CHAPTER III

RESEARCH METHODOLOGY

3.1. Description of Research Procedure

The assessment of ride comfort measurement and evaluation can be obtained by objective and subjective methods. The schematic diagram describing the overview of the whole working process and procedure is shown in Fig.3-1.

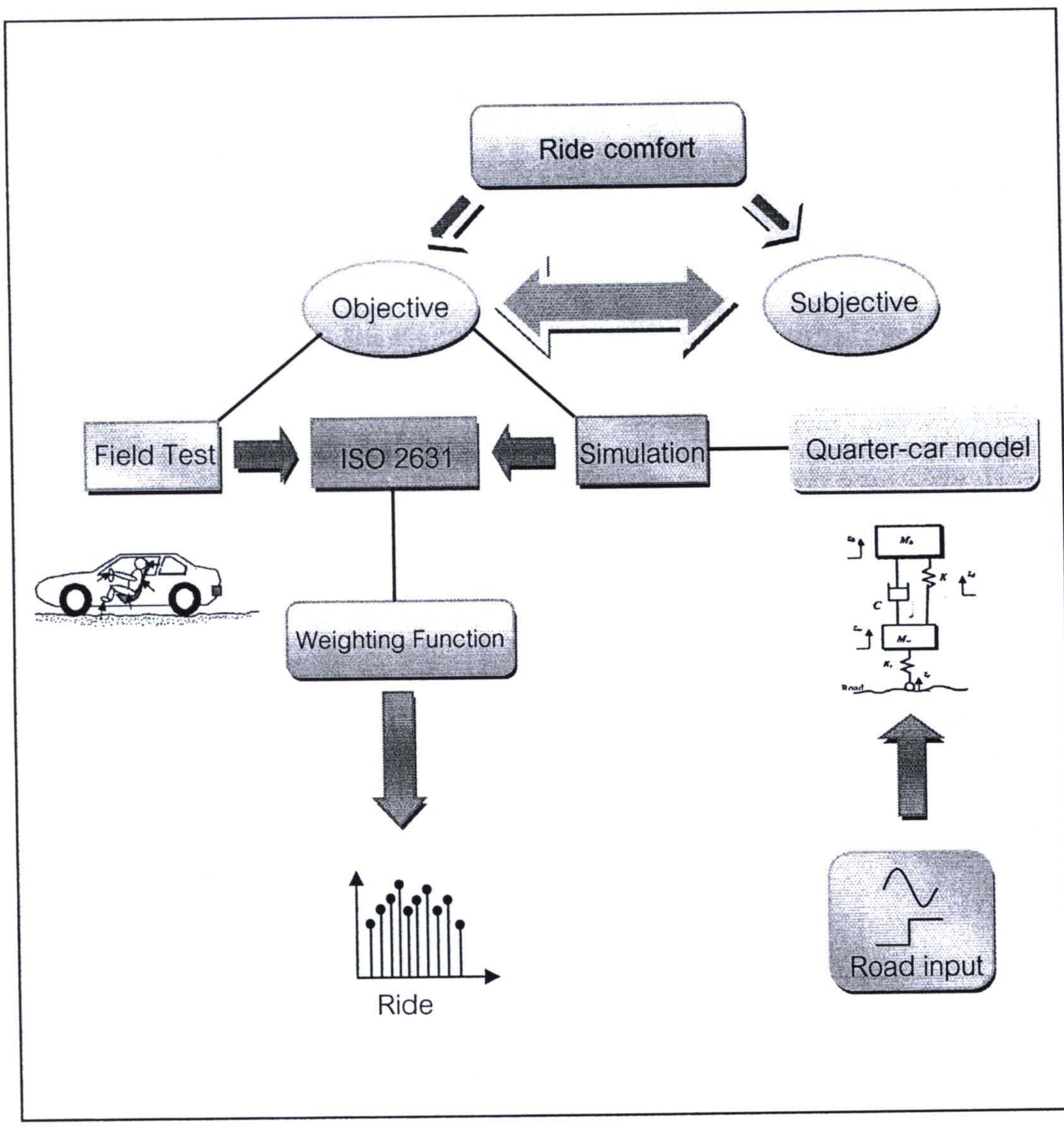

Fig.3-1 Schematic diagram of working procedure

From Fig.3-1, the objective experiments can be made by two measuring schemes, either simulation or field experiment. However, the relationship between ride comfort and suspension parameters was investigated by the first method for this research. The preliminary study was made once by field testing in order to study and practice ride comfort measurement. In the analyzing process, the application of ISO 2631-1 was also implemented as a tool for ride comfort evaluation. The results and detail, including discussion are given and reported in Chapter 4.

Another objective measuring scheme which is not a primary concern of this research is the real field experiment. In the test, the trained experts and the test subjects will rate ride comfort level for each test run. Different roads with various surface roughness and series of leaf springs with corresponding dampers will be used. However, this method was not conducted for this study. The early phase of the research was concerned with the investigation through computational simulation. With the help of MATLAB/SimMechanics program, a quarter car model was built with the main focus on its suspension properties and the investigation into the effect of suspension parameters on ride comfort level were observed similarly to what happened to the field experiment.

The description of a test scheme is given in Fig.3-1. In real situation, accelerations during the ride and other relevant data will be collected by the accelerometers mounted at human interfacing points, i.e., floor and seat. The raw data will be analyzed by using the evaluation method suggested by ISO 2631-1 such as RMS accelerations and weighting function. The ride index can be established from mean ride comfort level, rated by test subjects and parameters of leaf spring. In similar way, the process of simulation starts from road input which was generated by a simple road model. The acceleration response of vehicle can be obtained from the quarter-car model, corresponding to the applied road input and then ride comfort value for each ride was achieved by mean of frequency weighting of ISO 2631-1 standard.

3.2. Research Tools

The study required research tools for both simulation and field experiment so that they can be categorized into two categories as follows, 3.2.1. Field Experiment Tools

For real field test of the preliminary study, the accelerometers were used to collect raw data which are accelerations in different directions, both translational and rotational. One-axis accelerometers are used to measure acceleration in vertical direction. A three-axis typed accelerometer is used to measure accelerations in three orthogonal axes and a six-axis accelerometer is used to measure accelerations in three orthogonal axes with three rotational velocities (pitch, roll and yaw). These quantities were used to analyze the characteristic of the test vehicle and to evaluate ride comfort by mean of ISO standard. Apart from this, ride vision may also be captured by a video camera.

3.2.2. Simulation Tools

The main investigation of this research is based on simulation. The vehicle and suspension model were constructed and implemented on a computer program. MATLAB Simulink is very useful tool for vehicle modeling. For the simulation of leaf spring model, the results were also shown in animation mode so that the leaf spring configuration and behavior could be observed under consideration.

3.3. Methodology

The research methodology includes research approaches, data collecting, and definition of measured quantities are summarized in the following topics,

3.3.1. Data Collecting

In field testing, the accelerometers were attached to the proper positions of a test vehicle. Preparation was taken into account of the following consideration, 3.3.1.1. Measured quantities

When the vehicle is traveling along the road surfaces, vibrations are generated in all directions. The following quantities, related to the amount of vibrations are measured in the investigation. The illustration of measured quantities and directions of measure is shown in Fig.3-2.

1. longitudinal accelerations, A_X
2. lateral accelerations, A_y
3. vertical accelerations, A_Z
4. roll velocity, R_X
5. yaw velocity, R_Y
6. pitch velocity, R_Z

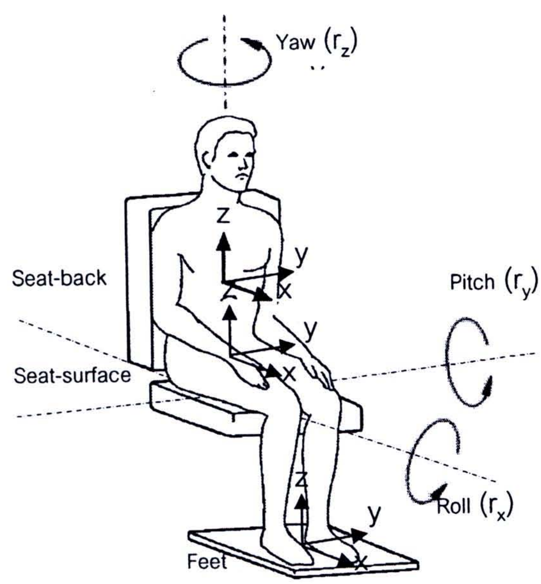

Fig.3-2 Basicentric axes of a seated person, adapted from ISO 2631-1 [11]

3.3.1.2. Sensor Positioning

According to the suggestion of ISO 2631 about transducer mounting, transducers should be attached at the contact area where vibration transmits to human body. It also suggested that vibrations are measured orthogonally at that point as illustrated in Fig.3-2. In the measurements performed within this research, the selected locations are the points on seat–back area and floorboard and the attachment positions and method in mounting were also subjected to the architectural structure inside the test vehicle.

3.3.2. Data Analysis

The analysis performed within this research were based on two categories, the time domain analysis and the frequency analysis. The following description of the two methods are briefly explained,

3.3.2.1. Time Domain Analysis

The time domain analysis includes data processing of raw acceleration data recorded by data logger and numerical solving of simulating models by computer program. For computer simulation, the response of a dynamic system is predictable, using differential and algebraic equations that describe dynamic equilibrium state of the system. The equations of motion were solved to predict how the system variables change with time as response to inputs. Simulated results were interpreted in the same manner as experimentally measured responses.

3.3.2.2. Frequency Domain Analysis

Direct interpretation of vibrations from the acceleration time histories in time domain is sometimes rather difficult and lacks of essential information. Normally, vibrations are random in nature, so that the signal was generated from number of frequencies. Transformation of time domain data into frequency domain can give more information into the analysis as the frequency content can also be reviewed. The method of Fourier transform is widely used for this transformation process. For ride comfort evaluation, Power spectral density (PSD) method is used to describe the value in term of RMS acceleration over a frequency range, according to the definition given in Eq. 2-8 and 2-10.

3.4. Summary of Research Approach

The study and investigation into the effect of suspension parameters on ride comfort of light commercial vehicles in this research is mainly based on computer simulation. However, the preliminary field test was performed by few test runs on road sections with different scenarios. During the rides, the acceleration signals were collected by a set of accelerometers and data logger. The data was analytically determined and processed within both time domain and frequency domain. The application of ride evaluating method suggested by ISO 2631-1 was then applied to the test data by the following steps,

1. RMS acceleration in each direction defined in section 3.3.1.1 and Fig.3-2 were calculated by PSD method according to Eq.2-8 and 2-10.

2. The total values of weighted acceleration obtained from calculation were compared with the values suggested by ISO 2631-1, approximate comfort/discomfort scale based on magnitude of overall vibration in Table 2-1.

3. The vibrations obtained from simulating model were determined only in vertical direction so that the values of a_{wx} and a_{wy} in Eq.2-10 were set to zero.

After the preliminary test was completed, the next phase of the research was focused on the investigation through the simulating models. The leaf spring model was constructed, regarding the effect of nonlinearities and friction. For this purpose, the three link equivalent model proposed by the Society of Automotive Engineering was developed and the effect of friction was also included with the additional part of the modified Dahl's model. The details on how the leaf spring was designed and constructed is given in Chapter 5. The leaf spring model includes the geometrical parameters and Dahl's model parameters which were adjusted by comparing the results obtained from real system measurement and the simulated results. A leaf spring test rig that can measure vertical static deflection of leaf spring under static loading condition was designed and used for this purpose. Finally, the proposed model was verified with the adjusted parameters to satisfy the concordance of both results.

The next phase of the research was the parametric study of the suspension model and its effects on ride comfort. In the study, the quarter-car model was combined with the previous verified leaf spring model to represent whole suspension system of a vehicle that contains nonlinearities. Simple road model was also established to generate synthetic road input to the vehicle model, based on road classification of ISO 8608 [14]. The interest parameter taken into the study was the shackle angle at installation. From the study, ride comfort indices were established to represent the relationship between different values of shackle angle and ride number both for non–linear and linear suspension models (For linear model, the component of Dahl's model was excluded).

The content of each part of the study will be reviewed in the next three chapters. Chapter 4 provides details and results obtained from the preliminary study. Chapter 5 presents the leaf spring modeling description and its verification process. Chapter 6 contains details on parametric study of suspension model's parameters and their effects on ride comfort.