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THE EFFECT OF VIBRATION ISOLATOR ON THE MAGNITUDE OF HAND-ARM VIBRATION (HAV) OF THE OIL PALM MOTORISED CUTTER (*CANTAS*)

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ABSTRACT

The oil palm motorised cutter (CANTAS) *is categorised as a type of machine that generates vibration which could cause hand-arm vibration syndrome (HAVS). It is necessary that the level of vibration be managed and controlled. This article highlights a study on the effect of two types of vibration isolators (D1 and D2) on the magnitude of hand-arm vibration (HAV) on two types of* CANTAS *(MC1 and MC2) at two holding points (P1- at the throttle and P2 – at the pole). The results showed that the use of isolator reduced the magnitude of HAV for MC2, but not for MC1. Fixing D1 to MC2 reduced HAV at P1 and P2 by 54% and 45%, respectively, while fixing D2 to MC2 reduced HAV at P1 and P2 by 28% and 42%, respectively. The results disclosed that D1 had a better effect on HAV reduction for MC2 where the average HAV was reduced by 49.5%. Minimum HAV of MC2 was obtained when D1 was fixed at 70 cm from the engine. The study discovered that installing isolators to MC2 reduced the magnitude of HAV significantly which helps to reduce the risk of HAVS to the operator.*

Keywords: oil palm motorised cutter, *CANTAS*, vibration reduction, damper system, vibration isolator.

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INTRODUCTION

The total oil palm planted area in Malaysia (as of December 2017) was about 5.81 million hectares, with the total planted areas in Sarawak, Sabah and Peninsular Malaysia were 1.56 million hectares (26.8%), 1.55 million hectares (26.6%) and 2.70 million hectares (46.6%), respectively (Kushairi *et al*., 2018). The majority of the planted area was owned by private estates (~61%) while those with government schames such as Federal Land Development Authority (Felda), Federal Land Consolidation and Rehabilititation Authority (Felcra) and Rubber Industry Smallholders Development Authority (RISDA), 16.1%; state schemes/government agencies, *i.e.* 39% from the total planted areas in 2017. An increasing trend was also observed for independent smallholders (ISH) accounting to 0.98 million hectares (Kushairi *et al*., 2018).

Efficient harvesting of fresh fruit bunches (FFB) is vital to ensure the FFB are harvested within the recommended harvesting rounds of 10 to 12 days interval. Manual harvesting (using a sickle or chisel) can only produce about an average of 1 t FFB per worker per day (Azman *et al.,* 2015). Estates are now looking for more efficient harvesting tools that could increase productivity and ultimately reduce the number of workers. The harvesting productivity needs to be increased to about 4 t FFB per worker per day if the country wishes to reduce labour requirement significantly (Abdul Razak *et al.,* 2013).

Oil Palm Motorised Cutter

One of the technologies that has been well accepted by the oil palm industry is the oil palm motorised cutter (called *CANTAS*) that was introduced in 2007 (Abdul Razak *et al.,* 2013).

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CANTAS is powered by a small petrol engine and utilises either a specially designed C-sickle or chisel as the cutting knife. The Malaysian Palm Oil Board (MPOB) is the technology owner with patents filed in Malaysia, Indonesia, Thailand, Brazil, Costa Rica and Colombia (Abdul Razak *et al.*, 2008). *CANTAS* is currently manufactured by several local and international companies. The machine is suitable for harvesting FFB from palms up to 7 m harvesting height and was reported to double up the harvesting productivity which increases the harvesters' take-home pay and reduces the number of harvesters which is currently dominated by foreign workers (Abdul Razak *et al.*, 2013). *CANTAS* benefits the smallholders, the individual harvesters, the contractors and the estates in terms of increasing productivity and income, and reducing workers and operational costs.

Hand-arm Vibration of *CANTAS*

Hand-arm vibration (HAV) is defined as the vibration transmitted into workers' hands and arms from the use of hand-held power tools (Health and Safety Executive, 2012). HAV can be an issue as regular and frequent exposure to HAV would lead to two forms of permanent illness known as hand-arm vibration syndrome (HAVS) and carpal tunnel syndrome (CTS) which relates to complex vascular, neurological and musculoskeletal disorder (Salihatun *et al.*, 2013; 2014). HAVS is a disease resulting from regular or frequent exposure to the HAV. For some workers, the symptoms may appear after a few months of exposure whereas others may take a few years. The continued exposure to vibration may likely get worse and become permanent. *CANTAS* has been categorised as a type of machine that generates vibration which could cause HAVS arising from over exposure of daily usage. Therefore, it is necessary that the risks from vibration generated by *CANTAS* be managed and controlled.

The HAV can be influenced by many factors such as higher magnitude of acceleration of vibration, poor tool maintenance, minimal handle insulation, increased weight of tool, duration in contact with the tool, increased surface area of hand in contact with tool, and harder material being contacted. It can also be influenced by tight gripping of the handle than necessary, awkward postures and working overhead, low operator skill, poor technique, individual lifestyle factors (*e.g.* smoking), and individual's medical history (*e.g.* disease or prior injury to fingers, hands or wrists) (Health and Safety Executive, 2012).

Severity of vibration exposure to the hand is evaluated according to the International Standard ISO 5349 based on the vibration exposure level set by the Directive 2002/44/EC of The European Parliament and of the Council (2002) . The European Directive 2002/44/EC requires that the vibration exposure level to be less than 2.5 m s^{-2} at all times and if it is exceeded, action should be taken to reduce the vibration exposure. Vibration exposure level shall not be greater than 5.0 m s^{-2} (Health and Safety Executive, 2012; Salihatun *et al*., 2013).

Salihatun *et al.* (2013) investigated the vibration level of *CANTAS* operated by an unskilled worker. The study revealed that the magnitude of HAV was in between 7.94 to 10.93 m s^{-2}, which was far higher from the threshold level (2.5 m s^{-2}). It was also found that increasing the pole inclination angle would decrease the level of vibration at both handle points. The study also discovered that the HAV at Point 2 (at pole) was higher than Point 1 (at throttle point). This might be due to the effort of the operator to balance up the degree of cutting and resulting to a stronger gripping at Point 1.

Another work by Salihatun *et al*. (2014) studied the HAV level of *CANTAS* operated by skilled and unskilled harvesters. The measurements were made according to ISO 5349, with evaluation of HAV assessed from three different angles of cutting (30^{o}, 45^{o} and 60^{o}), vibration values at both grip points and the standard limit exposure action A(8). Results of the study revealed that skilled harvesters were exposed to less than 2.5 m s^{-2} indicating safe condition of using the machine. While for unskilled harvesters, the HAV was more than 2.5 m s^{-2} indicating that caution should be exercised when handling the machine. It was then suggested that guidelines or training be provided for new harvesters to ensure reduced vibration when using this machine.

Earlier works by Salihatun *et al.* (2013; 2014) have prompted that efforts to minimise and control the magnitude of HAV of *CANTAS* should be carried out to ensure the use of the machine is safe from both short- and long-term usage.

Vibration Isolator

There are ways to reduce vibration such as having a proper design of the moving components, weight balancing and installing a damper system. Most of the hand-tools like jigsaw, chainsaw, brush cutter, pruners and tree shakers are normally incorporated with rubber damper on the handle, the place where the operator is holding the tool during operation (Rao and Gupta, 2014; Amitkumar *et al.*, 2015). Vibration can also be reduced by fixing a vibration isolator on the machine. The isolator acts by isolating and stabilising the vibration generated by the machine. The use of a vibration isolator is expected to reduce the magnitude of vibration which is transferred into the workers' hand thus reduces the potential of having HAVS.

There were reports of works on damper and vibration isolator to reduce vibration (Toshisuke *et al*., 1979; Skorgsberg, 2012; Klembczyk, 2009; Haruhiko *et al*., 2004; Lee and Taylor, 2001; Ladgaonkar, 2016). Skorgsberg (2012) explained that the industrial tools are normally designed with the main parts made of metal which are considered as rigid bodies which generates vibration. There are some basic principles for vibration management by incorporating a damper or vibration isolator which control the magnitude of the vibrating forces which makes the tool less sensitive to the forces. Toshisuke *et al.* (1979) used a mechanical low pass filter between the human hands and a portable vibrating tool of a grinder as a vibration isolator. Results of the study indicated that the use of vibration isolator was able to reduce the magnitude of vibration of the hand grinder. Klembczyk (2009) proposed the use of the isolation shock absorbing and damper with dynamic systems and structures to reduce vibration. Haruhiko *et al*. (2004) studied the use of damper system to address the vibration issues and he found that passive hydraulic damper for structural control was better than semi active damper. Lee and Taylor (2001) proposed the fluid damper technology for reduction of vibrations. The viscous dampers are always resisting structure motion by means of force proportional to relative velocity between the ends of the damper. Ladgaonkar (2016) designed a vibration isolator to isolate the tool vibrations from the waist belt by using an elliptical leaf spring which the spring will absorb the vibrations generated during drilling operations.

OBJECTIVE

The objective of the study is to investigate the effect of the vibration isolator on the magnitude of HAV on the two versions of *CANTAS*, namely MC1 and MC2.

MATERIALS AND METHODS

Vibration equipment, Dewesoft Sirius System SN: D00C018C2B by Dewesoft X Professional was used in the experiment. The equipment was directly connected with IEPE sensors (integrated electronic piezoelectric) to measure the magnitude of vibration of the sample of *CANTAS* according to ISO 5349. Five subjects participated in the experiment. The details of the subjects are in *Table 1*.

TABLE 1. AGE, WEIGHT AND HEIGHT OF THE SUBJECTS

Subject	Age (years)	Weight (kg)	Height (m)
1	29	75	173
2	21	70	168
3	32	90	170
4	24	60	170
5	23	55	165

Vibration Isolator Designs

Sources of vibration of *CANTAS* fundamentally come from both rotational and linear motions of the moving components such as engine, transmission shaft, shaft guiders and gear box (*Figure 1*). Rotational motions basically come from the engine, transmission shaft and bearings, while linear motions come mainly from the gear box, pole and sickle.

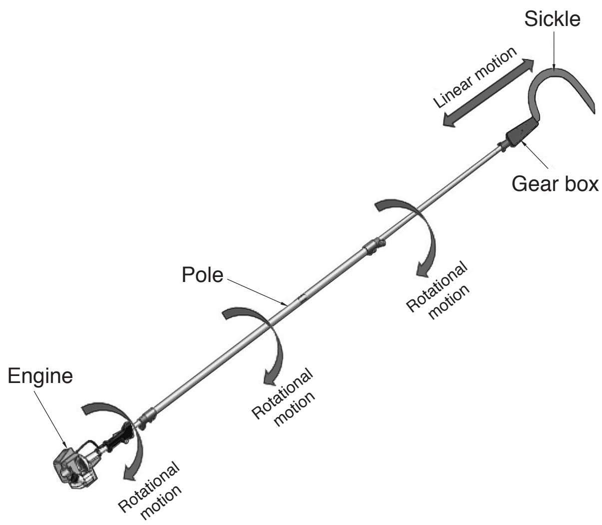


Figure 1. Sources of vibration of CANTAS.

The vibration therefore is developed throughout the length of the machine during operation with the magnitude which may differ from point to point. Vibrations arise when a body oscillates due to external and internal forces. Vibration may be transmitted to the human body through the part in contact with the vibrating surface such as the handle and the pole of the machine.

In this study, two types of vibration isolator were designed and developed. The vibration isolator is to be placed on pole of *CANTAS* and its best position would be determined from this study. Theoretically, the vibration generated by the machine would be collected and stabilised by the vibration isolator (*Figure 2*).

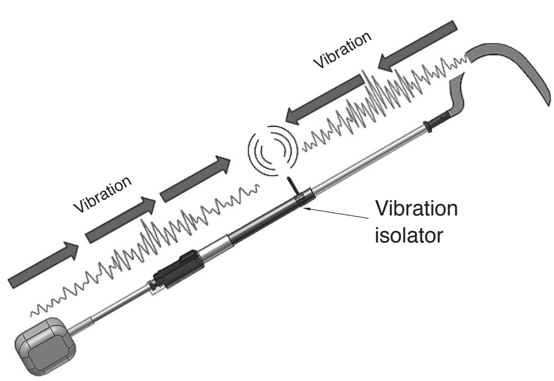


Figure 2. Vibration reduction of CANTAS *by the vibration isolator system.*

The vibration isolator comprises of two basic components, *i.e*. a compression spring and a pair of bearings installed at the edge of the spring. In the harvesting operation, when the motorised cutter vibrates, the spring with its nature of being elastic is functioning to isolate the vibration, while the bearings which are placed at both ends of the spring is functioning to stabilise the vibration collected by the spring.

A compression spring with the stiffness of 4903 N m^{-1} and two bearing type 6000 were used to build the prototype. The spring and bearings were fixed on a T-holder which was made from stainless steel. The weight of spring, two bearings and T-holder were 70, 45 and 35 g, respectively, making the total weight of the isolator at 150 g.

Two arrangements of bearings were made, *i.e.* (i) the bearings were fixed in line with the spring axis named as Vibration isolator 1 (D1), and (ii) the bearings were placed parallel to the spring axis named as Vibration isolator 2 (D2). The dimension of D1 and D2 are shown in *Figures 3* and *4*.

Experimental Design

In the experiment, the vibration isolators were fixed on two types of motorised cutters *viz*. MC1 and MC2. The effect of vibration isolator designs and its position on the magnitude of HAV were studied using a 2x3 factorial experiment (for MC1) and 2x2 factorial experiment (for MC2) with six replicates for each of experiments.

Details of the experiment are as follows:

a. Subject (MC): two types of oil palm motorised cutter (MC), *i.e.* MC1 and MC2. The difference between MC1 and MC2 is explained in *Table 1*.
b. Vibration isolator design (D): two designs, *i.e.* Vibration isolator 1 (D1) and Vibration isolator 2 (D2).
c. Vibration isolator position (L) - distance of vibration isolator from the engine:
   - For MC1: L1 (60), L2 (120) and L3 (180) cm from the engine; and
   - For MC2: L1 (70) and L2 (120) cm from the engine.

The reason why MC2 has only two positions of vibration isolator compared to MC1 (which has three positions) is due to the limitation of space on MC2 where the isolator could only be fixed on the pole guider with the minimum and maximum distance of 70 and 120 cm, respectively, from the engine. While for MC1, the isolator can be fixed throughout the entire length of the pole.

The total weight of MC1 and MC2 (dry weight – without fuel) were 7.40 and 7.20 kg, respectively; and 7.44 kg and 7.24 kg, respectively when filled up with fuel. In the experiment, the maximum throttle speed was set at 9000 rpm.

Oil Palm Motorised Cutter (MC)

Table 2 shows the detail specification of MC1 and MC2.

Holding Points (P1 and P2)

Figures 5 and *6* show the two holding points (denoted as P1 and P2) for MC1 and MC2, the positions where the magnitude of HAV was measured during the experiment. P1 is located at the engine's throttle, the point where the harvester controls the speed of cutting, while P2 is the point

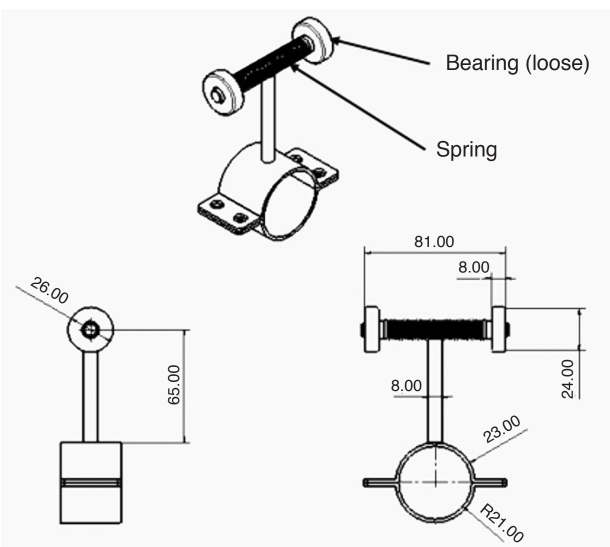


Figure 3. Schematic drawing of Vibration isolator 1 (D1).

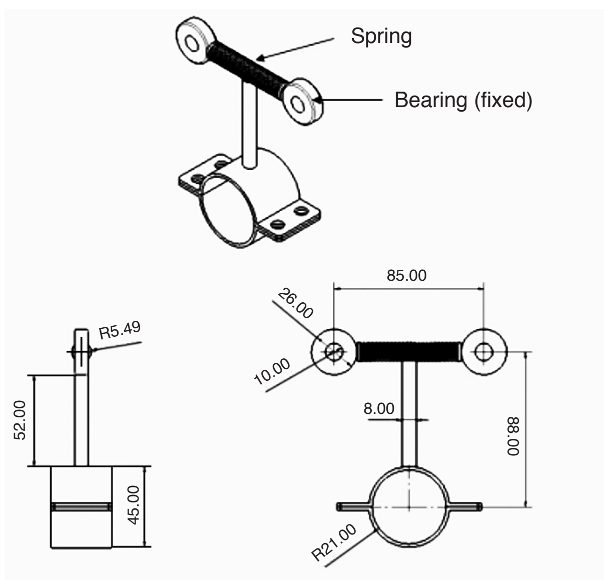
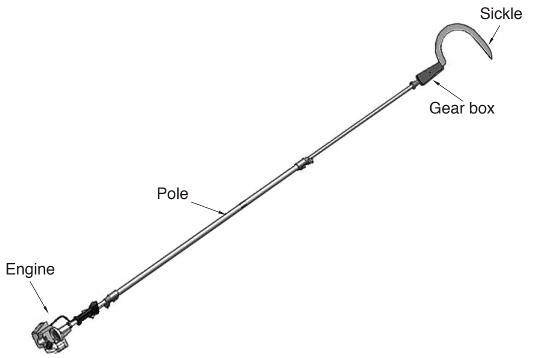
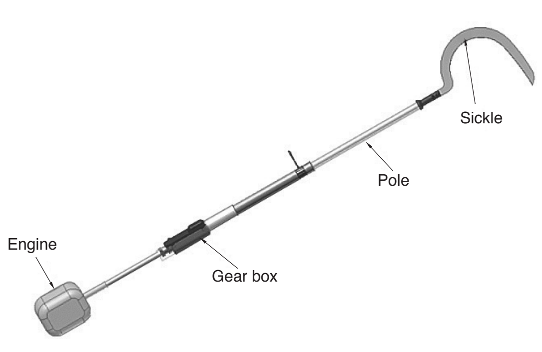


Figure 4. Schematic drawing of Vibration isolator 2 (D2).

TABLE 2. SPECIFICATION OF MOTORISED CUTTER

Subject	**Motorised cutter 1 (MC1)**	**Motorised cutter 2 (MC2)**
Drawing		
Concept	The rotational motion generated by the engine is transmitted via mechanical shaft (inside the pole) to the gear box. The rotational motion is then converted by the gear box into linear motion to allow the sickle to move linearly for cutting action. The gear box is placed at the top of the pole. The source of vibration comes from two rotational motions and one linear motion, *i.e.* • Rotational motion: engine and transmission shaft • Linear motion: sickle	The rotational motion generated by the engine is converted into linear motion by the gear box where a pole is fixed to it. This allows the sickle which is fixed at the end of the pole to move linearly for cutting action. The gear box is placed near the engine to reduce the point of the centre of gravity as to ease the handling of the machine. The source of vibration comes from one rotational motion and two linear motion, *i.e.* • Rotational motion: engine • Linear motion: gear box and pole/sickle
Length (m)	2.83	2.90
Weight (kg)	7.20	7.40
Specific weight (kg m^{-1})	2.54	2.55
Centre of gravity (cofg), (m)	1.40	1.07
Deflection at point of cofg (cm)	7.00	3.00

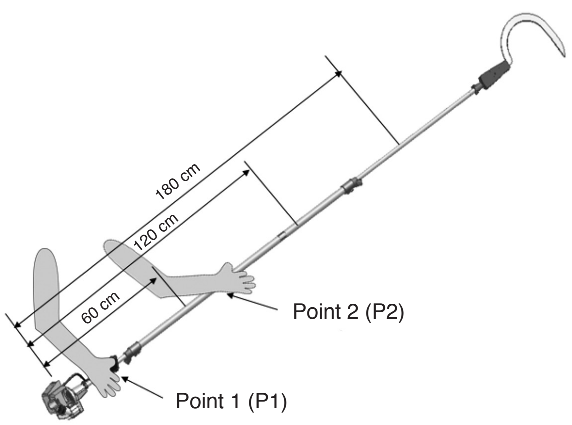


Figure 5. Vibration points (P1 and P2) and three distances of vibration isolator from engine for MC1.

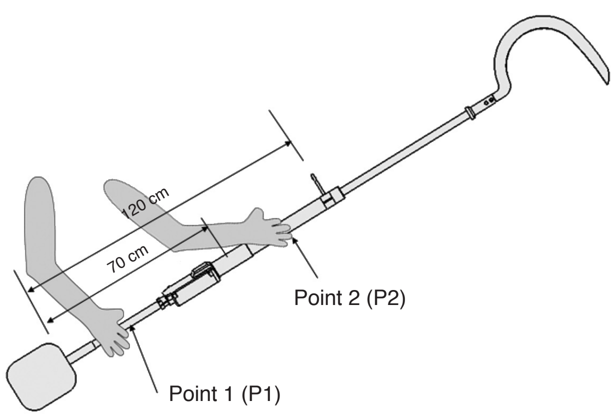


Figure 6. Vibration points (P1 and P2) and two distances of vibration isolator from engine of MC2.

where the harvester holds the machine during the cutting operation. Positions of P1 and P2 were fixed at 30 cm and 80 cm from the engine, respectively for both MC1 and MC2.

Measurement of Vibration

The study was conducted at MPOB Keratong Research Station in Pahang, Malaysia. The palms where the experiment was conducted were about 10 years old with the height range from 2.5 m to 3.5 m. The field topography was flat.

A tri-axial accelerometer was used to measure the magnitude of the vibration generated by the machine. The measurement complied with the standard ISO5349, the same standard used by other reports (Salihatun *et al*., 2013; 2014; Amitkumar *et al*., 2015). In the experiment, the vibration sensor was placed at the holding points (P1 and P2) with the machine's pole angle was set at 60^o as shown in *Figure 7*. The data was recorded when the worker started cutting the frond until finish.

The HAV of the motorised cutter fixed with the vibration isolators were compared against the HAV of the motorised cutter without vibration isolator. The experiment matrix is shown in *Table 3*.

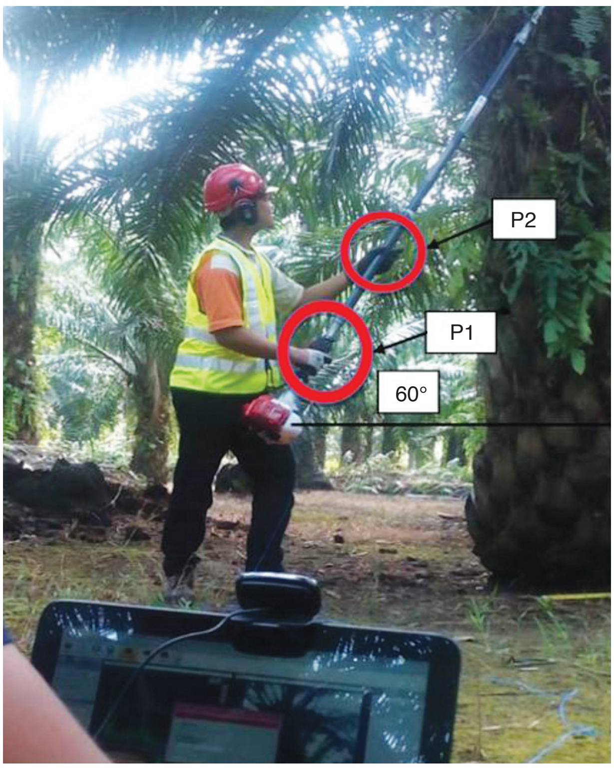


Figure 7. Vibration measurement during cutting of frond.

RESULTS AND DISCUSSION

Effect of Vibration Isolator on the HAV of Motorised Cutter 1 (MC1)

Figure 8 show the average data of HAV generated by MC1 from the experiment conducted. The highest HAV was obtained at D2L1P2 (2.5 m s^{-2}), and the lowest HAV was obtained at D1L2P1 (1 m s^{-2}). The maximum HAV for D1 and D2 were 2.3 m s^{-2} (L2P2) and 2.5 m s^{-2} (L1P2), respectively, while the minimum HAV for D1 and D2 were 1 m s^{-2} (L2P1) and 1.5 m s^{-2} (L3P1), respectively. As for comparison, the HAV of MC1 without vibration isolator were 1.6 m s^{-2} and 1.9 m s^{-2} for P1 and P2, respectively.

It was found that D1 affects in reducing vibration at P2 for L1 and at P1 for L2. This is due to the fact that the significant reduction of vibration occurred when the isolator is placed close to the holding point (P1 and P2).

Referring to *Figure 8*, generally fixing a vibration isolator to MC1 would not give any significant effect on the reduction of HAV. Only D1 gave some minor effect where the average HAV at PI and P2 were reduced by about 6.20% and 5.26%, respectively compared to without vibration isolator. Fixing D2 to MC1, on the other hand, has increased the HAV at P1 and P2 by 31% and 10.52%, respectively. Overall, D1 was found to reduce HAV by 5.73% while D2 increased the HAV by 20.76%. The results revealed that fixing D2 to the machine would not give significant effect on the reduction of HAV at the holding points (P1 and P2). The results of average HAV of MC1 with and without vibration isolator are shown in *Table 4*.

Effect of Vibration Isolator on HAV of Motorised Cutter 2 (MC2)

Figure 9 show the average data of HAV generated by MC2 from the experiment conducted. The highest HAV was obtained at D2L2P1 (2.0 m s^{-2}) and the lowest HAV was obtained at D1L1P1 (1 m s^{-2}). The maximum HAV for D1 and D2 were 1.8 m

TABLE 3. EXPERIMENT MATRIX

Motorised Cutter (MC)	**Motorised Cutter 1 (MC1)**							**Motorised Cutter 2 (MC2)**				
Vibration isolator design (D)	**Vibration isolator 1 (D1)**			**Vibration isolator 2 (D2)**			**Without vibration isolator**	**Vibration isolator 1 (D1)**		**Vibration isolator 2 (D2)**		**Without vibration isolator**
Distance of vibration isolator from engine (L)	60 cm (L1)	120 cm (L2)	180 cm (L3)	60 cm (L1)	120 cm (L2)	180 cm (L3)		70 cm (L1)	120 cm (L2)	70 cm (L1)	120 cm (L2)	
Replication	Six replicates for all experiments											

TABLE 4. AVERAGE OF HAND-ARM VIBRATION (HAV) OF MC1 WITH VIBRATION ISOLATORS *vs.* WITHOUT VIBRATION ISOLATOR

Holding point	Control [without vibration isolator (m s^{-2})]	With vibration isolator (m s^{-2})	
		D1	D2
P1	1.6	1.5 (-6.20%)	2.1 (+31%)
P2	1.9	1.8 (-5.26%)	2.1 (+10.52%)
	Overall	-5.73%	+20.76

s^{-2} (L1P2) and 2.0 m s^{-2} (L2P1), respectively, while the minimum HAV for D1 and D2 were 1.0 m s^{-2} (L1P1) and 1.8 m s^{-2} (L2P2), respectively. As for comparison, the HAV of MC2 without vibration isolator were 2.7 m s^{-2} and 3.2 m s^{-2} for P1 and P2, respectively.

Referring to *Figure 9*, generally fixing a vibration isolator on MC2 gave significant effects on the reduction of HAV. Both D1 and D2 were found to reduce HAV significantly. This is because the design of the machine itself where the major sources of vibration came from the engine and the gear box. Fixing the isolator near the gear box would have a great effect on the vibration reduction of the machine.

However, D1 had given a better effect where the HAV were reduced by 54% and 45%, respectively at P1 and P2, while D2 could only reduce the HAV by 28% and 42% at P1 and P2, respectively, compared to HAV without a vibration isolator. The experiment disclosed that D1 is superior than D2 with the overall HAV reduction of 49.5% compared to 35% by D2. The main reason why D1 was superior than D2 was due to the arrangement of bearing where D1 was designed to have in-line arrangement against the parallel arrangement in D2. In-line arrangement of bearings will produce smooth vibrating movement that produces a much efficient vibration disposal as opposed to parallel arrangement in which the vibrating movement was not consistent. The results of average HAV of MC2 with and without vibration isolator are shown in *Table 5*.

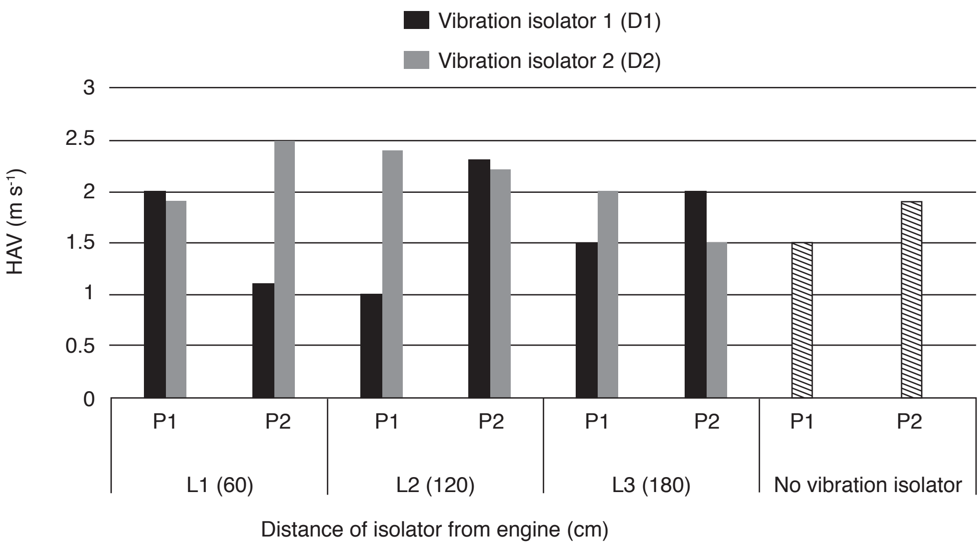


Figure 8. Results of hand-arm vibration (HAV) of Motorised Cutter 1 (MC1).

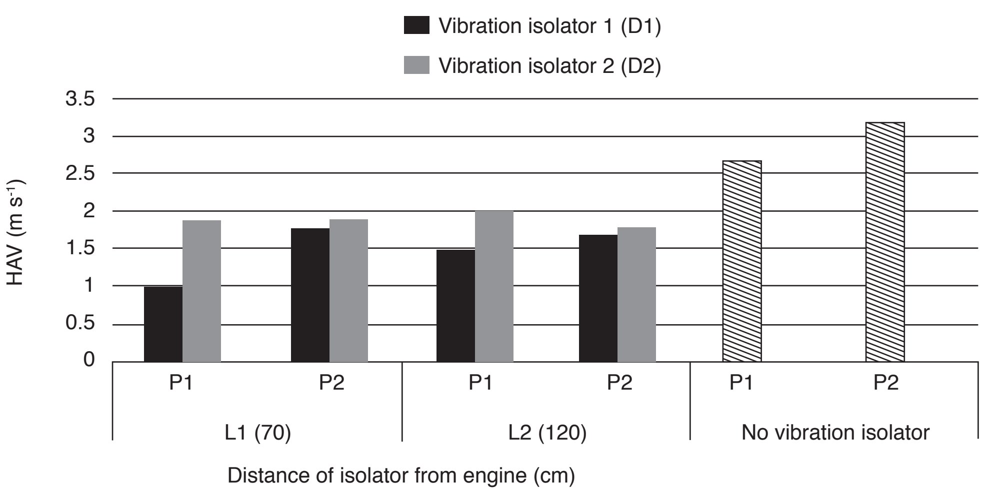


Figure 9. Results of hand-arm vibration (HAV) of Motorised Cutter 2 (MC2).

TABLE 5. AVERAGE OF HAND-ARM VIBRATION (HAV) OF MC2 WITH VIBRATION ISOLATORS *vs.* WITHOUT VIBRATION ISOLATOR

Holding point	Without vibration isolator (m s^{-2})	With vibration isolator (m s^{-2})	
		D1	D2
P1	2.7	1.25 (-54%)	1.95 (-28%)
P2	3.2	1.75 (-45%)	1.85 (-42%)
	Overall	-49.5%	-35%

Comparison of Minimum and Maximum HAV of MC1 and MC2

Table 6 shows the summary of results of the minimum and maximum HAV of the motorised cutter fixed with vibration isolators. For MC1, the minimum HAV at P1 and P2 occurred at the combination of L2P1 (1.0 m s^{-2}) when using D1 and L3P1 (1.5 m s^{-2}) when using D2, respectively. While for MC2, the minimum HAV at P1 and P2 occurred at the combination of L1P1 (1.0 m s^{-2}) when using D1 and L2P2 (1.8 m s^{-2}) when using D2, respectively. While *Table 7* shows the result summary of the effect of vibration isolator designs on MC1 and MC2 at holding points (P1 and P2).

CONCLUSION

The results of the study showed that the vibration isolator design and position of the vibration isolator were found to affect the magnitude of HAV of motorised cutter. The use of vibration isolators was found to reduce the magnitude of HAV for MC2 significantly, but not for MC1.

Fixing D1 to MC1 was found to reduce HAV by 5.73% while fixing D2 had increased the HAV of MC1 by 20.76%.

Both D1 and D2 were found to reduce HAV of MC2 significantly. HAV at P1 and P2 were reduced by 54% and 45%, respectively when fixing with D1, while fixing D2 to MC2 reduced the HAV by 28% and 42% at P1 and P2, respectively. The experiment disclosed that MC2 fixed with D1 generated lower HAV with overall HAV reduction of 49.5% compared to only 35% when fixed with D2.

Overall, D1 was found better than D2 for both MC1 and MC2. For MC1, minimum vibration could be obtained by fixing D1 at 60 cm from the engine. While for MC2, minimum vibration could be obtained by fixing D1 at 70 cm from the engine.

The minimum HAV at P1 and P2 for MC1 occurred at the combination of L2P1 (1.0 m s^{-2}) when using D1 and L3P1 (1.5 m s^{-2}) when using D2, respectively. While the minimum HAV for MC2 at P1 and P2 occurred at the combination of L1P1 (1.0 m s^{-2}) when using D1 and L2P2 (1.8 m s^{-2}) when using D2, respectively.

Finally, the study discovered that incorporating a vibration isolator on MC2 was found to reduce the magnitude of HAV significantly which helps to reduce the risk of HAVS to the operator.

RECOMMENDATION

The results were just solely based on the vibration isolators with limited fundamental data. It could,

TABLE 6. RESULT SUMMARY - MINIMUM AND MAXIMUM OF HAND-ARM VIBRATION (HAV) FOR THE MOTORISED CUTTER

	MC1					MC2				
	No vibration isolator	D1		D2		No vibration isolator	D1		D2	
	Mag*	Mag*	Com**	Mag*	Com**	Mag*	Mag*	Com**	Mag*	Com**
Minimum HAV	1.6	1.0	L2P1	1.5	L3P1	1.2	1.0	L1P1	1.8	L2P2
Maximum HAV	2.9	2.3	L2P2	2.5	L3P1	4.7	1.8	L1P2	2.0	L2P1

Note: *Mag – magnitude.
**Com – combination.

TABLE 7. RESULT SUMMARY – THE EFFECT OF VIBRATION ISOLATOR DESIGNS ON MC1 AND MC2 AT HOLDING POINTS (P1 and P2)

	MC1			MC2		
	No vibration isolator	D1	D2	No vibration isolator	D1	D2
P1	1.6	1.5 (-6.20%)	2.1 (+31%)	2.7	1.25 (-54%)	1.95 (-28%)
P2	1.9	1.8 (-5.26%)	2.1 (+10.52%)	3.2	1.75 (-45%)	1.85 (-42%)

however, be used as a benchmark for future design of vibration isolator. Further study on its characteristics such as dimension, weight, spring stiffness, bearing dimension and so on should be carried out in order to meet the minimum magnitude of HAV generated by *CANTAS*.

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