THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Vibrational analysis and mathematical modelling of vehicle suspension**
Author's name:	**Abdulmuhaiaman Alwair**
Type of thesis :	master
Faculty/Institute:	Faculty of Mechanical Engineering (FME)
Department:	Department of Instrumentation and Control Engineering
Thesis reviewer:	Ing. Stanislav Vrána, DiS., Ph.D.
Reviewer's department:	Czech Technical University in Prague, Faculty of Mechanical Engineering, Department of Instrumentation and Control Engineering

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **easy**

How demanding was the assigned project?

As the guidelines of the master thesis assignment has points
1. Meet potential modeling of vibration in the car suspension
2. Create mathematical model of quarter and half car suspension at Matlab Simulink
3. Analyze both models for vehicle suspensions vibration

and the quarter car model consists of two masses, two springs and one dumper and half car model in principle consists of two quarter car models and those models are well-known and possible to be found in many publications, the thesis assignment is easy.

Fulfilment of assignment **fulfilled**

How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.

Author of the master thesis fulfilled the assigned task. Above the task specification, student conducted analysis of bicycle car model and full car model and he analyzed possibilities in road modelling.

Methodology **correct**

Comment on the correctness of the approach and/or the solution methods.

Considering the master thesis assignment, author of the thesis made use of correct approach to the assigned task.

Technical level **E - sufficient.**

Is the thesis technically sound? How well did the student employ expertise in the field of his/her field of study? Does the student explain clearly what he/she has done?

Author of the thesis does not mention how the values of Rise time, Settling time, Peak, and Overshoot in tables 5.1, 5.2, and 5.3 and 5.4 and 5.5 and 5.6, 5.7, and 5.8 were obtained. He only mentions in the thesis that those values in tables 5.1 and 5.2 were calculated, but no equation and no method of calculation is mentioned.

To get the results when he clearly used simulation to get them, the author of the thesis conducted only limited number of simulations to make trustworthy conclusions. He does also does not provide conditions (sprung and unsprung mass, spring constants, damping constants), under which the simulations were conducted.

In the thesis, for models whose excitation by an obstacle depends also on velocities, the values of velocities are missing in most cases where influence of velocity is evaluated.

The author does not seem to have a sense for meaningful number of decimals in presented numbers. In the tables 5.1 and 5.2 the values of Rising Time, Settling Time and Overshoot have 4 decimals, in the tables 5.3 and 5.4 and 5.5 and 5.6, 5.7, and 5.8 they have even 7 to 9 decimals. The tables 5.7 and 5.8 are not ordered according the value of k_t which makes it hard to read. In the tables 5.9 and 5.11, the values of Rising Time, Settling Time, Peak and Peak time have 4 decimals.

Formally in equation 4.3, the two functions cannot differ just by using different arguments, they should be marked differently, for example. using a star or index.

About a half of figures 5.1 - 5.10 contain a part of the course of variables that is already almost steady or steady and so unimportant to show. Shortening the time shown in the graphs would shown the important parts in more details. for Figures 5.18 - 5.20 even about 75 % of the variable course shows almost steady or steady parts of their course.
Figures 5.6 and 5.8 are confusing as the lines for respective simulation results are too close to each other, so not real conclusion can be performed base on graphs in those figures.
In the page 54, there is a statement that responses of both front and rear wheel are identical, but the courses despite they are similar, they are not identical - just comparing the first overshoot, in the left part of the figure it does not reaches value of 0.16, while the overshoot in the right part of the figure reaches 0.16.
The chapters 5.3 and 5.4 contain mostly pictures of variable courses and they are very shortly and poorly evaluated.

Formal and language level, scope of thesis **D - satisfactory.**

Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?

Author of the thesis uses differently named corresponding variables for the quarter car model and for other models (x_s, x_u, k_s, k_u, and c_s for quarter car model, x, x_n, k, k_t, and c for other models) This is noticeable especially in Figure 1.3 (page 13), where he uses also different coloring of corresponding model parts for quarter car model and for the other models.
In some cases, author of the thesis writes indices of the variables with the letters of the same size as the size of common text and he uses different form of Greek letter PHI (φ and ϕ) to mark the same variable (for example in the paragraphs on page 28).
Author sometimes uses expressions as "in our case" (page 11), "we assume" (page 12), "why we monitor vibrations" and other in (page 13), "we represent" (page 16), "From table 5.10 we observe that" (page 57) that might evoke that despite his declaration that the thesis is own author's work somebody else helped him. But this is one of the common mistakes of authors of diploma theses.
The first sentence of section 4.3.2 refers to a section 1.8, but the last section of Chapter 1 is section 1.7. The section 4.3.2 mentions appendix section, but no appendix section is found in the text.
Number 4.3 is used twice as a section number.
The author used screenshot of the equations 4.3, despite the equations are not complicated, which makes them slightly blurry. Some graphs, for example in figures 5.7 and 5.8 are blurry, probably they were exported from Matlab in unsuitable format, probably JPG, which is known for this feature and thus not suitable for graphs.
The Chapter 6 (Conclusion) only contains the subchapter 6.1 of the same name (Conclusion) so there is no need for subchapter.
Abstract is only partially modified text in introduction and as so, it is very long.

Selection of sources, citation correctness **C - good.**

Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?

The selection of the sources is adequate, the authors used 13 publications to obtain the information that he needed. However, he does not use the publication [2] from the literature recommended in the thesis assignment. All the publications in the References are referenced in the text of the thesis.
In the chapter 4.2.2, it would be nice to add some reference to Indian Road Congress guidelines for construction of bumps, to be able to verify the data in the source of information.

Additional commentary and evaluation (optional)

Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading. Pose questions that should be answered during the presentation and defense of the student's work.

To fulfil the assignment the author used the differential equations that can be found in literature derived state space model and created Simulink models. The analysis of models is conducted mainly based on simulations. Author of the thesis claims that some results were calculated, but he does mention no equation and no calculation method he calculated those results. There are two types of results, results based on step response evaluation where the author evaluates the rising time, settling time, overshoot, and sometimes also peak time and the results based on comparing reactions to different types of excitation. The second type of results are just shortly commented and there is only a small number of conducted simulation to make trustworthy conclusions. For the case of bicycle car model, half car model and full car model, not all variables are even evaluated in the second type of results (for bicycle car model, the body pitch θ is not evaluated and not even shown in Figures 5.22 to 5.27, for half car model, the body roll φ is not evaluated and not even shown in Figures 5.32 to 5.37, for full car model, both the body pitch θ and the body roll φ are not evaluated and not even shown in Figures 5.38 to 5.48). Course of those variables are only analyzed in third type of result where the author evaluates the influence of velocity to the course of response to the excitation. Those results are only shortly commented, no deep analysis is performed. Author uses only limited set of excitation courses. In the cases, where the model has more wheel, he performs the simulations when excitations come in different times to individual wheels, but he does not study the influence of the time difference to the results. The effect of resonance, which may appear in oscillatory systems, is not studied at all. The chapters 5.3 and 5.4 contain mostly pictures of variable courses and they are very shortly and poorly evaluated, but it is need be pointed out, that the analysis of behavior of full car model and bicycle car model have been performed above the assignment specification. Also above the assignment specification, the author analyzed the possibilities of modelling the road. On the other hand, the author's work is presented with many issues, for example to numbers with too many decimals, various letters to mark the same (or corresponding to each other) variables, referring to non-existent parts of the thesis, not providing the conditions under which the simulations were conducted, and even concluding that two courses are the same when they evidently are not the same.

The grade that I award for the thesis is **D - satisfactory.**

Questions for the presentation and defense of the thesis

- In the Chapter 3.1 Quarter Car Model, there are mentioned the differential equations of motion of quarter car model, but later in the same chapter, the Lagrange method is used which gives the same equations, just differently organized. Why the Lagrange method is used, when the differential equations are already known?
- Is the assumption of $k_{t1} = 2$ on page 20 correct? Why the k_{t1} should be equal to value of two? Can you name cars that have rear tires stiffer than the front tires? Can you name cars that have rear tires and front tires of equal stiffness?
- According the figure titles of Figures 3.5 to 3.9 (pages 24 - 26), they should show half car model in Simulink, but they contain variable *theta* and expressions as *front wheel* and *rear wheel*. In the scheme of half car model, the angle is labeled as φ, and there is no front and rear wheel in the half car model, but there are left and right wheel. Do those figures really show the Simulink model of half car model?
- Is the equation 3.40 (page 28) correct? One k_{Rf} of both seems as it should be k_{Rr} according the text preceding the equation.

- Does the figure 3.11 on page 31 really represents whole Full car model if there are connection to somewhere outside the model? Where do those connection lead to? How are the figures 3.12 - to 3.15 connected to figure 3.11 as in Figure 3.11 contain only two blocks of Subsystem?
- Almost all references to item of Refence list are written as superscript. But the one in the last paragraph on page 36 is written in regular text size. Does it mean something?
- Why the figures A.1 to A.3 on page 39 do use the irregular numbering system using letters? When referred, it is hard to find those figures.
- The figures 5.1 and 5.2 (page 40) show the course of unsprung mass displacement, but the one in figure 5.2 is shifted by one second when compared with figure 5.1. Why?
- In the text it is mentioned that the figure 5.3 shows redirection results while the figure title is Tire deflection of QCM. Can you explain how the redirection results are related to tire deflection?
- How the Rise Time and Settling Time in tables 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, and 5.8 were evaluated? It is only mentioned that the parameters in tables 5.1 and 5.2 were calculated, but no equation or method of calculation is mentioned. There is a refence [2] in the paragraph on page 43 stating that those values were calculated? Does it mean, that those values were calculated in literature [2] and author of the thesis just used them?
- What is the unit of Overshoot in tables 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, and 5.8?
- What is the unit of peak in the tables 5.9, and 5.10?
- In the table 5.3 on page 44, the value of overshoot (about 3.6) for k_s = 30000 is significantly smaller than a value of overshoot for other values of k_s (from 59.3 to 61.3), while in corresponding figure 5.5, the overshoot for k_s = 30000 is bigger than the overshoot for other values of k_s. Can you explain why?
- There is a reference at in the paragraph at the bottom of the page 55 connected to text "from Table 5.9". Does it mean that the information in the table 5.9 were taken from the publication [3] in References?
- Where can be found the table 2 mentioned in the statement "It is clear from the table 2 that ..." on page 56?
- Why the term *overshoot* is used in tables 5.1 - 5.8, while the term *peak* is used in the tables 5.9 and 5.11. Is there any difference in meaning? Why the peak time is not evaluated for Quarter car model?
- Which velocities were used for showing displacement of car body at different velocities for BCM in figure 5.21 on page 58?
- The figure 5.28 contains four numbers with no explained meaning. What do the numbers mean? Is it the velocity? If yes, in which units?

In Prague, January 29, 2020 Signature:

Stanislav Vrána