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Design of The Mechanism for Auto Release Seat Belt in End-Button Release Buckle

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Abstract: This project revolves around the buckle of a seat belt, mainly push end release button type, where a feature was created to make it into an auto release seat belt through designing the mechanism within the buckle. The aim of the project is to design the mechanism part of a convertible end button release seat belt buckle, to simulate the designed mechanism part of the convertible auto release seat belt for vehicle cars and to analyze the designed mechanism regarding the effectiveness when installed. 3 different models of solenoid-triggered-parts were designed where Model 1 has no support on its side, presence of fillet and smallest surface area for the base. As for Model 2 and 3, there were no fillet used, presence of support of the side and Model 2 has larger surface area for the base, but Model 3 has the largest amongst the three models. The parameter of this project was the material used when running the simulation which is Polyphenylene Ether (PPE). Through the simulation results, a final model was designed consists of features such as, having support on the side, largest surface area for the base and presence of fillet as these features has shown the best results through the simulation. As for the conclusion, the study managed to achieve all of the objectives which are, the auto release mechanism was designed and simulated successfully using SolidWorks, and it was simulated through simulation within the software.

Keywords: Seat belt, push end release button, mechanism

1. Introduction

Cars, buses, trucks, motorbikes, mopeds, pedestrians, animals, taxis, and others share roadways all over the world. Motor vehicles make it feasible for many countries to develop both economically and socially. Throughout the year of 2009 until 2018, an estimated numbers of motor vehicle being manufactured has been increasing exponentially which reaches an all-time high record with 97 million which indicates that the number of users within a roadway is increasing overtime, globally [1-6]. With that being said, motor vehicles that are involved in crashes has resulted in millions of deaths and injuries each year. According to both the Centre for Disease Control and Prevention, CDC, and World Health Organization, WHO, approximately about 1.35 million people were killed on roadways from all over the world and resulted it to become the leading cause of death for children and young adults aged 5-29 years old [2-3]. One of the major factors that contributes to such results is closely related to the usage of seatbelts whether when it is fasten or being left unbuckled.

In recent times, an idea of "crash" sensing seat belt release system is being looked into. The crash sensing seat belt system suggest that a few modifications could be made onto the buckle mechanism of a 3-points seat belt within the locking system where it can react to certain parameters and determine whether to lock the seat belt, to prevent the passenger from being flung out, or to unbuckle the seatbelt to make ways for the passenger to escape out of the vehicle [4-5].

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Auto release seat belt system is an automatic seat belt release system developed primarily for passenger vehicles such as cars, school buses, and other similar vehicles. It has a customized locking method that uses a cylindrical coil instead of the traditional buckle found in automobiles' three-point seat belt systems. This modified buckle overcomes the limitations of a traditional buckle where it works on the principle that when a current is passed through a conductor, a magnetic force is generated. This generated magnetic force has sufficient strength to hold the seat belt latch in its desired position and is capable of bearing the impact of a collision, implying that it can restrict the movement of the occupants, which is the primary function of a seat belt system [9-12]. The Fig. 1 shows the methodology flowchart in completing this project.

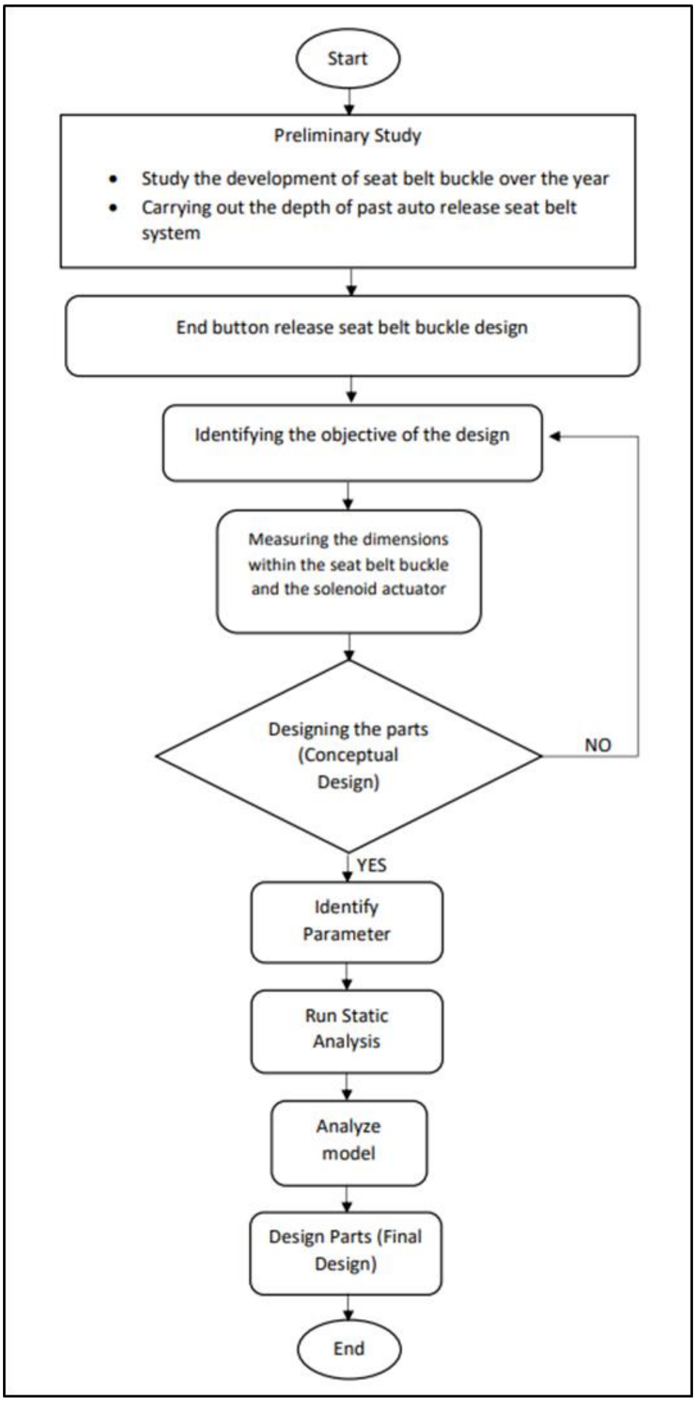

Fig. 1 - Flowchart of project methodology

When a crash happens, a signal is generated and transmitted by the transmitter unit or diagnostic module. The device's companion receiving unit, also known as a signal receiver, is tuned to the frequency generated by the transmitter unit or diagnostic module. The circuitry in the receiver generates a "enable" signal to a logic device, such as an "AND" integrated circuit chip or analogous, which applies a voltage level to the seatbelt lock, causing the system to be activated, upon receiving the signal generated by the transmitter unit. This action triggers the solenoid, which disengages the lock by activating springs that push the latch out, releasing the users from the seat belt [11].

During a road accident, the seat belt serves the purpose of holding the passenger in their seat from being ejected from the seat of the vehicle which could cause them to be flung out of the vehicle from the front windshield. Under rare occasion, the victim might be unable to exit their vehicle due to certain factors such as injuries or being unconscious, which prevent them from being able to remove the seat belt and exiting the vehicle. The purpose of this research is;

- To design the mechanism part of a convertible end button release seat belt buckle.
- To simulate the designed mechanism part of convertible auto release seat belts for vehicle cars.
- To analyze the designed mechanism regarding the effectiveness when installed.

1.1 Dimensions

The end button release seat belt buckle will be torn apart to further inspect the working mechanism of the buckle. The unlatching between the male and female parts of the seat belt occurs when the users push down the release button downward, causing the rod to push down the cantilever that is pushing the latch to lock the seat belt tongue. As the cantilever was pushed down, it will no longer push down the latch to lock the seat belt tongue thus unbuckling the users. In order to mimic the force of pushing down the end button, solenoid actuator was used, and another part is designed to receive the force exerted by the solenoid actuator to move the end button downwards.

While referring to the naked buckle, there is a space on the side of the end button where it can be used as a mounting point for the designed parts to move the push button downwards as the solenoid actuator apply force on the designed parts. In order to utilize the space on the side of the push button, the cover of the buckle will need to be modified to make room for the designed parts to come through.

With the knowledge gathered, the design objectives of the model were decided which are:

- The models designed must be able to fit in between the grooves within the cover of the buckle and fit in the buckle altogether.
- The model designed must have a large enough base to receive the force that is exerted by the solenoid actuator.
- The model must be able to withstand 20N of force as that is the amount of force generated by the solenoid actuator to push the model downwards.

The dimensions for the space on the side of the push button was 1.8 cm x 1.8 cm. With the dimensions measured, the models designed must have the dimensions of 1.8cm x 1.8 cm x 0.2 cm in order to mount to the side of the button and fit through the grooves of the buckle. The dimension of the solenoid actuator was also measured where it was 2.1 cm x 2.4 cm. Since that the moving parts that will be moving downwards to mimic the pushing motion was located on the middle of the solenoid, and it has a round surface, the base dimensions must consider the radius of the round surface. The base dimension must be at least 1.6 cm in order to reach the moving parts of the solenoid actuator. With these dimensions measured, a benchmark model was fabricated and then fitted within the buckle itself.

2. Simulation

With the help of the feature provided by SOLIDWORK, which is labelled as simulation, the static analysis can be run in which the value of stress, displacement and strain can be obtained. The software is initially used for project management, planning, visual ideation, modelling, feasibility analysis, and prototyping. The design and construction of mechanical, electrical, and software components are subsequently done using the program. The software can also be used for management, including cloud services, analytics, device management, and data automation [12]. By loading in all of the models designed earlier, each of the model will be put under simulation and the values of stress and displacement will be retrieved which then be analyzed. The process of simulating the model started with determining the material of the model which in this study, Polyphenylene Ether (PPE), was used as the material. The fixtures were then selected where the inner part of the side of the model was selected as the fixture as it will be placed on the side part of the push button of the buckle. Figure 2 shows the fixtures selected, pointed with green arrows and the load exerted, pointed with purple arrows.

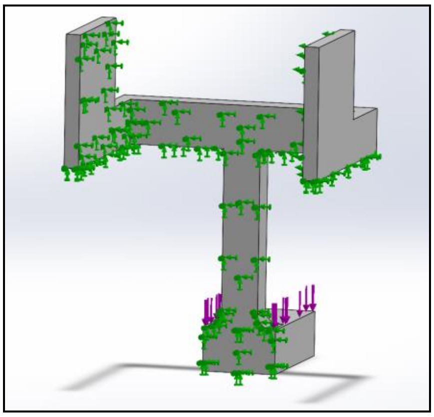

Fig. 2 - Fixture and loads setup

After that, the value of external loads was put in where 20N of load was used as that is the amount of load that will be supplied by the solenoid actuator, onto the base of the model designed. Following that, the mesh was then created where the slider on setting up the density of the mesh will be used as the option in determining the mesh of all 3 models. For each mesh of the model designed, the slider will be pointing to the right up to the part where 'Fine' is labelled. Figure 3 below shows the window of option in the SOLIDWORKS software.

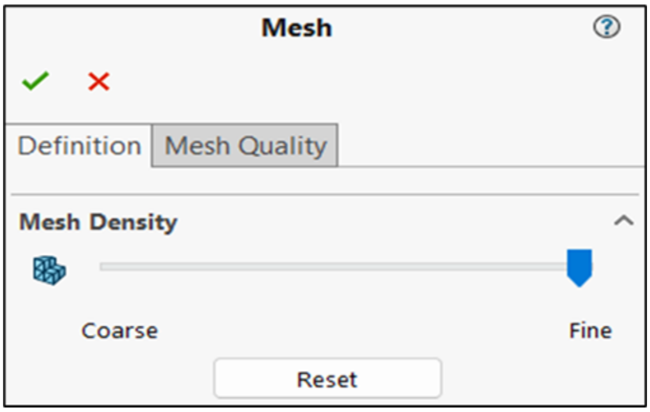

Fig. 3 - Mesh density slider

The purpose of meshing the model was to subdivide the model into small pieces, so that the FEA program will be able to look at the model as a network of interconnected elements [5]. This way, the value of stress and displacement can be analyzed accurately, and the meshing will provide the users the ability to pinpoint the spot with highest or lowest value of desired data (stress etc.).

With all of the values inserted, selecting the option labelled with "Run This Study" will generate all of the reading desired. The duration of the simulation depends heavily on the model designed and the mesh used. The finer the mesh used, the longer the time taken for the simulation to be complete. With the aid of the results generated, the finalized design of the model will be designed with using the best features according to the results generated.

3. Results and Discussion

The model that was designed must follow these specifications to achieve the design objectives which are:

- The model must have the minimum length of 1.6cm when designing the base of the model (In order for the base to reach the end of the solenoid actuator).
- The model designed must have the dimension of 0.2cm x 0.8cm x 1.8cm when designing the side part of the model (In order for the side part to fit in between the grooves within the cover of the buckle).
- The model must be able to withstand 20 N of load exerted on the base of the model (The amount of load exerted by the solenoid actuator to push down the model designed).

With the reference of the benchmark model designed, the other models were designed to add in other features. In doing so, the new models designed will always stay within the specifications stated earlier. With the aid of the benchmark model, 3 models were designed with each having distinct features between each of the model. There are 3 features of the models that was focused on which are, the side part, the base size, and the presence of fillet. The first model's side part has no support, and its dimension is just wide enough to fill in the grooves of the cover of the buckle. As for the dimensions for the base of Model 1 is smallest amongst the 3 models designed. As for model 2 and 3, both of the model has support next to the side part that sits in between the grooves of the cover of the buckle. The size of the base also increases for both of the model with model 3 being the biggest amongst the models. As for the presence of fillet, only model 1 has it whereas models 2 and 3 does not have fillet. These 3 models were then put into simulation with the same type of material use, PPE, same location of fixture and load applied, as shown in Figure 2, and the same setting in determining the density of the mesh. The Figure 4 below shows the models designed followed with the maximum stress and displacement of each of the models that were than tabulated as shown in Table 1.

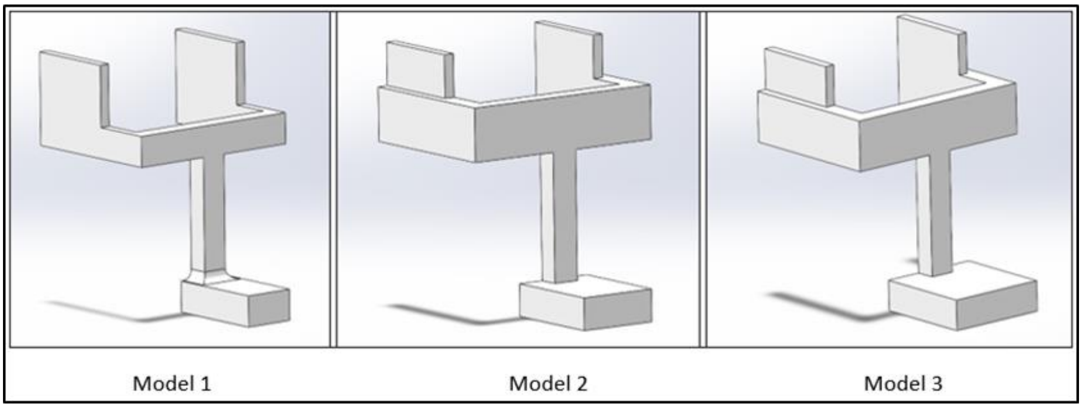

Fig. 4 - Models designed

Table 1 - Results of the simulation

Model	Max. Stress	Max. Displacement
1	$4.765^{6}\ N/m^{2}$	$5.070^{-2}\ mm$
2	$3.837^{6}\ N/m^{2}$	$3.265^{-2}\ mm$
3	$2.663^{6}\ N/m^{2}$	$2.492^{-2}\ mm$

From the results gathered, it shows that Model 3 experienced the least amount of stress and has the lowest displacement amongst all the models designed. Since that the size of the base gradually increases from Model 1, width of 1.0 cm, to 1.5 cm in width for Model 2, and lastly Model 3 which has the largest width amongst the 3 models, it shows that the dimensions of the base designed impacted heavily on the amount of stress experienced on the models. As for location of the maximum stress, Model 1 shows that it experienced the maximum stress on top of the fillet itself as compared to Model 2 and Model 3 that experienced the maximum stress on the connection between the base and the 'pillar' of the model. Figure 5 below shows the different maximum stress located.

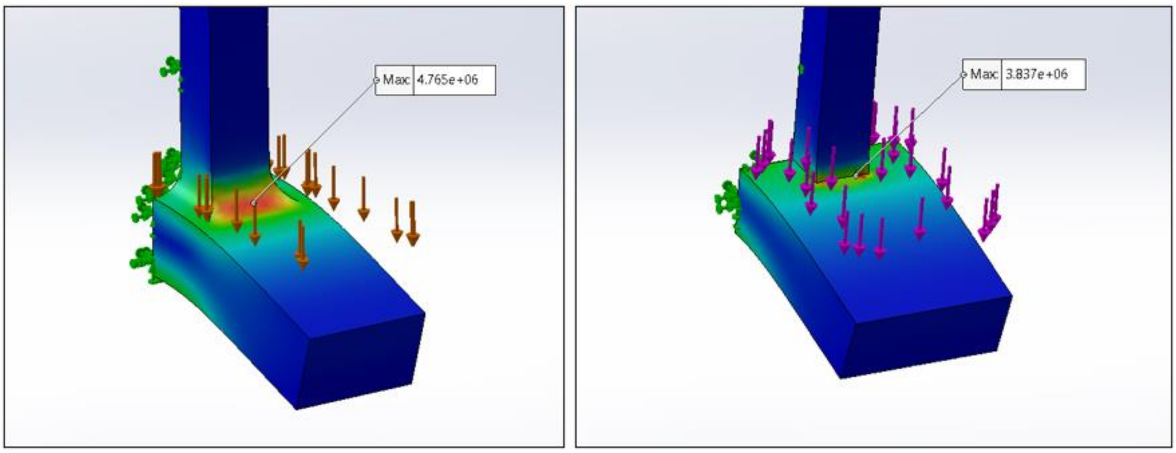

Fig. 1 - Location of maximum stress

It shows that the stress was distributed more evenly when there is a presence of fillet as compared to no fillet used. The surface area that experienced stress increases where instead of it being located on the edges, the stress was distributed on both the surface of the fillet and the base itself. With the presence of fillet, it can help in increasing the surface area that experienced stress as it largen the surface area of the base, which was found out to help in obtaining lower amount of stress. With these features stated out, the final design of the model was then made.

The final design was designed with the features that has the best results from the simulation run, which are, use the largest size of base designed and presence of fillet which can further increase the surface area of the base thus results in lower stress experienced. The drawing of the final design was shown in Figure 6. The model of the final design was then put under the same simulation that the earlier model had been through, and the results was then tabulated, can be seen in Table 2.

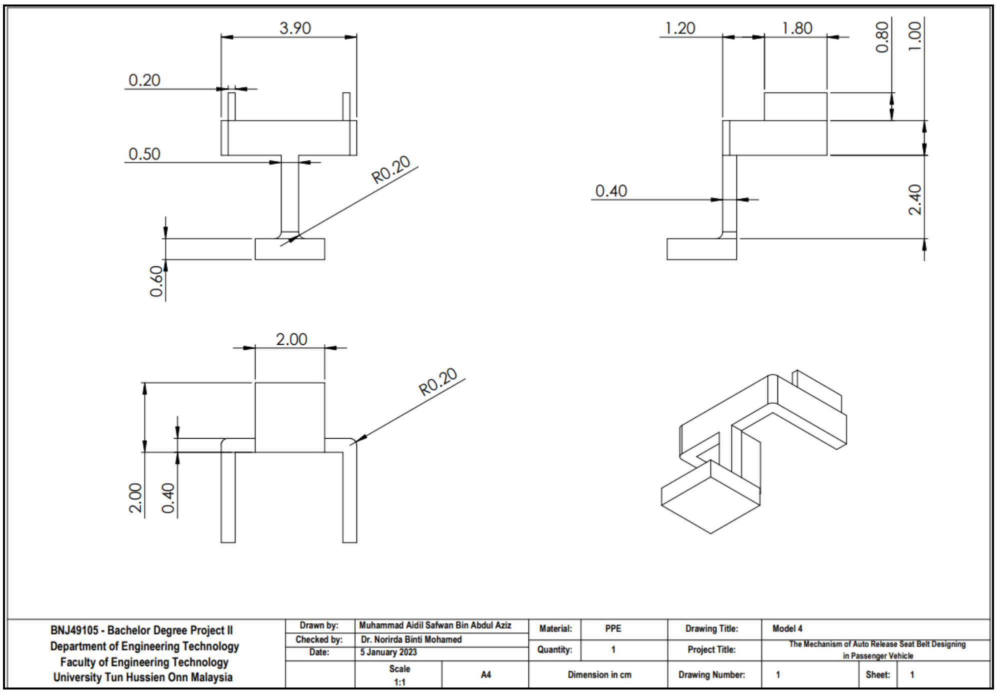

Fig. 2 - Final design drawing

Table 1 - Results of simulation

Model	Max. Stress	Max. Displacement
1	$4.765^6\ N/m^2$	$5.070^{-2}\ mm$
2	$3.837^6\ N/m^2$	$3.265^{-2}\ mm$
3	$2.663^6\ N/m^2$	$2.492^{-2}\ mm$
4 (Final Design)	$2.402^6\ N/m^2$	$2.487^{-2}\ mm$

From the results tabulated, it shows that with the presence of fillet can help in lowering the amount of stress. This is because, the presence of fillet helps in distributing the stress experienced much better instead of it being 'focused' on the edges. Fillet also cause the surface area of the base to become larger which helps in lowering the stress, as the study found out that the larger the size of the base designed, the lower the amount of stress experienced. The results show that Model 4 was the best model designed as it has the lowest amount of both stress and displacement.

4. Conclusion

In this study, the mechanism part of the auto release seat belt was designed successfully as it manages to achieve the design objective which was, can be mounted within the buckle of conventional vehicle, has enough space for the solenoid actuator to push down the model designed, and lastly able to withstand the amount of load applied by the solenoid actuator itself. The designed mechanism part of convertible auto release seat belts for vehicle cars was simulated using the software SOLIDWORKS. The designed mechanism was analyzed regarding the effectiveness when installed through analyzing the data generated from the simulation and designing the final model using the features that shows the best result. The results show that by taking the features of each conceptual model designed that resulted in a positive manner, the finalized model designed was able to lower the amount of stress and displacement experienced as the value was the lowest amongst all the conceptual model designed.

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