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Technical Research of Accelerated Durability Test and Road Load Correlation Analysis

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ABSTRACT: This study investigated the durability test of the vehicle. The durability test is to reproduce or simulate the use of the vehicle in the market in a short period of time. In order to find out the possible problems of the vehicle and make improvements to ensure the durability and reliability, vehicles must be with good durability. To keep the support of the public consumer maintaining good sales in the market is important. The execution of the real vehicle durability test must meet three requirements, including road load correlation, control and repeatability, among which the road load correlation is the most important. Accurate input correlation analysis depends on whether the market input data can be collected in the pre-stage. Different sales markets have different market inputs, and their durability test procedures are naturally different.

KEY WARDS: *Durability test, Reliability, Road load correlation, Repeatability.*

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I. INTRODUCTION

The durable quality of the vehicle refers to the problems that occur during the use of the vehicle. The type, quantity and period of the problems will form the basis for the evaluation of the overall vehicle durability. Therefore, the durability of the vehicle is often an important indicator of the user's confidence and trust in the brand of the car manufacturer. Each car factory uses various durability tests to confirm whether the design, development, and manufacturing quality of the vehicle have reached the initial goals, and to check the quality of the vehicle for consumers. Various durability tests are performed in the vehicle development process, targeting the durability of specific parts and components, such as: driving durability test for vehicle power and transmission system, door opening, closing operation durability test, and the initial stage of development. The different development stage of the vehicle must meet the requirement of the design strength of the vehicle chassis, body structure, the structural accelerated durability test, or the vehicle accelerated durability test to check the quality of the vehicle before mass production and before market sale. Therefore, the aim of this study is to explore the vehicle accelerated durability test.

Andrew Halfpennyet al. [1] used the proving grounds with an extremely efficient means of qualifying the durability of vehicle components. They accelerate damage accumulation rates were detectable in a very short period of time. It is important that proving ground damage is correlated with target customer usage. It is also important to determine the most efficient use of the proving ground in order to meet project targets and minimize overall development costs. This research described the latest techniques for proving ground correlation and optimization. Kumar Palanisamyet al. [2] used the vehicle information collected by the client to perform the market road input test, and used the test track of the proving ground to conduct the input test, and converted the input data to the frequency domain. The PSD(Power Spectral density) frequency domain equivalent damage method was used to carry out the accelerated degradation test on the proving ground. Through this method, it was found that the correlation between the vehicle life and the failure mode type was substantially improved. This optimized proving ground durability testing procedure can be developed for each commercial vehicle model by using the correlation of road load inputs used by customers. Shorter test cycles gave automakers a competitive advantage over others, providing customers with more durable products and reducing development and warranty costs.

Chen Jianci [3] installed acceleration gauges, strain gauges, and displacement gauges on the vehicle chassis. The real vehicle completed the road input data of 30,000km in the Taiwan market and 16,000km in the 4 mainland market and the endurance test track input data of the proving ground. The work used rain flow and The level crossing counting method to simplify the input signal, establish the input database of the market road and the test track. Then the n-Soft software was used to analyze the input correlation. The analysis results were used to establish the accelerated durability test program of the small car proving ground. Zhang Rongming et al. [4] took the scooter as the input test vehicle, and applied the rain flow counting method to conduct the road input test on the roads of the Taiwan market and the test track of the vehicle center. The test roads included the provincial and county roads, urban roads, mountain roads and the durability test track of the vehicle center proving ground in the northern, central, southern and eastern regions of Taiwan. According to the measured input data of the market and the test track, the input analysis and comparison of roads in different regions were carried out. Finally, the input force correlation analysis was carried out in a linear combination method, and an accelerated durability test program for laboratory tests simulating actual service conditions was established, so as to serve as the basis for product durability confirmation tests during the development of locomotive products in Taiwan.

The acceleration ratio of the accelerated endurance test procedure established by the measured input results was about 4.6 times for the general endurance procedure, and about 15.2 times for the accelerated endurance procedure. In terms of accelerated procedures, the 1-kilometer endurance test program input force test was equivalent to the fatigue effect of 15.2 kilometers on the market road. That is, if the vehicle structure meets the established accelerated durability test program for 3,289 kilometers, it can represent that it meets the market requirements of 50,000 Kilometer durability. Wu Yih Ming [5] introduced the durability test technology based on the measurement of the vehicle road surface input load and correlation analysis. The main purpose was to collect the actual input loads (road loads, environmental loads, pay loads, etc.), and use the test tracks with different input load in the proving ground and then establish acceleration durability test procedure. Durability testing was performed to confirm vehicle production quality and reduce vehicle development and validation time.

II. PROCEDURES AND METHODS

The basis of durability test technology is to define the test procedure. The planning of the test procedure is based on the measurement of the vehicle road load input and the analysis of the road load input correlation. The principle is to combine the input loads (road loads, environmental loads, payload conditions, etc.). Repeated execution of the durability test procedure could achieve accelerated degradation and simulate the actual input level, which can greatly shorten the vehicle development process for the durability test verification time schedule [5]. In terms of classification, the vehicle durability test can be divided into 3 stages: (1) the body structure durability test in the first stage of development; (2) the general durability test in the development stage; and (3) the practical durability test in the mass production verification stage. There are three types of durability tests. The road load input correlations considered by each type are different. Among them, the body structural durability test in the first stage of development is often used by the hydraulic cylinder durability test in the laboratory, as shown in Figure 1 [5].

Figure 1: Vehicle structure durability test

The execution of the vehicle durability test must meet three elements, including road load input correlation, controlling and repeatability, among which the road load input correlation is important. Accurate road load input correlation analysis depends on whether the road load measurement work in the pre-stage can objectively collect market input data. Different sales markets have different market road load inputs, and their durability test procedures are different. Figure 2 shows the process of vehicle durability test [5].

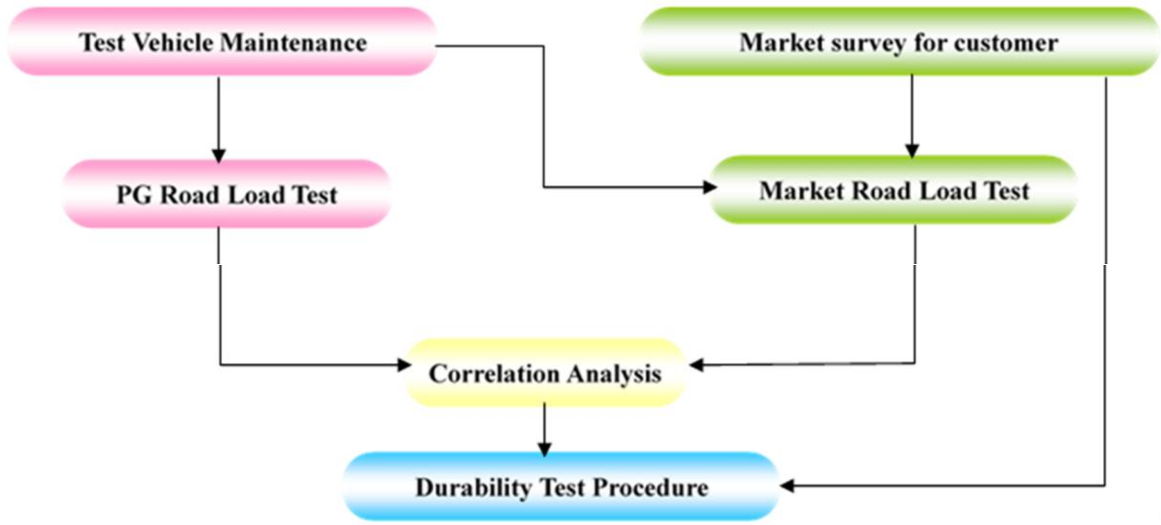

Figure 2: Process of vehicle durability test [5]

The market survey of vehicle usage conditions aims to collect objective information about the way vehicle owners use. This information serves as a reference for subsequent market input measurements and the planning of accelerated durability testing procedures. A common method for conducting market surveys is to distribute questionnaires to users of similar vehicle types and purposes. In this case, the survey targets non-commercial small car users. Google Forms can be used as an online tool for executing the survey. It allows for quick creation of the required questionnaire content and facilitates survey distribution and result analysis through its built-in email and social media integration capabilities. The content of the market survey questionnaire design can provide follow-up market road load measurement testing, proving ground accelerated durability test procedure planning and execution, and provide specific reference directions. There are several main considerations as follows：

1. Usage percentage of road type:

Vehicles driving on different road conditions impose varying degrees and types of loads on the vehicle. For example, winding mountain roads exert more lateral loads on the vehicle, while general provincial roads with frequent road surface potholes and repairs, coupled with higher speeds result in greater vertical input to the vehicle. In the case of urban roads with frequent stops and starts, there are more longitudinal loads on the vehicle due to frequent braking and acceleration by the driver. Therefore, when planning market road load input measurement, road types are usually divided into four categories: freeways (including expressways), mountainou roads, urban roads, and country roads (referring to provinces, counties, and township roads). Through the implementation of market survey, the usage percentage of vehicle users driving on various types of road surfaces can be obtained, which can then be used as a reference for market road input measurement and route planning.

2. Percentage of vehicle payload:

Due to the number of people and the amount of cargo carried by the vehicle, the weight load of the vehicle will change, which will produce different input force responses and fatigue effects on the vehicle. Therefore, the distribution of the vehicle's load weight was investigated in the questionnaire. For a 5-seater passenger car, it is generally divided into one-to-five-person load and luggage compartment load. Several levels of types were investigated, and the information obtained would be used as the test vehicle's weight distribution and the reference basis for the adjustment of the test mileage ratio.

3. Driving habits of drivers:

Vehicles driving on the same section of the road may also generate different levels of input loads on the vehicle due to the driver's driving habits (driving speed, brake use, overtaking, obstacle/pothole dodging habits, etc.). For example, according to the survey information, Americans usually drive directly through the potholes, causing more vertical loads on the chassis, while Europeans will dodge, which will cause more lateral loads on the vehicle. The surveys to obtain the actual driving habits of users are also very important in setting vehicle durability test mileage target.

4. Survey of vehicle life and mileage:

The survey results of the service life and mileage of the vehicle can be used to set the target mileage of the product's service life and durability test. For the part of the vehicle that belongs to the safety-critical components of a vehicle part (such as the chassis, the main structural parts), it is necessary to ensure the driving safety of the user and the vehicle. For interior decoration and audio-media system parts, different considerations should be given to the durability test standards for their service life and mileage. As for the obtained questionnaire survey results, it is necessary to screen the valid questionnaire data. For a few of extreme vehicle conditions, we can consider to eliminate them to avoid affecting vehicle design conditions and materials due to special conditions of use, and indirectly causing vehicle development costs or various performance.

III. RESULTS AND DISCUSSIONS

This research used the Google Form network tool to create a questionnaire titled "survey of the passage car market usage information" to collect vehicle usage data. The built-in e-mail and social software link methods of the Google Form were used. The total of 101 valid questionnaires was collected. The vehicle market usage data collection was divided into three parts. The statistical results of the driving percentage of road type were freeways (including expressways) 37%, county roads 26%, urban roads 28%, and mountain roads 9%. Based on the statistical results, the proportion of each road type of the market road input measurement route would be planned, and the target mileage of the vehicle would be set at 200,000 kilometers.

The road load input test vehicle was HONDA FIT for this plan, and the production year was 2009. Considering the vehicle driving on road surfaces, the primary input to the vehicle comes from the tires, which transmit vibrations to the vehicle structure through the chassis suspension system, resulting in fatigue effects. Therefore, near the front, rear, left, and right wheel axles of the vehicle, a vertical single-axis accelerometer was installed. Additionally, considering the braking and turning operations of the vehicle, which generate longitudinal and lateral accelerations, a longitudinal and a lateral single-axis accelerometer were installed at the vehicle's center of gravity. The sensor signals from these accelerometers were connected to data acquisition devices to record the road load input levels of the vehicle's dynamic driving. It can refer to Table 1 for the input measurement parameters and Figure 3 for the installation positions of the input measurement sensors. In addition, in the test process, it is necessary to record the speed and mileage of each driving. Therefore, a commercially available (OBD-II) [6] vehicle recorder was installed on the vehicle. Through its Bluetooth wireless transmission function, the vehicle speed, distance, and location information were recorded. The data were sent to the computer for statistical processing.

Table 1: Road load input measurement parameters

No	Measure Parameter	Parameter code	Accelerometer Specification
1	Vertical acceleration of left front axle (g)	AW_FL	±50g
2	Vertical acceleration of the right front axle (g)	AW_FR	±50g
3	Vertical acceleration of left rear axle (g)	AW_RL	±50g
4	Vertical acceleration of right rear axle (g)	AW_RR	±50g
5	Longitudinal acceleration of body (g)	CG_X	±5g
6	Lateral acceleration of body (g)	CG_Y	±5g

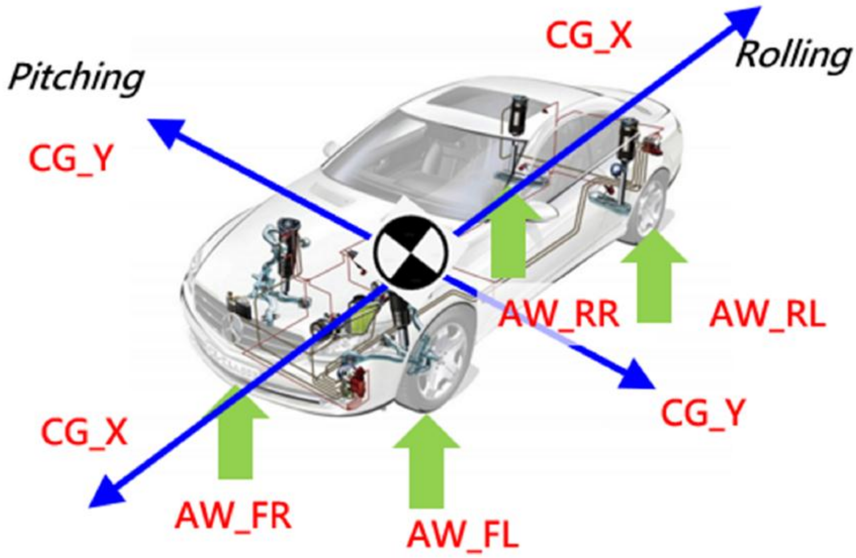

Figure 3: Installation location of road load sensors

In this implementation of the market road input measurement, the measurement mileage goal was set at 1,000 kilometers. The main consideration was the accuracy of the road load input data. If the measurement mileage is set too low, it will not be possible to obtain representative road load of the market road. If the mileage is increased, although it can be closer to the actual use of the vehicle, it may cause delayed schedule of the plan and increase the cost. In the market road load input measurement, although the planned target mileage was 1,000km, the actual mileage implemented was 1,062km, and the achievement rate is 106%, as shown in Table 2.

Table 2: Comparison of market road input measurement plan and results

Road Type	Survey Percentage (%)	Planning Mileage (km)	Actual Mileage (km)	Error Mileage (km)	Error Percentage (%)	Driving section
Freeway	37%	370	395.5	+25.5	+6.9%	No.1,No.3,No.4,No.6 Freeway and No.74,No.76 Expressway
Country road	26%	260	558.7	+18.7	+3.5%	Lukang to downtown Changhua and Taichung, etc.
City road	28%	280				
Hill road	9%	90	107.6	+17.6	+19.6%	County Road No.139 to Ershui forth and back

The completed market road mileage was 1,062 km. The road load input data and 6-channel input time domain data are shown in Figure 4, which included about 30.7 hours of data. Market road load input test, the vehicle payload and tire pressure conditions must be confirmed to ensure the accurate state of the vehicle.

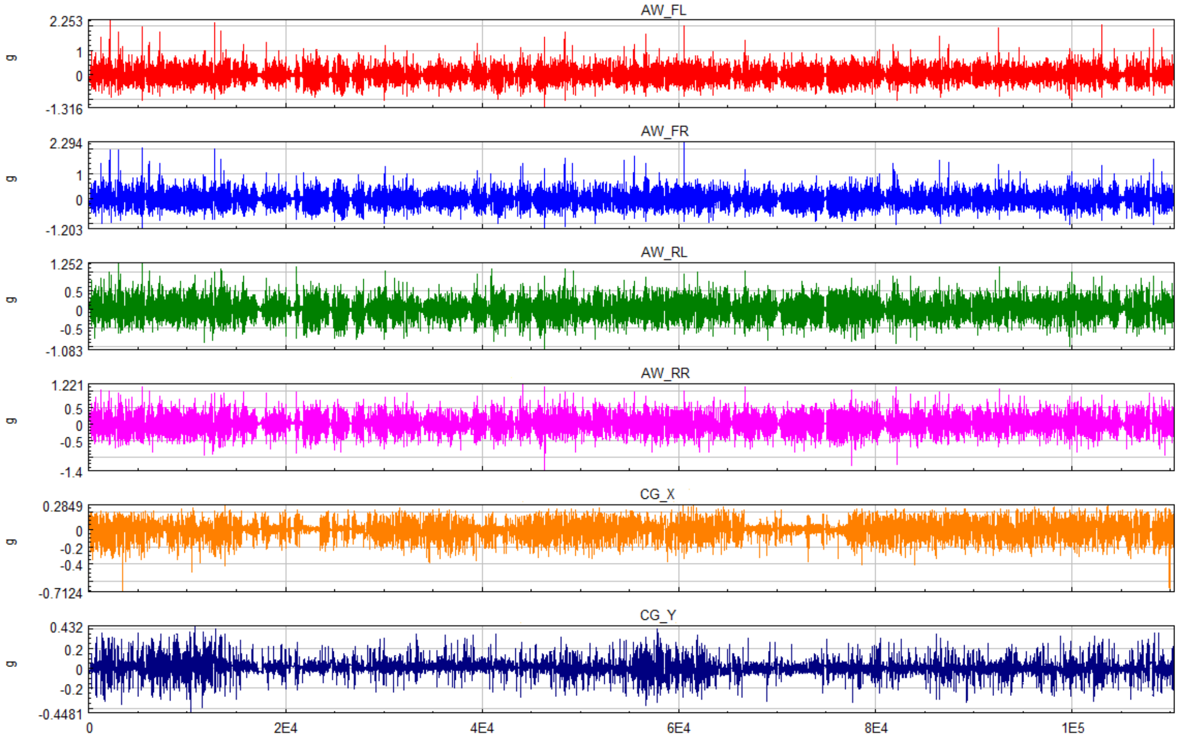

Figure 4: The time domain data of the market road with 1,062 km road load test

The road load input data of this plan were used for the correlation analysis process, as explained below:
1. Confirm the road load input time domain data, whether there are abnormal conditions such as (Spikes), (Zero drift), and correct the abnormal input data.
2. Perform low pass filter operation [7] to retain the road load input data mainly from the frequency range of road impact, braking, and turning operations. Among them, the vertical road load input measurement parameters were used for the frequency analysis of the general road surface filtered by a low-pass filter of 30Hz. Longitudinal and lateral road load inputs mainly came from the driving operation, braking and turning operations filtered by a low-pass filter of 5Hz.
3. Convert the vertical road load input data of the four axles into rain flow counting [8], and convert the three-dimensional matrix type (Cycle-Range-Mean) to the two-dimensional (rain flow counting)[8] data format (Cycle-Range). The measurement parameters (CG_X, CG_Y) at the center of gravity of the vehicle, the road load input data conversion using level crossing counting was performed, as shown from Figure 5 to Figure 8.

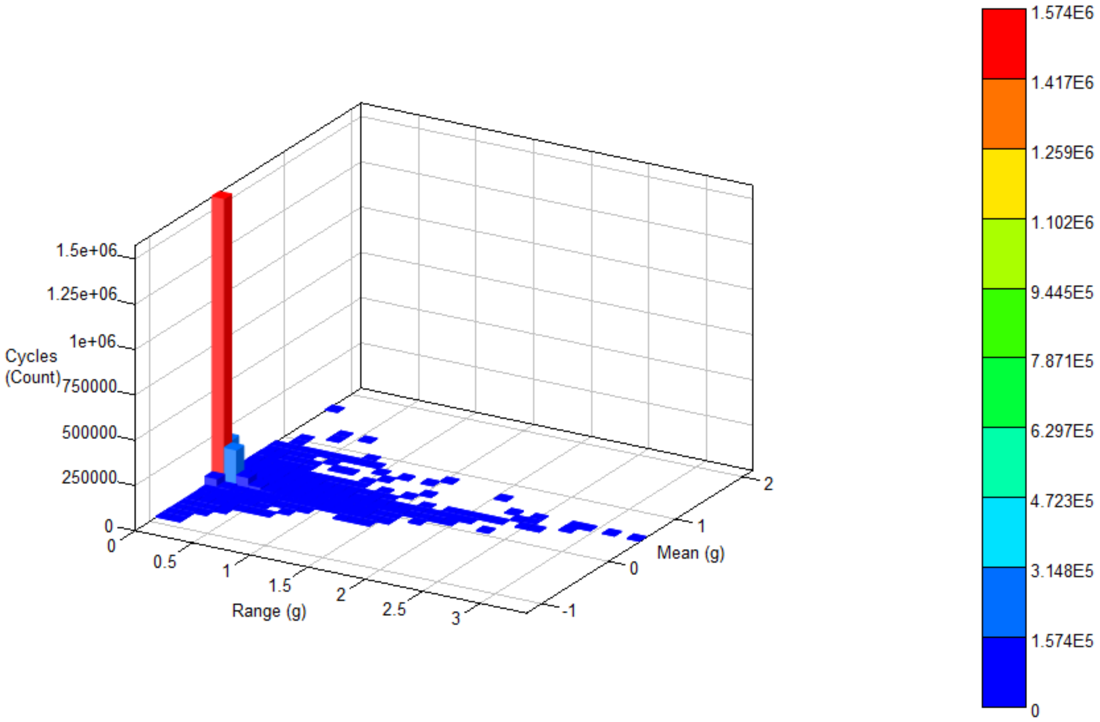

Figure 5: AW_FL counting data of market road 1,062 km road load test

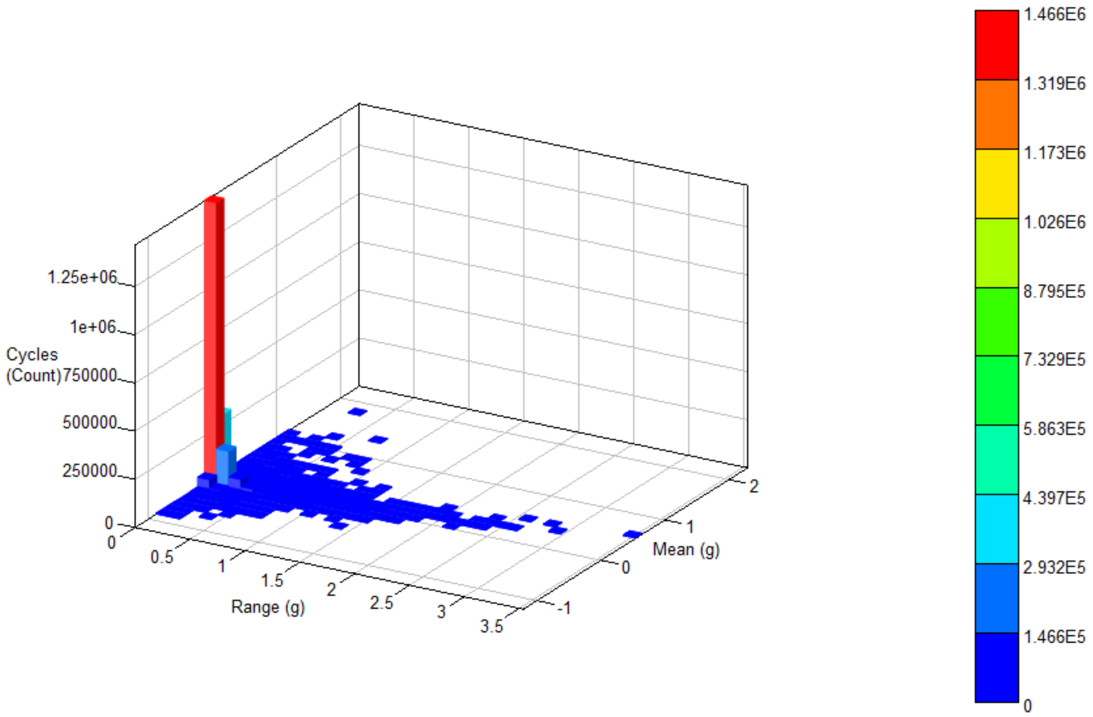

Figure 6: AW_FR counting data of market road 1,062 km road load test

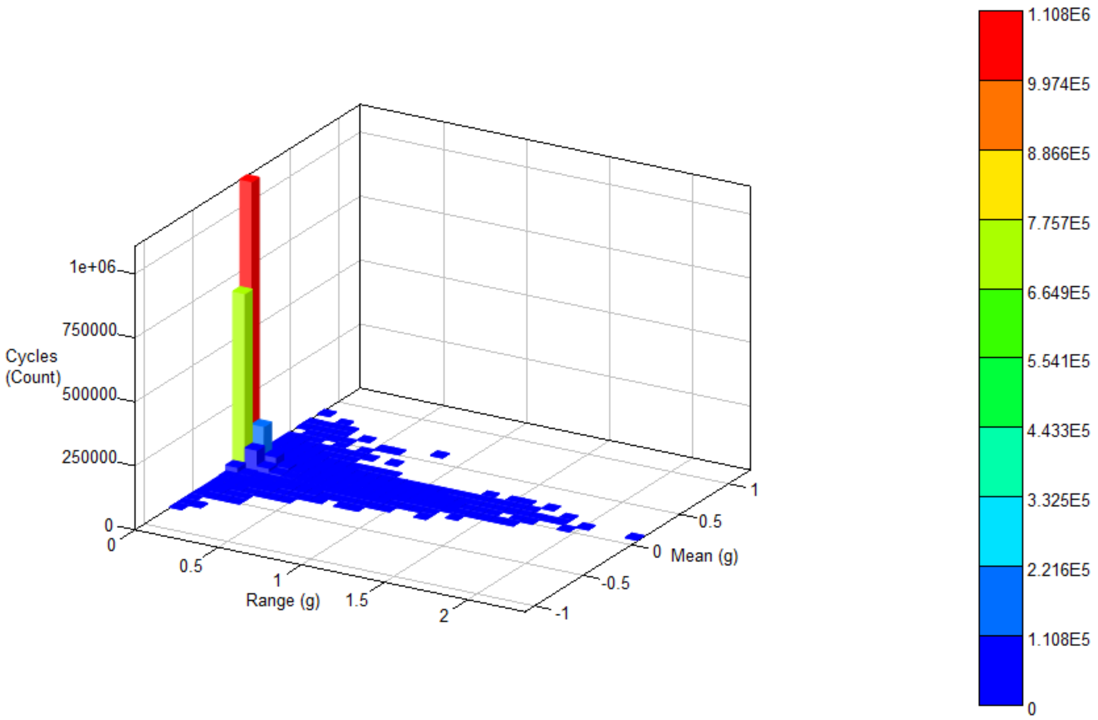

Figure 7: AW_RL counting data of market road 1,062 km road load test

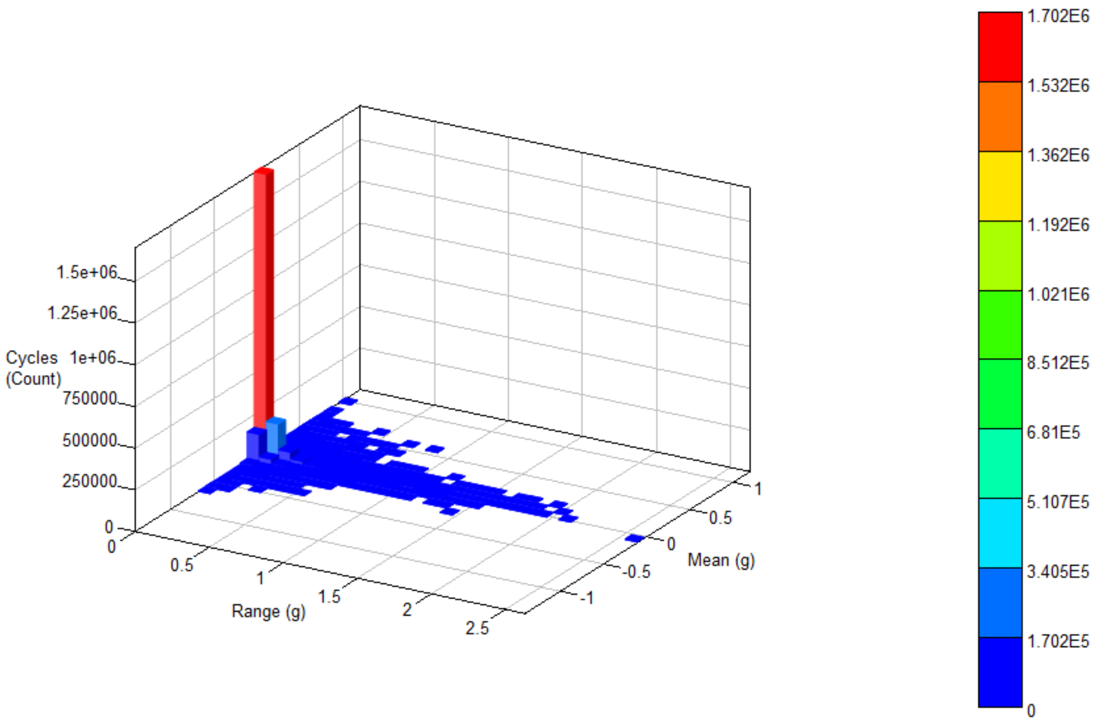

Figure8: AW_RR counting data of market road 1,062 km road load test

IV. CONCLUSIONS

This research used the non-paved and repaired road to carry out the durability test track of the proving ground, and conducted road load input correlation analysis with the market road. The analysis results showed that the accuracy of the correlation between the vertical road load inputs of the four axles was between 70% and 83%. The longitudinal and lateral road load input correlation accuracy was about 80%. How to accurately obtain the road load input on the vehicle body in the X, Y, and Z directions of the vehicle driving on the road surface was a very important issue for performing durability verification and structural fatigue analysis. International manufacturers often used expensive equipment (Wheel Force Transducer). However, this research used only four Z-axes and the X-axis and Y-axis at the center of gravity with total of six accelerometers to perform road load input measurement. The cost in this study was very low compared to the conventional road load test. The level crossing counting method was also used for road load input analysis for the first time. High accuracy of road load input correlation compliance was also achieved in the study.

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