REVIEW OF FINAL THESIS

I. IDENTIFICATION DATA

Title:	**CFD simulation of sedimentation of small particles**
Author:	**Özgür Tarik Kaplan**
Type of thesis:	master thesis (diploma thesis)
Faculty/Department:	Faculty of Mechanical Engineering (FME)
Department:	Department of Process Engineering
Reviewer:	Ing. Jiří Moravec, Ph.D.
Reviewer's affiliation:	CTU in Prague, Faculty of Mechanical Engineering, Dept. of Process Engineering

II. CRITERIA EVALUATION

Assignment — **average demanding**

Evaluation of the difficulty level of the assignment.

The goal of the work was to perform a numerical simulation of sedimentation of small particles in water column using a model made in ANSYS Fluent software. Within the work a literature research in the field of possible approaches for modelling of sedimentation of small solid particles in liquid should be made too. The difficulty level of the assignment is average, the assignment is adequate for a master thesis.

Assignment fulfilment — **fulfilled**

Evaluation whether the submitted work fulfils the assignment.

The work fulfils all the points of the assignment. Actually, in addition to the assignment goals, the author added a chapter with numerical simulation of a sedimentation process in a lamella clarifier section including the effect of the lamella inclination angle on the process of sedimentation.

Solution procedure — **correct**

Correctness of procedure or method used for solution of the work by the student.

The author chose a correct procedure of work. Particular steps of solution follow each other in a logical way.

Professional level — **B - very good**

Evaluation of the level of expertise and level of knowledge used by student.

Professional level of the work is very good. The work contains all the needed information (theoretical background, information about settings of the simulation software, mesh quality check, optimization of simulation parameters, results). Matlab scripts are used for evaluation of results or finding necessary parameters. However, one step is missing to an excellent work. In some parts, of the work I was missing a deeper discussion of the obtained results and their better comparison. In some places, the results were just presented in form of graphs and tables but without deeper explanation of consequences. Thus, some parts of work seem to be described superficially, which decreases the professional level.

Formal and language level, work extent — **B - very good**

Formal correctness, typographical and linguistic aspects of the thesis.

The extent of the work is quite wide. Typographical level is very good. Figures and tables are easily readable and referred in the text (in most cases). From grammatical point of view, the work contains more mistakes and misspellings which complicate reading in few places (some of them are mentioned in detail comments). In total, the work can be evaluated as very good from the formal and language point of view.

Bibliography, citation correctness — **A - excellent**

Selection of bibliography, relevance of sources, correctness of citing, distinguishing between student's own and taken information.

The author used almost 20 biographical references. Their choice seems to be relevant in most cases. The number of references is sufficient for the work. All the references are properly cited.

III. FINAL EVALUATION, QUESTIONS FOR THE DEFENCE, CLASSIFICATION DEGREE PROPOSAL

Summarize aspects of the final work, which influenced your final evaluation at most. Write out questions, which should be answered by the student at the thesis defence.

If I summarize all the above (and below) mentioned comments and evaluation notes, I suggest the thesis for the defence with the classification grade

B - very good.

Date: 25. 8. 2021 Signature: Ing. Jiří Moravec, Ph.D.
m. p.

Questions for the defence:

1) You wrote that the DDPM-KTGF model doesn't have a continuous phase for particles and that it causes problems in evaluation of GCI. In real life, solid phase also is not a continuous phase, but if we calculate volumetric fraction at some place (level in a vessel), for example, we take mean value at that cutting plane. So, if it is necessary to evaluate such value from the results in the simulation, it seems logical to me that we should also evaluate the value over the whole area in the given height (so we get mean value). If I understood it well, you probably tried to do something similar when you created more "lines" in the model, didn't you? The question is, whether such procedure (calculation of the mean value from all the values at the given height) shouldn't be done automatically when using the DDPM-KTGF. Would this attitude help to enhance the results so we get smoother lines of volumetric fraction along the height of the model for example? Would such data evaluation help also in evaluation of the GCI at this method?
2) Can you clarify to me, how did you get the times of simulation for different particle sizes (page 51, par. 1). What was the initial time and the initial particle size used for the scale-up criteria? Did you test the scale-up model using any experimental procedure?
3) There can be seen a diagonal "ruptures" in the contours in the figure 3.30(a), page 58. Is it just a problem of the 3D view or is it a problem in the mesh?
4) What is a granular temperature? The parameter was set in the model of lamella clarifier (p. 73)?

IV. DETAIL COMMENTS TO THE WORK (not mentioned in the previous parts):

- P. 3: Date should be added so the pronouncement is complete.
- P. 7, par. 2, last line: Units should not be placed in brackets if they follow a number (%).
- P. 8: „*Nodes & Elements*" – this table caption appears more times in the list. It is an example, why the table captions should be written more specifically, e.g. model description could be added here so the tables would be specific and the list of tables would serve as a content list for finding the proper table according to its name.
- P. 12: "*D: Diameter*" (missing unit); "*g: Gravitational acceleration*" instead of "*force*"; "$\bar{I}$*: Stress invariants*" – all of them or just the first stress invariant?
- P. 13: "$\bar{S}$*: Strain rate [1/s]*" to have the unit compliant with the formatting of all the other units; "$\vec{u}_s$*: Solid phase velocity*"; "λ_s*: Solid bulk*" – what is it, is it really dimensionless?

- P. 14: "τ*: Viscous stress tensor*" – missing unit and tensor symbol above the letter (arrows).
- P. 17, par. 2, l. 4: "*… solids are separated from the liquid by settling down.*" – this is valid only for solids having higher density than liquid.
- P. 18, par. 1, l. 4: "*… that can reach during it falls through a fluid*." – grammar.
- P. 18, par. 1, last line: Figure 1.5 shows the balance of forces more than figure 1.4.
- P. 19, Figure 1.5: The caption probably contains internal label of the TeX source code.
- P. 19: "*g: Gravitational force*" – it is not force, but acceleration.
- P. 19, below eq. (1.4): Missing explanation of symbols u_t and t. They are both in the list of symbols, so it is not a problem, but for the compliancy of the work formatting it is good to follow the same attitude at all the equations. If there are description of all the symbols at previous equations, it should be the same here. It looks more professional then.
- P. 20, l.2: S_p is not a surface of particle, but particle cross section area perpendicular to the flow direction.
- P. 20, fig. 1.6: Why it is necessary to have the figures in the work? They are not referred and, actually, their importance is probably zero.
- P. 20, ch. 1.1, par. 3, l. 1: "*I*" or passive should be used instead of "*we*" in such kind of work.
- P. 20, ch. 1.1, par. 4, l. 3: "*distribution of suspended solids of each phase*" – what does it mean?
- P. 21, fig. 1.7: The figure is not referred in the text. Is it important to have it in the work?
- P. 32, last line: "*Fluent*"?
- P. 22, fig. 1.8: The figure is not referred nor described. What is its importance?
- P. 22, ch. 1.2, par. 2, l. 1: "*CFD is used in a wide…*"
- P. 22, ch. 1.2.1, last line: "*in differential form*"
- P. 22, eq. (1.6): Missing vector above *u*.
- P. 23, ch. 1.2.2, par. 3, l. 1: "*gravitational acceleration*". It is not necessary to repeat meaning of the symbols everywhere, if they are in the list of symbols. It can cause mistakes sometime, e.g. at this line it is written that "$\nabla\tau$ *is the viscous stress tensor*", but in the list of symbols τ is marked as viscous stress tensor. So which one is correct? $\nabla\tau$ is something different than τ. Moreover, there are missing tensor marks above symbol τ.
- P. 23, ch. 1.2.2, last par., l. 1: Equations (1.10), (1.11) and (1.12) are not Navier-Stokes equations but Cauchy's momentum equations. And a formal comment – when referencing equations, their numbers should be kept in brackets.
- P. 24, eq. (1.13): Missing right square bracket at the right side of the equation.
- P. 24, ch. 1.4, l. 1: The first two sentences should be probably joined in one according to the verbs used in the first sentence.
- P. 26, par. 1, l. 3: I do not understand to the sentence: "*Volume fractions, as well…*".
- P. 27, par. 1, l. 3: "*model's geometry is…*" – why did you choose the shape and dimensions in this way? Does it represent anything real? It should be mentioned here.
- P. 29, par. 1, l. 2: It is not clear were the number 21.718 was taken. There is a different number in the Matlab script above (21.2105), but that is marked as t_s and even here it is not clear to me, where the number was taken, as there is not any parameter t_s in the script.
- P. 30, last line: "*seen*".
- P. 30, last two lines: "*GPUs*", "*seen*".
- P. 33, l. 1: "*was activated*".
- P. 33, l. 2: "*chosen*".
- P. 34, par. 2 + fig. 3.5: I would appreciate more detail discussion of the results. It is just stated here, what can be seen in figures 3.5 and 3.6 but without any explanation of consequences.
- P. 34, par. 2, l. 3: "in the Figure 3.5".
- P. 34, fig. 3.5: I think, that something like "height position in the model" would be better as a label of x-axis, than the used "Position of Line". Actually, the word "*Line*" is misleading a little, because there was written also

about a line placed in the middle of the model. The same comment holds for similar graphs presented later in the work (fig. 3.13, 3.17).

- P. 35, ch. 3.2.2, l. 4: "*It accounts the effect…*".
- P. 36, par. 2, l. 3: "*Eulerian*".
- P. 36, par. 2, l. 6: "*DPM has been…*"?
- P.38, fig. 3.10: The same line was created in the model at previous Euler-Granular method? If it is so, such explanatory figure should be placed already in that chapter to help for explanation written just in text.
- P. 40, par. 1: I am again missing discussion of the results (more information and deeper explanation of particular calculations and consequences).
- P. 40, tab. 3.2: Table captions use to be placed above the tables, not below.
- P. 40, par. 2, l. 2: Shouldn't be made the reference to figure 3.15 instead of 3.14? Actually, I am not sure that I am able to distinguish whether the line in figures 3.15 a 3.16 are smoother than the lines in fig. 3.13.
- P. 41, fig. 3.14: What does the surface line mean?
- P. 41+42, fig. 3.15 + 3.16: Missing axes labels.
- P. 43, par. 1, l. 4: "*no*" means "number"?
- P. 43, par. 1, last line: "*should asymptotically approach…*".
- P. 45, eq. (3.16)+(3.17): Subscript at ϵ_{21}.
- P. 46, par. 2: "*are greater*" instead of "*be greater*".
- P. 47, par. 1, l. 2: "*... from the slope, as seen in Figure 3.5*" – which slope do you mean? It is not clear to me.
- P. 47, par. 2, l. 2-4: Grammar in the sentence (missing verb(?), expresses instead of express).
- P. 48, fig. 3.19: Missing axes labels.
- P. 49, par. 2, l. 1: "*rates start*".
- P. 49, par. 2, l. 2: "*to decrease*" – this is not true, if we compare 3s and 5s.
- P. 49, eq. (3.24): There should be "6" instead of "*G*".
- P. 49, ch. 3.3, par. 4: "*Stokes*"
- P. 49, eq. (3.26): The equation shouldn't be divided by 8.
- P. 49, ch. 3.3, par. 5: "*μ is dynamic viscosity, d_p is diameter of paraticle.*"
- P. 49, eq. (3.27): Missing explanatory text to the equation.
- P. 50, par. 2: "*Settling velocity is*" instead of "*Where u is*" – there is no *u* in the previous equation so it is strange to continue using "*Where*".
- P. 50, Matlab code: Missing any comment in the text relating to the Matlab code. The code is just placed in the work.
- P. 51, ch. 3.3.1, l. 3: "*particles were used*".
- P. 52, par. 1, l. 2: I am not sure, that the contours in the figures can be described as similar to each other, as you write here. I see differences there.
- P. 52+53, fig. 3.22+3.23: Why weren't the curves drawn in one figure? It would be much easier to check differences between them.
- P. 54, fig. 3.24: I see anthracite in the material setup. Why did you not use chalk as in the previous calculations?
- P. 54, par. 1, l. 1: A midline was used for evaluation. Is it enough to use just one line? Wouldn't it be better to make more lines?
- P. 55, fig. 3.26+3.27: It would be much better to have both curves in one graph only.
- P. 56, fig. 3.28(b): The figure (b) shows a different mesh of is it the same mesh? The number 2 in the label is confusing and nothing is written about it in the text.
- P. 57, first line: It would be great if you would explain, whether the numbers are good or not (quality levels in relation to numbers presented in the table).
- P. 57, par. 2, l. 3: "*with the system described before.*"

- P. 58, fig. 3.30: I see diagonal "ruptures" in the contours in the figure (a). Is it just a problem of 3D view?
- P. 58, par. 2, last line: "*as seen in Figure 3.31 (red curve)*".
- P. 59, first line: "*Figures 3.30b and 3.32 show*".
- P. 59, last line: "*with the system described before.*"
- P. 60, fig. 3.33+3.34: There is no comment to the figures in the text.
- P. 60, last par.: The sentences should have been joined in one probably. There is missing verb "*packing limit was reduced*". It would be good to explain, why it was necessary to reduce the maximum packing limit.
- P. 61+62, fig. 3.35-3.38: The text referencing to figures follows after the figures. It complicates reading (skipping forward and back). It happened also at few places before. The figures 3.37 and 3.38 could be joined in one graph with two lines. Comparison would be easier.
- P. 62, l. 3: Where it can be seen, that the interface height is similar to the value obtained from 3D model?
- P. 63, l. 1: "*geometries were drawn*".
- P. 63, par. 1, l. 4: The particle size distribution was measured using a laser diffraction analysis, not an ultrasonic method.
- P. 63, par. 1, l. 7: "mean" instead of "means"; "*which is approximately 62%*" – 62 % of particles have a diameter lower than or equal to 2.85 μm.
- P. 63, par. 1, last line: How did you estimate the values "*around 100 mm to 110 mm*"? Is it just guessing?
- P. 65, par. 3, l. 4: I do not understand to the sentence: "*but at the same time…*".
- P. 67, l. 2: "*plates*" instead of "*plated*".
- P. 67, par. 2, l. 2: "*belt wash, battery*".
- P. 68, last line: How close is it? What is the value?
- P. 69, l. 1: "*selections were created*".
- P. 69, par. 2: Grammar.
- P. 70, ch. 4.3, 1. sentence: Grammar.
- P. 70, ch. 4.3, l. 3: "*was used*".
- P. 70, ch. 4.3, par. 3, l. 4: "*closed*".
- P. 70, ch. 4.3, par. 3, last sentence: Grammar.
- P. 71, last par., l. 1: "*was chosen*".
- P. 74, last line: "*data were obtained*".
- P. 75, par. 1, l. 3: "*data were obtained*".
- P. 75, fig. 4.15: Is the Plot title "*mass-part-outlet2-rplot*" correct in this setup?
- P. 79, par. 1, l. 4: "*in Figure 4.22*" instead of "*in Figure 4.7*"?
- P. 82, l. 1: "*shows*".
- P. 82, par. 2, l. 4: The sentence: "*The particles are leaving…*" is copied from the text. It looks strange in the summary. It shouldn't be used there. Moreover, the information in the sentence is not important in the summary.
- P. 82, par. 2, l. 6: "*exponentially increases*".
- P. 82, par. 5: "*from the bottom outlet*" – it should be mentioned, because "*outlet*" is the name of the outlet on the top of the model, so it would be confusing. It should be also stated, how is the efficiency defined.
- P. 83, par. 1: The units should not be in brackets.
- P. 84+85: There shouldn't be dots after the brackets.