1. **Influence of kb and cb to Comfort of the Patient**

From the previous study we can see that difference values of kb and cb have a great influence on vertical displacement and acceleration of the patient on the stretcher. We can make a plot of a indicator of comfort performance of patient varying kb and cb, showing the influence of kb and cb on  more clearly and find the optimum value of kb and cb more accurately.

* 1. **RMS value of the signal**

One good indicator of the comfort performance of the patients is the plot of . But it is more convenient to use just one value to represent the comfort of the patients in a defined condition. The mean value of  is equal to zero. The mean square value of  can be a good indicator, but in this case the unit of the indicator will be different from . To not change the unit, the RMS (Root Mean Square) value of  can be used as the indicator of comfort performance of the patient.

The RMS value of a signal f(t) can be expressed as the equation below:



Where f(t) is the function of the signal in time domain. T is the total time of the signal. For example if we have a plot of  like in figure 1.1, the RMS value of the signal can be seen as the root of the area between the signal and the horizontal axis. So, lower the RMS of , better the comfort performance of the patient.

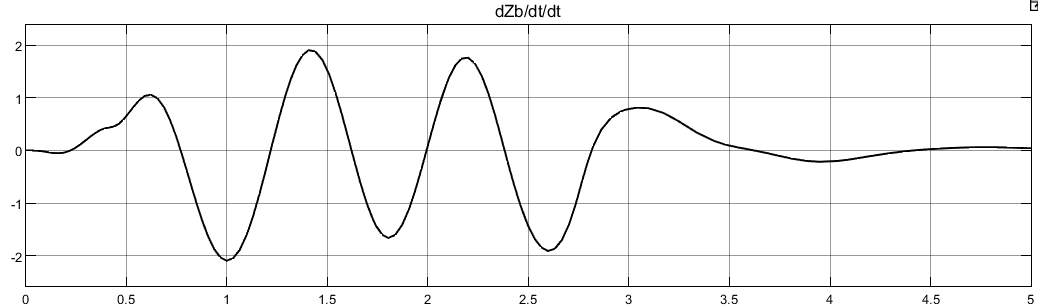


Figure 1.1 Plot of f(t)

Based on the grade C random road as input, fixing the kb and cb value, using the ambulance model we obtained before, we can plot  in time domain in Matlab/Simulink. Then using the block “To workplace” in Simulink, all of the data in this plot can be output to Matlab workplace. In this way, using some Matlab code the RMS value of these data can be calculated. For example, if kb=2000, cb=350, the RMS value of  is 4.3963.

* 1. **RMS value of  varying kb**

To analyse the influence of kb on the RMS value of , we fix the damping value cb=200, the velocity of the ambulance V=30 km/h and varying the kb from 2000 to 10000 at the distance of 250. With each value of kb corresponding to one value of RMS, all of the value of RMS of  can be plotted. As a comparison, the RMS of  can also be plotted. The results shows in Figure 1.2.



Figure 1.2 RMS of  and varying kb

In this figure, “.” represent the RMS values of ; “\*” represent the RMS values of . From the Figure, the relation between RMS and kb is clear: lower the kb, lower the RMS of , better the comfort of the patients. In addition, the RMS of  is much higher than the RMS value of , meaning that the comfort performance of the patients is much better than the comfort of sprung mass (ex. the driver). RMS values of  can also represent the comfort performance in the case that the connection between the stretcher and the sprung mass is rigid. In this case, we can find that the use of stretcher suspension greatly improve the comfort of the patients. Furthermore, it is clear that the RMS of  are almost not influenced by the changing of kb.

* 1. **RMS value of  varying cb**

In the same way, we fix the kb at its optimum value 2000. Then, varying the value of cb from 50 to 1000, at the distance of 25. With each cb value corresponding to one RMS value of  and one of the  . The results shown in Figure 1.3.



Figure 1.3 RMS of  and varying cb

In this figure, “.” represent the RMS values of ; “\*” represent the RMS values of . From the Figure, the relation between RMS and cb is not like in varying kb. In this case, there is a cb that corresponding to the minimum value of RMS of , which is cb equal to 250. In addition, the RMS value of  approximately not influenced by different values of cb.

* 1. **Responses of the system based on optimum value of kb and cb**

In this way, we obtain the accurate optimum values of kb and cb corresponding to the best comfort performance of the patients when ambulance is riding on the random road. The optimum values are: kb=2000 N/m, cb=250 Ns/m.

Based on this optimum value of kb andcb, the responses of roll motion, pitch motion and vertical motion of the sprung mass and vertical motion of stretcher are shown in Figure 1.4 to 1.7.

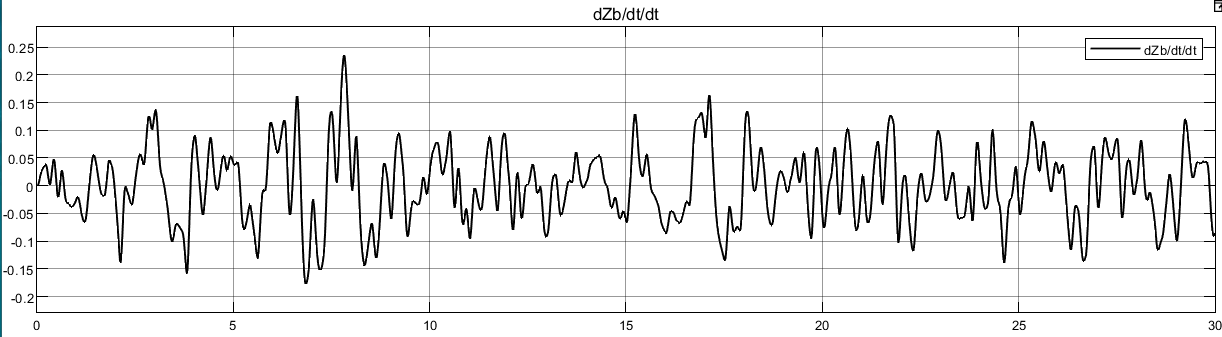


Figure 1.4 Vertical acceleration of the stretcher

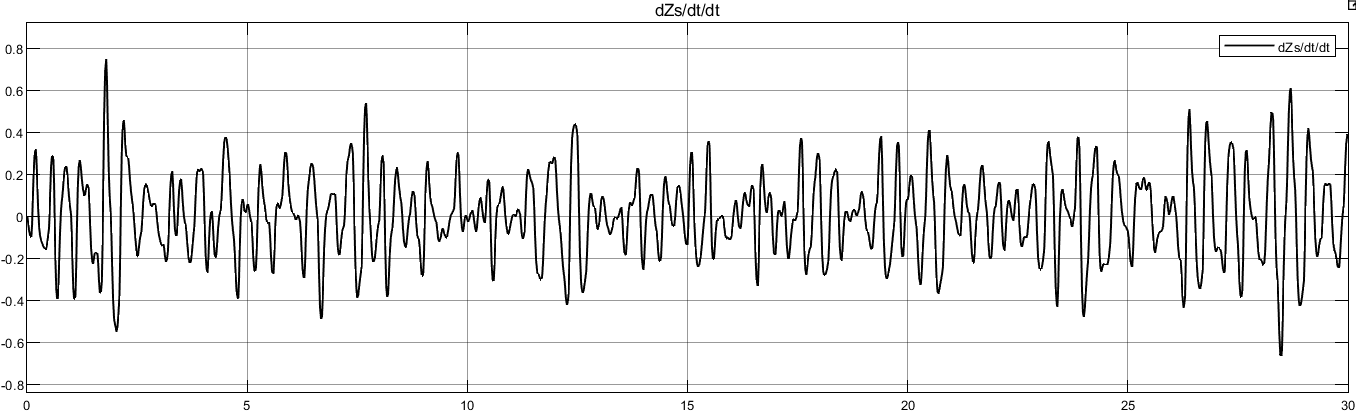


Figure 1.5 Vertical acceleration of the sprung mass

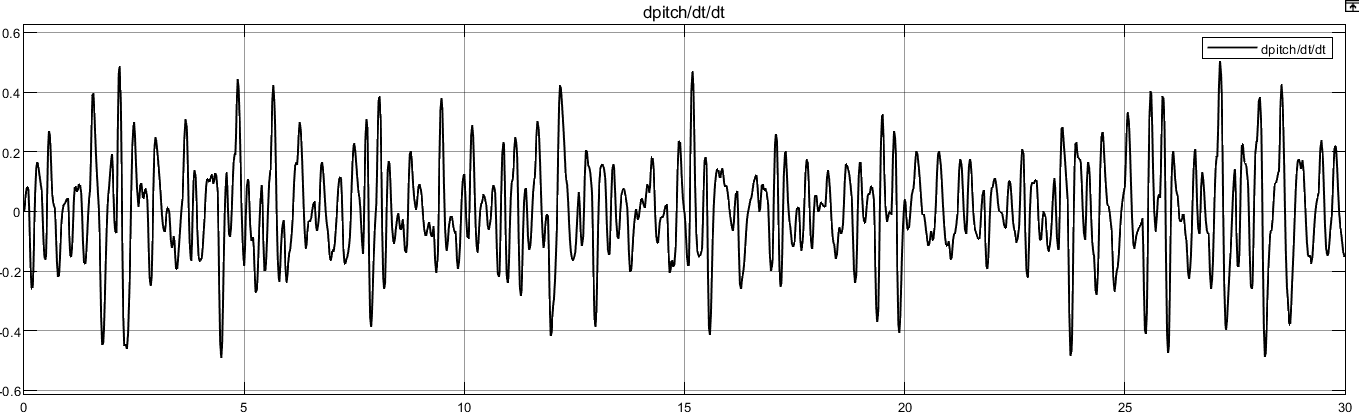


Figure 1.6 Acceleration of pitch motion of the sprung mass

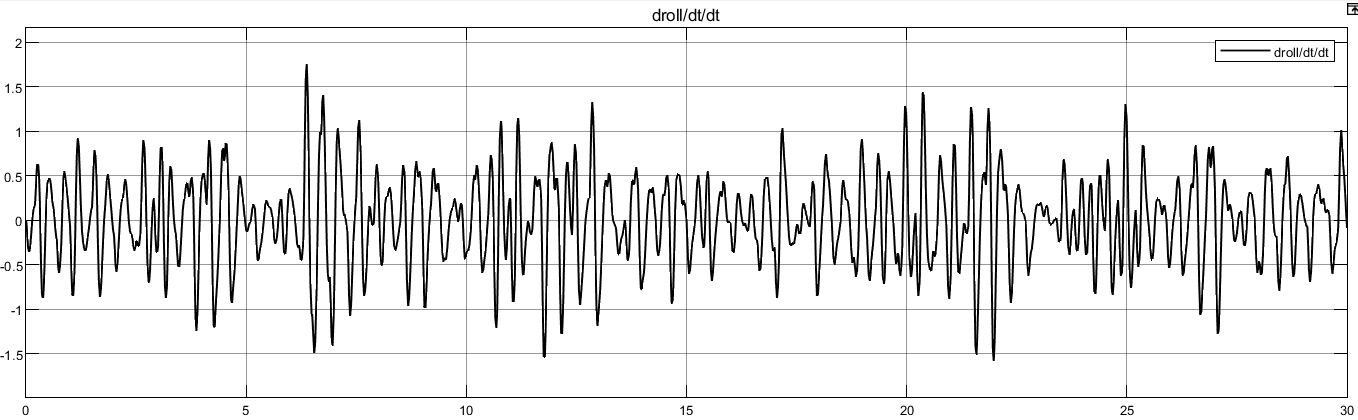


Figure 1.7 Acceleration of roll motion of the sprung mass

1. **Influence of Speed of Ambulance to the Results**

In real case, when ambulance is riding on the road, the speed of the ambulance is certainly not constant, and often much higher than 30 km/h, and the comfort performance of the patients is certainly not the same as the results obtained in 30 km/h. In this case, the influence of different speed on choosing optimum value of cb and on comfort performance of the patients and will be analyzed.

* 1. **Influence of different speed on comfort of the patients**

In this chapter, kb and cb will be fixed (kb=2000, cb=250) and the RMS of is still be used as the indicator of the comfort of the patients. To analyse the influence of different speeds on RMS value of , instead of varying kb and cb, we vary the speed of the ambulance from 10 km/h to 120 km/h, and output all the values of RMS corresponding to each values of the speed. The results is shown in Figure 2.1.



Figure 2.1 RMS of  and  from 10km/h to 120 km/h

In this figure, “.” represent the RMS values of ; “\*” represent the RMS values of . The figure tells us that higher the speed, higher the values of the RMS, worse the comfort performance of the patients. In addition, comparing to the comfort of the patients, the comfort of the sprung mass is much more sensitive to the change of the speed.

To further verify the results, we build the model in Matlab Simulink with a defined profile of the speed as input, and the time domain responses of vertical acceleration of patients and sprung mass, acceleration of pitch motion and roll motion of sprung mass as output. The Simulink diagram is shown in Figure 2.2.

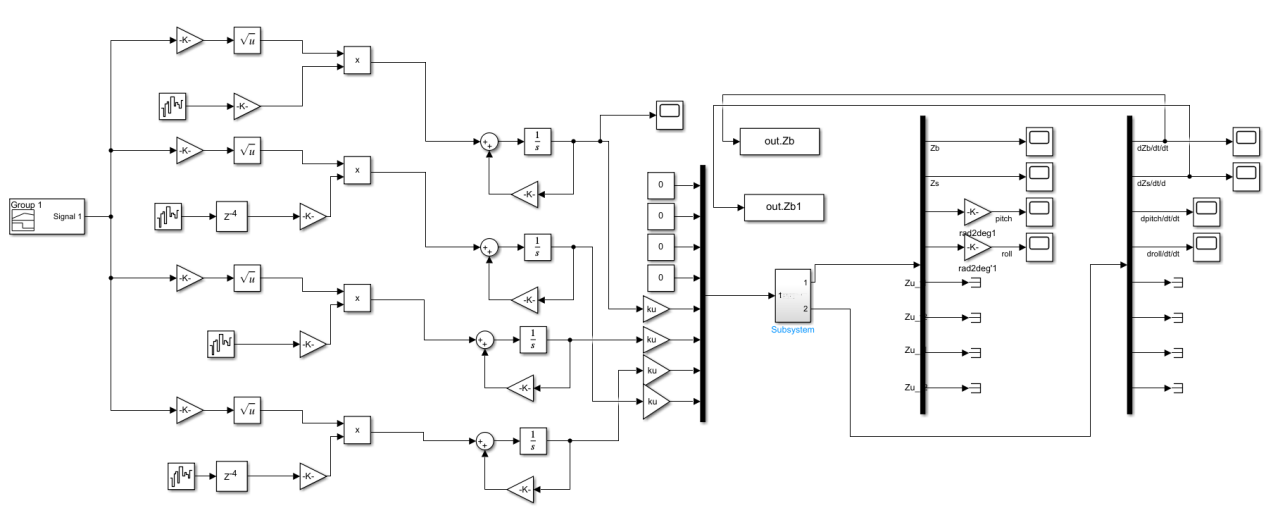


Figure 2.2 Random road profile Simulink diagram as input of a defined speed profile

Taking front right wheel as an example, the plot of defined speed profile is shown in Figure 2.3.



Figure 2.3 Defined profile of the speed

The ambulance is riding at constant speed of 30 km/h for 12.5 seconds and accelerate to 90 km/h by 5 seconds and keep the speed at 90 km/h for 12.5 second (30 seconds in total). The outputs is shown from Figure 2.3 to 2.6.

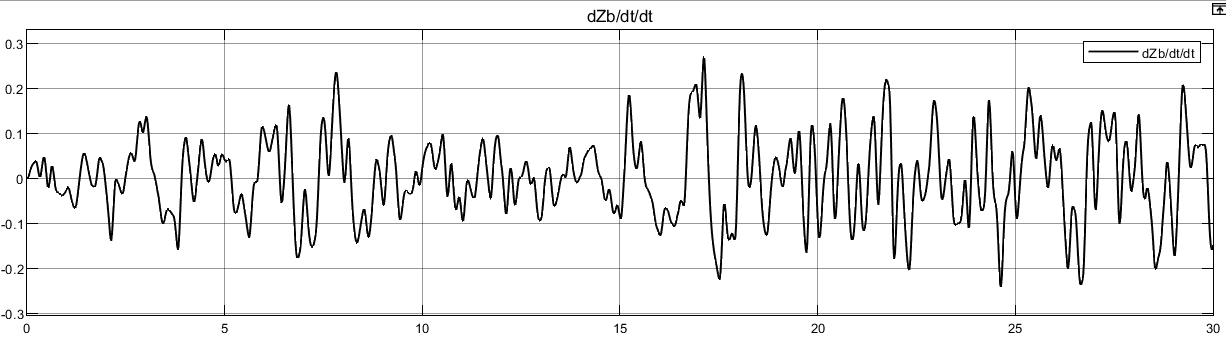


Figure 2.3 Output of 

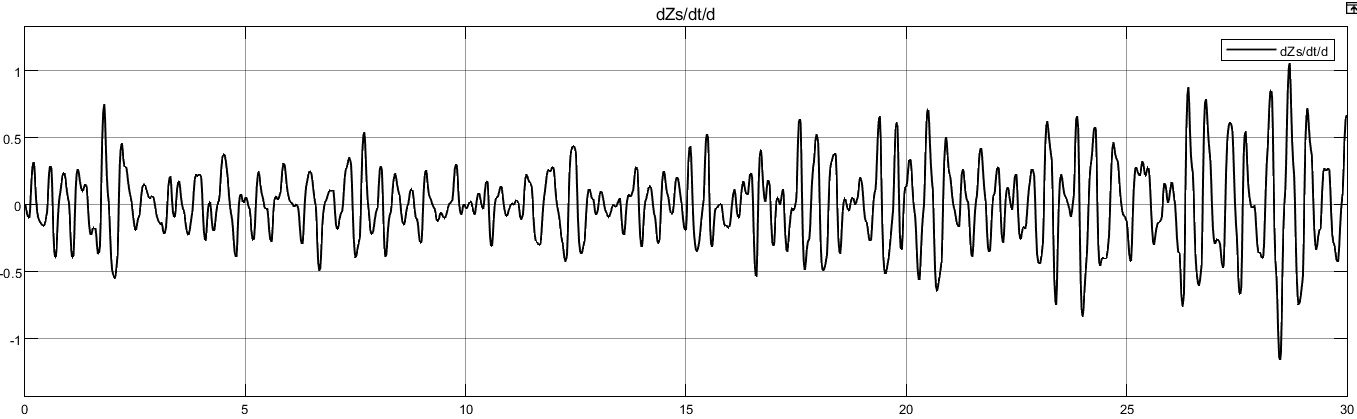


Figure 2.4 Output of 

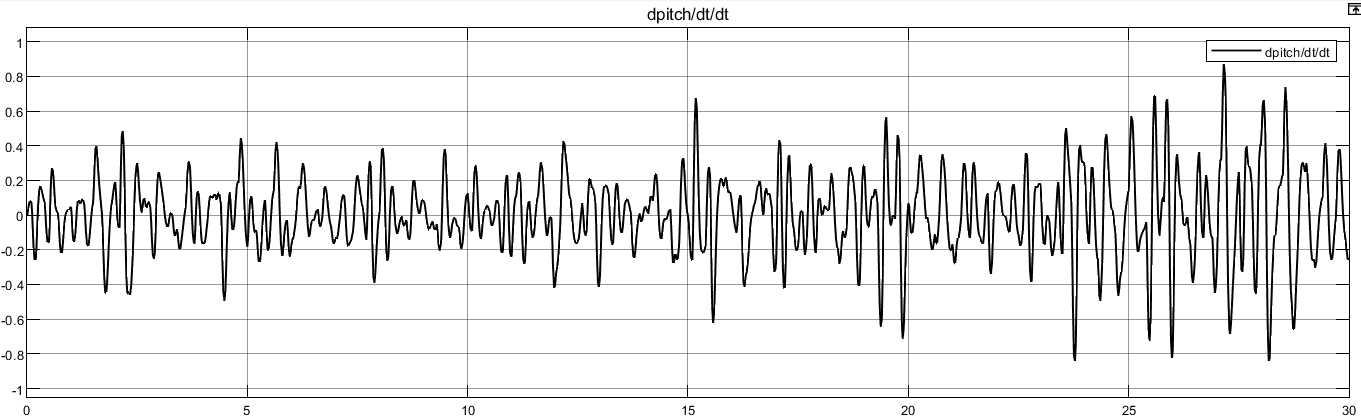


Figure 2.5 Output of acceleration of pitch motion of sprung mass

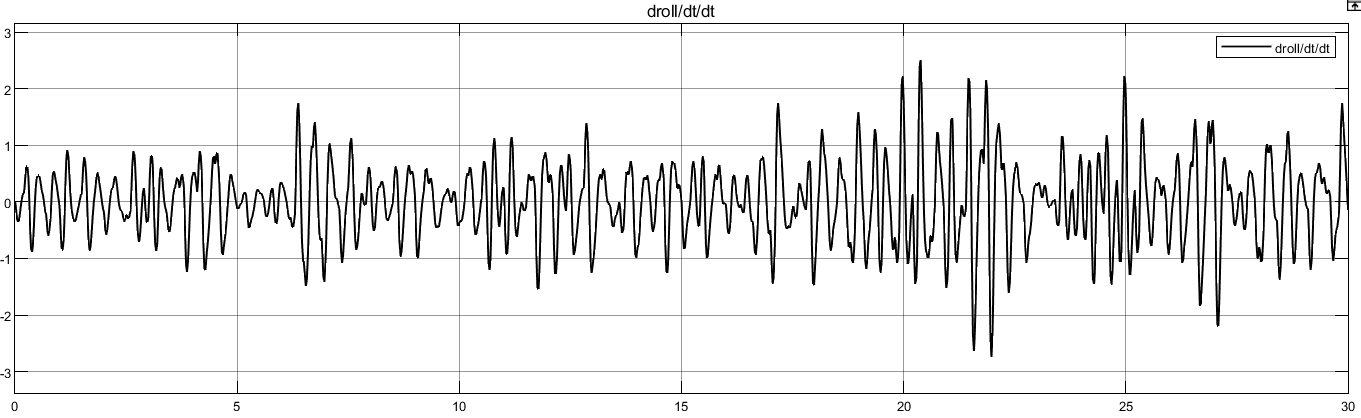


Figure 2.6 Output of acceleration of roll motion of sprung mass

In those four plots, the amplitude of first 12.5 seconds of the responses is lower than last 12.5 seconds of the responses.

* 1. **Influence of different speed on choosing optimum and cb**

In this chapter, four different values of the speed is tested and at the same time varying cb. The values of RMS of  in each different values of speed and cb is shown in Figure 2.1.



Figure 2.7 RMS of  varying speed and cb

In this figure there are approximately four curves, corresponding to four different speeds: V=30 km/h, V=45 km/h, V=60 km/h, V=90 km/h. We can find that no matter what the speed is, the lowest value of RMS all at the same value of cb=250. Changing the speed does not influence the optimum value of cb.

1. **Comparison Between Sinusoidal and Random Road Profile**

In this chapter, the road excitation is changed to see if the optimum value of cb is affected or not. The results of RMS values of  varying cb from 50 to 1000, at the distance of 20, is shown in Figure 3.1. The results are obtained from sinusoidal and random road profile respectively.



Figure 3.1 RMS of  varying cb in sinusoidal and random road profile

From the figure, it is clear that different road profile does not influence the optimum value of cb. So the same optimum value of cb can be applied to the cases of different road profiles.