Behavior and Characteristics of Rubber Blade Car Performance

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ABSTRACT

In this modern day, high technologies have contributed so much in improving and optimizing the engine design and performance of the car. Improved isolation has helped to minimize the engine noise by making other automotive part noises become more detectable. One of the noise sources are from the wiper blades. When a wiper operates on a windshield, it often results in vibratory phenomenon due to flutter instabilities and may in turn generate squeal noise. In order to obtain good wiping 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 behavior of the rubber blade. The primary objective of this research is to study the behavior and characteristics of rubber wiper blade performance in order to reduce the automotive windscreen wiper noise and vibration effects. Experiments confirm that the contact force distribution between the rubber blade and glass is limited to a set of fixed locations that normally produce such characteristics of the wiper rubber blade due to environmental conditions such as humidity, temperature and wiper stiffness. Therefore, the experimental results were compared with previous studies and the data analysis has been used throughout the study and clearly demonstrates that it is achievable.

Keywords: *Contact force, noise, wiper blade, vibration, test rig*

1.0 INTRODUCTION

In the present study, the behavior and characteristics of the car wiper rubber blades were investigated to confirm their performance for specific operating conditions. For example, during raining, car drivers usually experience uneasiness and discomfort with the noise that may be generated by vibration when pushed by the wiper blades (especially in the old ones) in an intermittent manner. This is normally beyond their control. In general, a windshield or windscreen wiper is one of the important devices that ensure the driver in the vehicle can view via the windshield a clear vision for a certain distance without any obstruction by removing the rain drops or any dirt from the windshield with a rubber blade that moves back and forth on the surface of the glass [1]. The automotive industry has been working towards producing a higher-quality wiper system, to obtain good wiping characteristics. The rubber blade 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 surface [2-3].

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A typical wiper angle for a passenger car is about 67°. The blades are typically 12 to 30 in (0.3 - 0.76 m) in length and up to 2-in (0.5 m) in maximum increment [1]. To suit every car needs various types of wiper blades have been designed as per each car specifications. Wiper blades come in many different lengths and types. In general, there are three different types of wiper blades which are the conventional, hybrid and flat types [1].

The noise and vibration are categorized into three groups which are reversal, running and squeal noises, respectively. Reversal noise is an impact sound with a frequency of 500 Hz or less and running noise (also an impact sound) is having a frequency of about 600 Hz but less than 1000 Hz. The most annoying noise is the third type, i.e., squeal noise which occurs due to vibration at a high frequency of about 1000 Hz during the rising of the wiper [4].

Thus, it is deemed important to have a good understanding about the behavior and characteristics of rubber wiper blade performance. Hence, it is the objective of this research to analyze and validate the dynamics of the wiper blade by assessing the wiper blade system performance based on the noise and vibration produced by the rubber blade. Further, it is to propose a method to reduce or suppress the noise and vibration through the modification of the wiper blade structure. The subsequent sub topic explains about the experimental set up used in this study followed by an analysis of the results (and data) and discussion from the experimental works performed earlier. Then, the conclusion of the outcome of the research was summarized at the end of the paper to include a comparison of the results with the previous studies and recommendations for future works.

2.0 EXPERIMENTAL SET UP

In this research study, a number of approaches have been used that are based on previous study involving the experimental and analytical methods from the data obtained via the experiments.

In order to measure the force exerted on the wiper blade a force sensitive resistor (FSR) sensor was used and the experimental set up is shown in Figure 1. The vibration data obtained was processed by a single-board microcontroller (*Arduino UNO*). The FSR sensor was attached to few selected points as depicted in Figures 2 and 3. The calibration was performed using a dead weight to verify the force exerted on the FSR sensor. In Table 1, a number of selected car models for this experiment was listed with the respective wipers' specifications.

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 original position [2-3]. These two movements of the blade produce different vibration effect. To investigate the maximum noise occurs on the wiper blade operation, an experiment using an uni-axial accelerometer *A MMA7660* was used as shown in Figure 4. A total of 48 numbers of experiments were done for three types of cars, namely, Car 1, Car 2 and Car 3 as shown in Table 1. The operating conditions for each car are shown in Table 2 to analyze the behavior of the wiper blades. The vibration data from the accelerometer was processed by a portable data acquisition module, *ADVANTECH USB-4716*. A thermocouple model *Fluke 714* was also used to determine the temperature when performing the experiments.

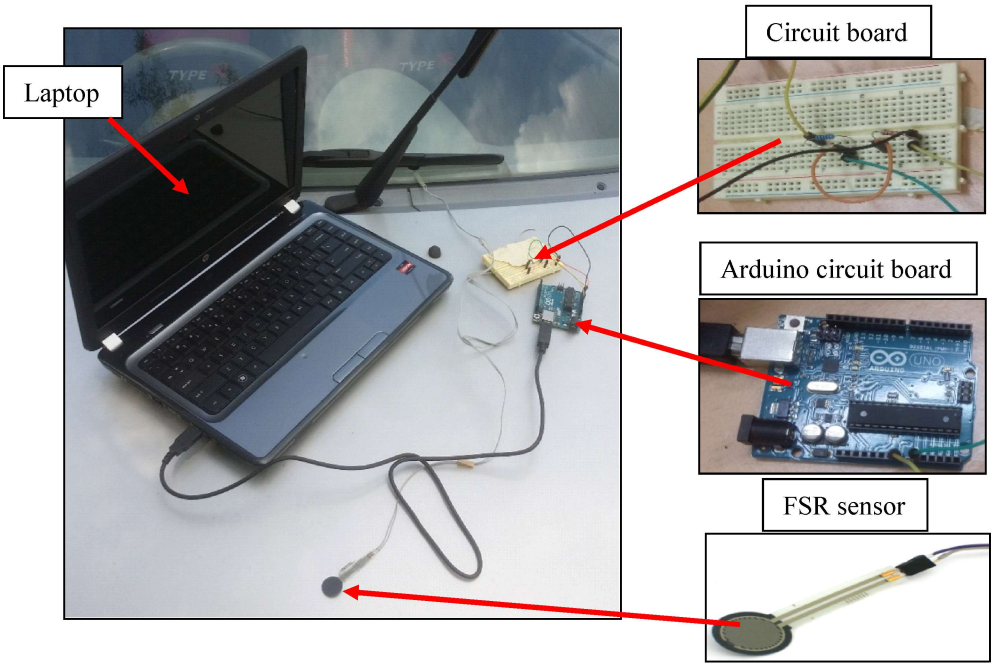


Figure 1: Experimental setup for studying the force distribution

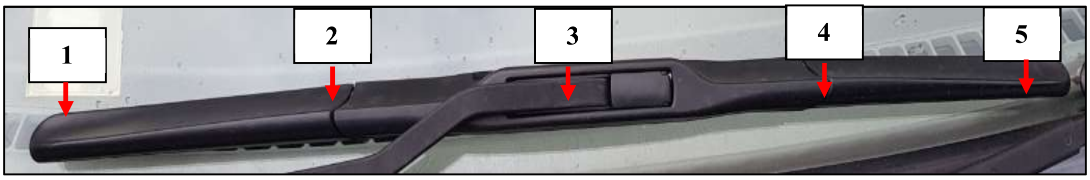


Figure 2: FSR point locations on the wiper blade for Car 1

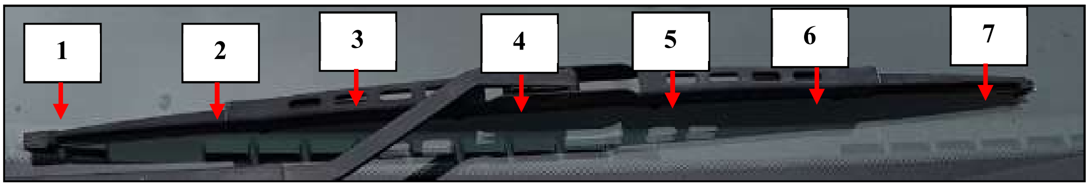


Figure 3: FSR point locations on the wiper blade for Car 2

Table 1: Specifications of the wiper blades

Car model		Wiper type	Hook type	Windscreen angle	Wiper blade size (right/left)
Car 1	Small city car (650 cc)	Hybrid	U	29°	18”/16”
Car 2	Saloon car (1500 cc)	Conventional	U	30°	20”/17”
Car 3	Sedan car (1300 cc)	Conventional	U	30°	20”/17”

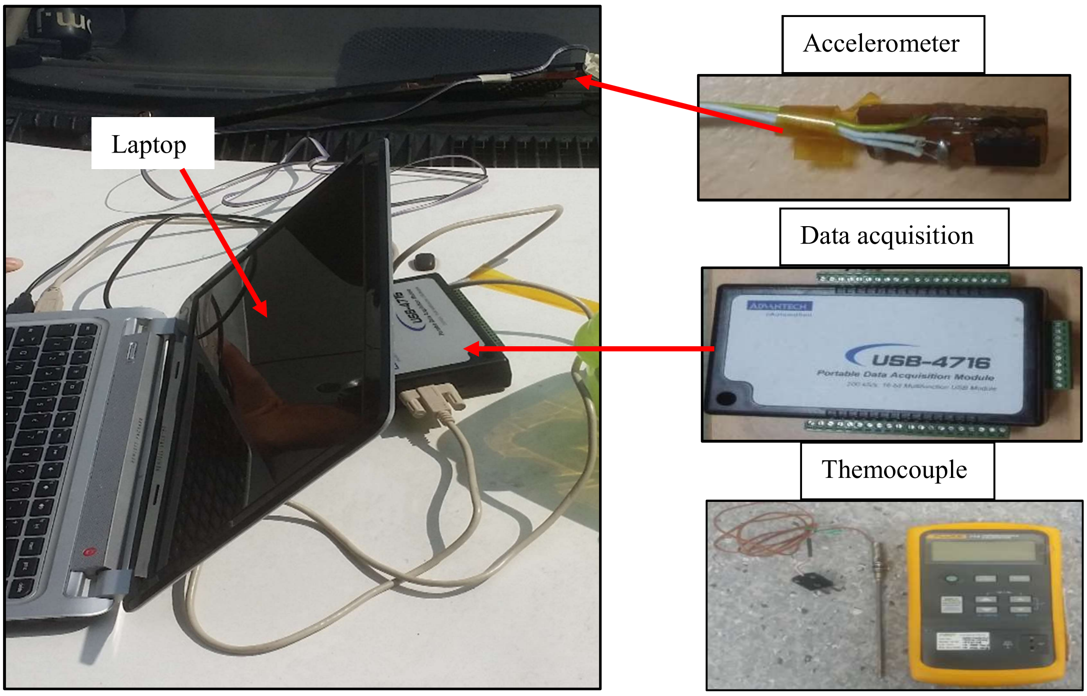


Figure 4: Experimental setup for studying the vibration and noise of the wiper blade system

Table 2: Comparison of the experimental conditions

No	Condition 1	Condition 2	Different parameters	Effect to observe
1.	Static car, wet surface (noon)	Static car, wet surface (morning)	Ambient temperature	Temperature
2.	Raining (static car)	Raining (moving car 20 km/h)	Car movement	Air friction
3.	Static car, dry surface (Car l)	Static car, dry surface (car 2)	Surface angle	Angle of surface
4.	Static car, dry surface (old blade)	Static car, dry surface (new blade)	Blade	Blade stiffness

3.0 RESULTS AND DISCUSSION

3.1 Force Distribution on The Wiper Blade

Figure 5 shows the force distribution reading from FSR for selected points that have been attached as shown in Figures 2 and 3. For the conventional wiper blade of Car 2, the distribution is not consistent and its concentration are at points 1 to 5 (Figure 2). The highest force distribution is in the middle of the wiper blade where the springs in the wiper blade arms were located due to the exertion of high pressure at the middle front glass surface of the windscreen. On the other hand, the hybrid wiper blade used in Car 1 has more consistent force distribution at points 1 to 3 as shown in Figure 3. The force concentration is also found to be the highest at the middle of the wiper blade similar to the conventional wiper blade until point 7. Based on the reports in [2-3], the load applied to the wiper blade influences the contact force distribution along the wiper blade in which the peak contact force (highest) is located at the center of the yolk compared to the other measured points which are more uniformly distributed. This is in-line with the experimental results obtained for both conventional and hybrid type of wiper blades in this research. In other words, the results are in good agreement with the those reported in literatures and hence the results are fully verified.

The distribution force on Car 2 is not well distributed because at points 5 to 7, it has a linkage mechanism called *Whippletree* which carries the higher load concentration of the force on the wiper blade. Note that Car 1 is having a hybrid wiper blade that uses an 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 [5-8].

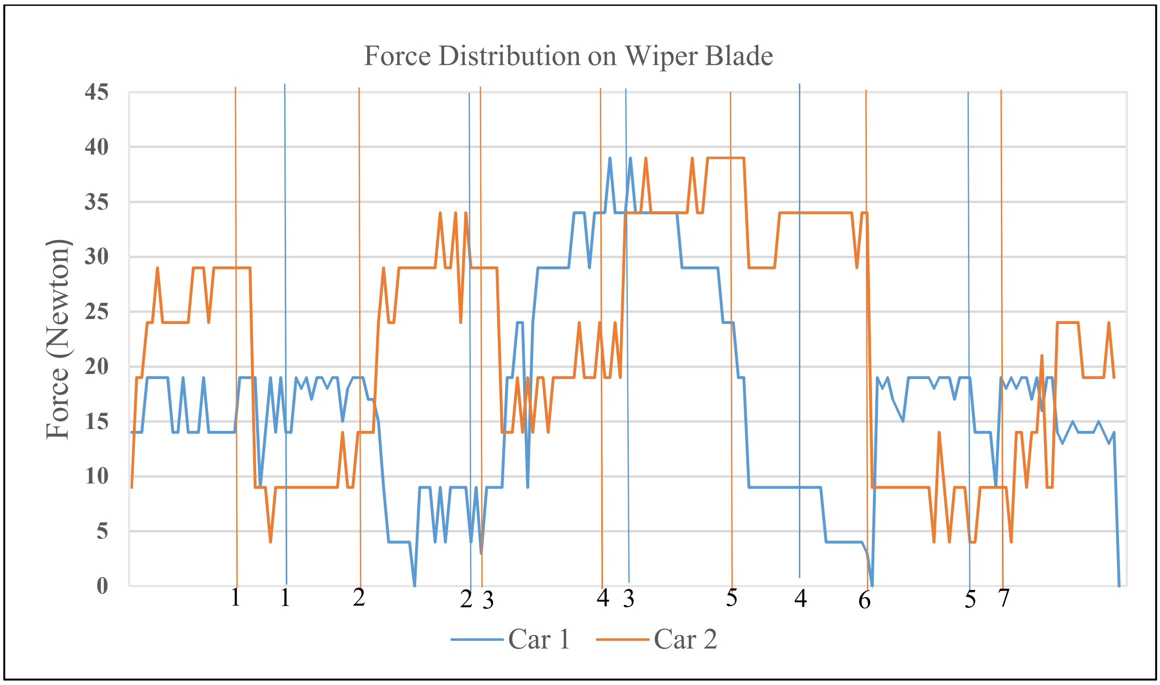


Figure 5: FSR measurements of the force distribution on the selected points (1 to 7) of the wiper blade for Cars 1 and 2

3.2 Vibration and Noise on the Wiper Blade

Noise and vibration measurements of the wiper blades were carried out under an environmental Condition 1 (refer to Table 2) which is for dry surface only for Car 1 and it was measured at a single speed of 1.8 rad/s. The acceleration response is shown in Figure 6. From the figure, the high vibration amplitude occurs particularly right at the beginning and end of the wiper stroke while in the middle of the stroke, the vibration amplitude is lower. This may due to two reasons, one is the stick-slip phenomenon and the second is related to the negative velocity-friction characteristic mechanisms, which is also in good agreement with other studies [6, 9-10].

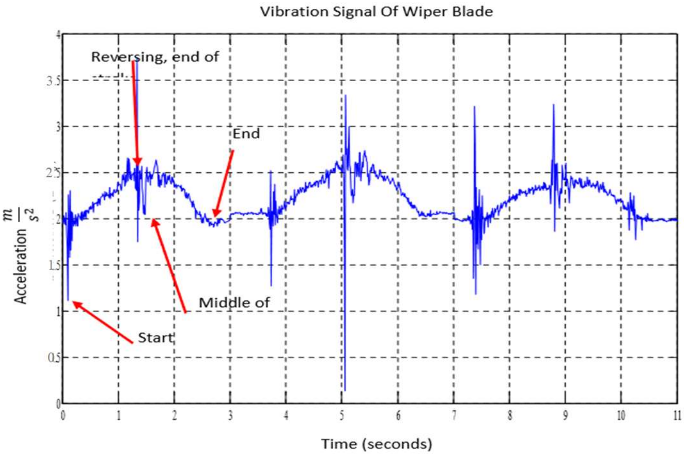
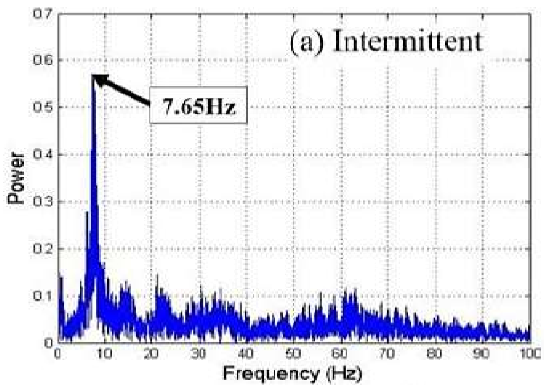


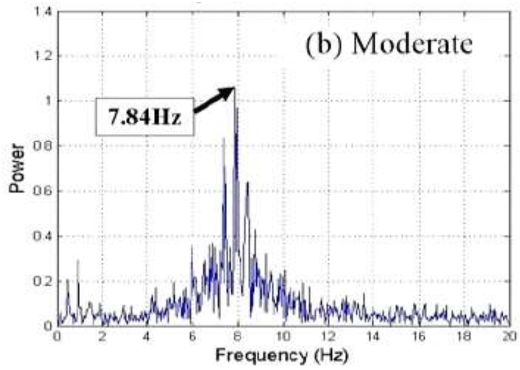
Figure 6: Experimental results of the vibration signal on the wiper blade of Car 1

3.3 Vibration Comparison of Wiper Blade in Three Operation Levels

The wiper blade of the any car can typically function based on three levels of operations, intermittent, moderate and fast speeds. Before proceeding with further comparison of the wiper blade for Car 3, the best suitable speed of the wiper operation needs to be determined to minimize the variant parameters in the experiment [11-13].

The wiper blade was tested under static condition and dry glass surface with three different levels of operation as shown in Table 2 for the experimental Condition 1 using an old wiper blade. From Figure 7, all the three levels of operation produce maximum frequencies of well below 10 Hz for Car 3. Comparing the three graphs, the wiper blade produces the highest frequency at 7.85 Hz for fast operating speed of 2.8 rad/s in one complete stroke without idle time while the lowest frequency is found to be 7.65 Hz for intermittent operation and a speed of 1.8 rad/s for one complete stroke with 4 s of idle time. Thus, the operating speed of the wiper blade system contributes to the generation of noise even the differences of the amplitudes of vibration between the three operating speed are not significant; the highest operational speed produces more vibration and noise compared to that of lower speed. For the next experiment, the intermittent operation will be used for all the tests for the least noise generation (Condition 2 of Car 3).





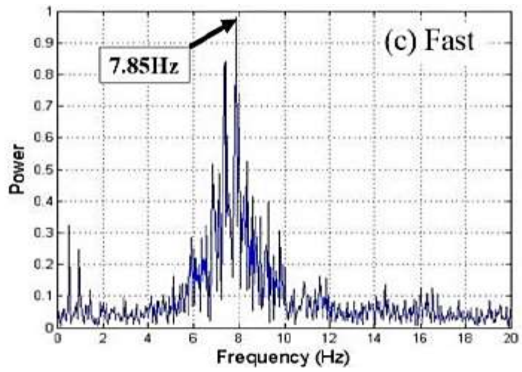


Figure 7: Comparison of the noises generated in Car 3 for all operating speeds in frequency domain

3.4 Wiper Blade Performance for Car 3 under Various Operating Conditions

Figures 8 to 10 show results based on various environmental Conditions 1 and 2 for Car 3. It is found that a chattering effect plus noise is generated both in the wet and dry conditions of the windscreen. The only noticeable difference was on the degree of vibration per one stroke cycle that concurs well with the findings by Awang *et al*. [4]. They stated that the wiper produced a steady motion in the dry condition compared to the wet condition due to the interfacial reaction of the water film and surface of the windscreen that subsequently may cause vibration. The wiper also produces higher vibration amplitude in the afternoon period due to an apparent increase in the blade stiffness and thermal expansion in comparison to the morning condition. It was also observed that due to high humidity incidence in the morning, the starting frequency was high due to the higher degree of moisture of the windscreen. Once the moisture was wiped clean and dry, the wiper blade frequency remains at low level [14].

At static but under raining condition, the wiper blade produces more noise frequency compared to the vehicle moving at 20 km/h under raining condition. This is due to a dynamic 'lift' force deemed to have occurred when the car is on the move. This force increases at higher speed as verified in the experimental investigation of the wiper system performance [7]. Since it creates a narrow gap between the wiper blade and windscreen, less vibration is produced.

The wiper blade stiffness difference of the new and old blade results in a slight displacement (overshoot) of the wiper blade, in terms of its stroke. From the experimental results, it can be seen that the displacement was affected by the vibration frequency. The higher the frequency of vibration, the higher the wiper blade was displaced (more stroke). The angle of the windscreen and the wiper blade type also contributes to the stroke displacement of the wiper blade in-line with those reported in [4, 10] with reference to the complex eigenvalue analysis.

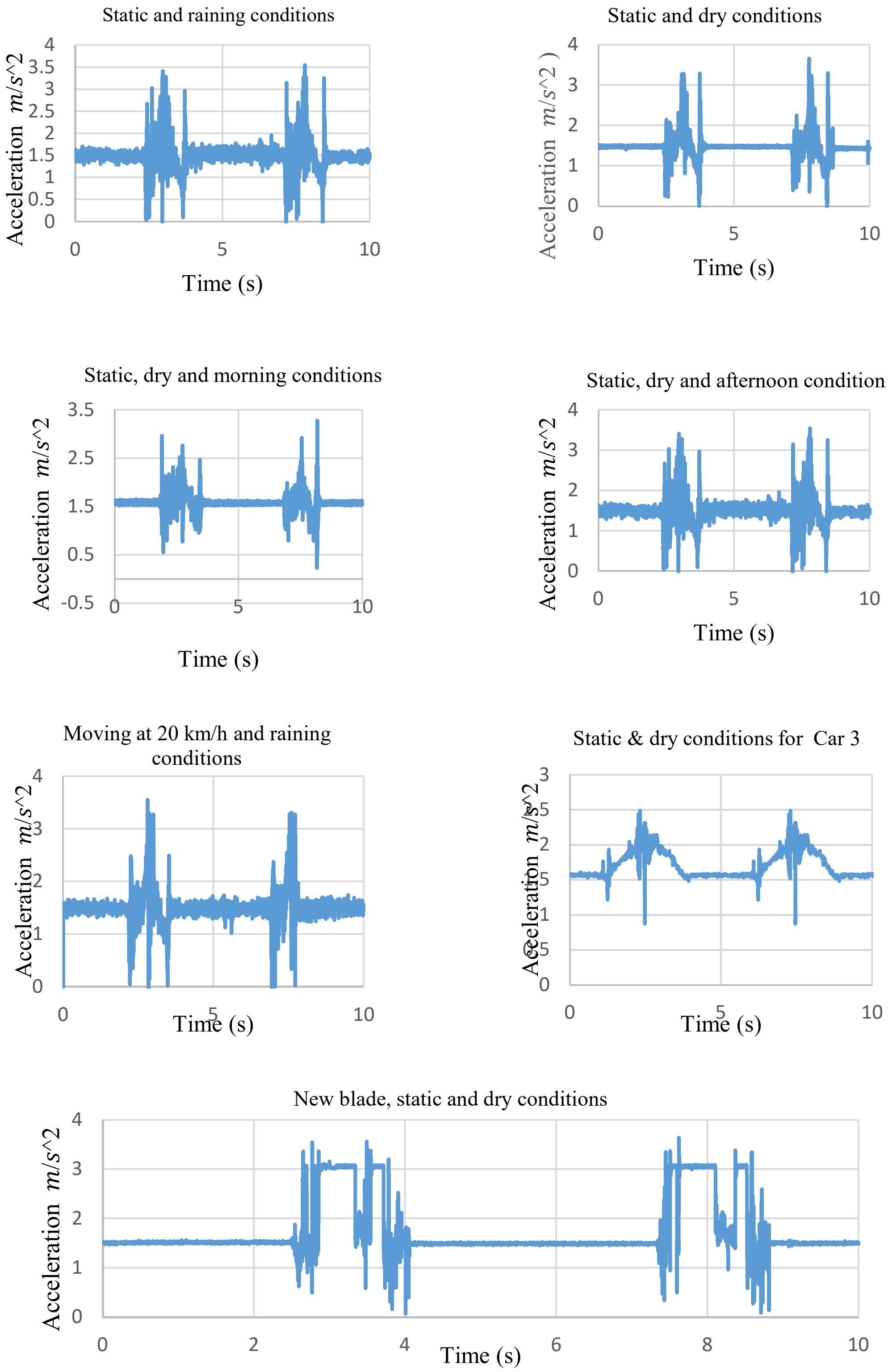


Figure 8: Results for various operating conditions in time domain

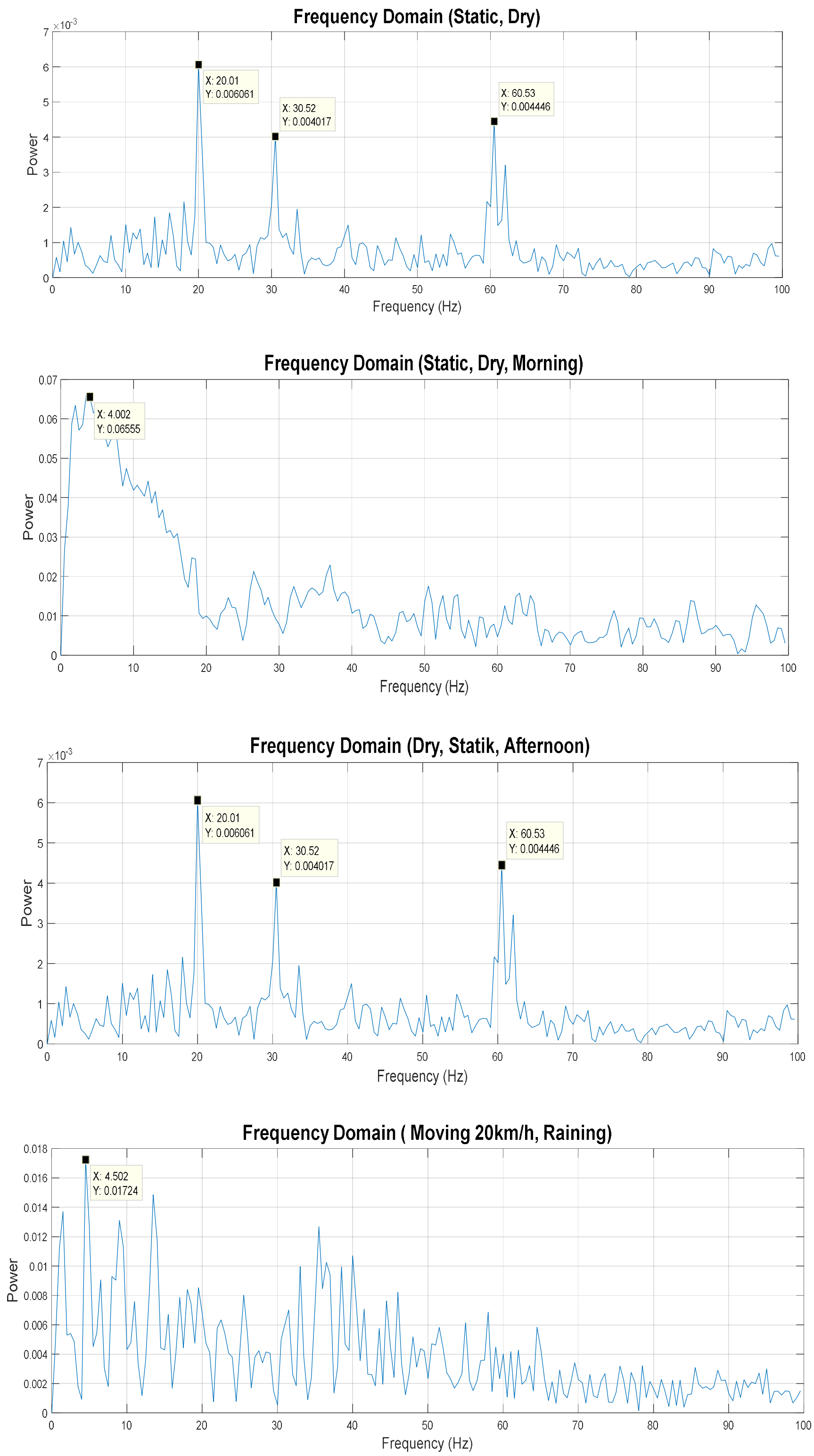


Figure 9: Results for various conditions in frequency domain

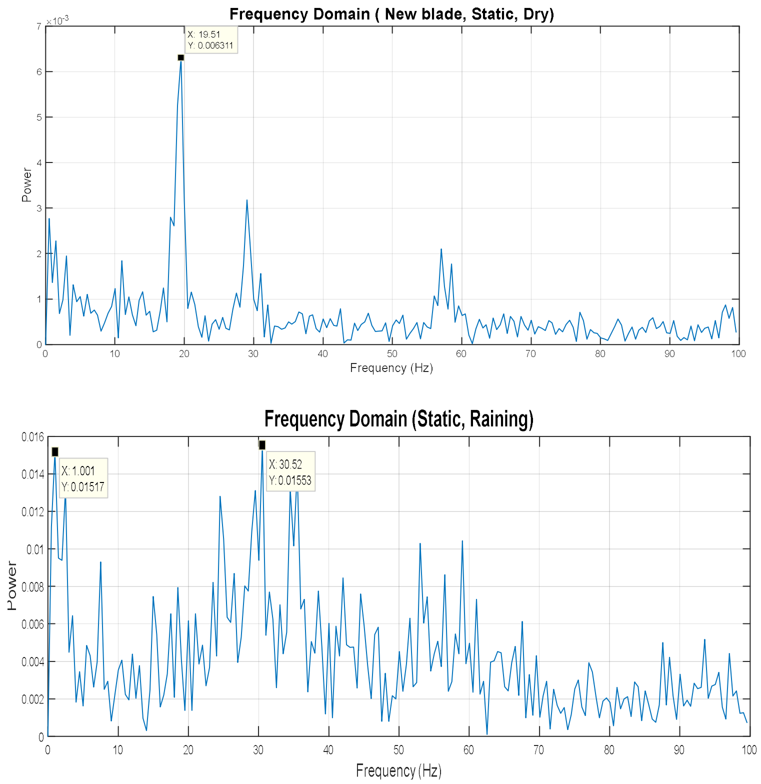
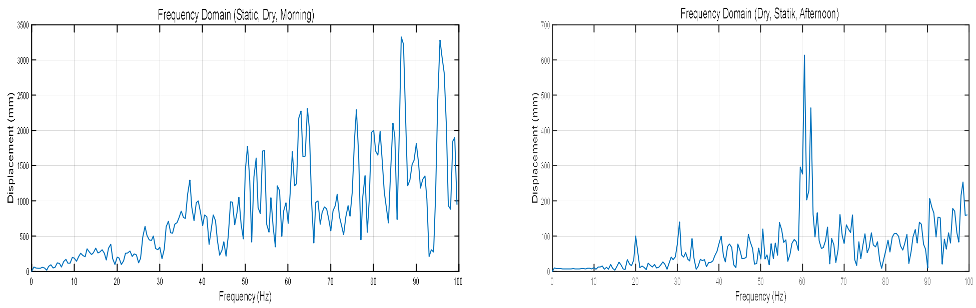


Figure 10: Results for various conditions in frequency domain

Figure 11 shows the compilation of the wiper displacements for all the experimental conditions of Car 3. The highest wiper blade displacement is 3.3 m when the vehicle is in static condition in the morning due to high humidity incidence and that the wiper blade easily glides on the surface of the windscreen. The second highest displacement of the wiper blade is 1.4 m when the car not moving and in a raining condition. This followed by the third highest displacement of the wiper blade at 0.9 m when the car moves at 20 km/h in the raining condition. When the car was in static condition in the afternoon with dry windscreen, the wiper blade was displaced at 0.6 m. The displacement was found to be only 0.2 m when using a new set of wiper blade. The old blade that has been exposed to direct sun and experienced different type of weather conditions for the past year or two exhibits higher stiffness of the rubber blade. The lowest displacement was observed for Car 3 producing a displacement of merely 0.01 m with dry windscreen and air-conditioned laboratory environment. Since Car 3 test was carried out in the air conditioned surrounding, the windscreen was cleaner with less debris and dust compared to Cars 1 and 2 which were kept outdoors, in-line with the findings reported in [4, 14-15].



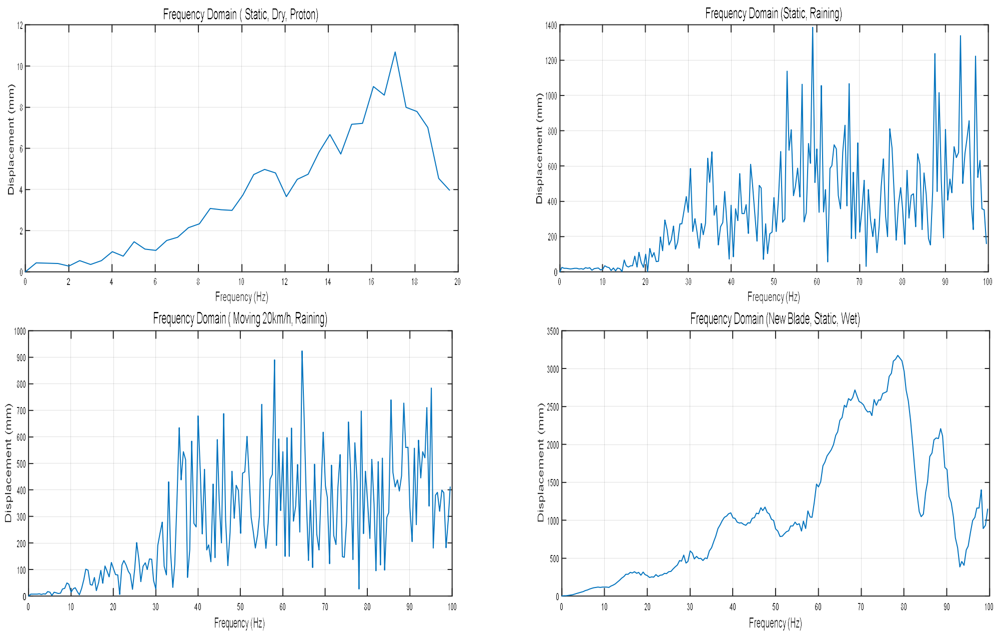


Figure 11: Displacements of the wiper blade of Car 3 for Conditions 1 and 2

4.0 CONCLUSION

This study concludes that there are three main factors that affect the wiper rubber blade performance. The first is attributed to the effects caused by the structure and shape of the wiper blade that in turn is related to the interfacial contact force distribution between the rubber blade and glass of the windscreen. Having more yoke on the wiper blade also affects the force distribution of the wiper blade. The hybrid wiper blade has more uniform distribution of the force compared to the conventional wiper bade. The aerodynamics of the wiper blade contributes to the lift force of the wiper blade when the car is moving resulting in less vibration incidence on the windscreen. This is due to the increase in the lift force that in turn creates a narrow gap between the wiper blade and windscreen, thereby reducing the vibration amplitude. The second is the characteristics of rubber blade are also influenced by the environmental conditions related to the humidity and temperature. It can thus be determined that the wiper blade produces more noise and vibration when it is in wet condition with high humidity in contrast to the dry and low humidity conditions, due to the friction effect between the water film and glass surface of the windscreen. The third aspect is the physical conditions of the wiper blade itself, particularly related to the blade stiffness (new or old) that results in the different stroke displacements of the wiper blade. New wiper blade produces less vibration compared to the old one due to more flexibility (lesser stiffness) and the fact that the old blade has worn out after being exposed to direct sunlight and experienced various weather conditions for longer period which results in increased stiffness (rigidity).

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