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Development of RhiNO v2.0 : An Enhanced Single User Paddock Stand

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ABSTRACT

Recently, studies concerning motorcycles have been an enormous area of research interest. Superbike motorcycles utilize a paddock stand to support the motorcycle in an upright and stable position, which can serve multiple purposes such as washing the motorcycle, tire changing and overall maintenance. Our previous study has developed RhiNO v1.0, a new single-user superbike paddock stand that is able to overcome the limitation of current paddock stands which require at least two persons for the operation. Although RhiNO v1.0 met its design requirements, there are still room for improvements relating to its size, weight, assembly method and also type of material used for the fabrication. This paper deals with the development of RhiNO v2.0 where enhancements was made to overcome the imperfections found from the first prototype without jeopardizing its function. For engineering design and simulation purposes, a combination of Computer-Aided Design (CAD) and Finite Element Analysis (FEA) through the state-of-art CATIA V5R20 software was extensively used. A prototype based on the design was fabricated and tested as a proof of concept.

Keywords: Paddock stand; Motorcycle; Computer-Aided Design; Finite Element Analysis.

Abbreviations

CAD	computer-aided design
FEA	finite element analysis
LBP	low back pain
MMH	manual material handling
MSD	musculoskeletal disorder

1.0 INTRODUCTION

Paddock stands has been widely used by superbike owners to temporarily support the motorcycle in an upright position which facilitates the user to perform either periodic or ad-hoc maintenance work [1]. Aside from its main function to support the motorcycle, a good paddock stand also has to be optimal in terms of the material selection, design and dimension [1], [2]. The current design of the conventional paddock stands available on the market, as shown in Figure 1(a), require at least two people to operate safely, which is inconvenient and impractical for most users [3]. Users may operate the paddock stand alone, however, there is a safety risk of falling aside due to position imbalance.

To eliminate this limitation, a single user paddock stand was successfully developed.The single user paddock stand is a name termed for a fabricated paddock stand that could be operated securely by one single person in lifting a superbike that comes with different types of design and concept compared to a conventional paddock stand [3]. Figure 1(b) shows the first generation of single-user superbike paddock stand named RhiNO v1.0 [4].

There are differences in the grip design presented between those products. The curved grip for handling of the conventional superbike paddock stand is located at the end center in between both of the holding arms that faced upwards. This curved handle grip design could also be seen at a motorcycle stand patent designed by Thompson [5]. In contrast, the RhiNO v1.0 prototype is fabricated with a long arm extended from the base, unlike the conventional paddock which has no extruded arm on it. These clear difference gives a major variance in operation and functionality between the conventional concept and single-person lifting theory.

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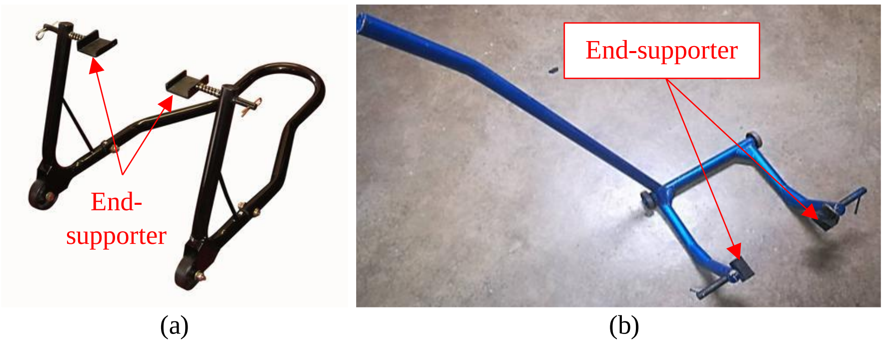


Figure 1. (a) Conventional paddock stand, and (b) RhiNO v1.0

The RhiNO v1.0 itself was presented and exhibited in some events such as World Engineering Conference (WEC) 2010, Invention, Innovation and Design (IID) 2010, International Conference and Exposition On Invention of Institutions of Higher Learning (PECIPTA) 2011 and Malaysian Technology Expo (MTE) 2011. Despite good reviews received, there are also few feedbacks and recommendations which led to this study. Even though the RhiNO v1.0 managed to fulfil its requirement in lifting the rear part of a motorcycle by only one single person, a few limitations were identified such as it was excessive in weight, bulky design, constraint in packaging for shipping purposes and slightly poor load distribution during operation.

The RhiNO v1.0 prototype was fabricated to be a 1-piece full-body solid paddock stand using mild steel which consists of low carbon content that contributes to its toughness and tendency to rust, having an excessive weight of approximately 9 kg which is quite heavy for a person to operate and carry. Due to these features, users will face some problems engaging the end-supporter (Figure 1) of the RhiNO v1.0 to the swingarm of te superbike before lifting it up because it requires the user to use only the right hand to perform this task. Handling a 9 kg paddock stand with only one hand is not suggested in the manual of material handling (MMH) . In the MMH, with respect to body posture and back injury, handling excessive loads may cause low back pain (LBP) which leads to severe musculoskeletal disorder (MSD) [6]. Most superbike riders face the risk of getting LBP when handling heavyweight paddock stand [7], [8].

The RhiNO v1.0 stand was fabricated with adjustable width up to 210 mm to hold the swing arm pivot points, which is only to be used for superbikes of 250cc and below. The stand was aimed to be fabricated with a structure that is able to withstand approximately 250kg load of weight exerted from various superbikes within the displacement between 250cc until 1000cc, where nowadays, these superbikes are fabricated with lighter weight. Despite the RhiNO v1.0 toughness, it also causes the chosen material to add to the weight because of high density than the material with no carbon content such as aluminum [9]. Most conventional paddock stands are commonly fabricated using either stainless steel or aluminum due to the presence of robustness and rigidity features. Besides that, the extended handlebar design was found to be obstructing people walking nearby the area. People may accidentally walk across the bulging out handlebar and causes the paddock stand to flip from its jacking position. As a consequence, the superbike will slip and fall to the ground. Last but not least, the stand itself was designed as a single structure with no detachable parts; thus, this may cause in more space consumption for packing and storage.

This paper reports the development, structural and functional analysis of RhiNO v2.0 which offers a more lightweight and better design compared to its award-winning predecessor, RhiNO v1.0. The material used for the new RhiNO v2.0 is aluminum alloy. Plunger connection is considered as the assembly method in developing the handlebar of RhiNO V2.0 with detachable and attachable features. It is used as a locking mechanism with push-on and push-off applications by using a spring-attached-pin to detach or attach a connection between two components. The detachable concept increases the portability of the stand where all of the components could easily be dismantled and assembled whenever is it needed. By the end of this project, the RhiNO v2.0 paddock stand should be able to cater for the limitations found within its predecessor, yet, increase the portability of the stand.

2.0 METHODOLOGY

Figure 2 shows the design process involved in the development of RhiNO v2.0 [10], [11]. The initial process stage was problem identification from the design of RhiNO v1.0. Ideas and concepts were generated before being selected using the Pugh Chart Decision Matrix selection method [11]–[13].

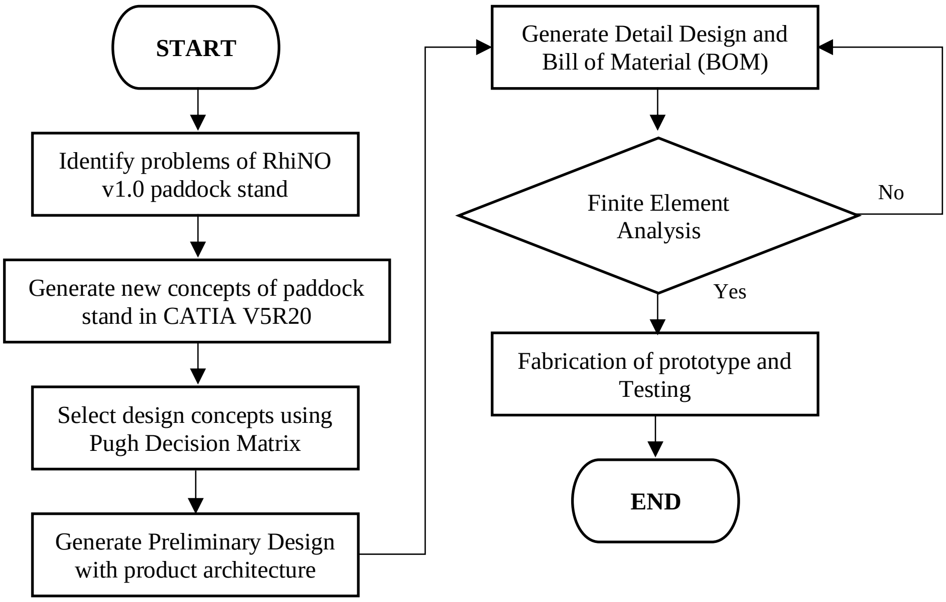


Figure 2. Flow chart of the design process for the RhiNO v2.0

Detail design of the RhiNO v2.0 was performed by using CATIA V5R20 software. Finite element analysis was done in order to analyze the maximum stress of the design. To verify its strength and not fail with the load acting upon it, a prototype was fabricated for testing with an actual superbike.

2.1 Conceptual Design

Three design concepts were generated, as shown in Figure 3, combining many factors considered when designing the stand including cost-effectiveness, portability, weight, functionality, stability, maintainability, safety, ergonomics and ease of handling the stand.

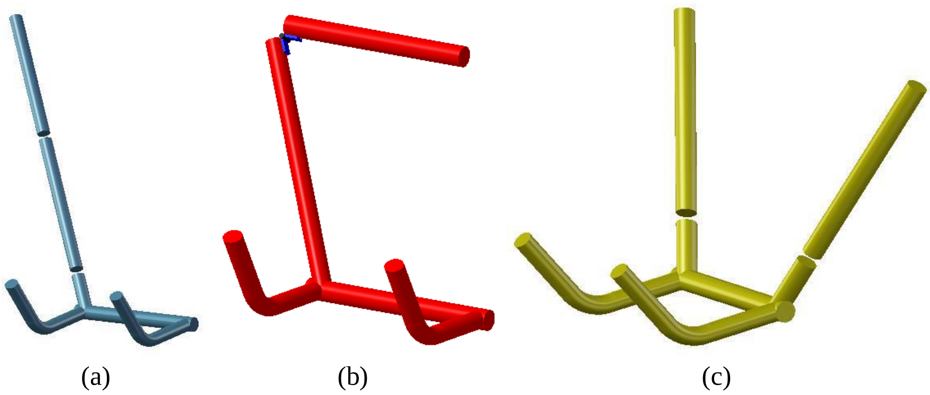


Figure 3. (a) Concept A, (b) Concept B, and (c) Concept C

Concept A has the handlebars with the detachable and attachable feature using the plunger connection at one side only. Meanwhile, concept B was sketched with the feature of a foldable handlebar which uses the connection of a hinge assembled in-between the handlebars. Lastly, concept C has the same concept as concept A, however, it could be assembled and dissembled from both sides of the paddock stand base to gain a more symmetrical and stable position.

Using the Pugh Decision Matrix selection method as shown in Table 1, scores were determined for each concept design's criteria and the concept with the highest total score was selected. Concept design C was chosen because having the highest total score for the criteria listed to develop the RhiNO v2.0 model, especially with regards to the aspect of safety criteria score. This could be seen when compared to the other two concept designs which was double to the score of concept design A and higher than concept design B. This is because concept design C has two protruding levers that will act as support arms for both left and right sides of the paddock stand, making it more stable during operation as compared to only one side of the support arm in concept design A and B respectively.

Table 1: Pugh Decision Matrix selection method

Criteria	**Score**		
	Concept Design A	**Concept Design B**	**Concept Design C**
Cost-effectiveness	6	7	6
High portability	9	5	9
Weight	8	7	7
Functionality	8	4	9
Stability	6	6	9
Maintainability	9	7	9
Safety	4	7	8
Ergonomics	9	6	9
Easy to handle	8	8	7
Total score	67	57	73

2.2 Detail Design

Based on the chosen concept, and after several revision updates to continuously improve the design, a finalized design for the RhiNO v2.0 was modelled as shown in Figure 4. The end of the handlebar was bent considering the user may need some space for grip to lift the handlebar and avoid fingers from clamped or hurt when jacking down the superbike. Knurling pattern was added as a grip on the bent part of the extended handlebar to provide a firm grip and avoid being slippery when handling with lubricant works on the superbike. This detail design includes all the elements to which the stand would adhere when fabricated.

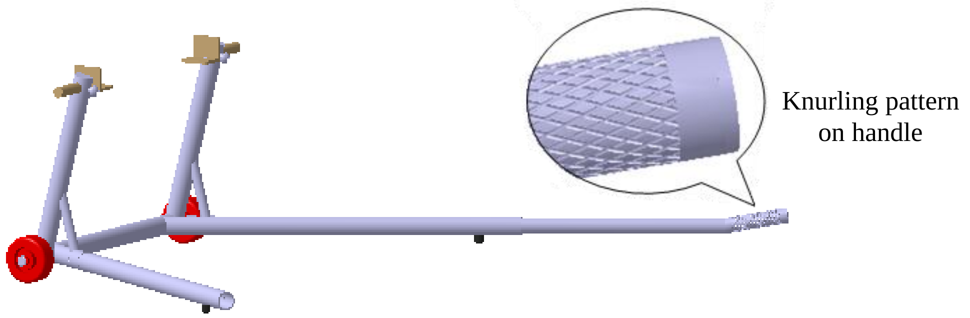


Figure 4. Detail design on RhiNO v2.0

2.3 Design Analysis

The critical position for the operation of the RhiNO v2.0 paddock stand is when the stand successfully lifts the motorcycle in an upright position. This is the situation where the total weight of the motorcycle is distributed on the stand. Figure 5 shows the free body diagram of RhiNO v2.0 in this critical position.

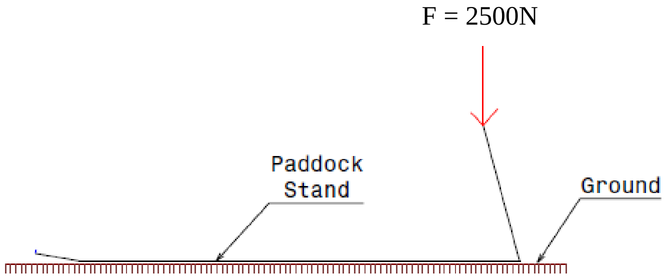


Figure 5. Free body diagram of critical position during operation of RhiNO v2.0

Finite Element Analysis (FEA) is a numerical method used by many researchers to solve complex structural problems using computers and technology [14], [15]. In this study, FEA was performed on the model to verify its structural rigidity. In CATIA V5R20 software, the finite element model was assigned with Aluminium Alloy 6061 T6 [17] for the main structure (properties as shown in Figure 6) which was recommended by the fabricator, Miester Technology (M) Pte. Ltd. It was assigned as clamped at the lever surface, where the stand would rest after the motorcycle is lifted, with 250 kg weight or equal to 2500 N of force acting on both ends of the support, as shown in Figure 7.

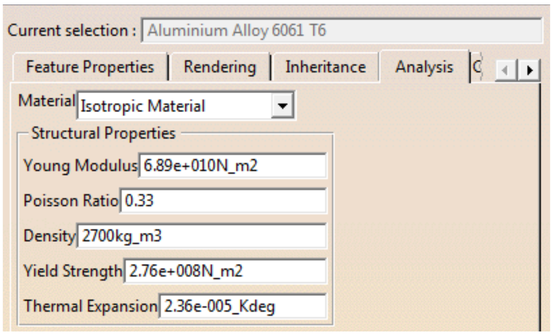


Figure 6. Material properties of the finite element model, Aluminium Alloy 6061, T6

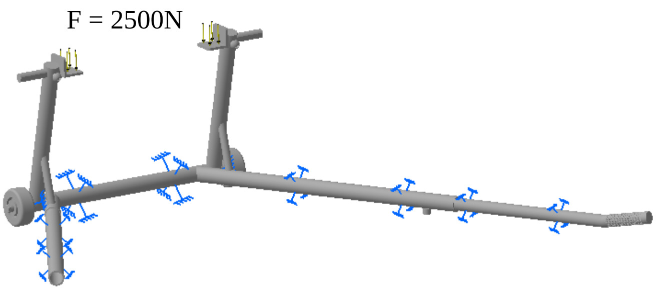
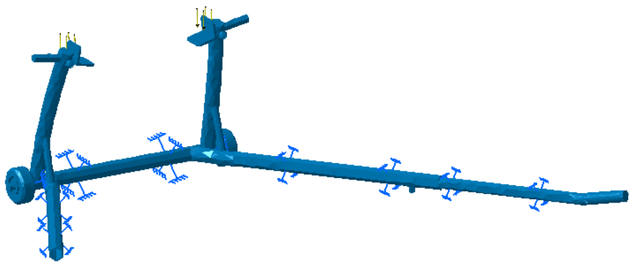
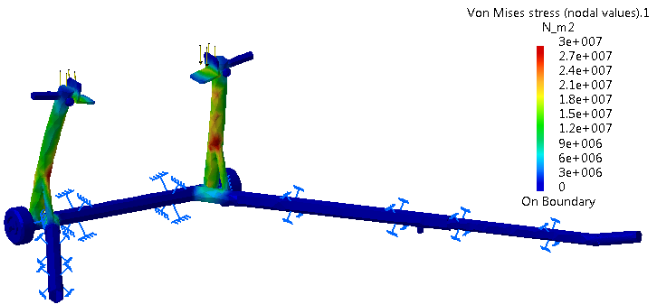


Figure 7. Boundary condition and acting load of the finite element model

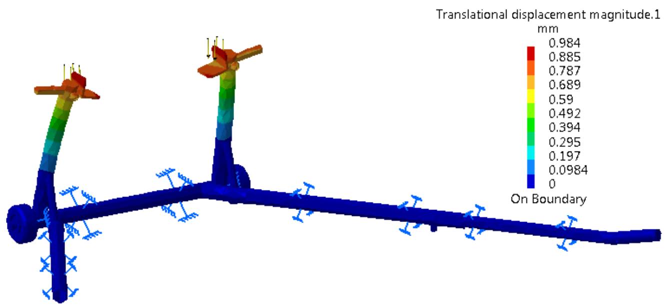
The FEA simulation analysis consists of the deformation, von Mises stress and translational displacement that occurs through stand structure. Figure 8(a) shows the deformation of the stand when the load acts on it. However, the FEA revealed that hardly any deformation occurs. Figure 8(b) shows the von Mises stress acting on the stand. The red area represents the maximum von Mises stress of 30 MPa, where the RhiNO v2.0 will be highly affected due to the load acting upon it. Figure 8(c) shows the translational displacement results when the load is applied to the stand where the red area represents the maximum translational displacement of 0.984 mm.



(a)



(b)



(c)

Figure 8. FEA in CATIA V5R20 (a) Deformation of the RhiNO v2.0, (b) von Mises stress acting on the RhiNO v2.0, and (c) Translational displacement on the RhiNO v2.0

Unlike its first generation, the FEA of the RhiNO v2.0 offer better stability and safety during operation with a much heavier superbike. The load distribution of the previous design was mainly focused at the hand lever part causing it to deflect. The RhiNO v2.0 offer better load distribution as the acting forces are evenly distributed along the stand, therefore offering better stability.

2.4 Prototype fabrication

The prototype for RhiNO v2.0 was fabricated at a steel fabricator company, Miester Technology (M) Pte. Ltd., Bukit Rambai, Melaka. The processes used in the fabrication were mainly welding and press fitting, apart from the knurling process patterned at the handlebar for better grip. Figure 9 shows the RhiNO v2.0 after being welded and press-fitted together. Figure 10 shows the full assembled parts of the RhiNO v2.0.

(a) (b)

Figure 9. (a) Frame of the RhiNO v2.0 base after welding, and (b) Handle of the RhiNO v2.0 after press fitting

Figure 10. Full assembly of RhiNO v2.0

3.0 RESULTS AND DISCUSSION

Table 2 shows the summary of the results obtained from the FEA simulation performed on the RhiNO v2.0 as compared to its predecessor, RhiNO v1.0 [16]. The nearly zero deformation indicates that the RhiNO v2.0 paddock stand can sustain the load acting upon it. The maximum von Mises stress obtained does not exceed the maximum yield strength of the aluminium alloy (276 MPa). This verifies that the RhiNO v2.0 paddock stand would not fail during operation when the exerted force is 2500N. The small maximum translational displacement shown does not have a big impact on the structural integrity of the stand.

Table 2: Summary results of the FEA

Static Case Solution	**Results**	
	RhiNO v1.0	**RhiNO v2.0**
Deformation	< 1.0 mm	< 1.0 mm
Maximum Von Mises Stress	81.2 MPa	30 MPa
Maximum Translational Displacement	1.38 mm	0.984 mm

Both prototypes have less than 1.0 mm deformation when the load is applied to it. This similarity shows that they can serve the lift of the rear part of a superbike without failing. However, the maximum von Mises stress obtained for RhiNO v1.0 is higher than RhiNO v2.0; thus, lowering the factor of safety which may increase the tendency of exceeding the maximum yield strength of the material if excessive weight is applied on the first version of the stand.

The value for factor of safety obtained is about nine (9) as calculated using Equation (1) which can be concluded that the stand is nine times safer from exceeding the yield strength of aluminium for failing due to plastic deformation that occurred on the structure.

$$Factor\ of\ Safety = \frac{Yield\ Strength\ of\ Aluminium}{Maximum\ Von\ Mises\ Stress} \quad (1)$$

Results from analyses and simulations through CATIA V5R20 reveal the theoretical ability of the RhiNO v2.0 paddock stand in receiving the maximum load of 250 kg. This indicates that the structure is completely robust to sustain the respective load. For testing purposes, a Kawasaki Ninja ZX-10R 2009 superbike was used in the lifting test with a weight of 208 kg which is lower than the amount of load applied in the FEA analysis. Figure 11 shows how the motorcycle is lifted by the supporter on the RhiNO v2.0 fitted under the superbike's bobbins. The supporter can be adjusted to various widths depending on the model of the superbike, by pulling the support lever on both sides of the stand.

(a) (b) (c)

Figure 11. (a) Left, (b) Centre, and (c) Right position of the RhiNO v2.0's supporter under the bobbins.

Figures 12 demonstrates how a single user operates the newly enhanced RhiNO v2.0 and how the stand lifted the rear tire of the superbike and put it in the upright position. For the first step to lift the superbike using this stand, the user's left-hand needs to hold the left throttle to maintain the superbike's chassis into a straight position. Then, using the user's right hand, RhiNO V2.0 is pushed downwards firmly until the handle of the stand touches the ground, lifting the rear tire of the superbike.

(a) (b)

Figure 12. (a) Single user demonstration of RhiNO v2.0 and (b) The RhiNO paddock stand with superbike's rear tire lifted

During use, the handle of the RhiNO paddock stand lies on the ground giving a firm and stable platform for maintenance work on the superbike. It will not topple over because the weight of the superbike acts downwards in front of the pivot point, which is at the paddock stand's wheels. This allows the stand to lock the superbike in a firm and stable elevated condition. Moreover, the extended handlebar can be slide inwards towards the main handlebar (resembles a telescopic feature) to avoid the possibility of obstructing people walking nearby the operating area. Figure 15 shows several views of the RhiNO paddock stand elevating and holding the superbike in position.

In comparison with its predecessor, both RhiNO v1.0 and 2.0 proved the ability to lift the rear part of a superbike by a single user only, with the enhanced design having a better design and features. The optimization towards the second generation of RhiNO manages to reduce the weight from 9 kg to only 4.5 kg, which contributes to a significant 50% reduction of the weight. RhiNO v2.0 also offer better handling due to its detachable feature. Figures 13 and 14 show the prototype design and application of both RhiNO side by side. There are a few differences between these two versions of RhiNO, which was summarized in Table 3.

(a) (b)

Figure 13. Prototype model of (a) RhiNO v1.0, and (b) RhiNO v2.0

(a) (b)

Figure 14. (a) RhiNO v1.0, and (b) RhiNO v2.0 in action

Table 3: Comparison between RhiNO v1.0 and RhiNO v2.0

Criteria	Version	
	RhiNO v1.0	**RhiNO v2.0**
Material	Mild Steel	Aluminium Alloy
Weight	Heavier (9 kg)	Lighter (4.5 kg)
Portability	Difficult to be carried because no parts could be detached	Easily carried with detach and attach parts by a plunger mechanism
Stability	Less stable due to unsymmetrical design	More stable with symmetrical design
Safety	Bulky design with extended handlebar could obstruct people walking nearby	Minimize the possibility of blocking people walking nearby by sliding inwards the extended handlebar using a telescopic concept
Corrosion Resistance	Easily corrode due to the presents of scratches caused by cyclic use on the painted stand	Highly resistant to corrosion due to low carbon content in aluminium properties
Maintainability	Hard to do maintenance if there are any defected or broken parts	Easily repaired by the separation of parts
Cost of Maintenance	Highly cost involving whole structure	Lower cost
Packaging Size	Consume more space because made in one main rigid structure	Minimize the space consumption by detaching parts
Manufacturing Cost	Cheaper	Costly (Lower cost in mass production)

4.0 CONCLUSION

This paper reports the structural and functional analysis in the development of an enhanced single user paddock stand named RhiNO v2.0. The enhanced and optimized design of the single user superbike paddock stand was fabricated based on the CAD modelling and tested using a real motorcycle, Kawasaki Ninja ZX-10R 2009. Having this product, it is proven that the RhiNO v2.0 is practical, convenient, and effortlessly operated by a single user, hence reducing the risk of LBP and MSD. Such development grants an enormous room and study for further research on motorcycle support structures.

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