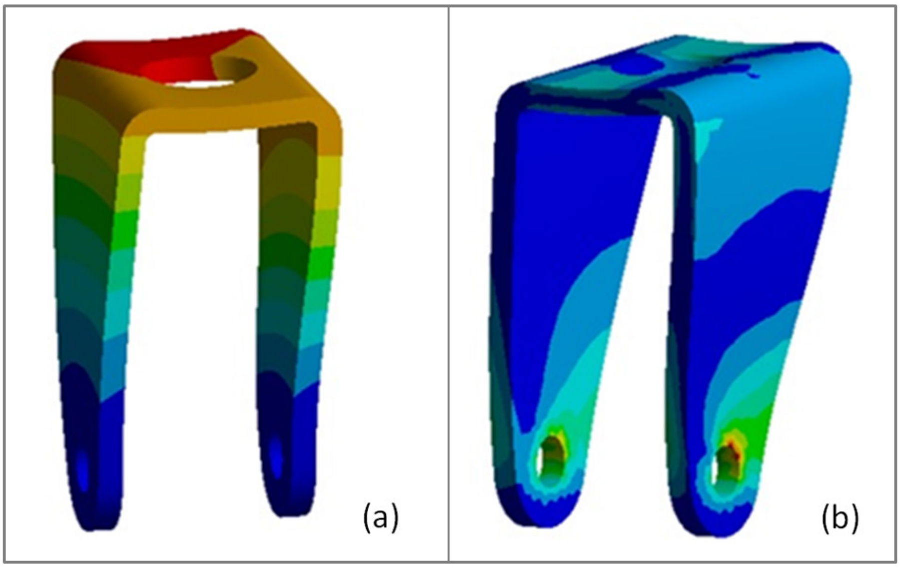


From the results presented in Table 1, it can be observed that for steel rods with a wall thickness of 3 mm onwards, the manufacturing can be accepted, since there is a good safety margin (safety factor higher than 1.96). When considering aluminum for the rods, it can be accepted a wall thickness from 4 mm onwards (safety factor higher than 1.81). For the caster bracelet, only 4 mm thickness steel was analyzed in the computer simulations. In this condition of 4 mm thickness steel, the calculated maximum total deformation was 0.119 mm, and the maximum von Mises equivalent stress was 246.7 MPa, which results in a safety factor of 1.70. Figure 13(a) shows the total deformations map for the caster bracelet; and, Figure 13(b) shows the von Mises equivalent stresses map. In both cases, the red regions have the highest solution values, and the blue regions have the lowest solution values.

*Table 1. Maximum total deformations and maximum von Mises stresses considering various thicknesses of the structural support rod.*

| **Material** | **AISI 1060 Steel** | | | | **Aluminum 6351-T6** | | | |
|---|---|---|---|---|---|---|---|---|
| Thickness (mm) | 2 | 3 | 4 | 5 | 2 | 3 | 4 | 5 |
| Total Deformation (mm) | 11.3 | 7.39 | 5.48 | 4.35 | 31.8 | 20.8 | 15.4 | 12.2 |
| von Mises Stress (MPa) | 356 | 214 | 156 | 125 | 364 | 218 | 156 | 126 |
| Safety Factor | 1.18 | 1.96 | 2.70 | 3.35 | 0.78 | 1.30 | 1.81 | 2.25 |

*Figure 13. Caster bracelet: (a) Total deformations map; (b) von Mises stresses map.*




Convergence analyses of the solutions were carried out in order to ensure reasonable reliability of the results. Table 2 shows the comparison among the solution values calculated before and after adaptive mesh refinements for the various rod thicknesses. Table 3 shows the comparison among the solution values calculated before and after adaptive mesh refinements for the caster bracelet. In both cases, it is possible to observe a small variation Δ[%] in the solutions regarding the initial and final meshes, which demonstrates that all the solutions converged to stabilization and, therefore, the achieved results have a good degree of reliability.

*Table 2. Convergence analyses for the structural support rod.*

| **Quantity** | **2 mm Thickness** | | **Δ [%]** | **3 mm Thickness** | | **Δ [%]** |
|---|---|---|---|---|---|---|
| Nodes of the Mesh | 8769 | 10914 | 24.5 | 8787 | 11246 | 28.0 |
| Elements of the Mesh | 8713 | 10865 | 24.7 | 8732 | 11194 | 28.2 |
| Total Deformation [mm] | 11.30 | 11.29 | -0.02 | 7.396 | 7.394 | -0.02 |

| Quantity | 2 mm Thickness | | Δ [%] | 3 mm Thickness | | Δ [%] |
|---|---|---|---|---|---|---|
| von Mises Stress [MPa] | 355.3 | 356.4 | 0.30 | 212.6 | 213.9 | 0.63 |
| **Quantity** | **4 mm Thickness** | | **Δ [%]** | **5 mm Thickness** | | **Δ [%]** |
| Nodes of the Mesh | 8769 | 11973 | 36.5 | 8787 | 12389 | 41.0 |
| Elements of the Mesh | 8713 | 11923 | 36.8 | 8732 | 12340 | 41.3 |
| Total Deformation [mm] | 5.488 | 5.485 | -0.06 | 4.351 | 4.348 | -0.08 |
| von Mises Stress [MPa] | 153.6 | 155.7 | 1.36 | 124.0 | 125.4 | 1.15 |

*Table 3. Convergence analyses for the structural support caster bracelet.*

| Quantity | 4 mm Thickness | | Δ [%] |
|---|---|---|---|
| Nodes of the Mesh | 9345 | 16275 | 74.2 |
| Elements of the Mesh | 2472 | 8904 | 260 |
| Total Deformation [mm] | 0.120 | 0.119 | -0.74 |
| von Mises Stress [MPa] | 257.8 | 246.7 | -4.33 |

## Conclusions

This work aims to serve motorcyclists with reduced or lack of mobility in lower limbs in order to provide them with the opportunity to ride motorcycles again, overcoming physical limitations through the construction of low-cost accessibility adaptations. The accessibility adaptations presented in this work include gear shifting, rear brake actuation and the development of a structural support. All adaptations have been proposed considering the Honda CBR1000RR motorcycle. However, the ideas and concepts presented in this work can also be implemented in practically any existing motorcycle. A small, low-cost electronic circuit was elaborated to enable fault-free activation and deactivation of the structural support. In addition, a gear transmission system was developed to allow torque amplification and angular speed reduction from the DC electric motor by approximately 10 times. All the structural support design was performed on the SolidWorks CAD platform. Stresses and deformations analyses by the finite element method were conducted to avoid failures and to ensure a proper functioning of the mechanism. In this way, the material and geometry of the structural support were defined. The applied boundary conditions were estimated considering a reasonable scenario according to the application. Convergence analyses of the solutions were carried out in order to ensure good reliability of the results. For steel rod, a wall thickness from 3 mm onwards can be considered acceptable for manufacturing. For aluminum rod, it is possible to accept the manufacturing from a wall thickness of 4 mm onwards; however, the existing deformations for aluminum alloy would be more significant when compared to steel alloy. Considering the caster bracelet, only 4 mm thickness steel onwards was considered approved for manufacturing. If aluminum alloy or thinner steel were used instead, there would be, according to the applied boundary conditions, acting stresses very close to the material's yielding limit, which would probably fail. Finally, at this stage of the project, we are focused primarily on the engineering aspects of the components. However, as future objectives, we will also focus on usability, design and aesthetics issues.

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## References

[1] Agostoni, S.; Cheli, F.; Leo, E. and Pezzola, M. (2012). An innovative multi dof TMD system for motorcycle handlebars designed to reduce structural vibrations and human exposure. Mechanical Systems and Signal Processing, 31, 298-315. DOI: 10.1016/j.ymssp.2011.11.018

[2] Atahan, A.O.; Hiekmann, J.M.; Himpe, J.; Marra, J. (2018). Development of a continuous motorcycle protection barrier system using computer simulation and full-scale crash testing. Accident Analysis and Prevention, 116, 103-115. DOI: 10.1016/j.aap.2017.04.005

[3] Carvalho, H.B.; Andreuccetti, G.; Rezende, M.R.; Bernini, C.; Silva, J.S.; Leyton, V.; D'andréa Greve, J.M. (2016). Alcohol and drug involvement in motorcycle driver injuries in the city of Sao Paulo: analysis of crash culpability and other associated factors. Drug and Alcohol Dependence, 1, 162, 199-205. DOI: 10.1016/j.drugalcdep.2016.03.007

[4] Chen, C.-S.; Liu, T.-C. (2012). Medical cost and motorcycle helmet law in Taiwan. Economics Research International, 2012, 1-9. DOI: 10.1155/2012/920901

[5] Chen, P.-L.; Pai, C.-W.; Jou, R.-C.; Saleh, W.; Kuo, M.-S. (2015). Exploring motorcycle red-light violation in response to pedestrian green signal countdown device. Accident Analysis and Prevention, 75, 128-136. DOI: 10.1016/j.aap.2014.11.016

[6] Erdogan, M.O.; Sogut, O.; Colak, S.; Ayhan, H.; Afacan, M.A.; Satilmis, D. (2013). Roles of motorcycle type and protective clothing in motorcycle crash injuries. Emergency Medicine International, Cengage Learning, Inc. ISSN: 2090-2840

[7] French, M.T.; Gumus, G. (2018). Watch for motorcycles! The effects of texting and handheld bans on motorcyclist fatalities. Social Science & Medicine, 216, 81-87. DOI: 10.1016/j.socscimed.2018.09.032

[8] French, M.T.; Gumus, G.; Homer, J.F. (2009). Public policies and motorcycle safety. Journal of Health Economics, 28(4), 831-838. DOI: 10.1016/j.jhealeco.2009.05.002

[9] Hong, C.-Z. (2012). Motorcycle for persons with disabilities. American Journal of Physical Medicine & Rehabilitation, 91(5), 461-461. DOI: 10.1097/PHM.0b013e31824662e2

[10] Gil, G.; Savino, G.; Piantini, S.; Pierini, M. (2018). Motorcycle that see: multifocal stereo vision sensor for advanced safety systems in tilting vehicles. Sensors, 18(1), 295(1-34). DOI: 10.3390/s18010295

[11] Jolly, K.; Krzywinski, S.; Rao, P.V.M.; Gupta, D. (2019). Kinematic modeling of a motorcycle rider for design of functional clothing. International Journal of Clothing Science and Technology, 31(6), 856-873. DOI: 10.1108/IJCST-02-2019-0020

[12] Kostopoulos, V.; Markopoulos, Y.P.; Giannopoulos, G.; Vlachos, D.E. (2001). Finite element analysis of impact damage response of composite motorcycle safety helmets. Composites Part B, 33(2), 99-107. DOI: 10.1016/S1359-8368(01)00066-X

[13] Leme, A.D.S.; Creci, G.; Jesus, E.R.B.; Rodrigues, T.C.; Menezes, J.C. (2019). Finite element analysis to verify the structural integrity of an aeronautical gas turbine disc made from inconel 713LC superalloy. Trans Tech Publications, Switzerland, Advanced Engineering Forum, 32, 15-26. DOI: 10.4028/www.scientific.net/AEF.32.15

[14] Murakami, S.; Nishimura, H.; Zhu, S. (2012). Front-steering assist control system design for a motorcycle stabilization during braking, Journal of System Design and Dynamics, 16, 6(4), 431-446. DOI: 10.1299/jsdd.6.431

[15] Seedam, A.; Satiennam, T.; Radpukdee, T.; Satiennam, W.; Ratanavaraha, V. (2017). Motorcycle on-Road driving parameters influencing fuel consumption and emissions on congested signalized urban corridor. Journal of Advanced Transportation, Hindawi Limited, 2017, 6 pages. DOI: 10.1155/2017/5859789

[16] Sheng, N.; Xu, Z.; Li, M. (2015). The performance of CRTN model in a motorcycle city. Mathematical Problems in Engineering, 2015, 7 pages. DOI: 10.1155/2015/369620

[17] Silva, D.W.; Andrade, S.M.; Soares, D.F.P.P.; Mathias, T.A.F.; Matsuo, T.; Souza, R.K.T. (2011). Factors associated with road accidents among Brazilian motorcycle couriers. The Scientific World Journal, 2012. DOI: 10.1100/2012/605480

[18] Singhania, S.; Kageyama, I.; Karanam, V. (2019). Study on low-speed stability of a motorcycle. Applied Sciences, 9(11):2278. DOI: 10.3390/app9112278

[19] Teoh, E.R.; Campbell, M. (2010). Role of motorcycle type in fatal motorcycle crashes. Journal of Safety Research, 41(6), 507-512. DOI: 10.1016/j.jsr.2010.10.005

[20] Toma, M.; Njilie, F.E.A.; Ghajari, M.; Galvanetto, U. (2010). Assessing motorcycle crash-related head injuries using finite element simulations. International Journal of Simulation Modelling, 9(3), 143-151. DOI: 10.2507/IJSIMM09(3)3.164

[21] Tong, C.-C.; Jwo, W.-S. (2007). An assist-mode hybrid electric motorcycle. Journal of Power Sources, 174(1), 61-68. DOI: 10.1016/j.jpowsour.2007.08.095

[22] Truong, L.T.; Nguyen, H.T.T.; De Gruyter, C. (2018). Correlations between mobile phone use and other risky behaviours while riding a motorcycle Accident Analysis and Prevention, 118, 125-130. DOI: doi.org/10.1016/j.aap.2018.06.015

[23] Uberti, S.; Copeta, A.; Baronio, G.; Motyl, B. (2018). An eco-innovation and technical contaminated approach for designing a low environmental impact off-road motorcycle. International Journal on Interactive Design and Manufacturing (IJIDeM), 12(1), 281-295. DOI: 10.1007/s12008-017-0382-3

[24] Vasconcellos, E.A. (2012). Road safety impacts of the motorcycle in Brazil. International Journal of Injury Control and Safety Promotion, 1-8. DOI: 10.1080/17457300.2012.696663

[25] Xiao, Y.; Huang, H.; Peng, Y.; Wang, X. (2018). A study on motorcyclists head injuries in car-motorcycle accidents based on real-world data and accident reconstruction. Journal of Mechanics in Medicine and Biology, 18(4):1850036. DOI: 10.1142/S0219519418500367

[26] Zienkiewicz, O.C. (1997). The finite element method. McGraw-Hill, 3 ed. University of Michigan, p. 787. ISBN: 0070840725.

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