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Determination of Stopping Distance for Low CC Motorcycles with Antilock Braking

(Jarak Berhenti Motosikal Berkapasiti Enjin Rendah dengan Brek Anti-kunci)

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ABSTRACT

Motorcycles are among the favorite transportation preferred by Malaysians. Almost half of the vehicles registered in Malaysia are motorcycles. This is due to the price affordability and size, where almost 80% of the motorcycles owned are categorized under engine capacity below 250 cc. Similar to other Southeast Asia countries, motorcyclists remain the highest contributor to road traffic fatalities and injuries in Malaysia. The New Car Assessment Program (NCAP), has elevated the importance of safety technology in passenger cars such as anti-lock braking system (ABS) and autonomous emergency braking (AEB) in order to protect the occupants. However, the limitation of space and power requirements in two-wheel motorcycles deferred the technology implementation. Previous studies have attempted to study the effectiveness of ABS for motorcycles with 250 cc and above. Focusing on the low cc motorcycle of less than 250 cc, this paper compares motorcycle braking distance and rider stability between motorcycles with ABS and motorcycles without ABS during dry and wet conditions. The braking distance produced by ABS is reduced by 50% and 12% in dry and wet conditions respectively. In addition, motorcycles with ABS were tested at higher speeds of 50 km/h. ABS motorcycles shows consistent data for a series of tests. This finding demonstrates the effectiveness of ABS in improving braking performance for low cc motorcycles.

Keywords: Antilock brake system (ABS); Stopping distance; Two-wheelers; Braking performance; Active safety

ABSTRAK

Motosikal merupakan mod pengangkutan yang digemari oleh rakyat Malaysia. Sekitar separuh daripada kenderaan yang berdaftar di Malaysia adalah motosikal. Hal ini disebabkan harga yang mampu milik dan saiz yang kecil, di mana 80% daripada pemilikan motosikal di Malaysia adalah dalam kategori kapasiti enjin bawah 250 cc. Seperti negara Asia Tenggara yang lain, penunggang motosikal merupakan penyumbang terbesar angka kematian dan kecederaan disebabkan nahas jalan raya di Malaysia. Program Penilaian Kereta Baharu (NCAP) telah menekankan keutamaan teknologi keselamatan dalam kenderaan penumpang seperti sistem brek anti-kunci (ABS) dan brek kecemasan automatik (AEB) bagi tujuan melindungi penumpang. Namun, kekurangan ruang dan keperluan kuasa menyebabkan penangguhan pelaksanaan teknologi tersebut dalam kenderaan dua roda. Kajian-kajian terdahulu memfokuskan kepada keberkesanan teknologi ABS pada motosikal berkapasiti enjin 250 cc dan ke atas. Dalam kajian ini, motosikal berkapasiti enjin bawah 250 dengan dan tanpa ABS digunakan bagi mengkaji jarak berhenti brek dan kestabilan penunggang pada keadaan permukaan kering dan basah. Jarak berhenti brek yang dihasilkan oleh motosikal dengan ABS berkurang sebanyak 50% and 12% masing-masing dalam keadaan kering dan basah. Tambahan, motosikal dengan ABS diuji pada kelajuan yang lebih tinggi iaitu 50 km/h. Motosikal ABS menghasilkan *data yang konsisten walaupun ujian dilakukan secara berterusan dan berulang. Hasil kajian ini menunjukkan keberkesanan ABS dalam meningkatkan prestasi brek bagi motosikla berkapasiti enjin rendah.*

Kata kunci: Sistem brek anti-kunci (ABS); Jarak berhenti; Kenderaan dua roda; Prestasi pembrekan; Keselamatan aktif

INTRODUCTION

During the past ten years, motorcycles have remained the uppermost transportation mode contributing to traffic death in Malaysia. Around 40% of the casualties involved persons aged 16-25 (RMP,2017). Even during Movement Control Order in 2020 and 2021, the traffic death involving motorcycles remained at 67% (RMP, 2021). This might be due to the surging demand for parcel hailing (p-hailing), motorcyclists delivering food and parcel delivery by online transaction. Statistical data by Social Security Organization (SOCSO) found that 90% of commuting accidents involved motorcyclists and 42% involved young workers less than 30 years old (Bernama 2023). Further analysis of SOCSO commuting accidents also showed that more than half of fatalities involving self-employed persons were contributed by food delivery riders. To improve the safety of motorcycles, one of the priority areas in Malaysia Road Safety Plan 2022-2030 has been set to enhance safer motorcycle riding by implementing safety technologies.

Recently, the Ministry of Transport Malaysia announced the mandatory of anti-lock braking system (ABS) in new motorcycles with engine capacity above 150 cc, commencing by 2025 (Abdul Kadir 2022). ABS technology in motorcycles was introduced in 1988 and works to prevent wheels from locking during braking and increases motorcycle stability. The fitment of ABS in motorcycles has also been mandated in Europe, Japan, New Zealand, Australia, and India (engine capacity above 125 cc). Thailand has also announced the mandatory ABS for all new motorized two-wheeler vehicles starting in 2024 and existing models above 125 cc by 2026. Table 1 shows the lists of current motorcycles with engine capacity less than 250 cc sold in the Malaysian market equipped with ABS. Single ABS is installed in the front wheel and dual ABS works on both front and rear wheels. From the observation, street motorcycles have the highest number of motorcycles equipped with ABS, followed by scooters and underbones representing the least popular. The main Precisely, ABS does not prevent the crash from happening. Nevertheless, the prevention of wheel locking during braking will help the riders stabilize their motorcycles during emergency braking(Lich et al. 2016) .

There is a considerable amount of literature that has compared the braking performance of motorcycles with and without ABS. (Anderson et al. 2010). run braking tests for motorcycles with single ABS, integrated ABS, CBS, and non-ABS. By using both brakes, a motorcycle with integrated ABS exhibits the highest deceleration at 9.88 m/s^2 followed by single ABS at 9.13 m/s^2. Non-ABS motorcycles produced the lowest deceleration at 6.93 m/s^2. In another study, (Vavryn & Winkelbauer 2004) found that the mean deceleration of experienced drivers improved by 18% when they used ABS motorcycles compared to riding their motorcycles (non-ABS). Green (2006) has indicated that the braking distance of ABS motorcycle is more consistent compared to non-ABS motorcycle and reduced braking distance by 5%. Previous studies have only focused on the performance of ABS for motorcycles engine capacity of 200 cc or above. A recent study conducted by Koetniyom, Chanthanumataporn & Dangchat (2021) has compared ABS, non-ABS and CBS motorcycles with an engine capacity 125 cc. Instead, the result shows that the braking distance for ABS is better than other motorcycles in low friction coefficient, but slightly longer in high friction coefficient testing. Thus, there is still a need for a discussion on the performance of ABS in low cc motorcycles.

This paper aims to evaluate the braking performance of an ABS motorcycle with an engine capacity below 200 cc currently available in the Malaysian market. The braking test was conducted using ABS and non ABS motorcycles in dry and wet conditions, and ABS motorcycle at higher speeds. Our experimental setup bears a close resemblance to the study conducted by Anderson et al. (2010) except that this test was only conducted using both brakes. Findings from this research will be used to educate motorcyclists on how ABS technology works during emergency braking.

METHODOLOGY

There are two experiments being conducted in this study. The first experiment compares the braking distance of motorcycles with ABS and non-ABS during dry and wet conditions. In the second experiment, the braking distance of a motorcycle with ABS at a higher speed is tested. In the first experiment, two types of motorcycles are used to compare the braking distance for ABS (SYM VF3i PRO) and non-ABS type (Yamaha Y15ZR). Both riders are experienced drivers who have attended motorcycle defensive riding training. The specifications of the models are listed in Table 2. The tests are conducted at 30 km/h in dry and wet conditions. The outrigger is installed on both motorcycles to prevent slipping during testing.

TABLE 1. Motorcycles (<250 cc) equipped with ABS in the Malaysian market (ref: open source manufacturer website)

Make/Model	Type	Engine (<250 cc)	ABS
Honda RS-X	Underbone	149.16 cc	Single
Honda CBR150R	Sports	149.2 cc	Dual
WMOTO Xtreme 150i	Scooter	149.3 cc	Dual
Honda ADV 150	Underbone	149.32 cc	Single
Yamaha NVX ABS	Scooter	155 cc	Single
Yamaha YZF-R15M	Sports	155 cc	Dual
Vespa Primavera S 150	Scooter	155 cc	Dual
Vespa Sprint S 150	Scooter	155 cc	Dual
SYM Jet 14 200 ABS	Scooter	168.9 cc	Single
Royal Alloy GP180 ABS	Scooter	169 cc	Single
Aprilia SR GT 200 ABS	Sport	174 cc	Dual
SYM VF3i 185 LE Pro	Underbone	185 cc	Single
Modenas NS200 ABS	Scooter	199.5 cc	Dual
Modenas Pulsar RS200 ABS	Sport	199.5 cc	Single
KTM RC200	Sport	199.5 cc	Dual
KTM 200 Duke	Sport	200 cc	Dual
Royal Alloy TG250 ABS	Sport	244 cc	Single
WMOTO ES250i	Sport	244.3 cc	Single
WMOTO RT3	Sport	247 cc	Dual
Yamaha MT-25	Sport	249 cc	Dual
KTM 250 Duke ABS	Sport	249 cc	Single
Kawasaki Ninja 250 ABS	Sport	249 cc	Dual
Kawasaki Z250 ABS	Sport	249 cc	Dual
Modenas Elegan 250 ABS	Scooter	249.1 cc	Single
CFMoto 250SR ABS	Sport	249.2 cc	Dual
CFMoto 250NK SE ABS	Sport	249.2 cc	Single
Honda CBR250RR	Sport	249.7 cc	Dual

In the second experiment, a motorcycle with ABS was equipped with a data acquisition system and tested in dry conditions at 50 km/h. The data acquisition used for this study is Racelogic VBOX 3i (Figure 1), equipped with GPS signal and secured at the back of the motorcycle (as in Figure 2). The speed of the test is based on a previous study by (Huertas-Leyva et al. 2019), where the average impact speed during a motorcycle crash collected from MAIDS (Motorcycle Accidents In Depth Study) shown between 40 km/h and 60 km/h. The rider was asked to achieve a speed of 50 km/h before applying braking at the start of set-up traffic cones. The experiment setup can be seen in Figure 3. The test is performed up to ten times to study the consistency of braking produced by motorcycle ABS. The difference between theory, satellite and physical data is compared. The braking distance for theory is calculated based on Equation 1.

$$s = \frac{u^2}{2a} \quad (1)$$

where u is initial velocity (m/s), and a is acceleration in (m/s^2). In this study, the initial velocity referred velocity of rider before applying brake. Value a is calculated using the formula in Equation 2.

$$a = fg \quad (2)$$

where f is the drag factor using 0.7 (dry condition) and g refers to acceleration due to gravity (9.8 m/s^2). Satellite data refers to the braking distance generated from data acquisition and physical data refers to manual measurement from the start of the safety cone (cue point for the rider to brake) until the motorcycle stops. For both experiments, the rider used both front and rear brakes simultaneously during all testing.

TABLE 2. Tested motorcycles with ABS and non ABS

Model	SYM VF3i PRO	Yamaha Y15ZR
Weight (kg)	128	115
Displacement (cc)	183	150
Wheelbase (mm)	1290	1290
Front brake	Disc brake, ABS	Disc Brake
Rear brake	Disc brake	Disc Brake

FIGURE 1. Data acquisition system VBOX 3i

FIGURE 2. Equipment setup at the back of the motorcycle

FIGURE 3. Experiment setup showing rider applying the brake at the start of traffic cones.

RESULTS AND DISCUSSION

Figure 4 compares the braking distance produced by ABS and non-ABS motorcycles tested under different surfaces. In general, testing with an ABS motorcycle produces the shortest distance in both setup conditions. Under the dry surface, the braking distance of an ABS motorcycle is reduced by nearly two times compared to a non-ABS motorcycle. Testing in wet conditions slightly increased the braking distance, in which ABS motorcycle stopped at the braking distance of 9.9m, slightly lowered 11.6% compared to non-ABS motorcycle at 11.2m. This result is in accordance with findings by Green (2006) that reported the braking distance for ABS motorcycle is improved by 10.8% than non-ABS motorcycle in wet conditions.

Regarding the stability of the rider, the sequences of the brake testing for both ABS and non-ABS motorcycles under wet surfaces are highlighted in Figure 5. The red dot line represents the starting point for braking (marked by the safety cone) and the yellow line shows the endpoint of the braking. Figure 5(a-d) shows the braking distance of a motorcycle with ABS. It is important to note that while the braking distance is shortened, the position of the ABS rider after applying brake on the wet surface is straight, showing that the rider has full control of the handling bar during braking. In Figure 6 (e-f), the rider produces a higher stopping distance while using the non-ABS motorcycle. A close inspection in Figure 6(e-g) shows that the rider was tilting towards the right (shown by the arrow) of the motorcycle during braking. The wheel of the outrigger on the right is in touch with the ground after braking is applied, proving that the rider might lose balance during testing and may result in falling if the outrigger was not installed. According to a study conducted by Rizzi et al. (2016), riders with ABS motorcycles who applied brake before crash are in the upright position compared to riders with non ABS motorcycles.

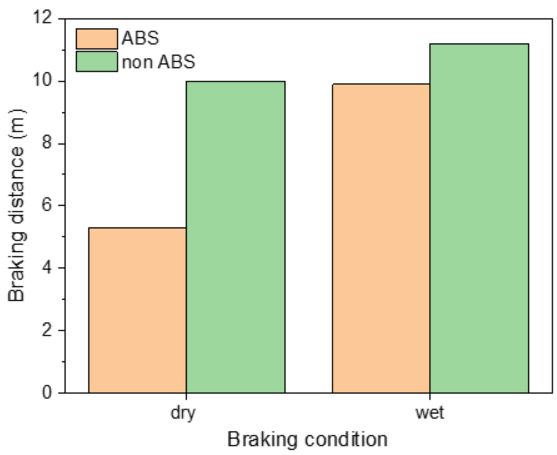

FIGURE 4. Braking distance for ABS and non-ABS motorcycles at a speed of 30 km/h

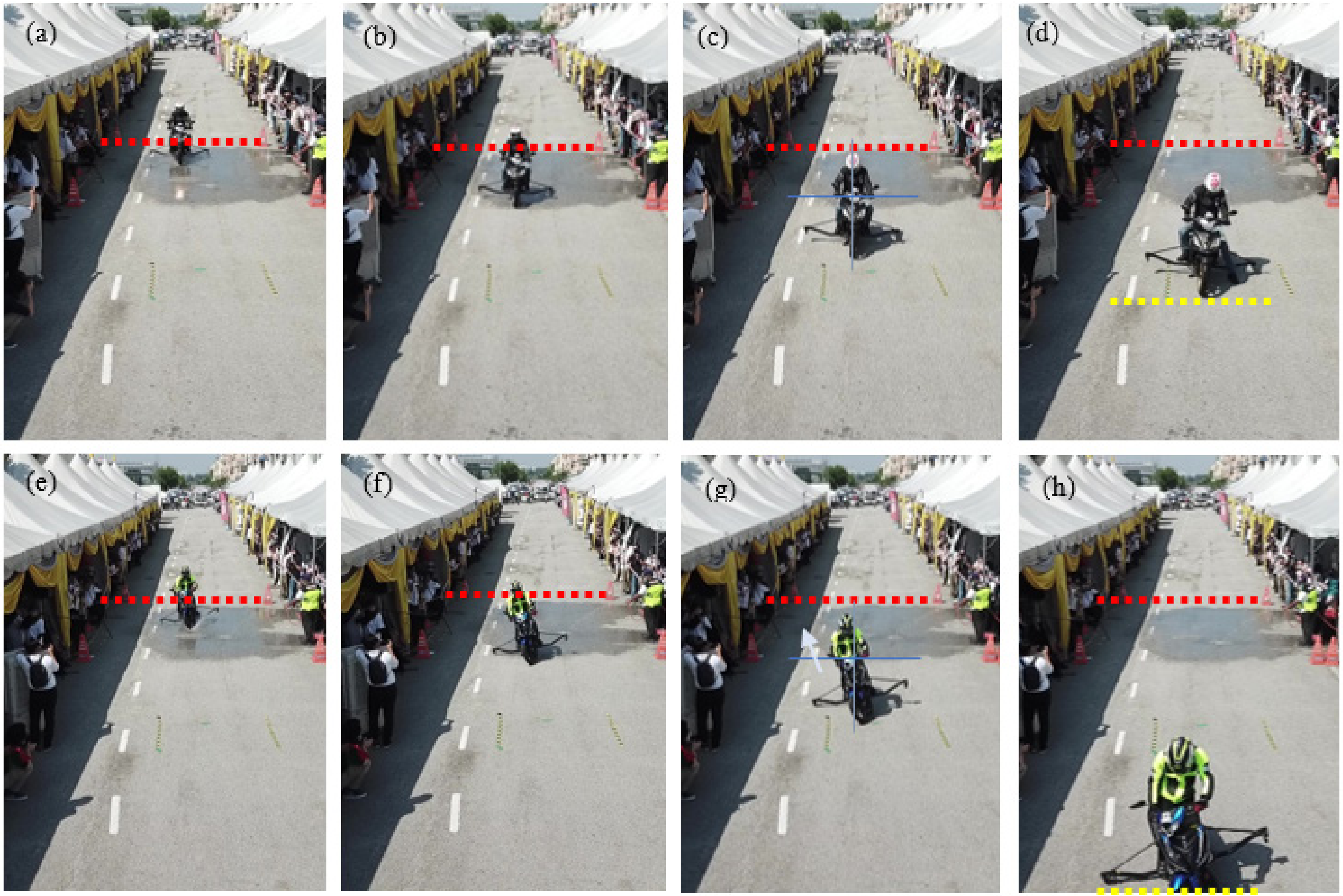

FIGURE 5. (a-d) The braking sequence for ABS; and (e-h) non-ABS motorcycles

Figure 6 and Figure 7 compare the braking distance values between theory, satellite, and physical measurements. T1 to T10 in the graph refers to the number of tests. The theory and satellite are being compared to understand the function of ABS in improving motorcycle braking distance, particularly during emergency braking. It is expected that the value generated by the satellite is slightly less than the braking distance calculated by theory. In the second graph, the physical measurements are compared with the satellite to observe how much the deviation is if the study is conducted in the absence of VBOX 3i. The lowest braking distance generated by theory is at T1 (11.64 m) while in the satellite is during T5, at 11.78m. Nevertheless, the average braking distance for the theory and satellite showed slight differences, with the satellite producing the shortest braking distance at 13.33m compared to 13.47m for the theory. Ninve out of the ten tests show less braking distance in satellite data compared to theory. In comparison, Figure 7 displays the comparison between satellite and physical measurements. All the values of the physical measurement were less than the satellite by 4.6% up to 56.4%. This is due to the accuracy of the satellite data that automatically detect the braking distance when the rider applies force for braking up until the motorcycle stops. In the case of physical measurement, we assume that the rider started applying the brake at the cue point (cone), but the data clearly shows that the rider may have pulled the brake earlier than the reference point. The huge discrepancy between the average value of satellite (13.33m) and physical (9.99m) suggests that data acquisition is needed to achieve an accurate result for braking distance measurement. The stopping distance produced is in the order of theory>satellite>physical.

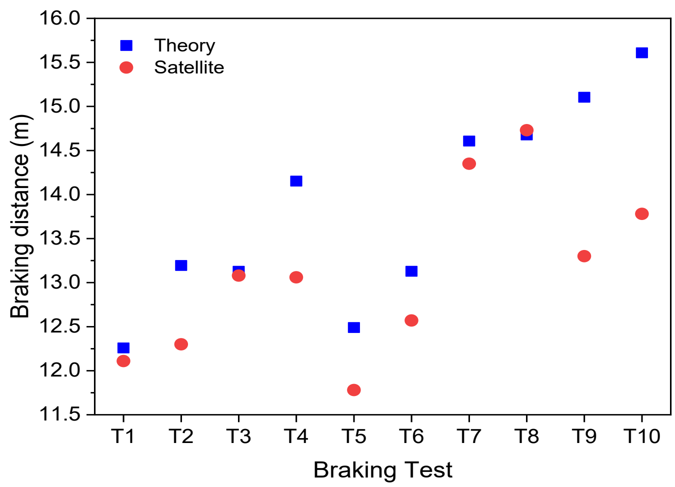

FIGURE 6. Braking distance of 10 braking tests by theory and satellite

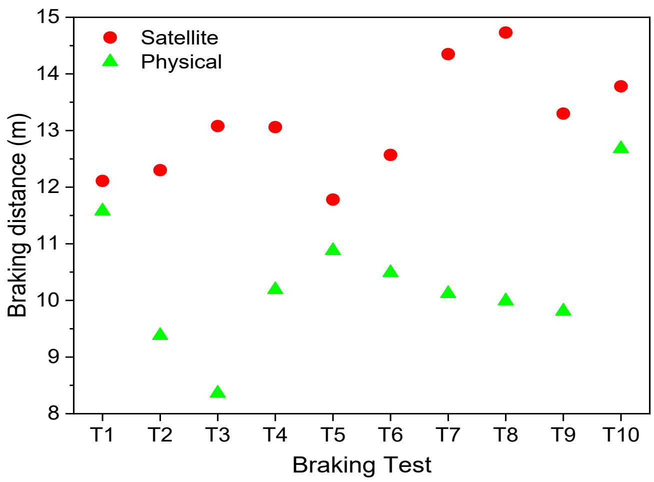

FIGURE 7. Braking distance of 10 braking tests by satellite and physical

From Figure 6 and 7, five results generating the lowest braking distance (highest deceleration) are selected to plot the graph of speed and time as shown in Figure 8. The initial speed before braking exhibits variation between (±5 km/h) from the requirement speed, 50 km/h. With 5km/h speed variation, the result of braking time is between 1.8 to 2.1 seconds, exhibiting a consistent result from an ABS motorcycle. The vehicle deceleration is represented by the slope of the graph, and is nearly consistent for all the tests, demonstrating the braking efficiency for the speed range. It is noted that the test was done repeatedly back-to-back, without any break. In general, braking generates heat because of frictional contact between brake components. This study demonstrated that the heat generated from repeated braking action does not affect the ABS braking efficiency, in which the braking distance and time to stop the vehicle are coherent for all the tests. The test was conducted in good weather, with a temperature range between 28 to 32°C. The combination of heat resulting from the braking mechanism and the surrounding weather expected to be accumulated are well dispersed by the motorcycle ABS and consequently exhibit satisfactory braking performance. The area under the curve represents the braking distance. Lower traveling speed results in a comparatively smaller area, and vice versa. This result is expected and in line with kinetics theory.

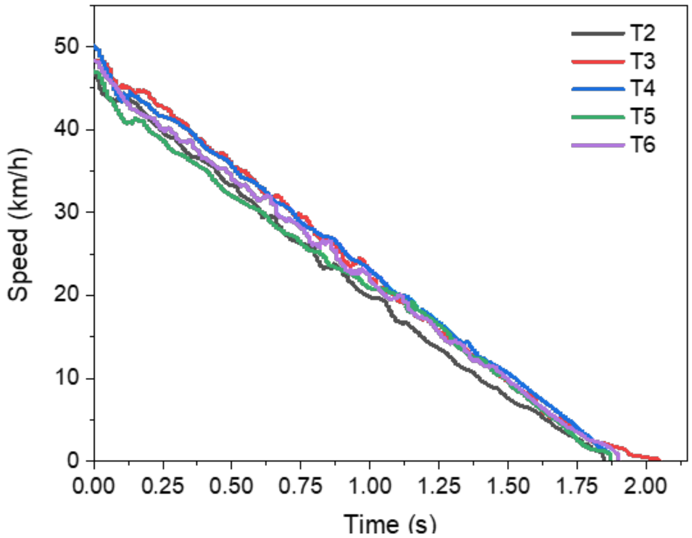

FIGURE 8. The graph of braking speed and braking time for 5 braking tests

CONCLUSION

This paper has investigated the braking performance for ABS motorcycle with engine capacity below 200 cc. The results from this study support the idea that ABS in motorcycles does improve the stability of the rider and reduce the braking distance during emergency braking on both dry and wet surfaces. The evidence from the repetitive testing shows that the ABS motorcycles produce consistent braking performance. It is noted that our investigations into this area are still ongoing and future work will concentrate on the braking force applied by riders using ABS motorcycles during emergency braking.

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