VIBRATION ANALYSIS OF BABY CARRIAGE USING THE MULTI-BODY DYNAMICS

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Abstract— For the purpose of reducing the vibration of a baby carriage, this study deals with analyzing the vibration of a baby carriage. A baby carriage receives the vibration depending on the shape of a road surface. This vibration gives a baby and a user an unpleasant feeling. Reducing the vibration of a baby carriage is essential for a baby and a user. In order to analysis the vibration of a baby carriage, the simulation model is created by using the multi-body dynamics. In addition, the experiments are performed using a baby carriage and an accelerometer. Experimental results differences of road surface and sampling points of a baby carriage are shown. The simulation results and experimental ones are compared to show the effectiveness of the analytical model, and influences of driving speed and weight of a baby are matched in experiments and simulations. The vibration of a baby carriage is analyzed by this analytical model. Influences of stiffness of suspensions, radius of wheels and gap of tiles for the vibration are shown by the analytical model numerically.

Keywords— Baby Carriage, Vibration Analysis, Multi-Body Dynamics, Simulation, Experiment.

I. INTRODUCTION

A baby carriage is a handy tool helping a walking with a baby [1]. The using a baby carriage is easier than the carrying a baby in arms. A baby carriage eases the physical restraint. A folding baby carriage and a baby carriage having baggage holder make it easy to walk with a baby. However, there are many babies disliking a baby carriage. One of the cause is the vibration from a road surface. This vibration is transmitted to a baby and a user. In fact, previous research [2], [3] has reported that a baby riding on a baby carriage feel stressed by the vibration from a road surface. In addition, Kubo [4] shows that the vibration of about 4.0 [Hz] makes the ride quality worse. Tsujiuchi et al. [5] shows that there is some possibility of causing the acute subdural hematoma by the shaking a head of baby of about 3.0 [Hz] and amplitude of ±40 [mm]. As mentioned above, the vibration is bad influence for a baby. Therefore, reducing the vibration of a baby carriage is essential for a baby and a user. There are some previous researches about the vibration analysis of a baby carriage. Kawashima [6] developed a baby carriage shaking system to analyze the vibration of a baby carriage. Miyauchi et al. [7] performed modal analysis of baby carriage. However, these researches can not analysis the vibration when a baby carriage drives on real road surfaces.

In this study, the vibration is the target when a baby carriage drives on real road surfaces. The analytical model is created to improve the performance of a baby carriage efficiently. A baby carriage is modeled by the 3D multi-body dynamics. Experiments using a baby carriage are performed to improve a precision of the analytical model. The effectiveness of the analytical model is proved by comparing the simulation results with the experimental ones. This study shows influences of stiffness of suspensions, radius of wheels, and gap of tiles for the vibration by the analytical model numerically.

II. EXPERIMENTS

A. Experimental Devices

In this work, the baby carriage made by company A was used. This baby carriage is highseat and
lightweight. The height of the seat is 450 [mm] and the weight of the baby carriage is 5.4 [kg]. Fig. 1 shows the experimental baby carriage and sampling points. The accelerometer was attached to handle (A), armrest (B), front leg (C), rear leg (D) and frame (E). Fig. 2 shows the experimental accelerometer having three axis. This accelerometer was used to measure the vibration from a road surface. The mass was put on seat to model weight of a baby.

B. Road Surface

Fig. 3 shows road surfaces used in experiments. Asphalt (a), tiles (b) and vinyl floor material (c) were the target of experiments.

This study focused on the tile road surface particularly. Fig. 4 shows the dimension of the tile. One side of the tile is 295 [mm] and gap of between tiles is 10 [mm].

C. Experimental Condition

Experiments were performed varying sampling points, driving speed and weight of the mass. The sampling points are shown in Fig. 1. The driving speed is about 600, 700, 800 and 900 [mm/s]. This driving speed was controlled by using a metronome and step size of the experimenter. The mass modeling weight of a baby is 0, 5, 10 and 15 [kg]. This study defines acceleration of perpendicularly downward direction as the vibration of the baby carriage.

III. Simulations

A. Analytical Model

Analytical model considering contact between wheels and the road surface and elastic deformation of suspensions was developed. The creation of the multi-body model and numerical calculations were performed by using generic multi-body dynamics software of RecurDyn [8]. The baby
carriage and the tile road surface were modeled by using experimental devices as a reference. Fig. 5 shows overview of the analytical model in this work.

Fig. 6 shows the suspension model. Suspensions were modeled by linear springs between wheels and legs. Fig. 7 shows the mass model. The mass modeling weight of a baby put a spherical object on the seat. This object was connected to the frame of the seat by using springs in three directions.

Fig. 7 Mass to model weight of a baby by putting a spherical object on the seat in simulations

This object receives the vibration from the frame. Table 1 shows the stiffness of contact between wheels and the road surface.

B. Analytical Condition

Analyses were performed varying driving speed, weight of the mass, stiffness of suspensions, radius of wheels and gap of tiles. The driving speed is 600, 700, 800 and 900 [mm/s]. The mass modeling weight of a baby is 0, 5, 10 and 15 [kg]. The stiffness of suspensions is 5, 10, 15 and 20 [N/mm]. The radius of wheels is 60, 70, 80 and 90 [mm]. The gap of tiles is 5, 10, 15 and 20 [mm]. The rough surface of tiles were not considered in this work.

Table. 1 Stiffness of contact between wheels and the road surface in simulations

<table>
<thead>
<tr>
<th>Spring constant</th>
<th>800 [N/mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damping coefficient</td>
<td>1 [-]</td>
</tr>
<tr>
<td>Friction coefficient</td>
<td>0.8 [-]</td>
</tr>
</tbody>
</table>

Fig. 8 Experimental results differences of road surfaces in acceleration of the sampling point C

(a) Experiment result
IV. RESULTS OF EXPERIMENTS AND SIMULATIONS

A. Data Processing

Fig. 8 shows waveforms of the vibration driving on asphalt, tiles and vinyl floor material in experiments. The horizontal axis is the time, while the vertical axis is the amplitude of acceleration. We see that, the acceleration of vinyl floor material is the smallest of the three. The tile road surface is often seen in daily life. From this point on, this study reports the results of experiments and simulations limiting the tile road surface.

Fig. 9 shows examples of waveforms of the vibration in experiment (a) and simulation (b). In result of experiment, the high frequency vibrations were seen by the rough surface of tiles. The large peaks were seen when the baby carriage get over the gap of tiles. After this, the average of five peaks (A₁~A₅) are shown when the baby carriage get over ten gaps of tiles.

Fig. 9 Examples of results in acceleration from the tile road surface

(b) Simulation result

Fig.9 shows examples of results in acceleration from the tile road surface

Fig.10 Experimental result differences of sampling point in average of acceleration peaks

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The comparison of experimental result with simulation result in average of acceleration peaks

The comparison of experimental result with simulation result in average of acceleration peaks

The comparison of experimental result with simulation result in influence of driving speed for vibration

The comparison of experimental result with simulation result in influence of driving speed for vibration

The comparison of experimental result with simulation result in influence of weight of a baby for vibration

The comparison of experimental result with simulation result in influence of weight of a baby for vibration

Fig. 10 shows the comparison of sampling points in experiment. The horizontal axis is the sampling points, while the vertical axis is the average of acceleration peaks. We see that, the sampling points are the nearer to road surface, the vibration is the larger. In this study, experiments and simulations were performed focusing on the tile road surface and the sampling point C.
B. Comparison of Experiments and Simulations

Fig. 11 shows the comparison of experimental result with simulation result in average of acceleration peaks. These were performed setting driving speed of 600 [mm/s] and weight of the mass of 10 [kg]. The simulation result is accord with experimental result in a fairly good agreement.

Fig. 12 shows the comparison of experimental results with simulation results in influence of driving speed for vibration. The horizontal axis is the driving speed, while the vertical axis is the average of acceleration peaks. We see that, the driving speed is the faster, the vibration is the larger in experiments and simulations.

Fig. 13 shows the comparison of experimental results with simulation results in influence of weight of a baby for vibration. The horizontal axis is the weight of a baby, while the vertical axis is the average of acceleration peaks. We see that, the influence of weight of a baby is matched in experiments and calculations. By these results, the effectiveness of the analytical model is shown.

C. Example of simulations

The comparisons of experiment and simulation results presented in the previous section demonstrate are validity of the analytical model used in this study. In this section, simulations are performed to assess the impact of the various parameters in the system.

Fig. 14 shows influence of stiffness of suspensions for vibration. The horizontal axis is the stiffness of suspensions, while the vertical axis is the average of acceleration peaks. In this range, the stiffness of suspensions is the larger, the vibration is the smaller.

Fig. 15 shows influence of radius of wheels for vibration by MBD simulation.

Fig. 16 shows influence of gap of tiles for vibration by MBD simulation.

V. CONCLUSIONS

The purpose of this study is to reduce the vibration of a baby carriage. The 3D multi-body dynamics model was developed by using experimental devices as a reference. The key points of this study may be summarized as follows.

1. Analytical model of a baby carriage was created by the 3D multi-body dynamics.
2. Experiments were performed to measure the acceleration when the baby carriage drive on the tile road surface.
3. The simulation results and the experimental ones were compared to show the effectiveness of the analytical model.

4. Influence of stiffness of suspensions, radius of wheels, and gap of tiles for vibration were shown by simulation numerically.

REFERENCES


