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Dynamic Behaviour and Characteristics of Rubber Blade Car Performance

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ABSTRACT

High technologies have helped so much in improving an optimizing the engine design and performance of the car. Improved isolation has helped to minimize the engine noise making other automotive part noises become more detectable. One of the noise sources are the wipers. When a wiper operates on a windshield, vibratory phenomena may appear due to flutter instabilities and may generate squeal noise. In order to obtain good wiping behaviour and characteristics, the rubber blade should be in complete contact with the glass and under uniform contact pressure while not generating vibration as it moves over the glass. A good wiping performance can be achieved by a proper design of the wiper structure as well as a good understanding of the mechanical behaviour of the rubber blade. The primary objective of this research is to investigate the dynamic behaviour and characteristics of rubber wiper blade performance in order to reduce the automotive windscreen wiper noise and vibration effects. In order to achieve the objective of this research, two types of wiper is used. One is hybrid type and second is conventional type. Then the behavior of wiper can be investigated. The force resistive sensor is used to measure the force distribution exerted on the windshield for the characteristics wiper noise for specific points. The obtain vibration data is processed by single-board microcontrollers. Behaviour movements of blade produce different vibration that can be investigated the maximum noise occurs on wiper blade operation using Uni-axial accelerometer A MMA7660. As a result, confirmation behaviour is shown the contact force distribution between rubber blade and glass is produce non-uniformly contact force and identical for hybrid type wiper and uniform contact force and not identical for conventional type wiper. In addition, characteristic of wiper rubber blade due to environment condition such as humidity, temperature and wiper stiffness are major factor in this research. As a conclusion, the results for behaviour of wiper blade depends on structural effect of the wiper blade related to the contact force distribution between the rubber blade and the glass. Secondly the characteristics of wiper rubber blade depends environment condition such as humidity and the temperature. The methodology is achievable to discovery the knowledge of dynamic behaviour and characteristics of wiper rubber blade in future.

Keywords: Contact force; noise; wiper blade; vibration; test rig.

INTRODUCTION

In the present study, the dynamic behavior and characteristics of car wiper rubber blade is investigated to confirm their performance for certain condition. The problem is facing when user is uncontrollable with the noise and vibration happen during raining time. This situation makes car's driver feel uncomfortable. In general windshield wiper is one of the important devices to ensure the safety and visibility of the vehicle driver especially on a rainy days to view in the vehicle is clear from any obstruction by removing rain or dirt from the windshield with a rubber blade that moves back and forth on the glass [1]. Due to this movement, it sometimes produces unwanted noise and vibration. Various reason can contribute the noise and vibration such as the force distribution exerted on windshield is not good and environment condition dry, wet or high movement of wiper [2].

The automotive industry has been working towards a higher-quality wiper system, including research about the force distribution exerted along the wiper arm, strong or elastic the structure of wiper, wiper blade problem, improvement the performance and high reliability of wiper rubber blade [3]. In order to obtain good wiping behavior and characteristics of the rubber blade, it should be in complete contact with the glass and under a uniform contact pressure while not generating vibration as the blade moves over the glass [3]. In general the typical wipe angle for a passenger car is about 67ºC. The blades are 12 to 30 in (0.3-0.76m) long with lengths increasing in 2-in (0.5m) increments. In order to suit every car needs various type of wiper blades have been designed as per each car requirements [4]. Wiper blades come in many different lengths and type. In general, there are three different styles of wiper blades which are 'conventional type', 'hybrid type' and 'flat' type [5]. In addition, the noise and vibration are categorized into three groups which are reversal noise, running noise and squeal noise, respectively [6]. Reversal noise is an impact sound with a frequency of 500 Hz or less. The running noise is an impact sound with a frequency of 600 Hz and less than 100 Hz [7]. The most annoying noise is squeal noise [8], a high frequency vibration of about 1000 Hz occurred during rising of the wiper [9][10].

As a result, knowledge discovery about the high-quality wiper is not establish well especially for local Malaysia car. The dynamic behaviour and characteristics of wiper rubber blade are still difficult to find [11]. The knowledge about the wiper noise and vibration only a few in Malaysia. This reason shows the important of investigating dynamic behaviour and characteristics of rubber wiper blade performance. In order to explore the knowledge and understanding the windscreen wiper blade system and subject to environmental parameters such as wet and dry condition, dry and raining condition [12], moving and static condition were also investigated. The paremeters have an influence on the appearance of the noise and contribute to the complexity of the phenomenon were the research is applicable in this study.

Therefore, the objective of this research is to investigate and determine the dynamic behavior and characteristics concept of wiper blade. Then, testing to the wiper blade performance can be done and focused on the noise and vibration of the rubber blade for selected cars to reduce the noise and vibration [13]. In order to achieve the goal of this study, the small city car for example Perodua Kancil and Sedan type for example Proton Wira were used. the continuing sub topic explains about experimental set up used in this project. Third sub topic is the results and discussion of the experiment done and the data analysis for this project. Then the conclusion of the outcome from the project was summarized for this project. Also includes comparison with the previous studies and recommendation suggestion for future studies.

EXPERIMENTAL SET UP

In this research study, there is a few approaches have been used, which are review on previous study [3], experimental and analytical method from the data obtain by experiment. In order to measure the force distribution exerted [14] on the wiper blade a Force Sensitive Resistor (FSR) sensor was used and the experiment set up as shown in Figure 1. The vibration data obtain is processed by single-board microcontrollers [15](Arduino UNO). The FSR sensor was attached at few selected points as per Figure 2(a) and (b). Calibration was performed using dead weight to verify the force exerted on the FSR sensor. In Table 1, there are the selected cars, such as Car 1 is small city car, Car 2 is sedan type car and Car 3 is sedan type car but use for noise and vibration performance using rubber blade for this experiment and it specification of their wipers [8].

The wiper blade movement can be classified into two parts which are start rising until the middle of the stroke and reversing back to its origin. These two movements of blade produce different vibration. To investigate the maximum noise occurs on wiper blade operation, an experiment using Uni-axial accelerometer A MMA7660 was used as shown in Figure 3. The vibration data from the accelerometer was processed by Portable Data Acquisition Module ADVANTECH USB-4716. Thermocouple model Fluke 714 was also used to determine the temperature when performing experiment. The same setup as per Figure 3 was used in the third experiment but was set same as Car 2. The experiment was done in various conditions as per Table 2 to analyse the behaviour of the wiper blade.

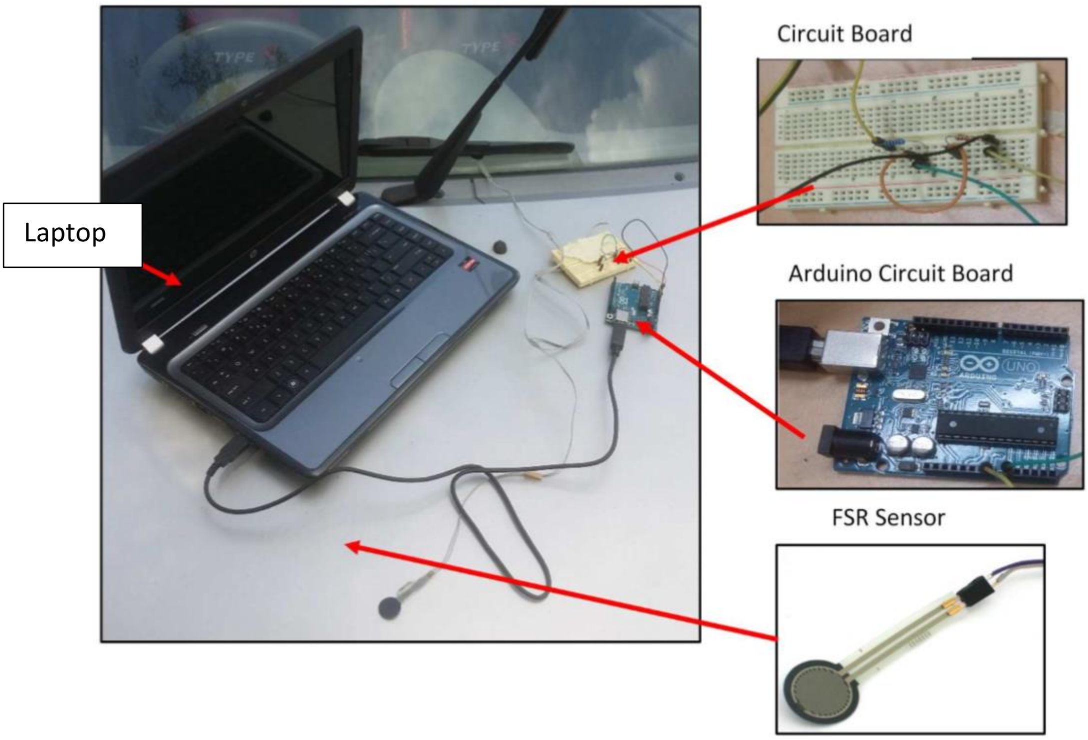
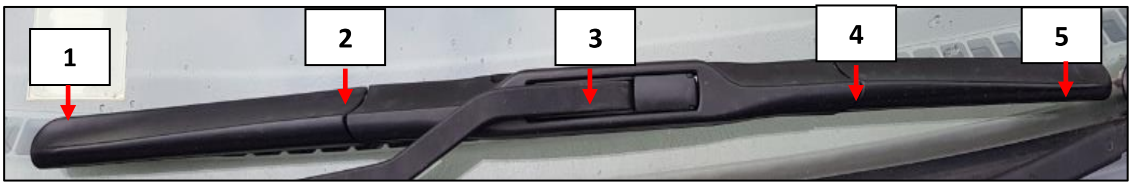


Figure 1. Experimental setup for force distribution on Car 1 and Car 2.



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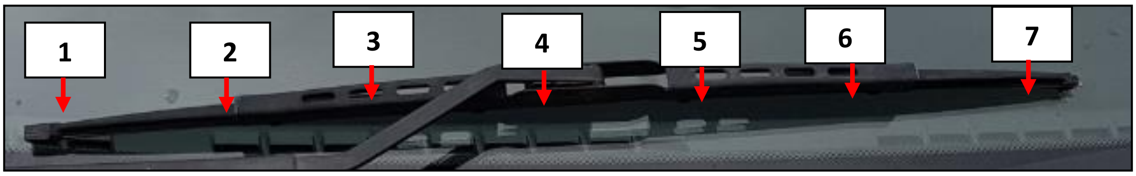


(b)

Figure 2. FSR point location on wiper blade on (a) Car 1 and; (b) Car 2.

Table 1. Specification of wiper [12].

Type of Car		Wiper Type	Hook Type	Windscreen angle	Wiper Blade Size (Right/Left)
Car 1	Small city car (650cc)	Hybrid	U	29°	18”/16”
Car 2	Sedan (1.5cc)	Conventional	U	30°	20”/17”
Car 3	Sedan (1.5cc)	Conventional and setting with experiment rig from Figure 3.	U	30°	20”/17”

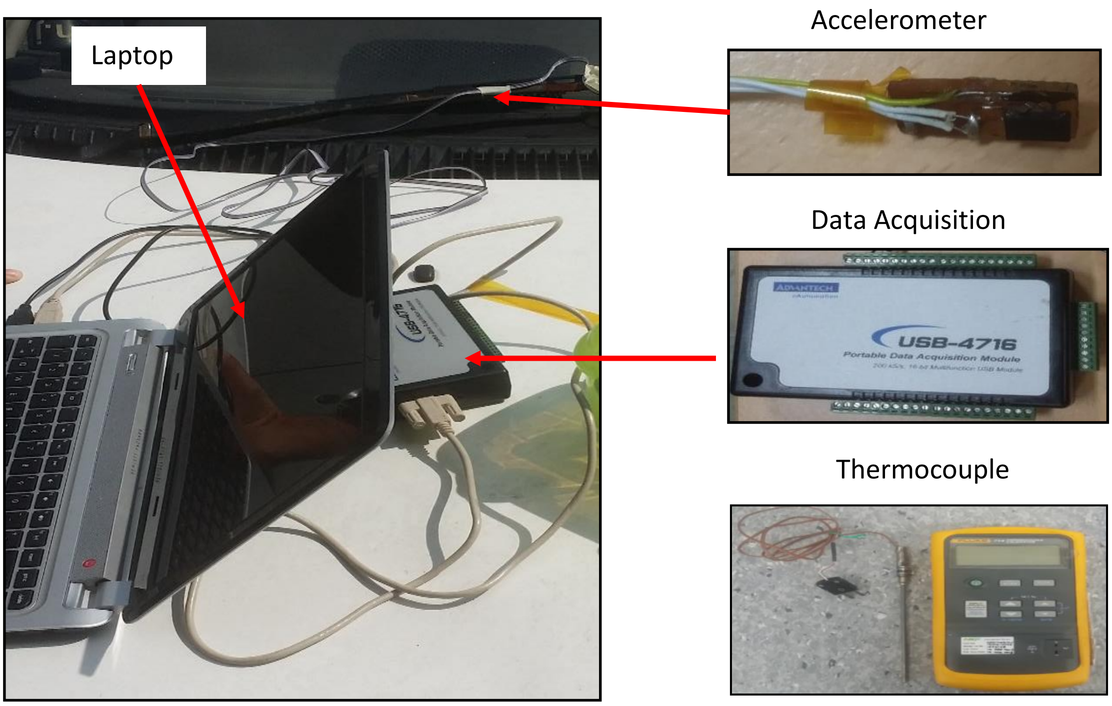


Figure 3. Experimental setup for vibration and noise specifically for Car 3.

Table 2. Comparison of condition in experiment.

No	Condition 1	Condition 2	Different Parameters	Effect to observe
1	Static car, wet surface (noon)	Static car, wet surface (morning)	Different ambient temperature	Effect of temperature on blade
2	Raining (static car)	Raining (moving car 20km/h)	Different movement of car	Effect of air friction
3	Static car dry surface (car l)	Static car dry surface (car 2)	Different surface angle	Effect of angle on surface
4	Static car dry surface (old blade)	Static car dry surface (new blade)	Different blade	Stiffness of blade

RESULTS AND DISCUSSION

Force Distribution on Wiper Blade

Figure 4 shows that the force distribution on the Car 1 and Car 2 on certain location and position based on Figure 2(a) and (b). The force distribution exerted on the points was measured using FSR and the reading was Newton (N) as shown in Figure 4. Car 1 was used 5 points on wiper because it was small city car and shorter than wiper Car 2 which is Sedan type. According to conventional wiper blade, Car 2 was not consistent and concentrated on certain part of the wiper blade. The highest force distribution is in the middle of the wiper blade where the springs of the wiper blade arms were located. The hybrid wiper blade, Car 1 on the other hand have more consistent force distribution but still the forces are more concentrated in the middle of the wiper blade similar to the conventional wiper blade. It shows that Car 1 has more identical contact force and uniformly distributed compared to Car 2 which has not uniform contact distribution and not identical. Based on the load applied to the wiper blade influence the contact force distribution along the wiper blade. The peak contact force at the center of the yolk is the highest compared to other points which are more uniformly distributed.

The distribution force on Car 2 is not well distributed because the series of 5 to 7 linkages, called ‘Whippletree’ meaning that the forces exerted on the wiper blade only concentrated on the 5 to 7 point of the wiper blade [1]. However for Car 1 which is hybrid wiper blade uses aerodynamic shape of the flat style wiper blade with reliable performance of the conventional style wiper. This wiper blade design includes an integrated “Linked” spoiler that runs the whole length of the blade [16].

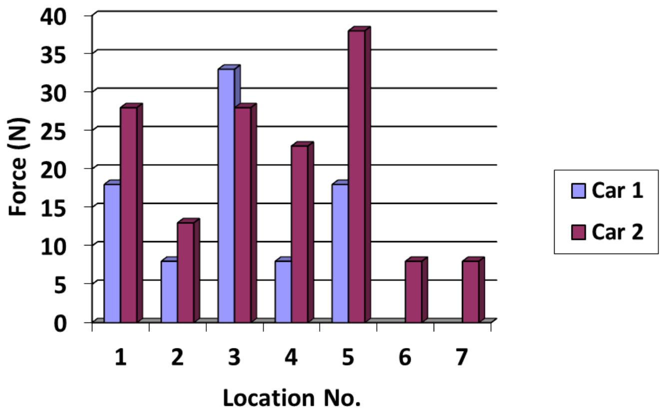


Figure 4. Wiper blade contact force measured at different locations.

Vibration and Noise on Wiper Blade

Noise and vibration measurements of the wiper are carried out at one environmental condition (refer to Table 2) which is dry surface only for Car 1 was measured at one speed 1.8rad/s. Acceleration response is shown in Figure 5. From the figure, the high vibration amplitude was occurred right at the beginning and end of the wiper stroke. In the middle of the stroke, the vibration amplitude is lower than the start and end of the stroke. The vibration amplitude is higher at the beginning and end of wiper stroke may due to two reasons, one is stick-slip and second is negative velocity-friction characteristic mechanisms [17][18]. Figure 6 show the time domain of vibration signal. The unwanted vibration level occurred right at the beginning and end of the wiper stroke [19].

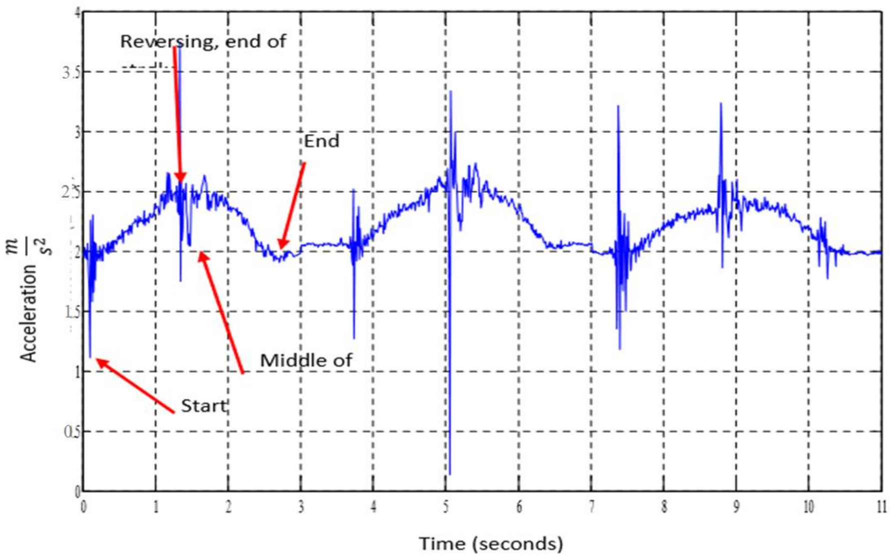


Figure 5. Experimental results of vibration signal on wiper blade.

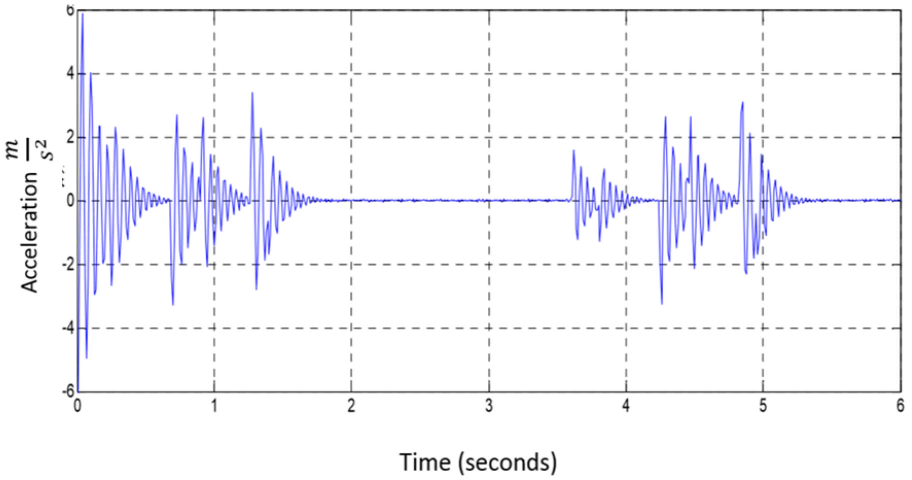
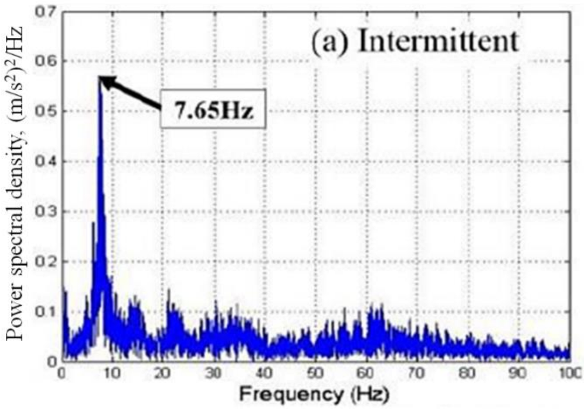


Figure 6. Time domain for experimental results of vibration signal on wiper blade.

Vibration Comparison of Wiper Blade on Three Operation Level

The wiper blade of the car can function in three levels of operations, which are intermittent, moderate speed and fast speed. Before proceeding with further comparison of the wiper blade Car 3 (using experiment rig), the best suitable speed of the wiper operation need to be determined to minimize the variant parameters in the experiment [18][20].

The wiper blade was tested under static condition and dry glass surface with three different level operation. From Figure 7, all three wiper rotational speeds produced vibration at a frequency around 7.65 Hz -7.85 Hz. This indicated that chatter noise was generated by the wiper blade. Comparing those three charts the wiper blade produces the highest frequency at 7.85Hz in fast operation speed 2.8 rad/s as shown in Figure 7(c) for one complete stroke no idle time and the lowest frequency at 7.65Hz in intermittent operation speed 1.8rad/s for one complete stroke with 4 seconds of idle time as shown in Figure 7(a). In Figure 7(b) was moderate level with high frequency at 7.84Hz which close to fast highest frequency. The operation speed of wiper blade system does contribute to the noise even the differences of vibration between the three operational speed is not significant, the highest operational speed produces more vibration and noise compared to the lower speed. For the next experiment, intermittent operation will be used for all testing to reduce the noise due to speed.



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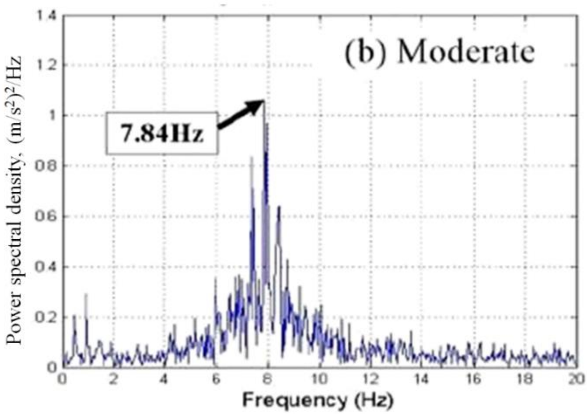

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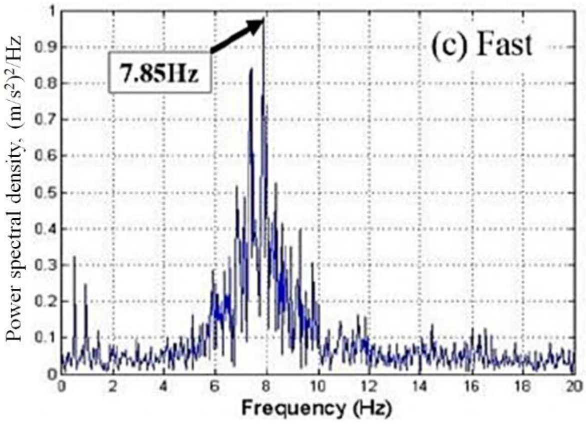


(c)

Figure 7. Frequency domain graph comparison on noise generated. (a) intermittent. (b) moderate. (c) fast.

Wiper Blade Comparison in Various Conditions

Figure 8 is comparing various environmental conditions. In Figure 8(a), it is found that the chattering noise is generated both in wet and dry conditions of the windscreen. The only difference was on the amount of vibration occur per cycle [3]. The wiper has a steady motion in the dry condition compared to wet condition due to disturbance of water film and the windscreen interfaces that leads to vibration. The wiper also produces higher vibration amplitude in the afternoon due to wiper blade stiffness increases compared to in the morning as shown in Figure 8(b). It is also observing that due to high humidity in the morning the frequency at starting was high due to the wetness of the windscreen. Once the wetness is wiped clean the frequency of the wiper blade remains low [20].

When at static under raining condition the wiper blade produces more noise frequency compared to moving at 20km/h under raining condition as shown in Figure 8(c). This is due to lift force occur when the car is on the move. When the car is moving, lift force increase as per experimental investigation of wiper system performance at high speed [8] and make some distance between wiper blade and windscreen thus less vibration created. In addition, in Figure 8(d), the old blade at dry condition and static movement shown the acceleration fluctuate but the new blade seem to be more elastic to product flat level to clean up on the windshield. This shows the new rubber blade more efficient then old rubber blade.

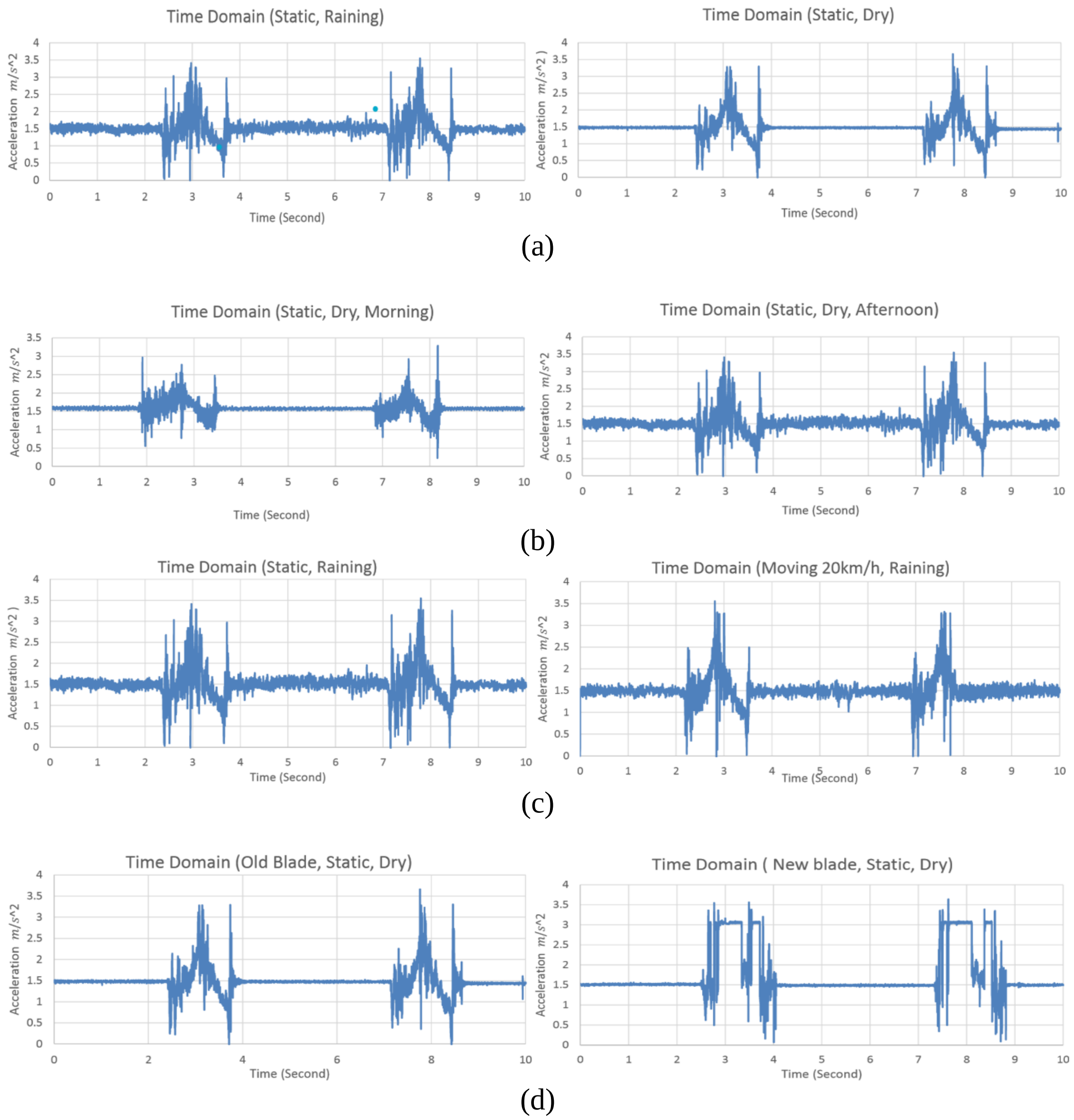
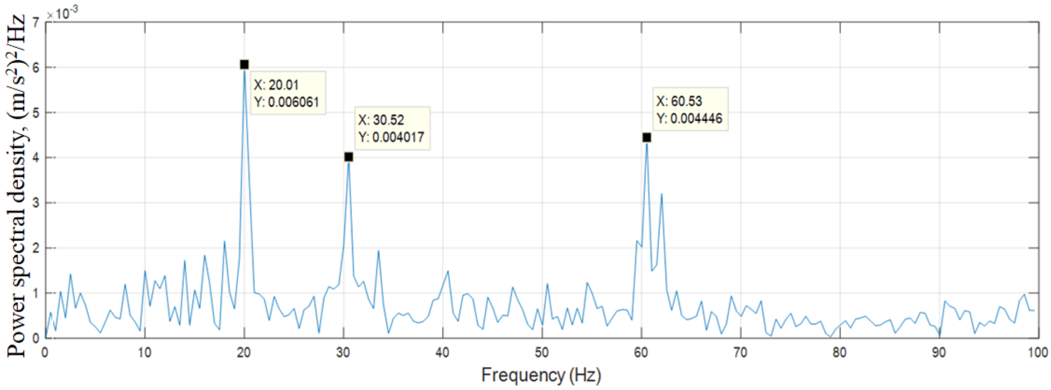


Figure 8. Time domain graph results on various conditions.

Figure 9 shows the frequency domain for all various environmental conditions. Figure 9(a) shows the power spectral density was higher at frequency 20Hz at static and dry conditions and it is identical result to the condition static and dry in the afternoon as shown in Figure 9(c) but different for condition static and dry in the morning as shown in Figure 9(b), this is because in the morning the frequency approximate to and high power spectral density to move out all the wet on windshield in the morning compared to afternoon. In addition, Figure 9(d) shows the frequency domain for movement 20km/j for wiper blade compared to static and raining condition as shown in Figure 9(e). For moving wiper the power spectral density was fluctuated until the frequency to 40Hz and maximum power was 4.5Hz but for static and raining the maximum power was around 30Hz. This is because the moving wiper has produce lift force when wiper was moved

[21][22]. Then, Figure 9(f) shows the new blade power spectral basically identical for 19Hz is maximum value. This is the less vibration and noise to show the new rubber blade is good. The displacements were affected by the vibration frequency. The higher the frequency of vibration, the higher the wiper blade displaced. The angle of the windscreen and the type of wiper blade also contributes to displacement of the wiper blade as per the complex eigenvalue analysis.



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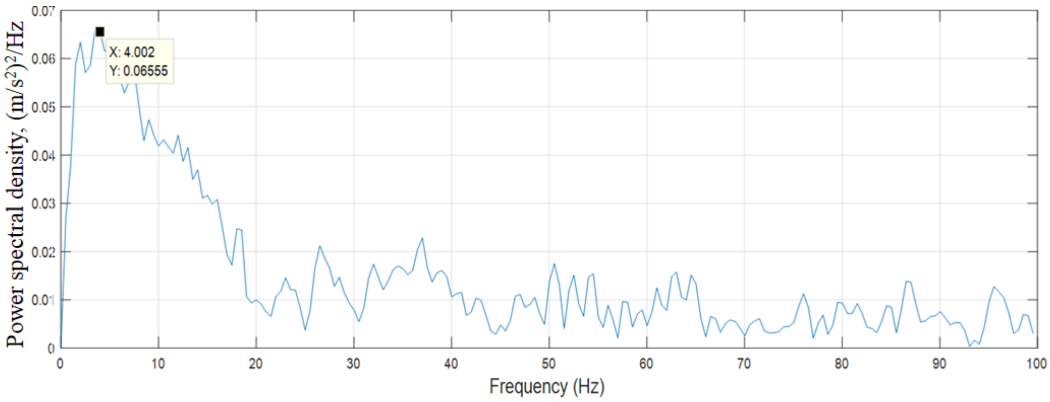

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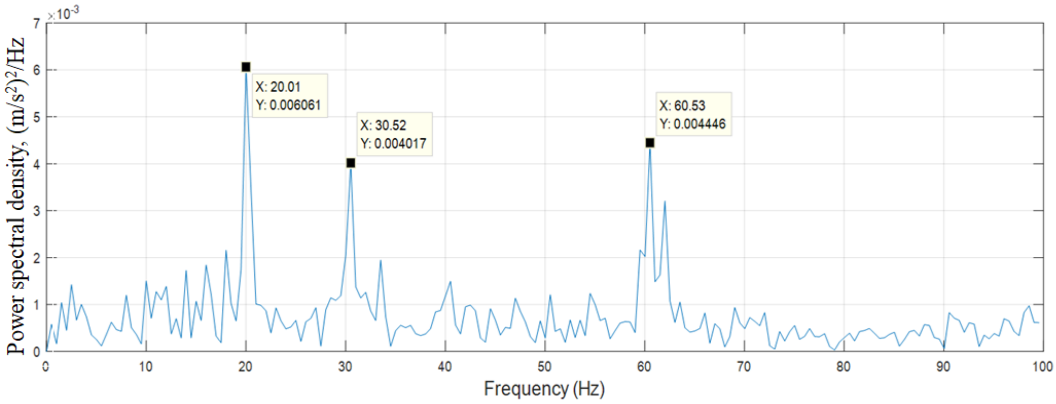

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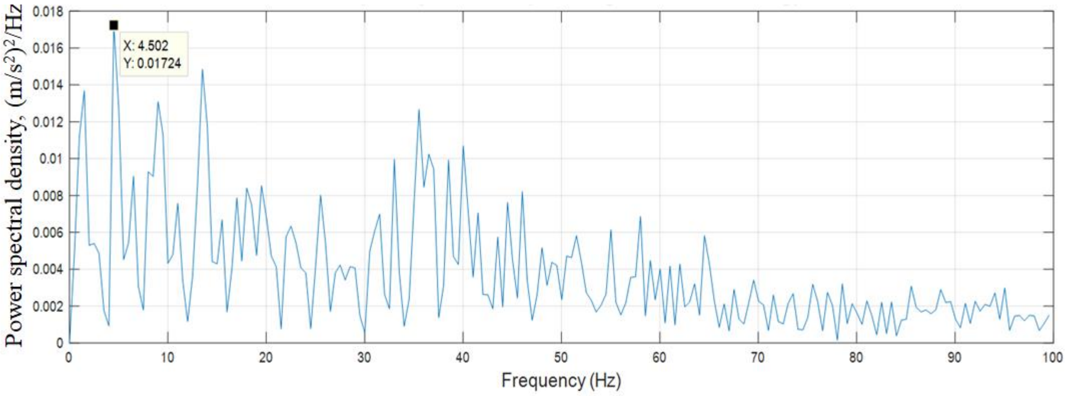

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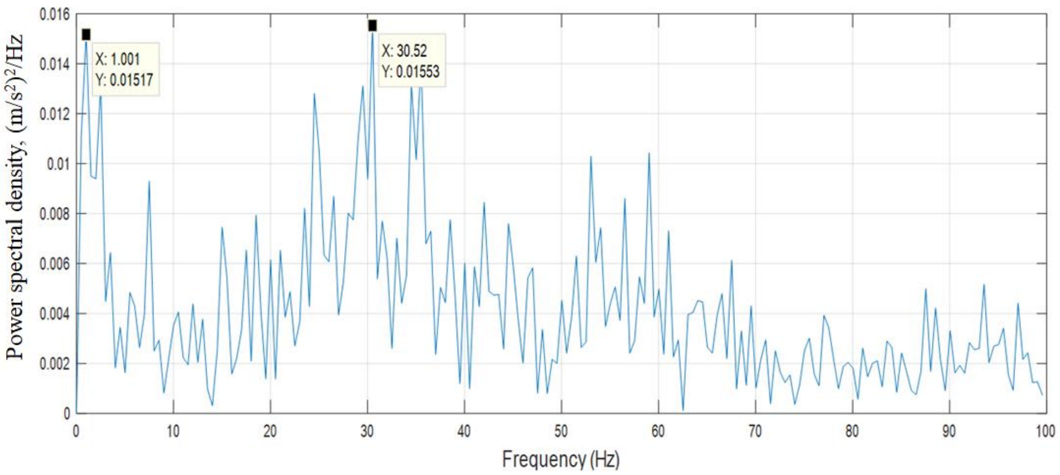

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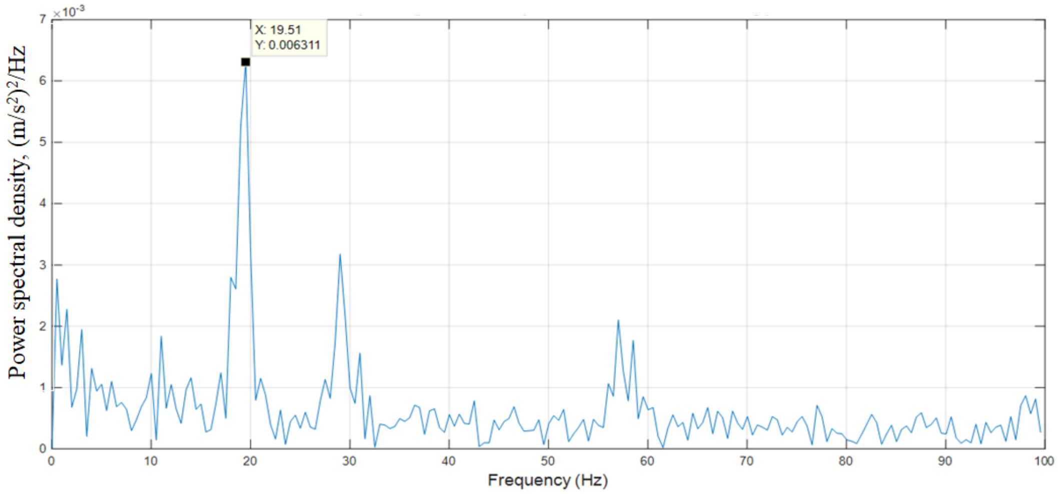
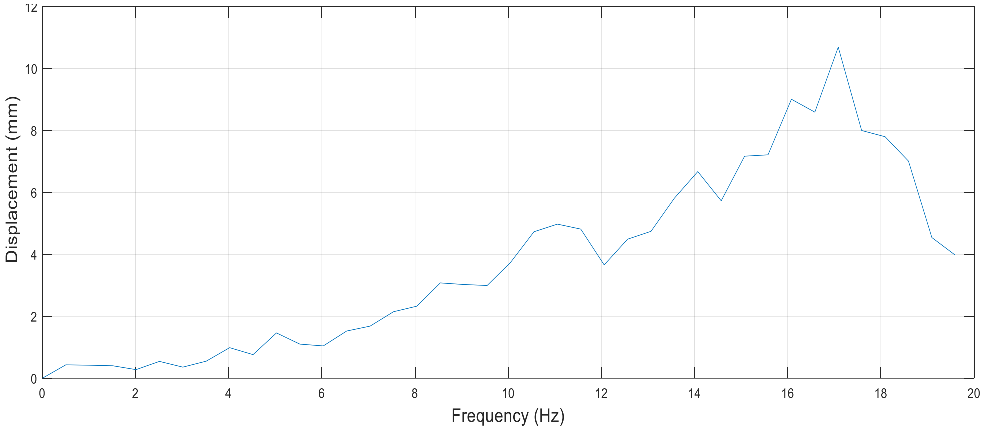


(f)

Figure 9. Frequency domain graph results on various conditions. (a) static, dry. (b) static, dry, morning. (c) static, dry, afternoon. (d) moving and raining (e) static and raining. (f) new blade at static and wet.

Figure 10 shows the compilation of wiper displacement for all the experiment condition. Figure 10(a) shows the highest wiper blade displacement 0.011m because no others effect such as wet or raining.1 Figure 10(b) shows the highest wiper blade displacement was 3.3m when in static condition at morning due to high humidity, the wiper blade glides easily on the windscreen. Second highest displacement of wiper blade was 1.4m when the car in static and raining condition as shown in Figure 10(e). Third highest displacement of wiper blade was 0.9m when the car moves at 20km/h in raining condition as shown in Figure 10(d). When the car was in static condition in the afternoon with dry windscreen the wiper blade displaced at 0.6m as shown in Figure 10(c). The displacement was only 0.2 m when using a new set of wiper blade as shown in Figure 10(f). The old blade has been exposed to direct sun and different type of weather for the past two years hence the stiffness of the rubber blade increases because the condition if rubber blade is less elastic and become harden to pull it or bend it. The lowest displacement was Car 3 with only 0.01m with dry windscreen and air conditioned room. Since the rig test was kept in the air conditioned the windscreen was cleaner with less debris and dust compared to Car 1 and 2 which were kept outdoor [21].



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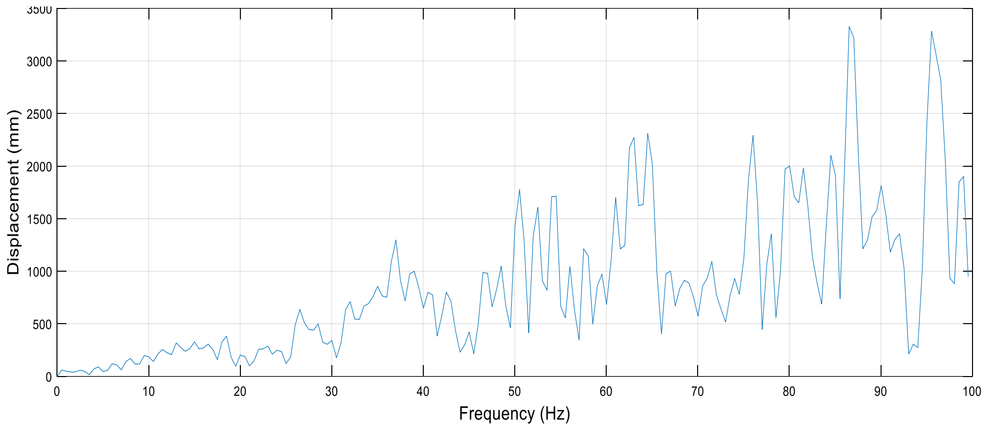

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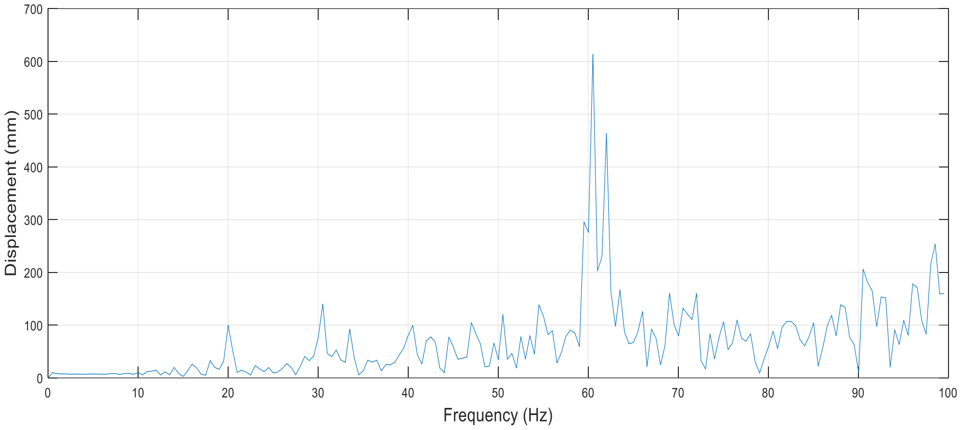
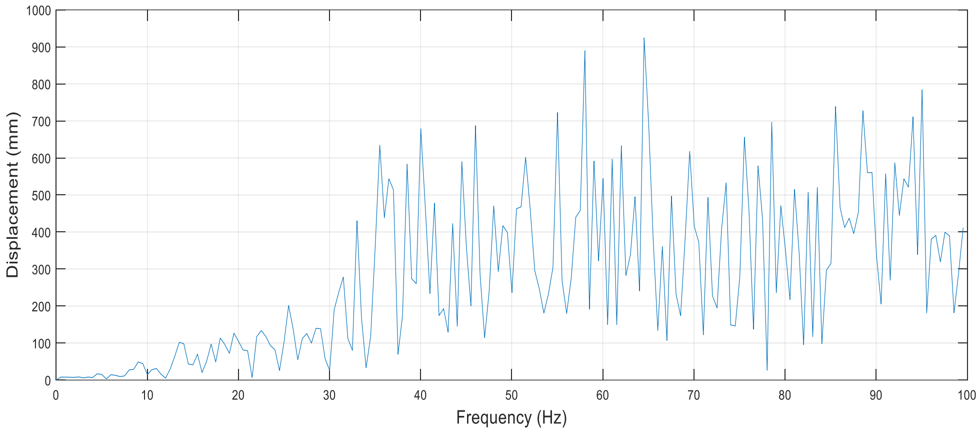

Displacement (mm)
Frequency (Hz)

(c)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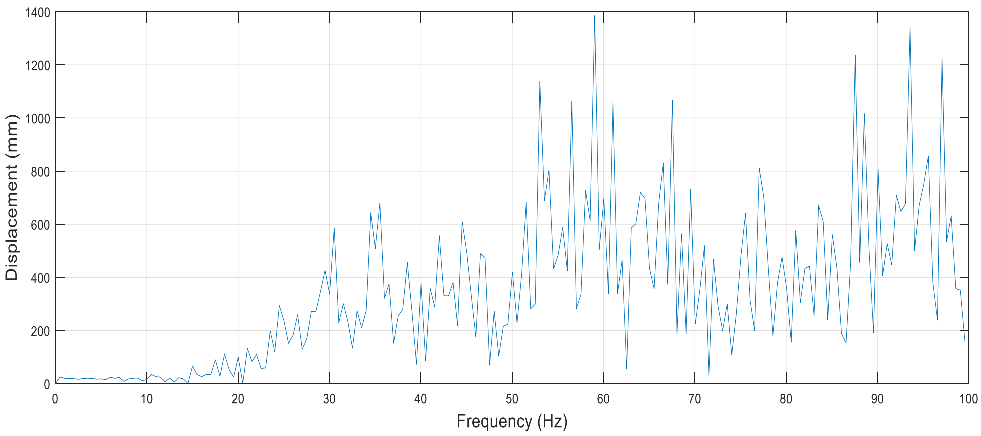
Displacement (mm)
Frequency (Hz)

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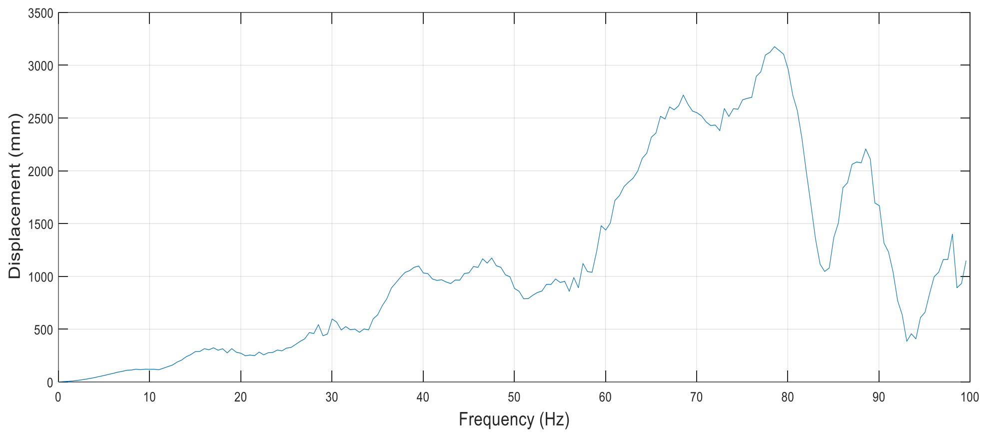

(f)

Figure 10. Displacement versus frequency of wiper blade on various conditions. (a) static, dry. (b) static, dry, morning. (c) static, dry, afternoon. (d) moving and raining (e) static and raining. (f) new blade at static and wet.

CONCLUSION

This study concludes two main effects for the rubber blade performance. The first is the structural effect of the wiper blade related to the contact force distribution between the rubber blade and the glass. Having more yoke on the wiper blade will effect on the force distribution of the wiper blade. Hybrid type of wiper blade have more uniformly distributed force exerted compared to the conventional wiper bade. The aerodynamic of the wiper blade also contributes to the lift force of the wiper blade when the car is moving less vibration occur on the windscreen due to lift force increase and makes some distance between wiper blade and windscreen thus less vibration created.

The second is the characteristics of rubber blade due to environment condition such as humidity and the temperature. We can conclude that the wiper blade produces more noise and vibration when it is in wet condition with high humidity compared to dry condition with low humidity due to friction of the water. The third aspect is wiper blade stiffness of new and old blade results in the displacement of the wiper blade. New wiper blade produces less vibration compared to the old wiper blade due to the old blade have been exposed to direct sun and different type of weather for the past two years hence the stiffness of the rubber blade increases stiffness of the rubber blade.

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