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MOTORCYCLE CRASH TEST CENTRE: A MOVEABLE BARRIER APPROACH

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ABSTRACT

Over recent years, researchers have used full-scale motorcycle crash tests in the field of road safety research to simulate different types of crash technique and scenario. This study focuses on the development of laboratory-based motorcycle crash tests. A moveable barrier, designated as a 'trolley' in this study, is designed, developed and implemented in a laboratory-based motorcycle crash test. The design of the trolley underwent several versions prior to the final selection. Various design considerations and factors, such as the trolley's flexibility in various impact conditions, were weighted. Finite element analysis and experimental tests examine and explain the details of the design. The purposeful selection of this trolley is discussed, such as how it might meet wide industrial market applications. With a laboratory-based crash test facility, various crash scenarios and motorcycle crashworthiness could be determined in-situ, coupled with a reduction in expense and time. Therefore, this research would serve to enhance yet another aspect of automotive engineering.

Keywords*:* motorcycle, crash test, movable barrier, W-Beam guardrail.

INTRODUCTION

Previously, full-scale motorcycle crash tests have investigated the post-crash injuries of motorcycle accidents against various barriers, including roadside guardrails and four-wheeled vehicles. However, full-scale motorcycle crash tests are inefficient in terms of money and time and are subject to the weather's grace. Thus, introducing a moveable barrier, known as 'trolley' in this study, not only overcome deficiencies in a full-scale crash setup but creates a new platform for laboratory-based motorcycle crash tests. The purposeful multi-configuration of the trolley not only suits various crash objectives but also offers repeatability; a feature necessary to ensure the results is sufficiently free from bias prior to performing an analysis.

LITERATURE REVIEW

A considerable amount of literature has been published on full-scale motorcycle crash tests. The trolley developed by TNO Crash Safety Research, is designed in such a way that it provides forward momentum to the motorcycle through its rear axis with support at the handlebar (Nieboer et al., 1993). The purpose is to guide the motorcycle and provide support for the dummy prior to impact, which is similar to the method developed and used by DEKRA. In this setup, an improvised trolley provided support to the motorcycle as it slid along a rail at a predetermined speed. The motorcycle was released prior to impact with the crash object, which in this case was a guardrail (Berg et al., 2005). In another test by Chawla et al. (2005), the kinetics of crash simulations are matched with full-scale crash tests that were conducted by the Japan Automobile Research Institute. A trolley guides the motorcycle at a predetermined speed before it is released for impact with a passenger car (Chawla et al., 2005). In a similar method, Ibitoye et al. (2006) developed a jig for a full-scale crash test, in order to validate simulations on motorcyclist’s kinematics during impact. The jig consisted of rectangular welded metal frames to guide the motorcycle before it crashed into a W-Beam guardrail (Ibitoye et al., 2006).

Research has tended to focus on full-scale crash tests rather than on a laboratory-scale crash tests, especially for two-wheeled vehicles. In existing laboratory-based crash tests, the sled test is widely used to evaluate four-wheeled vehicle safety systems and dummy injuries. Fixed and moving barriers were also developed and used in side impact crash tests on four-wheeled vehicles. Moveable deformable barriers with pole side impact tests are being used as one of the standard certified tests on passenger cars for side impact safety analysis (Mizuno et al., 2004; Wang et al., 2006). In addition, a moving deformable barrier, in accordance with National Highway Traffic Safety Administration (NHTSA) specifications, was also developed and is widely adopted in four-wheeled vehicle side impact tests in the United States. In Europe, standard specifications are adopted in ECE R95 Dynamic Side Impact Regulations. The wheelbase for the trolley is 3 metres with a total mass of 950 kg (UNECE TD, 1995). It is important to note that all the moveable barriers that have been developed so far, are only suitable for four-wheeled vehicles and not for motorcycle crash tests. However, with the variety of moveable barriers being developed worldwide, specifically commissioned for four-wheeled vehicle crash tests, some could be improvised for laboratory-based motorcycle crash tests.

METHODOLOGY AND DESIGN CONSIDERATION

Prior to the actual design of the trolley, a few draft versions were drawn and these drafts studied and improved. At this early stage, all design factors and test considerations have to be incorporated. Finite element analysis (FEA) is then used to further determine the actual representation of the trolley's attachment, especially the W-beam guardrail. This is important as it represents the actual soil-planted C-post at the roadside, which is 1.12 metres deep (MPW, 1993). Once the design of the trolley was finalised, it was fabricated and underwent a few trial runs, validating its travelling velocity, before it was implemented in actual motorcycle crash tests. Figure 1 below shows the design flow chart.

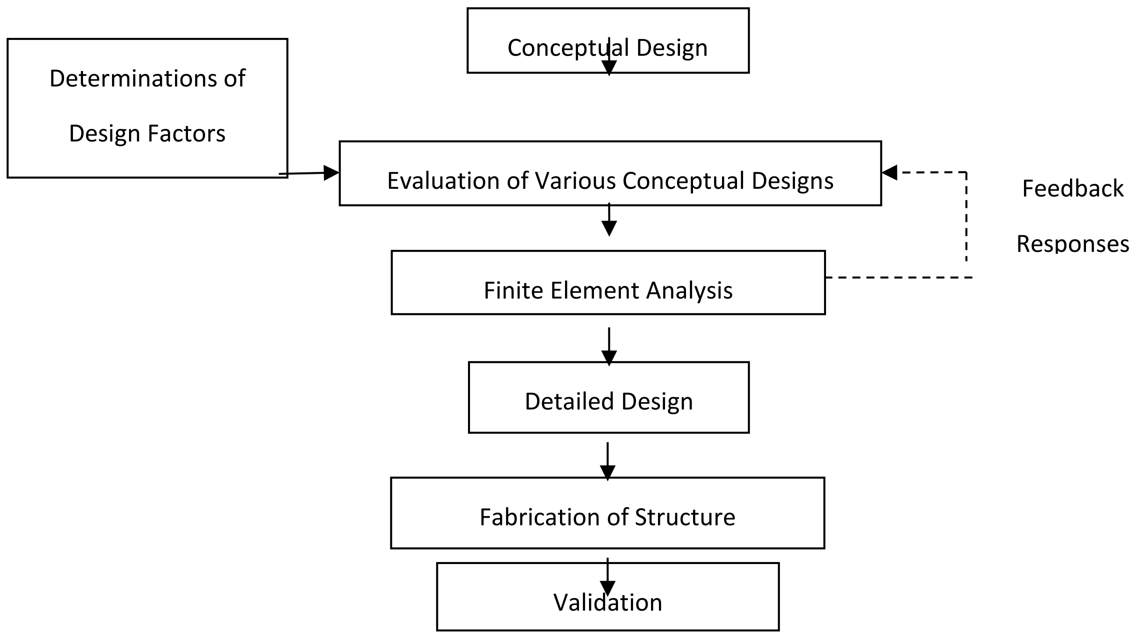


Figure 1. Design flow chart.

A few design factors should be considered prior to setting up a laboratory-based motorcycle crash test facility, which includes essential requirements and constraints. In addition, it must be able to simulate a full crash scenario and perform dynamic testing, something which is not possible with the conventional sled test. The motorcycle must be free to steer after release from the guidance system with the front wheel aligned straight in the direction of the crash. The facility should also able to accommodate dummy testing for investigative purposes of post-crash dummy kinematics. The barrier, a front-loaded detachable fixture, should offer flexibility in material fixture as well as crash objects. It may also allow consideration of frontal or angled impacts. These options facilitate the most important factor, which is repeatability.

Wong et al. (2006) developed a patented machine known as the MechT^{TM} Impactor, which is capable of undertaking various impact configurations. With the MechT^{TM} Impactor, kinetic energy is transferred to the crash object via the trolley. Figure 2 shows the trolley placed in the MechT^{TM} Impactor prior to impact.

Figure 2. Trolley and MechT impactor.

FABRICATION AND ANALYSIS

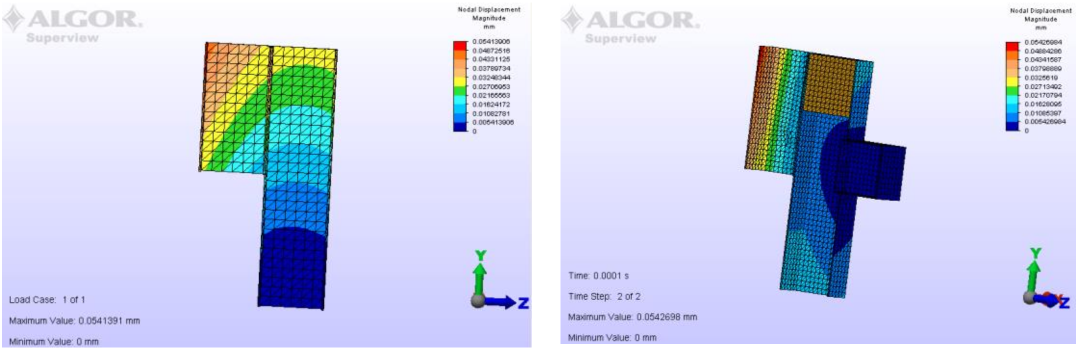
The dimension for a generic trolley is at 1325 mm long, 1000 mm wide and 600 mm in height. An attachable barrier is also incorporated to enable flexibility in material fixture for each selective crash test. The body structure is developed from 25.4 × 25.4 mm square bars that are welded together to form rectangular frames, to which four wheels are then fixed, as shown in **Error! Reference source not found.**3. The top of the trolley is equipped with a removable steel fencing mesh for safety considerations. This barrier-exchangeable feature enables either a solid metal plate, which acts as a 'rigid wall' or W-beam guardrail, or deformable honeycomb structures, which act as 'passenger car bumper elements', to be attached to suit specific test requirements. With the purpose built W-beam guardrail attached at the front acting as the crash barrier, the trolley with barrier would be 2085 mm long and 1960 mm wide.

Figure 3. Trolley with four wheels.

To determine the structural integrity on the trolley, a simple FEA was performed with a front attachment of C-posts of a W-beam guardrail in place. In an actual scenario, long C-posts are planted deep into the ground alongside highways. In this setup, attaching the long C-post onto the trolley, results in reduced lateral strength due to the free end fitting arrangement. During an impact, translational and rotational deformation is observed along the C-post. Based on FEA, it was determined that a rigid block with similar width but height of 162 mm needed to be added to the upper portion of the long C-post, as shown in **Error! Reference source not found.**4.

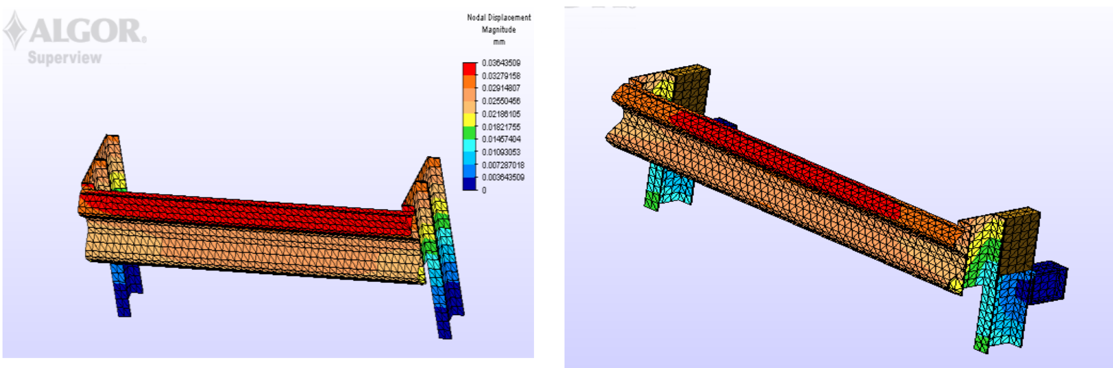
Figure 4. Special designed rigid block.

The modified structure, re-analysed via FEA, revealed that the stress is still well within the elastic region but with a maximum difference in deformation between the two C-posts of less than 0.00017 mm. This provides a high correlation between the trolley's C-post versus the soil planted C-post. The results are shown in **Error! Reference source not found.**5 and full views of the W-beam guardrails are shown in **Error! Reference source not found.**6.



(a) (b)

Figure 5. (a) Deformation on soil planted C-Post (b) Deformation on trolley's C-Post fitted with rigid block



(a) (b)

Figure 6. (a): Actual Soil Planted W-beam Guardrail Deformation; (b): Trolley's W-beam Guardrail Deformation Fitted with Rigid Block

The trolley is also designed with a rear solid metal back plate, as shown in

Figure 7: Back plate 7. The purpose of the rear-affixed plate is to provide a counter impact zone from the pendulum that in effect will project the whole trolley forward; hence, providing a moveable barrier while the weight of the solid metal plate acts to counter balance the weight of the W-beam guardrail at the front. With flexibility

in mind, this trolley is designed to accommodate various load configurations. There are two adjustable height bars at the front and back of the movable barrier, as shown in Figure 8. Loads or specially designed weights can be hooked horizontally either to the front or back of the trolley depending on crash test requirements. Different weights added along the structure may shift the centre gravity of the trolley and this feature could be exploited further in future studies. The height of the bars can be adjusted depending on impact configurations. This trolley with an attachable barrier is designed not only for ease of operation and maintenance but also for the ability for customisable impact conditions with flexibility in varying the impact loads.

Figure 7: Back plate.

Figure 8: Adjustable height bar for extra load requirement.

CONCLUSIONS

The moveable barrier provides adaptability for a wide range of use. It can act as a replacement for laboratory-level full-scale motorcycle crash tests. It can also be instituted as a test standard for motorcycle design approval. Through laboratory-based motorcycle crash tests, various design factors and motorcycle crashworthiness could be determined, with reduced costs and most importantly, independent of the weather. Motorcycle manufacturers would be able to use the facility to improve in-house motorcycle parts or complete structural designs. In accident reconstructions, the facility would greatly contribute to assessing accident impact velocity via its flexible crash configuration settings.

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