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Design and Development of Bikes-Spoke Guard (BSG)

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Abstract: Motorcycle is an essential mode of transportation in many countries. In recent years, there are increasing trend of accident involving motorcyclist, which concerning to spoke injury. This research study was attempted to develop a prototype model of bike-spoke guard (BSG) in preventing the spoke injury. The proposed design was based on a comprehensive literature and industrial pattern search to suit with the design specification of underbone type of motorcycle. The design employed polyester resin as main material. The analysis method involved Failure Modes and Effects Analysis (FMEA) and Finite Element Analysis (FEA). Based on FMEA results, the risk of passenger's feet trap on bikes spoke was considered high priority. The result of FEA by means of stress and displacement ascertained the computer-aided design (CAD) model of BSG could withstand weight of passenger up to 150 kg. The findings revealed the proposed model could enhance the design and safety performance of the existing spoke protective device toward reducing the spoke injury. Recommendations are also highlighted including fabrication process, functional test and variety of design for the further development of BSG.

Keywords: Bikes-Spoke Guard (BSG), Failure Modes and Effects Analysis (FMEA), Finite Element Analysis (FEA), Motorcycle, Spoke Injury

1. Introduction

Motorcycles or bikes in the form of two-wheelers play an important role of transportation in many countries in the world. In Asia and South America for instance, there are thousands of bikes running on the road every day. Despite the popularity of bikes for daily use, the percentage of road traffic accidents involving motorcyclists also increase. In fact, there are increasing trend of accident related to spoke injury mainly towards motorcycle passengers [1].

In Southeast Asian region such as Malaysia, the occurrence of spoke injuries are common, where motorcycle is used as commuting purpose. The injury has been reported in literature since 1948 [2]. The spoke injury is often happens when the leg of the passenger pass through the spokes of the wheels

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of the vehicles. Previous studies concluded that without proper safety or protective device such as footrest and spoke guard, severe spoke injury to the feet could occur, especially of young passengers [1-3]. Although some efforts have been introduced to prevent the problem, the spoke injury related to motorcycle passenger is unresolved issue up to the present day [5-6].

Moreover, the existing safety devices such as spoke guard to prevent spoke injury in the market is limited to certain variants. This is due to the design of motorcycle varies greatly to suit a range of different purposes such as long distance travel, commuting, cruising, sport including racing, and off-road riding. In the context of Malaysia, the underbone type of motorcycle is widely used nationwide. Therefore, this research project was attempted to develop a spoke guard or protector in preventing the passenger of underbone motorcycle from spoke injury.

2. Materials and Methods

2.1 Materials

The material used for the bikes-spoke guard in the design is polyester resin. Polyester resins are unsaturated synthetic resins that are formed by dibasic organic acid and polyhydric alcohol reactions. Polyester resins are used in compounds for sheet forming, bulk moulding compounds and toner for laser printers. These are usually based on isophthalic acid and cut with styrene at high levels, which are typically up to 50 percent. Polyesters are often used in adhesives for anchor bolts, while materials based on epoxy are also used.

2.2 Design specification

In general, a design specification of a product is a document providing a list of points regarding a product such as dimensions, aesthetic factors, ergonomic, safety, and other requirements that will be needed. The proposed preliminary design specification of a prototype model in this research as summarized in Table 1 is mainly based on thorough search of literature and market study, and outcomes of brainstorming and web forum session.

Table 1: Preliminary design specification of bike-spoke guard

Items	Existing Design	Proposed Design	Justification
Type of motorcycle	Limited variant	Underbone	Underbone type is commonly used as mode of transportation in Malaysia
Attachment	Complex design	Relatively simple design	Common protective devices required simple and low cost design
Safety	Fix / adjustable mechanism	Adjustable mechanism	Use of foot rest for adjustable mechanism

2.3 Detailed part drawing

The proposed prototype design of bikes-spoke guard has single part so it does not need an assembly drawing and exploded drawing. Figure 2 outlines the detail part drawing with a complete dimension.

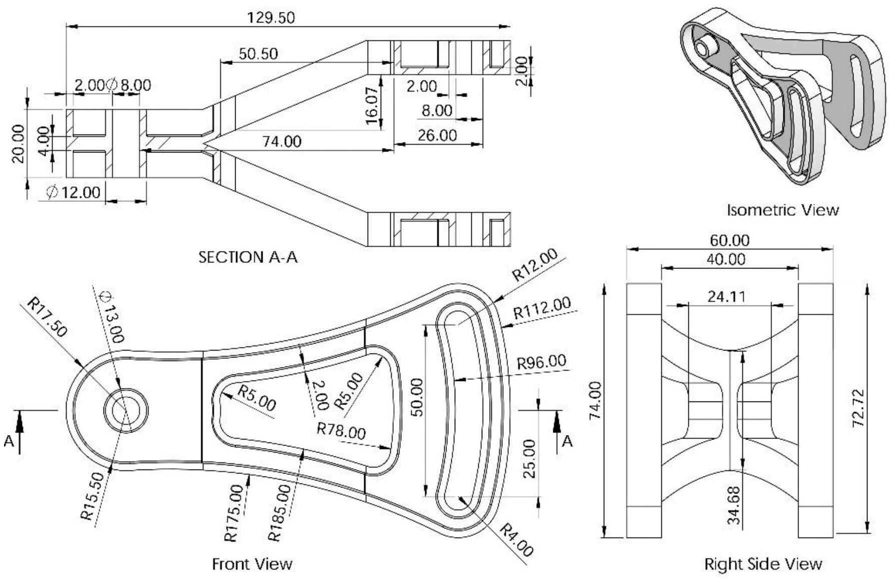

Figure 1: Detailed part drawing

2.4 Failure mode and effect analysis (FMEA) method

An FMEA is an engineering analysis done by a cross-functional team of subject matter experts that thoroughly analyses product designs or manufacturing processes early in the product development process. An FMEA should be the guide to the development of a complete set of actions that will reduce risk associated with the system, subsystem, and component or manufacturing / assembly process to an acceptable level.

2.4.1 Procedure of FMEA

Step 1: Review the design

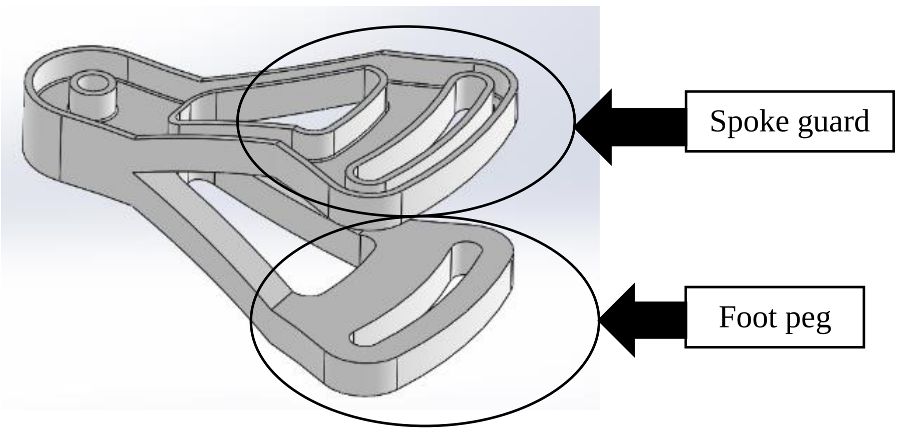

Figure 2: Bikes spoke guard

The main component of the product comprises:

i. Foot peg: provide a foot rest for the passenger
ii. Spoke guard: to prevent passenger's feet from motorcycle spoke.

Step 2: Potential failure modes

The possible potential failure modes include:

i. Passenger does not place their feet between the spoke guards.
ii. Risk of passenger's feet caught on motorcycle spoke.

Step 3: Potential effects of failure

The potential effects of failure are:

i. Spoke injury.
ii. Fall off from bike.

Step 4: Severity ranking

Severity is a ranking number associated with the most serious effect for a given failure mode, based on the criteria from a severity scale. It is a relative ranking within the scope of the specific FMEA and is determined without regard to the likelihood of occurrence or detection. The ranking is described in **Appendix A**.

Step 5: Occurrence ranking

Occurrence is a ranking number associated with the likelihood that the failure mode and its associated cause will be present in the item being analyzed. For System and Design FMEAs, the occurrence ranking considers the likelihood of occurrence during the design life of the product. For Process FMEAs the occurrence ranking considers the likelihood of occurrence during production. It is based on the criteria from the corresponding occurrence scale. The occurrence ranking has a relative meaning rather than an absolute value and is determined without regard to the severity or likelihood of detection. The ranking described in **Appendix A**.

Step 6: Detection ranking

Detection is a ranking number associated with the best control from the list of detection-type controls, based on the criteria from the detection scale. The detection ranking considers the likelihood of detection of the failure mode/cause, according to defined criteria. Detection is a relative ranking within the scope of the specific FMEA and is determined without regard to the severity or likelihood of occurrence. The ranking described in **Appendix A**.

Step 7: Calculate the RPN

The RPN is the acronym for Risk Priority Number. The RPN represents a relative risk ranking. The higher the RPN, the higher the potential risk. The RPN is calculated by multiplying the three rankings together. Multiply the Severity Ranking times the Occurrence Ranking times the Detection Ranking to calculate the RPN for each failure mode and effect (RPN = Severity x Occurrence x Detection).

Step 8: Develop the action plan

The action plan defines who will do what by when taking action means reducing the RPN. In this context, the RPN can be reduced by lowering any of the three rankings (severity, occurrence, or detection) individually or in combination with one another.

2.5 Finite element analysis (FEA)

The method of finite element analysis (FEA) is the most widely used method to solve engineering problems and mathematical models. The conventional fields of structural analysis, heat transfer, fluid flow, mass transport and electromagnetic potential are common problem areas of concern. In this finite element study, 150 kg of force is applied on the Bikes-Spoke Guard to represent the load as shown in Figure 3. The green color represent a prototype attached with the motorcycle while the purple color represent a 150 kg force applied to the prototype

Figure 3: Force applied on bikes-spoke guard

3. Results and Discussion

3.1 Final design

Figure 4 presents the final design of a prototype model of bike-spoke guard. The mass properties of assembly of the bike-spoke guard is 44.03 grams which means the product is lightweight.

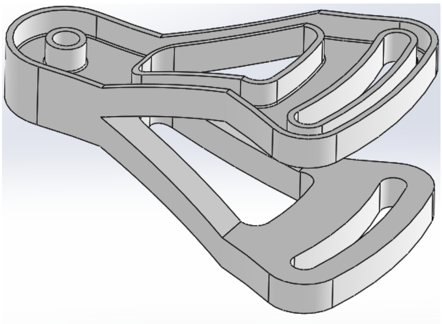

Figure 4: Bike-spoke guard (BSG)

3.2 Failure mode and effect analysis (FMEA) result

The model was evaluated by using the method of failure mode and effects analysis (FMEA). The result of analyses comprised severity ranking, occurrence ranking, detection ranking, and risk priority number (RPN) as summarized in Table 2. Based on the value of RPN obtained, the risk of passenger's feet trap on motorcycle spoke for the product could be considered high priority.

Table 2: Design failure mode and effect analysis

Item	Potential failure mode	Potential effect mode	Potential cause of failure	Current design control	RPN	Recommended action
1	Passenger does not place their feet between the spoke guard	Spoke injury	Human error	Properly place their feet between spoke guard	105	Design easy to place feet between spoke guard
2	Risk of feet trap on motorcycle spoke	Fall off from bike	Human error	Properly place their feet between spoke guard	140	Design a spoke protective device

Based on the result given from the procedure of the bike spoke guard design, the FMEA result revealed the product has a highest risk of passenger's feet trap on motorcycle spoke. Meanwhile, the moderate risk signifies the passenger does not place their feet between the spoke guards.

3.3 Finite element analysis (FEA) result

The design of bike-spoke guard was evaluated through finite element analysis (FEA) method by using Solidworks software. The analysis was carried out to specifically determine the value of stress and displacement. The result of the study obtained the minimum stress is 0.010 N/mm^2 (MPa) which the lowest stress applied to the prototype, while maximum stress is 1,464.979 N/mm^2 (MPa) shows a highest stress applied to the prototype. Figure 5 shows the stress occurs on the bike-spoke guard (BSG).

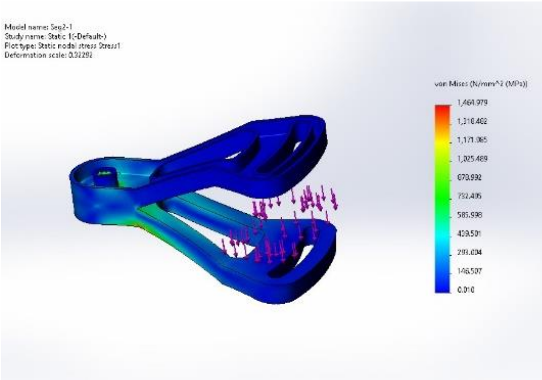

Figure 5: Stress on bike-spoke guard

For displacement, the value obtained in the study for minimum displacement is 0 mm, while the maximum displacement is 4.158e+01 mm. Figure 5 exhibits the stress occurs on the bike-spoke guard.

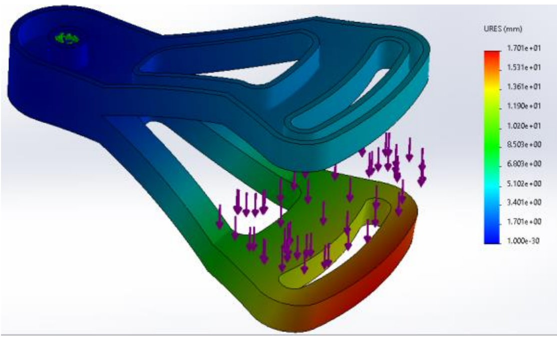

Figure 6: Displacement on bike-spoke guard

Based on the result given from the procedure of the bike spoke guard design, the result of FEA by means of stress, strain and displacement ascertained that the guard is applicable up to 150 kg, which could withstand most weight of the passengers.

4. Conclusion

This research study has attained and achieved the objectives that has been set beforehand. The characteristics of specification for the design has been discovered by thorough literature search. The study has successfully produced a CAD model of bike-spoke guard. The design is comprehensively validated thorough FMEA and FEA. The overall findings of the study are considered as an important outlook in enhancing the design and safety performance of the existing spoke protective device. Nevertheless, several recommendations are highlighted including fabrication and testing to further development of bikes-spoke guard.

Acknowledgement

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Appendix A

Severity Ranking

Effect	Severity of Effect	Ranking
Hazardous without warning	Very high severity ranking when a potential failure mode affects safe system operation without warning	10
Hazardous with warning	Very high severity ranking when a potential failure mode affects safe system operation with warning	9
Very high	System inoperable with destructive failure without compromising safety	8
High	System inoperable with equipment damage	7
Moderate	System inoperable with minor damage	6
Low	System inoperable without damage	5

Very low	System operable with significant degradation of performance	4
Minor	System operable with some degradation of performance	3
Very minor	System operable with minimal interference	2
None	No effect	1

Occurrence Ranking

Probability of failure	Failure probability	Ranking
Very high: Failure is almost inevitable	>1 in 2	10
	1 in 3	9
High: Repeated failures	1 in 8	8
	1 in 20	7
Moderate: Occasional failure	1 in 80	6
	1 in 400	5
	1 in 2,000	4
Low: Relatively few failure	1 in 15,000	3
	1 in 150,000	2
Remote: Failure is unlikely	<1 in 1,500,000	1

Detection Ranking

Detection	Likelihood of detection by design control	Ranking
Absolutely uncertainty	Design control cannot detect potential cause/mechanism and subsequent failure mode.	10
Very remote	Very remote chance the design control will detect potential cause/mechanism and subsequent failure mode.	9
Remote	Remote chance the design control will detect potential cause/mechanism and subsequent failure mode.	8
Very low	Very low chance the design control will detect potential cause/mechanism and subsequent failure mode.	7
Low	Low chance the design control will detect potential cause/mechanism and subsequent failure mode.	6
Moderate	Moderate chance the design control will detect potential cause/mechanism and subsequent failure mode.	5
Moderately high	Moderately high chance the design control will detect potential cause/mechanism and subsequent failure mode.	4
High	High chance the design control will detect potential cause/mechanism and subsequent failure mode.	3
Very high	Very high chance the design control will detect potential cause/mechanism and subsequent failure mode.	2
Almost certain	Design control will detect potential cause/mechanism and subsequent failure mode.	1