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Assessing Motorcycle Safety Helmet Standards Compliance

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Abstract – *This study attempts to analyse new helmet performance which was certified to MS1:1996 standards (impact energy attenuation and penetration resistance) with respect to a newly established standard MS1:2011 which has a strong resemblance to the United Nations Regulation No 22 (UNR22). Few helmet models were randomly purchased and tests were performed in an established technical laboratory. The result indicated that one of five popular models was able to meet the requirements of the new standards. The rest of the helmet samples were only managed to pass partially, for example they performed well in the frontal impact test but performed poorly in the lateral impact. Few helmets failed to meet the minimum impact speed requirements. In brief, the new standards are more comprehensive and have more demanding requirements for existing product range to comply with and some changes to the existing helmet design may be necessary and it is achievable.*

Keywords: Helmet, helmet standard, impact test, penetration test

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1.0 INTRODUCTION

The new helmet standards for Malaysia, coded as MS1:2011 was officially gazetted for enactment and made public in the year 2012 (Malaysian Standard, 2011). It shall replace the previous version dated the year 1996 and awaiting implementation (Malaysian Standard, 1996). Comparatively, the new standards encompass more comprehensive tests and stringent requirements, and very similar to United Nations Regulation No. 22 (UNR22) protocols (UNECE, 2001). Among the notable and significant changes are the adoption of lower head acceleration values of 275*g* (previously 300*g*, where g represents gravitational acceleration, $g=9.81m/s2$) and the inclusion of Head Injury Criterion (HIC) of 2,400 (previously not addressed) for impact attenuation test performance requirements (Malaysian Standard, 2011). The new standard maintains the 'resistance to penetration' test from previous standard though the UNR22 does not address such requirement. Almost all established helmet standards mandated the energy absorbing performance and penetration resistance performance in their impact test protocols (JIS, 2015; Malaysian Standard, 2011; AS/NZS, 2006; BSI, 1985). Helmet performance in protecting the motorcyclist's heads is usually measured by how good the helmet could attenuate crash impact energy and resist penetrative impacts.

The motorcycle helmet primarily comprises of a hard-outer shell, impact liner (referred as liner throughout this report), comfort liner, chin strap and face visor (Figure 1). In local scene, open face helmet type is over-represented on the road (>90%), revealing motorcyclists helmet type preferences for warm and humid tropical climate and presumably due to its relatively wider visual freedom to manoeuvre in traffic congestions, relative to full-face helmet (Hamzah, 2015).

Figure 1: Open face helmets (l) and EPS impact liner (r)

1.1 Helmet Standards Comparison

Table 1 below demonstrates the main differences between the MS1:1996 and the MS1:2011standards, with respect to impact attenuation tests (Malaysian Standard, 2011, 2006).

Table 1: Helmet Standards comparison

Test specifications	MS1:1996	MS1:2011	Remarks
Impact test			
○ Impact speed	N/A	7.5m/s	Speed specified for flat and hemispherical anvils
○ Drop height			Drop height specified 1.83m equals 6m/s 2.15m equals 6.5m/s
• Flat anvil	1.83m	N/A	
• Hemispherical anvil	2.15m	N/A	
○ Acceleration limit	≤300g	≤275g	
○ HIC value	N/A	≤2400	
○ Impact points on helmet	4 sides, 2 times per side	4 sides, 1 time per side	MS1:2011 do not require successive impact at same side
Penetration test			Such test not required in UN R22
• Striker mass	4.5 kg	4.5 kg	
• Drop height	2m	2m	

In details, MS1:2011 is relatively more comprehensive, encompassing more severe testing parameters. For instance, it designates a constant impact speed of 7.5 m/s for both anvils whilst the previous standard only specifies drop height which is equivalent to 6 m/s and 6.5 m/s, (27% and 15% higher, respectively). In addition, head form peak acceleration limit was improved to 275g (8% lower) and Head Injury Criteria (HIC) of 2400 was introduced into the pass/fail limit. In short, the MS1:2011 requirements promote greater impact energy to be dispersed away by helmet thus limiting it from reaching the head form or the users' head in reality. Additionally, the successive impact test requirements at all helmet sites were no longer applicable. Maintaining the shell penetration resistance test makes MS1:2011 slightly more challenging to comply with, relative to the UNR22. Such stand was taken possibly due to lack of evidence to say otherwise.

This report attempts to explore and determine the standard-compliant helmets performance with respect to the MS1:2011 standards relative to their impact and penetration resistance performances. It is hoping the result may provide information to relevant authorities on the newly established helmet standards implementation plan.

2.0 METHODOLOGY

Helmets for this study were purchased new off-the shelves, in good working conditions and unutilized on roads. Prior to procurement, a short survey was performed to analyse helmet availability and accessibility. Budgetary constraints have limited the test to popular helmet models only and in limited numbers, thus the results are only indicative of helmet performance and does not provide any conclusive evidence for generalization for all certified helmets in the market. Additionally, although the test sought to determine the failure limit for impact attenuation and penetration resistance, impact speed increment, however, was kept restricted to a predetermined value to safeguard the test equipment integrity and functionality.

Market surveillance for standard-compliant helmets was performed at motorcycle shops in Klang Valley to scout for availability including makes, models, and types. The procurement of helmet samples was done based on the popular lists. Among the selection criteria defined for the procurement were standard-compliant helmets with approval marks (Figure 2) and with ABS as the shell material due its dominant presence in the market.

The helmet attributes such as model, mass, shell and liner thickness were recorded prior to the test. Important information includes test speeds, peak head form resultant acceleration values and head injury criterion values (HIC) were automatically captured during test conduction, as shown in Figure 3 (left). The study will look at pass/fail performance, and in case of a pass, the impact speed was increased further to establish the failure limits.

The test parameters for impact attenuation and penetration resistance tests were in accordance with MS1:2011. Since all the samples were certified to MS1:1996, the initial impact speed was 6 m/s and increased gradually for the subsequent side, until failure sets in. All the samples were conditioned to room temperatures. The apparatus used to perform both tests are shown in Figure 3 (right). The obvious difference between the 2 tests is that the impact test requires the helmet to drop down to hit the anvil while for penetration test, a metal striker would be dropped onto the helmet outer shell.

Figure 2: Approval mark and material specification

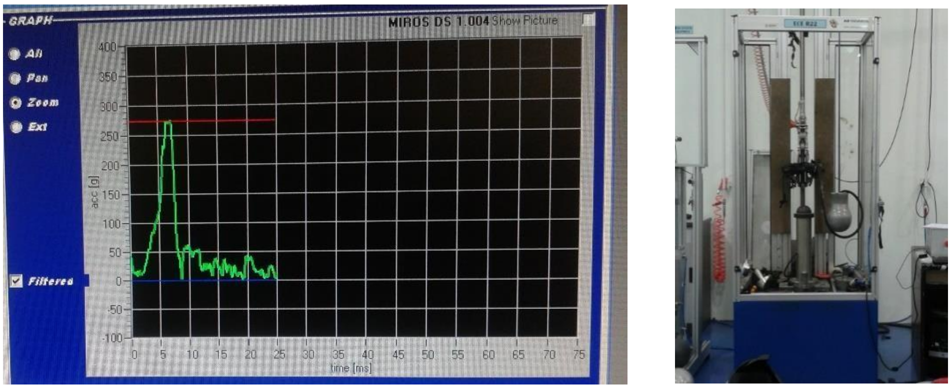

Figure 3: Peak acceleration record (left) and monorail impact test machine (right)

During crash impact, the energy is managed by the hard outer shell and the inner impact liner or commonly known as impact liner or impact foam. For this study, open face helmets (Figure 1) with shell made of acrylonitrile polybutadiene styrene (ABS) and foam made of expanded polystyrene (EPS) were selected due to their market dominance (Hamzah, 2015). For energy absorption, it is estimated that the shell will take up approximately 34 percent while the liner normally experiences 35 to 50 percent (Liu et al., 2008). Penetration resistance performance is commonly tested in laboratory and measured by evaluating penetrative marks on the head form, post-impact. Any sign of contact of the striker to the head form would be considered as failure of the shell and foam to resist penetration to the rider's head. The points chosen for impact tests are located at front, rear, crown and either lateral left/right (as shown in Figure 4). Flat anvil was selected as the impacted surface since it represents the most struck surface (Liu et al., 2008; MAIDS, 2004). For penetration test, impact point was around the crown area.

For impact test data, head acceleration values for first and second impact on the same sides were compared. A similar comparison was performed for different helmet models. For penetration tests, the experiment tried to explore the limit of protection for impact with sharp pointed objects, in other words to find out the speed when failure starts, that is by increasing the impact speed and holding other variables constant.

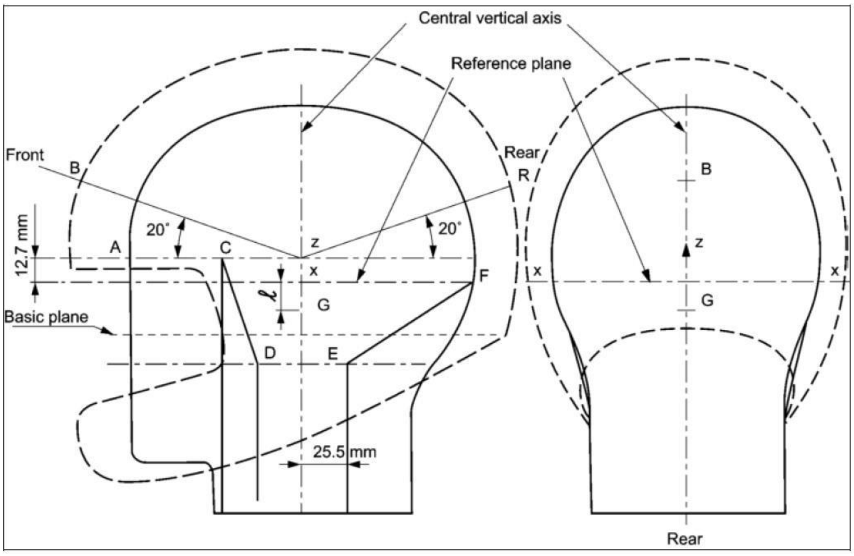

Figure 4: Location of impact sides (Malaysian Standard, 2011)

3.0 RESULTS AND DISCUSSION

The overall results of the test are shown below in Table 2.

3.1 Samples Attributes

In short, five different helmet models were procured, at random, from motorcycle shops in Klang Valley and their attributes are reflected in Table 2. All models were labelled A to E to obscure their make identity to avoid any potential negative implications to manufacturers or consumers. All helmets were open-face type and classified into three price ranges, namely low, medium, and high. Attributes of mass, shell thickness, and liner thickness were measured to provide some indications relative to the price group.

Table 2: Helmet attributes

Model	Unit price, RM	Price category	Mean mass, g	Shell thickness, mm	Liner thickness, mm
A	121	Medium	1460	3.2	25
B	115	Medium	1310	3.0	30
C	150	High	1490	3.2	32
D	70	Low	1250	3.0	42
E	55	Low	940	3.5	30

All helmets open-face type
Price category: Low ≤ RM 70, Medium ≤ RM125, High > RM125

3.2 Impact Attenuation

The energy-absorbing capability is measured by the head form peak resultant acceleration and the HIC, during the impact duration. Failure to meet both requirements, at any impacted side, will result in non-compliance with the helmet for certification. Table 3 depicts the impact test passing rate of 4 samples each for every model, with respect to each impacted side. Obviously, only model B was able to meet the MS1:2011 requirements for impact test (Peak acceleration≤275g and HIC≤2400). Model A and C were able to meet the requirements at the rear and centre sides only. Model D and E failed to comply with the requirements (except at centre for model E). Model B belongs to the medium price category but able to pass at all impacted sides, for all the samples.

For the impact speed, only model B was able to comply with the minimum speed of 7.5m/s (by 6%), while the rests were not able to comply. Nevertheless, all the speed records were beyond the requirement of the MS1:1996 (6m/s), in which the helmets were originally designed to meet. The worst performer Model C was 7.5% better in speed compliance of MS1:1996. Other models were 10% (Model A), 13% (Model D) and 9% (Model E) better. In other words, the MS1:1996 compliant helmets were able to exceed the stipulated speed by a margin of between 7.5% to 13 %. With respect to the impact side, performance of lateral right/left was the worst in which only model B was able to meet the requirements. This could be explained by the lack of liner materials near the earlobe zone to absorb the impact. The distribution of all the individual peak acceleration records over varying impact energy for all the samples are tabulated in Figure 5 below.

Table 3: Impact test pass rate for all helmet models

Model	MS1:2011 Pass rate				Max. impact speed, m/s	Impact energy, J
	Front	Rear	Centre	Right/Left		
A	0/4	4/4	4/4	0/4	6.61	122
B	**4/4**	**4/4**	**4/4**	**4/4**	**7.95**	**177**
C	3/4	4/4	4/4	0/4	6.45	116
D	0/4	0/4	0/4	0/4	6.78	129
E	0/4	0/4	4/4	0/4	6.55	120

Note: 4 helmets per model

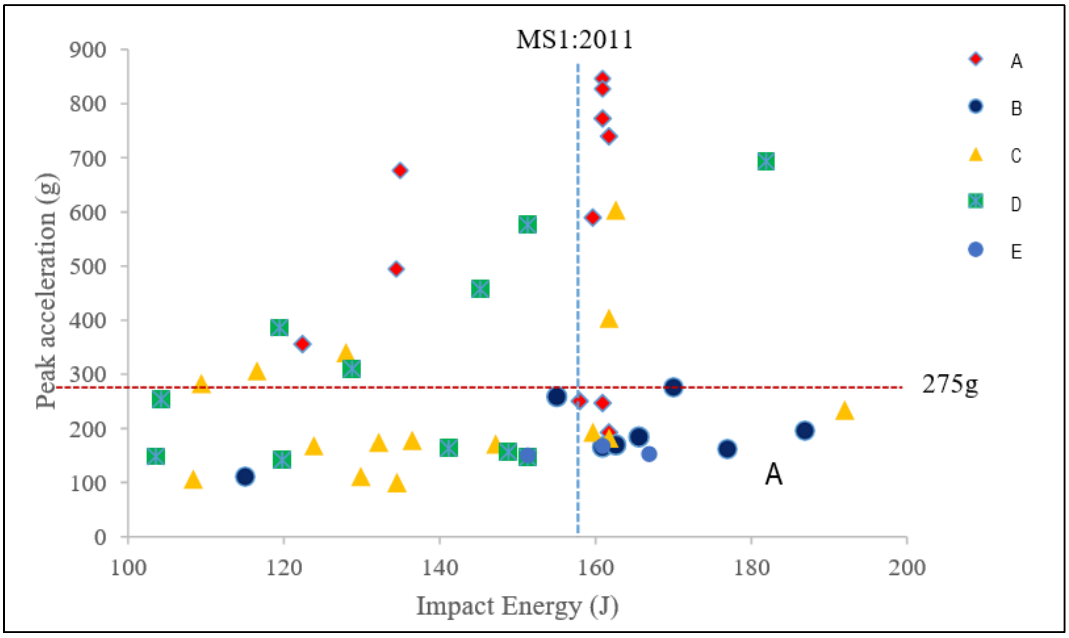

Figure 5: Peak acceleration over impact energy

Since the objective was looking for pass/fail and performance limit of helmets, the impact energy experimented at value exceeding 100J. Dividing into regions relative to the peak acceleration of 275g, only those model falls into region marked A passed the MS1:2011 requirements. Nevertheless, if reference is made to the earlier standard MS1:1996 requirements (300g), quite a substantial portion of the samples indicated inferior performance (>300g), possibly due to manufacturing variability and the batch approval process. In addition, as reported by Demarco et al., 2010, the shell and liner thickness may have contributed to the differences in which thinner liner tends to reach densification phase earlier than the ones which reflect favourable results (DeMarco et al., 2010). The pattern of peak acceleration displayed in Figure 5 showed that only one model was able to meet the MS1:2011 acceleration requirements.

The individual HIC records over impact energy are displayed in Figure 6 below. The dotted horizontal and vertical lines mark the minimum limit for helmets to comply with the MS1:2011. Model A performed poorly where approximately 70% of all impacted sides exceeded the 2400 HIC mark, even at lower than 158J impact. Model C and E performed well at almost all sides while Model D showed too wide HIC variation across the impact energy range and very unlikely to meet the HIC requirement. In other words, region denoted B reflected samples that have performed beyond the minimum and showed potential of standard compliance. At lower impact speed (lower impact energy), more than half of the samples were likely to meet the HIC requirement. Considering that HIC was never a requirement in MS1:1996, the result indicates that further improvement of the helmet designs is highly necessary to meet the new standard requirements, and maintaining the status quo was not an option.

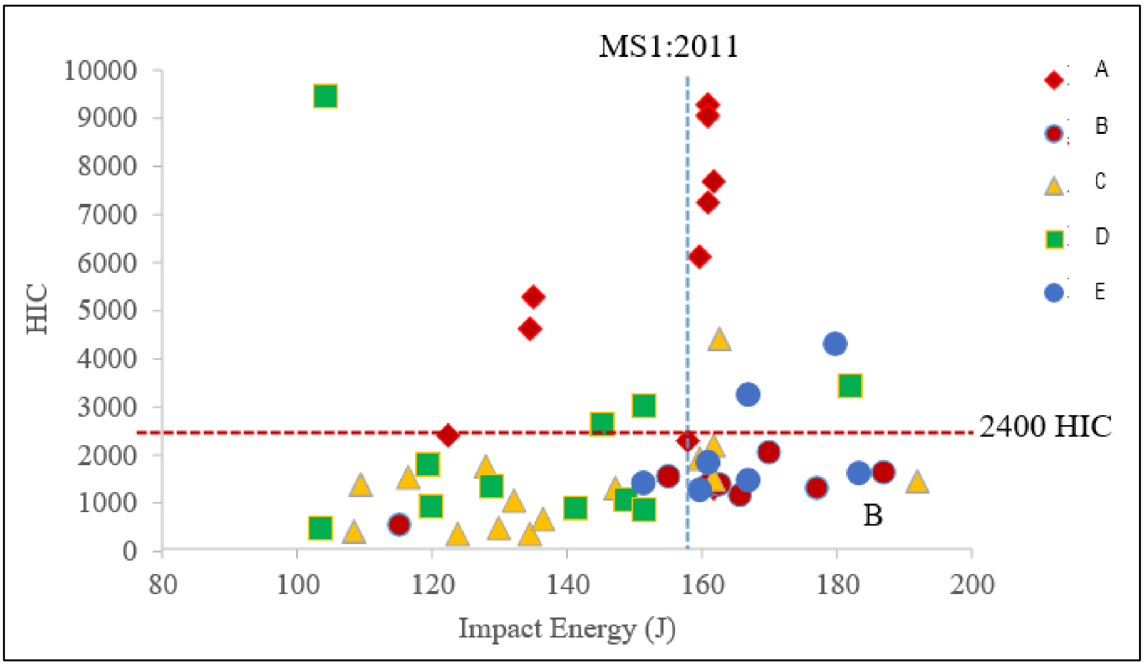

Figure 6: HIC over impact energy

3.3 Penetration Resistance

The hard shell plays a vital role in dictating the penetration resistance performance for helmet. To get the failure limit, samples were tested a number of times with the drop height varied each time until failure sets in. Each time the impact point was relocated to avoid hitting the weakened spot, in this case, the successive points must be 76mm away from the centre of earlier impacts (Malaysian Standard, 2011). The standards test height is 2m (equivalent to 88J). Table 4 reflected the maximum height of drop which resulted in the failure of the shell. Generally, relative to the height and impact energy, all models performed beyond the penetration resistance criteria, with the lowest score 30% above standard requirement and the top performer was 60% better. In short, all models were able to meet the penetration resistance requirements, regardless of their price category, possibly contributed by the shell thickness and the ABS material.

Table 4: Penetration resistance test results

Model	Shell thickness, mm	Max height, m	Impact Energy at failure, J
A	3.2	3.2	141
B	3.0	2.8	124
C	3.2	3.2	141
D	3.0	2.6	115
E	3.5	2.6	115

4.0 CONCLUSION

The study had addressed and met the objectives of evaluating MS1:1996 compliant-helmets protective limits, relative to MS1:2011 impact and penetration resistance performances. Overall, only one of the five models was able to meet the impact test requirements of MS1:2011. The higher impact energy and lower passing limit requirements in the MS1:2011 standards prove very perplexing for the MS1:1996 compliant helmets. The reduction in peak acceleration values (22% decrement, from 300g to 275g) and the inclusion of HIC (not a requirement in MS1:1996) as pass criteria are something very challenging to the helmet industry to strive at, but not impossible. For penetration resistance test, all helmets performed beyond standard requirements, at a range of 30 to 60% better than the requirement. In other words, changes to the existing design are very necessary for the helmets to comply with the new requirements. Nevertheless, the new standards are perceived to bring greater benefit in terms of superior protective performance from the former standards, thus providing a better option for consumers. It is recommended that the authorities and the industry take a leap forward in implementing and complying with the new standard requirements soonest possible for the benefits of the users in general.

REFERENCES

AS/NZS (2006). *Protective helmets for vehicle users*. AS/NZS 1698:2006. Australian/New Zealand Standard.

BSI (1985). *Specification for protective helmets for vehicle users*. BS 6658:1985. British Standards Institution.

DeMarco, A.L., Chimich, D.D., Gardiner, JC., Nightingale, R. W., & Siegmund, G.P. (2010). The impact response of motorcycle helmets at different impact severities. *Accident Analysis & Prevention*, *42*(6), 1778-1784.

Hamzah, A., (2015). *Experimental determination of safe service life of motorcycle helmet*. Master Thesis, University Putra Malaysia.

JIS (2015). *Protective helmets for motor vehicle users*. JIS T8133:2015. Japanese Standards Association.

Liu, B.C., Ivers, R., Norton, R., Boufous, S., Blows, S., & Lo, S.K. (2008). Helmets for preventing injury in motorcycle riders. *Cochrane database of systematic reviews*, (1).

MAIDS. (2004). *In depth investigations of accidents involving powered two wheelers*. Final Report 1.2, Brussels. Retrieved from http://ec.europa.eu/transport/roadsafety/library/publications/maids report 12 Sep 2004.

Malaysian Standard (1996). *Specifications for protective helmets for vehicle users (2nd Revision),* Malaysian Standard MS1:1996. Department of Standards Malaysia.

Malaysian Standard (2011). *Protective helmets and visors for vehicle users – specification-part 1: protective helmets (3rd revision).* Malaysian Standard MS1:2011. Department of Standards Malaysia.

UNECE (2001). *Uniform provisions concerning the approval of protective helmets and their visors for drivers and passengers of motor cycles and mopeds*. UN Regulations No 22. United Nations Economic Commission for Europe (UNECE).