Progress in Engineering Application and Technology Vol. 4 No. 2 (2023) 574-582

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Analysis of Handling Performance on Vehicle due to Installation Vehicle Rear Subframe

Usman Jamal[1], Syabillah Sulaiman[1]*, Muhamad Asri Azizul[1]

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2023.04.02.058
Received 01 July 2023; Accepted 12 July 2023; Available online 12 July 2023

Abstract: Handling performance are essential for a vehicle's dynamic properties, but it lack evaluation method consistency with subjective assessment, while subframes isolate vibrations, distribute loads, support the body structure, and emphasizing the importance of efficiently absorbing vibration impacts for customer satisfaction and driving comfort and excessive subframe vibration can lead to oversteer and loss of control. The objective of this study is to study the factor which affected vehicle subframe dynamic performance, develop a data acquisition system for capturing vehicle dynamic motion, and analyze the vibration of the rear subframe during handling motions, while the scope includes conducting the experiment on a Perodua Myvi 1300cc at UTHM Pagoh campus. The experimental study utilized subframe bar, Arduino Uno, accelerometer, Arduino IDE, and MATLAB Simulink to measure the lateral acceleration of the vehicle conducted within the speed limit of the institution. The result of the absence of a subframe bar in a vehicle leads to increased acceleration, slightly higher dynamic behavior and requiring precise steering control to maintain stability safely. The study aimed to examine subframe vibration during handling motions, particularly the impact of a subframe bar, through tight double-lane change maneuvers at 10 km/h, the left subframe mount shows a difference of 0.08 g and 0.03 g between subframe bar and no subframe bar conditions, while the right subframe mount shows a difference of 0.28 g and -0.41 g. At 20 km/h, the left subframe mount shows a difference of 0.15 g and 0.34 g, while the right subframe mount shows a difference of 0.19 g and -0.38 g. At 30 km/h, the left subframe mount shows a difference of approximately 0.22 g and -0.29 g, while the right subframe mount shows a difference of 0.39 g and -0.09 g. This study provides valuable insights into subframe behavior, vehicle dynamics, and the importance of the subframe bar in enhancing rigidity and stability, with recommendations for improving research accuracy and reliability.

Keywords: Subframe, Acceleration, Double-Lane Change

Corresponding author: syabillah@uthm.edu.my

1. Introduction

Handling capability are integral aspects in defining the dynamic properties of a vehicle, traditionally treated as the study of a vehicle's dynamic behavior [1]. The mechanical requirements of the subframe system for vibrational control and cornering forces are dynamic and vary depending on driving conditions and depends on roads condition [2]. The study of noise, vibration, and harshness (NVH) in vehicles involves analyzing and modifying their vibration characteristics. While vibration and can be quantitatively measured, the perception of harshness is subjective and requires human assessment or analytical tools that can capture subjective impressions. Excessive vibration on the vehicle subframe can affect body roll and lead to oversteer which could cause the vehicle to turn more sharply than driver intention and potentially result in a spin [3]. The objective of this experimental study is to investigate the vibration of the rear subframe, develop a data acquisition system for capturing vehicle dynamic motion, and analyze the subframe during handling motions. The experiment aims to observe and evaluate the dynamics and behavior of the vehicle in the lateral direction, including its cornering stability, and control on dry road conditions, with variables such as lateral acceleration providing insights into the vehicle's handling performance [4].

2. Materials and Methods

The approach of this study is conducting an experimental method on the acceleration of the vehicle subframe. The use of Arduino as a microcontroller, accelerometer as a sensor and MATLAB Simulink as an interface to collect data while detecting vibration are the essential part.

2.1 Integrated Development Environment (IDE)

The Arduino Uno board features the ATmega328P microcontroller, and a user-friendly programming language [5], IDE for basic microcontroller programming to calibrate the sensors before it can be used to gather data from the accelerometers [6]. The use IDE software (Integrated Development Environment) is to find acceleration on a vehicle using an accelerometer because it provides a convenient platform for writing, compiling, and executing code that can process the data from the accelerometer, perform necessary calculations, and display or analyze the acceleration values in a user-friendly manner. Figure 1 shows the interface of IDE software.

Figure 1: IDE software interface

2.2 MATLAB Simulink setup

MATLAB is a powerful software program that includes Simulink, a graphical programming environment for modeling, simulating, and analyzing dynamic systems using block diagrams, allowing engineers and scientists to build models with preset blocks representing different system components [7]. The MATLAB Function block within Simulink enables users to extend their models and generate precise C/C++ code for Arduino hardware [8]. The steps to enable the MATLAB Function block are as follows:

i. Connect the computer and Arduino board, launch MATLAB, and download the Arduino IO file. Open the "install_arduino.m" file to run the program.
ii. Execute the program using the downloaded "Arduino.m" code.
iii. Open the Arduino Io Simulink library by navigating to "open > ArduinoIO > Simulink > Arduino_io_lib.slx".
iv. Create mathematical data acquisition model from the Arduino block library as in figure 2.

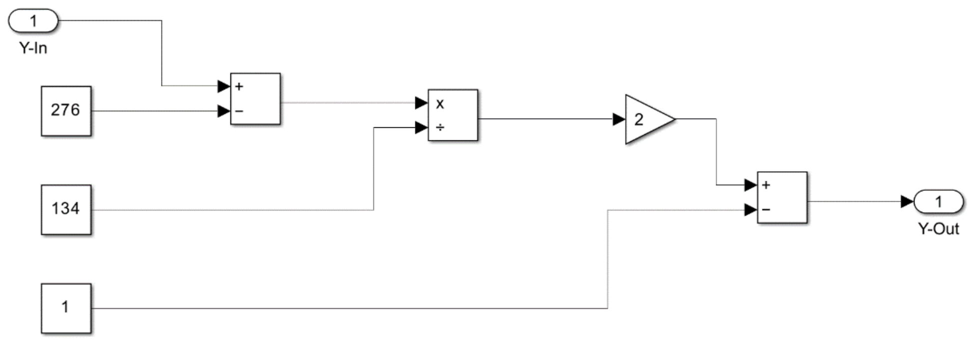

Figure 2: Mathematical model in MATLAB Simulink Software

A data acquisition model was created for the subframe of the test vehicle, utilizing two accelerometer sensors. The model involves analogue input and output subsystems, with the analogue input capturing acceleration data for the subframe's left and right sides. Figure 2 shows the calibration block diagram for the accelerometer to get g value of the acceleration as in Equation 1 below.

$$g = 2\left[\frac{sensor-276}{134}\right]-1 \quad Eq.1$$

The sensors are attached to the subframe using a hot glue gun, enabling real-time graph generation during the experiment and complete graphs afterwards.

2.3 Experimental setup

When setting up an experiment to analyse the dynamic motion of a vehicle under handling conditions and at different speeds, there are several steps to consider:

i. Sensor installation on the subframe is positioned at both left and right side of the subframe as shown in Figure 3. The test vehicles are tested in two conditions which are with subframe bar and without subframe bar.

Figure 3: Accelerometers position

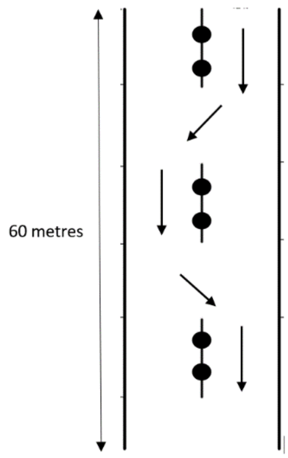

Figure 4: Tight double-lane change course

ii. The experiment was carried out on a test track inside the campus facility that replicates tight double lane changes encountered by the vehicle in real-world use. The total length for the track is 60 m as shown in Figure 4. The experiment was conducted on a normal road pavement at 10 km/h, 20 km/h and 30 km/h in dry road conditions.

iii. Conduct the experiment in a repeatable test procedure that yields consistent results. The experiment will be conducted three times repeatedly so the data can be analyzed for the best results without any technical error. Before beginning the main experiment, include a pilot test to validate the course.

iv. Analyze the data collected during the experiment. This step is necessary to draw meaningful conclusions about the vehicle's dynamic motion under different speed conditions and handling,

3. Results and Discussion

The information was entered into Microsoft Excel to create graphs that contrast lateral motion with and without a subframe bar. The car was driven at 10, 20, and 30 km/h depending on the type of lateral experiment.

3.1 Double-Lane Change Test at 10 km/h

A double-lane change test is a controlled maneuver used to gauge a car's handling and stability during a quick lane change at a speed of 10 km/h.

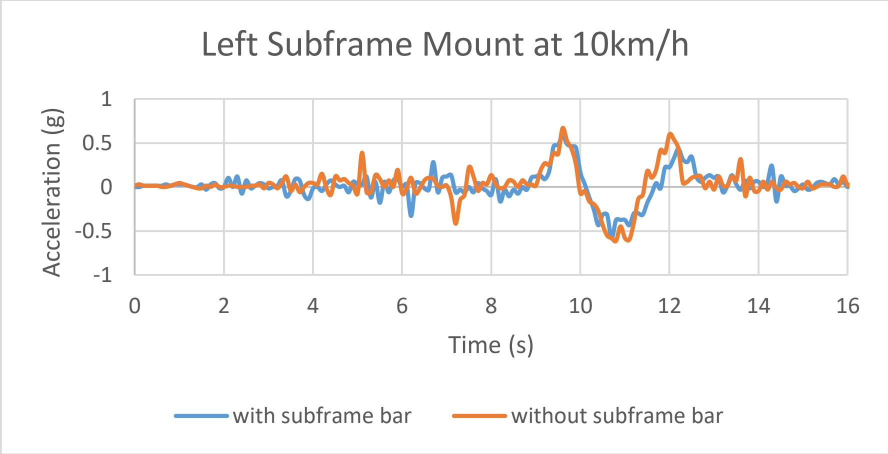

Figure 5: Left subframe mount acceleration at 10 km/h

The acceleration peaks on the left side of the subframe that mount with subframe bar at 10 km/h are 0.58 g at 9.6 seconds and -0.58 g at 10.7 seconds in Figure 5, respectively. A double lane shift from right to left and from left to right at 10 km/h requires roughly 4 seconds. In comparison to subframes with subframe bars, the acceleration of subframes without the subframe bar climbs a little bit. At 9.6 and 10.8 seconds, respectively, the acceleration reaches its maximum values of 0.66 and -0.61 g. The graph shows a slight change of 0.08 g and 0.03 g between with subframe bar condition and without subframe bar condition.

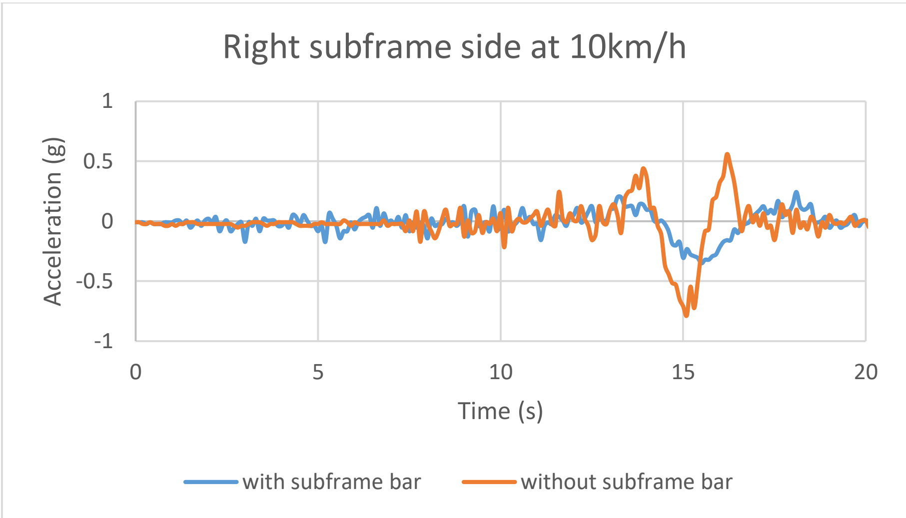

Figure 6: Right subframe mount acceleration at 10 km/h

With a subframe bar mounted, at 10 km/h the acceleration peaks on the right side of the subframe are 0.05 g at 13.3 seconds and -0.49 g at 15.5 seconds in Figure 6, respectively. at the end of the lane change, the vehicle sways to the point of 0.44 g at 16.2 seconds before it settles down at 16.6 seconds. When subframe bars are absent, the acceleration of subframes increases beyond the typical levels observed with subframe bars. The maximum acceleration values without subframe bars are 0.33 g at 13.9 seconds and -0.9 g at 15 seconds. Comparing the conditions with and without subframe bars, there is a slight difference in acceleration: an increase of 0.28 g and -0.41 g. This demonstrates that even at lower speeds, the absence of a subframe bar results in increased acceleration and slightly affects the vehicle's lateral motion.

3.2 Double-Lane Change Test at 20 km/h

A little more dynamic behavior during the double-lane change would be introduced by raising the speed to 20 km/h.

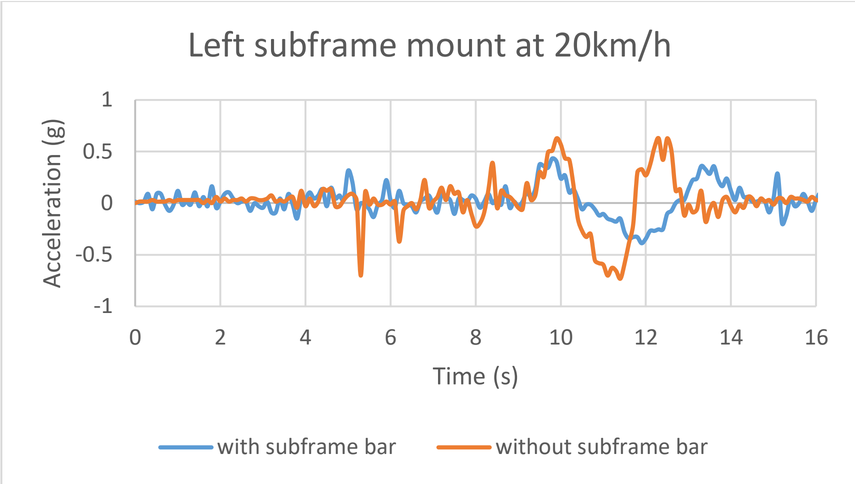

Figure 6: Left subframe mount acceleration at 20 km/h

In Figure 4.4, the acceleration peaks on the left side of the subframe with a subframe bar mounted are 0.42 g at 10 seconds and -0.39 g at 12 seconds, respectively. Changing lanes from the right to the left and from the left to the right takes roughly 5 seconds. For the acceleration of the subframe without the subframe bar, the acceleration achieves its maximum values of 0.57 and -0.73 g at 10 seconds and 11.5 seconds, respectively. The graph shows a little difference between the subframe bar condition and the lack of the subframe bar condition of between 0.15 g and 0.34 g.

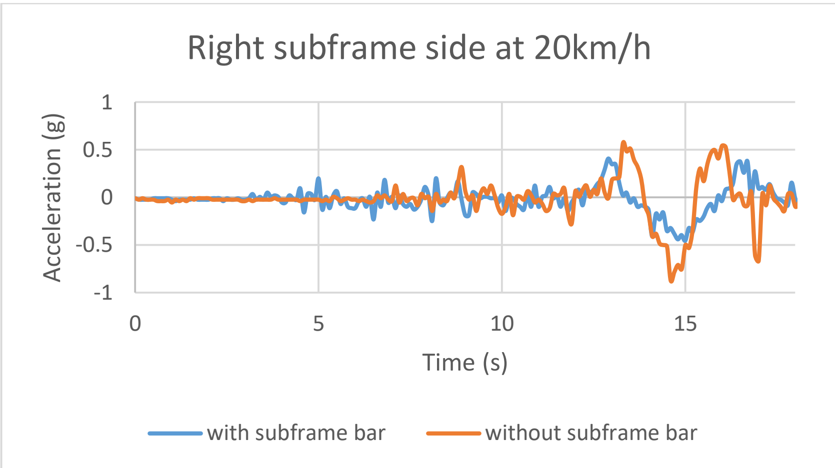

Figure 7: Right subframe mount acceleration at 20 km/h

Regarding the state of the subframe on the right side based on Figure 7, we can describe the graph as indicating a notable contrast between the subframe with a bar and the subframe without one. The subframe equipped with the subframe bar exhibits a peak acceleration of 0.27 g at 13 seconds and reaches a minimum value of -0.6 g at 15 seconds and 0.23 g at 16.7 seconds, after which the vehicle continues to sway until it stabilizes at around 18 seconds. The vehicle takes approximately 5 seconds to complete the entire course. For acceleration without the subframe bar, it indicates a peak acceleration of 0.46 g at 13 seconds, and it is exerting a minimum acceleration of -0.98 g before it can turn back to the left and reach the maximum acceleration of 0.41 g at 16 seconds until it settles down. The graph shows a big difference of acceleration in between with subframe and without subframe bar to the value of 0.19 g and -0.38 g.

3.3 Double-Lane Change Test at 30 km/h

With the speed raised to 30 km/h, the challenges faced by the vehicle's handling capabilities become more evident.

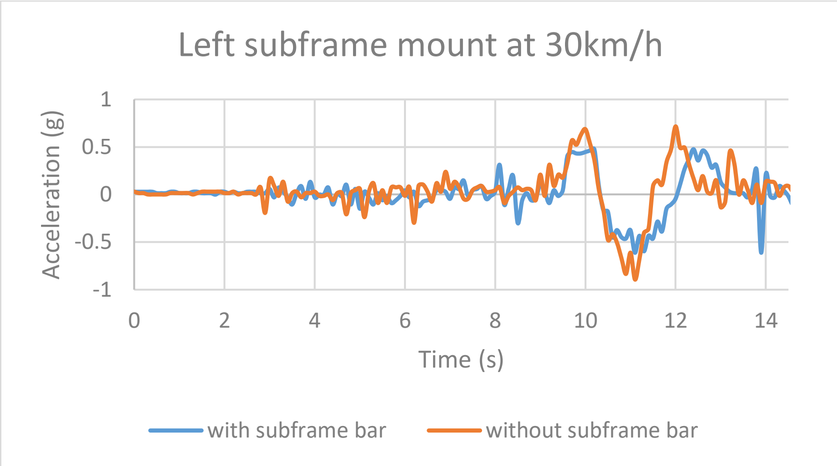

Figure 8: Left subframe mount acceleration at 30 km/h

In Figure 8, the acceleration peaks on the left side of the subframe with a mounted subframe bar are recorded at 0.47 g at 10 seconds and -0.61 g at 11 seconds. When undergoing lane changes from right to left and left to right, each lane change takes approximately 4 seconds. Towards the end of the lane change, the vehicle experiences a peak acceleration of 0.46 g at 12.6 seconds, settling at 13.6 seconds. As for the acceleration of the subframe without the subframe bar, the acceleration reaches its maximum values of 0.69 g and -0.9 g at 10 seconds and 11 seconds, respectively. The vehicle's acceleration continues to sway beyond the intended point before settling down, resulting in a difference of 0.25 g higher acceleration compared to the vehicle equipped with a subframe bar. The graph displays a slight distinction of approximately 0.22 g and -0.29 g between the subframe bar condition and the absence of a subframe bar condition.

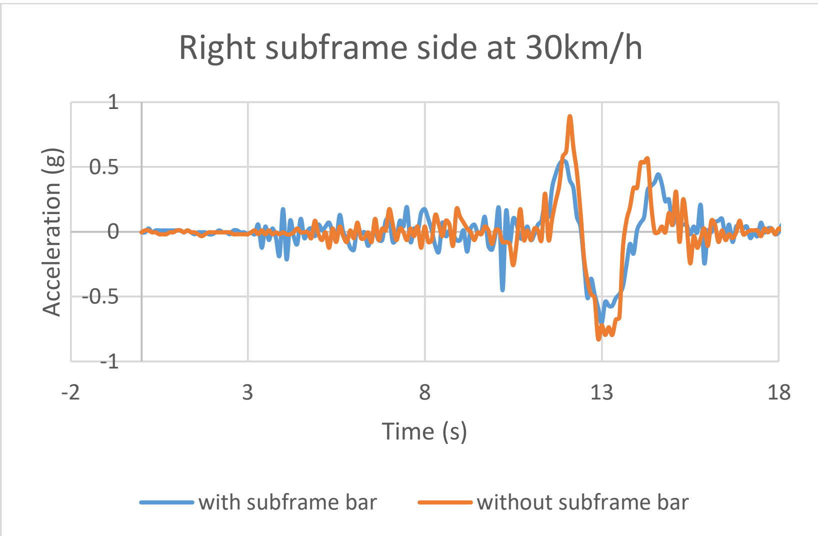

Figure 9: Right subframe mount acceleration at 30 km/h

The subframe equipped with the subframe bar demonstrates a peak acceleration of 0.37 g at 12 seconds and a minimum value of -0.87 g at 13 seconds. Regarding the acceleration without the subframe bar, it exhibits a peak acceleration of 0.76 g at 12 seconds when the vehicle changes to the right lane. As the vehicle transitions from right to left, it experiences a minimum acceleration of -0.96 g and achieves a maximum acceleration of 0.43 g at 14.3 seconds until it settles down. The graph displays a substantial difference in acceleration between the subframe with and without the subframe bar, amounting to 0.39 g and -0.09 g.

3.4 RMS of vehicle subframe

	with subframe			without subframe		
Speed (km/h)	10	20	30	10	20	30
Left subframe mount	0.1703	0.1466	0.2004	0.1927	0.2308	0.2363
Right subframe mount	0.1007	0.1399	0.1887	0.1662	0.2066	0.2197

Table 1: RMS of vehicle subframe at double-lane change course

The root mean square (RMS) values of the vehicle subframe during a double-lane change course are provided as shown in Table 1.

Speed (km/h)	10	20	30
Left subframe mount (%)	11.6	36.5	15.2
Right subframe mount (%)	39.4	32.3	14.1
Average improvement of subframe bar (%)	25.5	34.4	14.7

Table 2: Improvement of vehicle subframe bar

Overall, the average improvement of the vehicle equipped with a subframe bar is higher compared to the vehicle without a subframe bar. The table results also demonstrate a significant reduction in acceleration when maneuvering through the double-lane change course. A comparison between the vehicles with and without a subframe bar reveals that the lateral acceleration of the vehicle without a subframe bar is higher, which can potentially disrupt the vehicle's handling performance.

3.5 Discussion

It demonstrates how, even at lower speeds, the acceleration of a vehicle without a subframe bar is increased. When the vehicle is not equipped with a subframe bar, the lateral motion will be slightly affected at lower speeds. To change lanes quickly and safely, the driver must steer precisely and react quickly to keep the car on track. This requires good control, responsive suspension, and tires with good grip. The driver may also need stability control systems. By considering these factors, the driver can change lanes smoothly without any noticeable change in how the car handles.

4. Conclusion

The study aimed to examine subframe vibration during handling motions and its relationship to subframe bars. Through experiments and data analysis, researchers gained insights into the behavior of the subframe under different conditions. The study's findings contribute to understanding vehicle dynamics, identifying potential issues, and improving performance. The results provide a basis for further investigation into the impact of oversteer and understeer on vehicle acceleration. The study emphasizes the importance of subframe bars in enhancing rigidity and stability within the drivetrain system. Overall, the study enhances knowledge about subframe vibration, subframe bars, and their effects on vehicle performance. It provides valuable information for future research and development efforts aimed at improving vehicle safety and performance.

Acknowledgement

The author would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for providing the necessary facility during this study

References

[1] Crolla, Mashadi. B, "Influence of ride motions on the handling behaviour of a passenger vehicle," *Journal of Automobile Engineering,* p. 1047, 2005.

[2] Gillespie T.D, "Evaluation of Human Exposure to Whole Body Vibration," in *Fundamental of Vehicle Dynamics*, 1997.

[3] Löcken. F, Kruse. E, Reinauer. A, Hendrik Sell, "Holistic approach to axle NVH assessment and optimization," 2022.

[4] Singh. A, P. Singh. P, Safe. M, Joga Dharma Setiawan, "Modeling, simulation and validation of 14 DOF full vehicle model," 2015.

[5] Jo'rayev. Z. B, Ismailov. A. S, "Study of arduino microcontroller board," 2022.

[6] Banzi. M, Getting started with Arduino, Maker Media, Inc, 2015.

[7] Constantin. V, "Introductory Chapter: Matlab and Simulink Applications," 2022.

[8] Vyatkin. V, Yang. C, "Model transformation between MATLAB simulink and Function Blocks," August 2010.