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DESIGN, FABRICATION, AND ANALYSIS OF A SMART MOWER

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ABSTRACT

This paper focusses on optimisation of vibration and sound levels of a lawnmower from process cutting with the cutting blade. Technical requirements have been defined for the project including customer requirement, cost model of the product, the checklist of product design specification, concept generation, concept selection and prototyping. These are the fundamental technical requirement to build a safe and efficient of Smart Mower. The experiment was analysed using 200 to 900 wedge angles of cutting blade to cutting grass field simulation for the test of levels of vibration and sound. From the results, it is observed that the analysis of changing wedge angle will provide changes on levels of vibration and sound. The obtained results indicate that the smaller wedge angle gives smaller levels of vibration and sound. The results can also significantly meet all customer requirement according to product development. Therefore, the wedge angle is promising the reduction of vibration level and sound level. At last, this result can reduce the cost, time to market and improve product reliability and customer confidence.

INTRODUCTION

Malaysia is a country with a high humidity temperature ranging from 230C to 310C throughout the year and abundant rainfall averaging about 2500 mm annually [1]. The petrol-engine driven lawnmower are widely used in Malaysia for cutting long grass along the roadside and general agriculture work. Axonopus compressus [2] also known as broadleaf carpet grass in West Africa and Cow Grass was called in Malaysia. The lawnmower can be categorised into a few ways, which are the petrol-powered engine and electric powered engine. Lawnmower with a standard motor is an inconvenience; elderly, younger or disabled people cannot easily accomplish it. Also, the petrol-powered engine will create noise pollution due to the loud engine and air pollution due to the combustion in the engine. Other than a petrol-powered lawnmower, most of the lawnmower produces vibration and noise while operating, which may have a negative influence on the human body. Also, a motor-powered engine is requiring maintenance such as changing the engine oil, cutting blade after a certain period. Even though electrical powered lawnmower is better than a petrol-powered lawnmower, but there was a limitation of the power source with using the battery, and it will take time to recharge the battery.

In this research will mainly focus on design and analysis of Smart Mower from studying about vibration and noise characteristics of an electrically powered lawnmower. Also, the cause and effect of the vibration and noise characteristics from an electrically powered lawnmower. Of course, the design part is including design a conceptual of Smart Mower according to the product development process and fabricate to a fully functional Smart Mower. In the analysis part, some experiment is conducting to test the source of vibration and noise and redesign on certain component of Smart Mower for reducing the level of vibration and noise characteristics.

A lawnmower is a piece of essential equipment used in maintaining grass areas as in tropical areas that made grass grow very fast. In most cases, lawnmowers are generated by the petrol engine, electric motor and those mechanical devices in operation are produce a vibrational motion that is undesirable, wasting energy and creating an unwanted sound. [3] elaborated that human and wildlife have to pay more concern about noise pollution because it already brings issues to be environmental and become a global burden. Environmental noises are including traffic, construction, industry, business or entertainment activities [4]. In 2012, there have 110 workers claim that musculoskeletal disorders from hand-transmitted vibration (HTV) because of harmful activities to the workers who used the vibrating machine of exposure eight hours daily that already excess vibration level limit. It can give chronic injuries in hands and arms and lead to difficulties in the performance of daily activities or reduced working capacity after a long exposure from hand-held vibrating instruments [5]. Hand-Arm Vibration Syndrome (HAVS) is a syndrome that happened in the fingers, hands and arm caused by vibration damages after working with vibrating tools or machinery. Symptoms of HAVS typically happened after a long period of exposure to a hand-vibrating instrument and leading the hands or arms in a chronic pain difficulty perform daily activities [6]; [7].

In 2009, the Department of Occupational Safety and Health collected the statistics which accounted for 427 cases of Occupational Noise Hearing Loss claimed from using a massively high level of noise while working. The human auditory system will get harmful effects or injury when exposed to excessive noise, and it may cause Noise-Induced Hearing Loss (NIHL). Noise-Induced Hearing Loss can be defined as a permanent sensory neural hearing loss when accumulated constant noise exposure of high amplitude [8], and it is incurable as no treatment or medicine can regrow the damaged hair cells on the cochlea in the inner ears.

Besides that, lawnmowers are not just a threat by the excess noise or vibration; it also includes the users and bystanders that may be injured by flying debris from the relatively powerful engines and fast-moving blades. The most commonly involving extremities are contacting with the rotating blades causing an acute trauma of the injury [9]. The concentration of this project is to investigate and identify the source of vibration and the noise characteristics on a particular component of a traditional lawnmower through a journal that exists on the internet. In this research, the source of the vibration and noise from the specific component of lawnmower will get approach for improvement of the Smart Mower by reducing the level of vibration and noise characteristics. The product development process will have conducted for fabricating a complete specifications prototype that meets the requirement of the customer and helps to solve the problem that exists form current traditional lawnmower. Each stage of the product development process will be documenting and use a method for selecting the suitable design or material for the product Smart Mower. Indeed, a fully function Smart Mower will be fabricated according to the selection of conceptual design from the product development process. Then, the Smart Mower will be taken to conduct some experiment to reducing the level of vibration and noise characteristics on some specific component with several parameters.

METHODOLOGY

This part will explain the methodological choice. The prototype is the early "proof of concept" which is to demonstrate the feasibility and functionality of the product. The prototype is vital in the concept development process; it is served to provide a working specification system including semantics, design, computer programming and the electronics part. Also, it can be testing in different parameter experimental to evaluating the performance of the product.

The lawnmower is comprised of an induction motor, a battery, two collapsible sharp edge blade, ultrasonic sensor and a connection system. The design of the frame was one of the most difficult mechanical aspects of the project. The design of the frame needs to be light but durable than enough to sustain the cutting force toward the grass. Besides that, the design needs to be anti-rusting so that it can stay longer life. It also required storing all electronic component into the inside of the frame to prevent any damage to the electronic component. Besides that, the Smart Mower included a sensor for the autonomous mode to avoid the obstacles in front of the mower. In the fabrication, the part can separate into few parts which are the Frame, Wheels, Blade and Mounting Blade. Furthermore, some machines are necessarily needed for fabricate the part like Shearing Machine, Bending Machine and including advance machining such as Electrical Discharge Machine (EDM) Wire cutting machine.

Electronics components are a significant part of fabrication and controlling the performances for the Smart Mower. An effective organisation must utilise ‘smart’ components in the design. In this section, some simple comparison with each different brand product, choosing electronics component to meet the minimum requirement according to the customer’s needs. Including component Dc Gear Motors, Microcontroller, Sensor, Battery and Motor Driver.

CAD which stands for Computer-aided design models and it is used for visualising the three-dimensional form of the design. It also can compute physical properties such as mass or volume and creating photo-realistic images for assessment of product appearance. Computer-aided engineering (CAE) tools essential for analytical prototypes to eliminating one or more physical prototypes. Besides that, 3D CAD models can be relying on the computer-based analyses including the finite-element analysis of thermal flow or stress distribution and some complex mechanism as well.

Besides that, the block diagram was introduced to clarify overall concepts without starting the implementation of Smart Mower. The schematic diagrams of electronic design and flow chart of software design are conducting for showing the principle of each component to operate the Smart Mower automatically.

Design of Experiments (DOE) is used as the function to identify the parameter that can be controlled and measurable for example, level of vibration and noise. In this design of experiments will analyses experiments determine the parameter setpoint to achieve the best performance of the product. In 1980, a shearing test was conducted in evaluating the shear strengths of the grasses [10]. In the same journal, it provided mechanical and physical properties of various grasses and proved a slight effect on the sheer energy of grass influence of wedge angle inclination of cut.

The experimental material was regular grass from Malaysia, which is called Cow Grass. The material used in the experimental was fresh, healthy and free mechanical damaged. The Cow Grass was cut through by a blade that contains certain different angle with a high-speed DC geared motor. The wedge angle of blades was used in the test were a straight edge with a various wedge is increased from 200 to 900 according to the predictions of [11]. Instruments Amplified DC Accelerometer Model 4312M3 is used for collecting the vibration level during the experiment. It enables both static and dynamic response with the acceleration range 2 to 200 and frequency response (Hz) 0-300. Also, this accelerometer capable of taking data within sensitivity range 0.4 mA/g to 4 mA/g.

Instruments SONIK-S Sound Level Meter for Occupational Noise as shown in Figure 3.9 is used for the noise level during the grass cutting. It can measure the noise level from 25dB to 140dB with a simple operation set up button. It also including measurement parameter Lp, Leq, Lmax, Peak, %Dose per Hour, Dose and Exposure Points.

RESULT AND DISCUSSION

This part will explain the methodological choice. The prototype is the early “proof of concept” which is to demonstrate the feasibility and functionality of the product. The prototype is vital in the concept development process; it is served to provide a working specification system including semantics, design, computer programming and the electronics part. Also, it can be testing in different parameter experimental to evaluating the performance of the product.

Confirmation Measurement for Wedge Angle of Cutting Blade

Each cutting blade was ground into a certain length according to different wedge angle, as shown in Figure 3.1. Optical Measurement System was used for measuring length for each different wedge angle; all measurement is taken in unit millimetre as shown in Table 3.1.

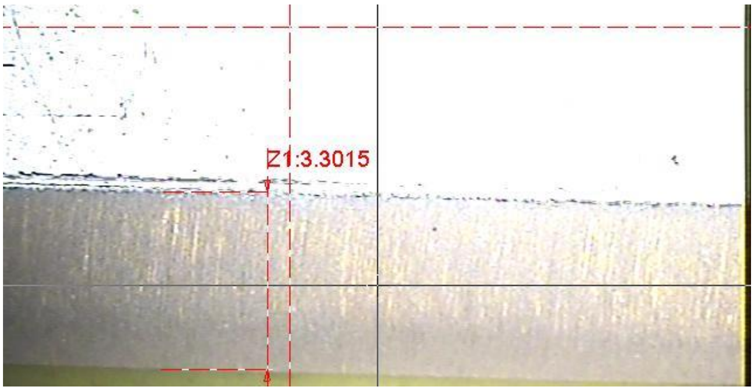

Figure 3.1: Measurement using Optical Measurement System

Table 3.1: Measurement of Length for Wedge Angle Blade

Angle	Measurement 1, mm	Measurement 2, mm	Average, mm	Actual, mm	Different
20	5.7398	5.2435	5.49165	5.495	0.061%
30	3.3367	3.3015	3.3191	3.4641	4.186%
40	2.3952	2.5541	2.47465	2.3835	3.824%
50	1.6615	1.6399	1.65025	1.6782	1.665%
60	1.1005	1.1436	1.12205	1.1547	2.828%
70	0.7984	0.7768	0.7876	0.7279	8.202%
80	0.3668	0.3453	0.35605	0.3527	0.95%

Laboratory Testing Vibration Level and Noise Characteristics

Vibration is a mechanical phenomenon, and it is a restricted responding movement of a molecule or occurs of the inverse bearing from its situation of harmony in the medium when that has been irritated. An object will vibrate when after the body or system meeting two characteristics which are the elasticity and mass. Then the amplitude can be defined as the maximum displacement of a vibrating particle or body from its position of rest. The lawnmower is a vibration system that subjects to an external force or repeating type of force.

Noise is offensive or undesirable sound. There is a qualification among the airborne and commotion using strong items and airborne noise-causing by the development of expansive air volumes and high-weight application.

Data of vibration level and noise sound level were collected at the same time by using the vibration sensor and sound level meter. Level vibration was collected through software DASY Lab data per millisecond and made 20000 data in approximately three seconds which is a massive amount of data as shown in Figure 3.2. In Figure 3.3 shows that a selection of average ranges from 200ms to 350ms for the average of the vibration level.

Table 4.1 and 4.2 showing the average vibration level and sound level from five reading was taken. After the experimental testing for vibration level and noise characterises generated by a different wedge angle of grass-cutting blades. With the variables studied, the experiments showed that the blade sharpness was found increases with reducing tip radius. It was found that the single wedge angle blade was sharper, and this was due to the wedge angle nearest the tip is smaller than that of the double wedge angle blade. Also, the wedge angle nearest the blade tip controls the sharpness of the blade, as would be expected. The smaller the wedge angle will be reducing the level of vibration and noise characteristic. In Figure 3.4 and 3.5 were shown the graph of all five readings taken of vibration level and sound level during the experiment. It indicated a consistent increasing slightly according to the increase of wedge angle.

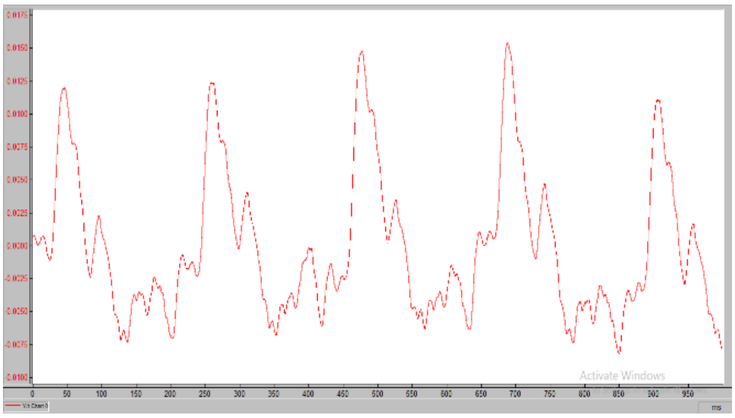

Figure 3.2: Vibration Level Taken during Experiment

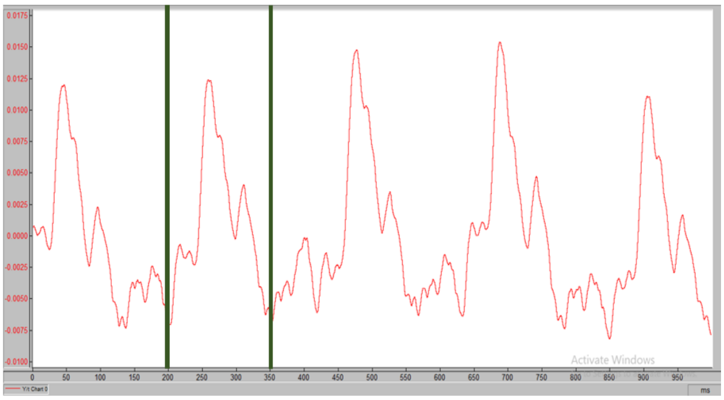

Figure 3.3: Selection Range of Vibration Level

Table 4.1: Average Vibration Level

Angle	Average	Max	Min
20	3.511761	14.311724	0.0009
30	3.738722	14.58556	0.00046
40	3.906253	14.979724	0.00046
50	4.130901	15.09792	0.00078
60	4.134555	15.206524	0.00098
70	4.171236	15.364272	0.00118
80	4.185679	15.576656	0.00142
90	4.198248	16.256314	0.00158

Table 4.2: Average Sound Level

Angle	Average	Max	Min
20	80.32	84.9	63.16
30	81.66	85.68	67.84
40	82.04	69.74	85.9
50	82.64	86.1	70.44
60	82.92	86.2	71.52
70	83.06	87.32	73.28
80	83.42	87.32	73.8
90	83.74	87.38	74.8

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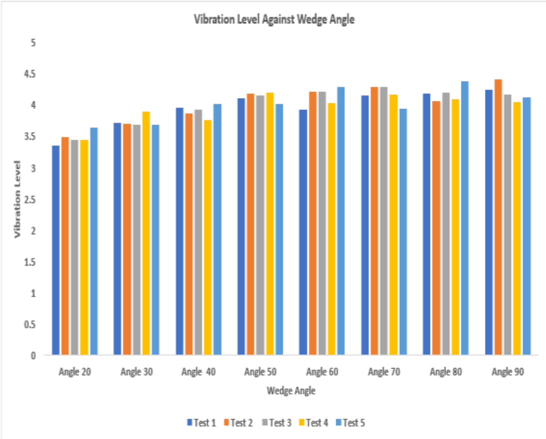

Figure 3.4: Graph Showing All Reading Taken of Vibration Level

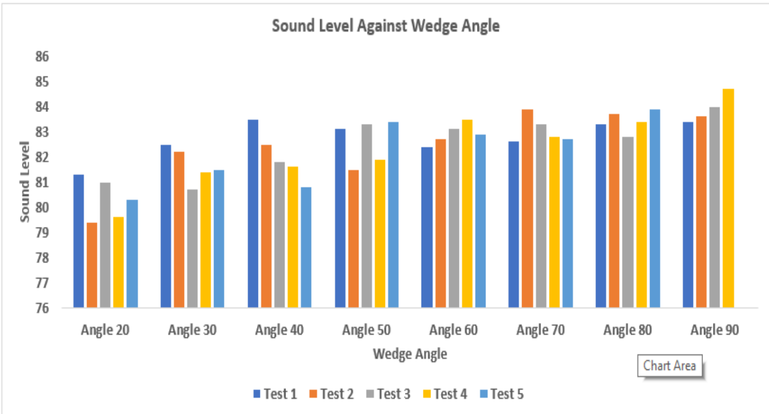

Figure 3.5: Graph Showing All Reading Taken of Sound Level

CONCLUSION

This study was carried out to investigate the level of vibration and sound at a different wedge angle of the blade when cutting the grasses. The results show that increase slightly when the wedge angle is getting small. Although the cutting process depends primarily on the design of the cutting assembly, the shape or wedge angle of the cutting edge, the parameters of operation of the device and on the physical properties of the plant material-its strength properties and structure. From the experiment shown that decrease the wedge angle causes decrease the levels of vibration and sound. Changing the smaller wedge angle of the cutting blade will affect the blade sharpness increases with reducing tip radius. However, reducing the wedge angle would result in less material being present at the tip to resist the high compressive force acting there. After the experiment test, it has shown 200 and 900 Wedge angle blade taking minimum vibration level 3.51(s2)-1 and maximum 4.19(s2)-1 respectively which is still in normal condition in whole-body vibration. Also, it has shown minimum sound level 80.32 dB for Wedge angle 200 and maximum sound level 83.74 dB for wedge angle 900 which is in profound condition.

The further experiment test will be carried in a real grass field and areas of irregular shape will take place. Besides that, Smart Mower can improve into the graphical user interface (GUI) to enables a user to communicate with the computer using symbols. Also, Smart Mower equipped global positioning system (GPS) with precise localisation for optimised coverage path planning in further improvement.

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