Responses to the comments made by Dr Balabani

The author would like to begin by thanking Dr. Balabani for taking the time and effort required read and asses this thesis. As per the recommendations made by Dr Balabani major revisions have been made in this revised submission.

The author would like to thank Dr Balabani for pointing out the shortcomings of this thesis as well as highlighting the positive points of the thesis in her report.

Overall the shortcoming of the thesis pointed out by both examiners was the clarity of the presentation. Thus, most of the chapters were re-written to make the arguments more clear. Chapter 5 of the previous submission was merged with Chapter 4 of the same submission and re-written. The typographical errors have been fixed.

The responses to the questions raised in the evaluation report sent by Dr Balabani are addressed first followed by the annotated thesis.

**1) Response to the comments made in the evaluation report**

The thesis opens with a very extensive abstract (it is informative but very length, typically an abstract is expected to be about 1-1.5 pages long)

The reviewer is correct the abstract was too long. This has been rewritten to be more focused and condensed to 1.5 pages.

Chapter entitled Preliminary Remarks; this should be called introduction and provide the rationale and context of the work and not the outline, which normally comes after the objectives.

The author was referring to the template of the thesis by Leontini (2007) during thesis writing. Thus, the author feels the heading and the template suitable for the flow. Preliminary remarks set the context of the research. The review of literature discusses the work has been currently done and based on this review the gaps of the existing knowledge are identified and the objectives are presented.

However, the author agrees that there was a lack of clarity in the initial submission which was ratified through more clear explanation.

A literature review follows (chapter 2) which appears brief. The first section on FIV seems to be missing. There is little on energy harvesting from flow induced motion overall. Although the study focuses on energy from galloping and as the student states there is not much published on the field a review of technologies or studies on energy harvesting from FIV would be beneficial and strengthen the rationale for the study (e.g. why galloping?). VIVACE is the only such technology mentioned in the thesis but others might have been developed (e.g. Cornel has developed a harvester prototype based on galloping, Vibro-Wind). The effect of structure geometry could have been discussed more perhaps by looking at various bluff body studies and show some evidence of delayed separation and afterbody effects that could be useful in the discussions later on.

A section regarding FIV was added in the amended thesis (refer page 5). The section on “Galloping as a mechanism of energy harvesting” was updated (kindly refer to pages 17-19).

The discussion on the afterbody shape was updated (kindly refer pages 15-17). The term “delaying shear layer reattachment” was changed to “inhibition of the shear layer reattachment” to provide a clearer picture of the study.

The objectives of the study are clearly stated; they are justified by the state of the art presented. One would expect the outline of the thesis to be given at this stage, not earlier.

The preliminary remarks and the literature review have been re-written and re-structured in an attempt to improve the flow of the thesis and the presentation of ideas. The outline of the thesis now concludes the literature review section.

The methodology is explained well in chapter 3; both the DNS and QSS model implementation are described in detail. However, the geometry and domain are mentioned quite late in the chapter, the reader is left wondering what the galloping structure modelled will be.

The QSS model and the DNS modeled are presented first because theses models apply to any domain, which followed by the specific domain to this study presented afterwards. However, the wording of the introductory paragraph to this chapter has been amended to make it clear the modeling is focused on the flows past square, or similar bluff cross sections.

I would have expected some mention of a systematic process in deriving non-dimensional groups (perhaps Buckingham or Pi theorem?). Also the introduction to the chapter is more of a summary as it also lists the findings (perhaps due to paper).

The non-dimensionalised groups are formed in a systematic manner, as explained on pages 45-46. The equation of motion was linearized, and the eigenvalues of this linearized equation found. Then, the original equation of motion was non-dimensionalised using this timescale. Buckingham Pi theorem would not lead to these groups naturally as the parameters used are actually combinations of other dimensionless groups.

The introduction to this chapter has been updated kindly refer to pages 43-44.

Chapter 5 presents the frequency response as a function of the new parameters; this chapter is rather brief. I am not sure if the frequency equation 5.6 -5.7 is correct as the LHS has not been multiplied by the mass ratio, only the RHS has and this needs to be checked. The frequency response of the structures with different afterbody would also be of interest.

As the reviewer has pointed out this chapter was very short. Essentially the frequency study was carried out to study the influence of PI\_1 and PI\_2 on the galloping frequency. Thus, the data and the analysis of this chapter was merged with the chapter “**Governing Parameters of Fluid-Elastic Galloping”**

As the reviewer has also pointed out, the analysis of this section was not adequate. Thus, a clearer presentation of data and discussion was added.

The equations were corrected with the multiplication of the mass ratio.

The major objective of this section was to investigate the influence of PI\_1 and PI\_2 on the galloping frequency. Thus an expression was obtained for the frequency in terms of PI\_1 and PI\_2. The frequency data obtained using the QSS model, linear frequency and DNS simulations were compared.

Kindly refer to pages 65-75 for the results and discussion of this section.

The final result chapter reports on a parametric study looking at the effects of geometry especially after body shape. The decision to use a triangular afterbody seems smart but the choice is not explained well; in theory a square cylinder could have a curved or even a splitter plate as afterbody and d/l could be varied even in the case of a rectangle. The study clearly demonstrates the effect of afterbody on power extraction. However, reading through the thesis one wonders where are all these FSI DNS results? Surely there is a lot more to present from the DNS simulations to strengthen the thesis (flow fields, force histories etc.). The flow fields could be better illustrated.

The reviewer is correct a clear explanation was lacking in this chapter.

The key facts which lead to the cross section geometry were identified and are now presented in section 5.2 (page 81). The optimum cross section was identified, at least the optimum of the cross sections tested. However, the main objective of this chapter was to test possibility of achieving higher power output through inhibition of the shear layer re-attachment (refer pages 95).

An explanation for the initial range of angles of attack θ that produce negative lift in the Cy vs θ curves is now provided via the pressure and velocity magnitude plots. The behavior of the shear layers is now explained through contours of magnitude of the strain rate tensor. The results and discussions of this chapter were rewritten to make the arguments clearer please refer pages 77-97.

The thesis ends with a conclusion summarizing the work, findings, limitations and future work. It would have been much better if this final chapter was structured with separate sections for main findings, limitations of the study and the recommendations for future work. An issue that should be discussed is the application of QSS in cases of non-standard geometries for which no force data is available.

The conclusions chapter was re written to incorporate these points and all the other amendments made in this thesis. Even though separate sub headings were not used the flow of the conclusions chapter in the amended thesis now proceeds in the same order as the results chapters from which these conclusions are drawn. Kindly refer to Chapter 6 of the amended thesis (pages 99-102).

**2) Response to the comments made in the annotated thesis**

**Abstract**

“abstract is too extensive, need to be 1-1.5 page max too many grammar mistakes”

The response to the query was made in the previous section.

**Chapter 2- Literature review**

**“**The body does not have to movie for lift**”**

The author is correct. The body does not have to move to generate a lift force. Here lift refers to the induced lift which is a result of the motion of the body. A clearer explanation was made in the amended thesis refer page 5

“Figure 2.1 caption not clear”

The caption was changed (page 6).

Caption of figure 2.3 updated (page 11)

**Methodology and Validation**

“ ‘ode15s’ function was used when the equation became more stiff.”

Stiff means the scheme is restricted to a small time step (due to one timescale of the problem becoming small) added in page 25

“the left hand side represents the inertial forces and the right hand side represents the pressure forces.”

Corrected (page 27)

Equation 3.12 terms missing

Missing terms added (page 30)

Equation 3.13 “N” is not defined

N is the non linear convection term in the Naiver-Stokes equation. This was added in the Nomenclature.

“The choice of various integration schemes are not explained.”

The DNS simulations were carried out using the same numerical code as Leontini and Thompson (2013). This is because this code provides accurate data for 2 dimensional flows. This numerical method developed by Leontini and Thompson and is not the original work of the author and due reference is made in the thesis (pages 26 and 38) The choice of the various integration schemes are based on choice of those researchers.

The section “boundary conditions” was shifted after the introduction of the domain.

The current domain and the special and temporal parameters were obtained from Leontini and Thompson (2013). The author has tried for the current study to obtain a converged value for the average velocity amplitude. This fact is quite vital as the velocity directly affects the mean power and a difference of less than 1% was achieved for both mean velocity amplitude of the body and galloping frequency using these spatial and temporal parameters.

Overall a clearer explanation of this chapter was made in the amended thesis kindly refer to pages 22-56.

**Governing parameters of fluid-elastic galloping**

The introduction was reworded for the reader to gain a better understanding (pages 42-43)

“An example case is presented in Figure 4.2", do you mean Figure 4.3?”

The reviewer is correct. The error was corrected.

The explanation regarding Pt and Pd was not added and in the initial submission and was added kindly refer to page 51 of the amended thesis.

The unclear section of page 46 was rectified by a clearer explanation on page 54 of the amended thesis.

p53 “what is the meaning of this correlation since it is specific to this study ”

While the particular fit is specific, it is interesting that the power found comes out to be close to -0.5, or that the relative contribution of the vortex shedding scales like 1/√Π1. The percentage error in the prediction of the power by the QSS model compared to the DNS simulations also scales similarly. This similarity in scaling suggests the error in the QSS model can be attributed to not accounting for the vortex shedding, a point made explicitly in the thesis, see page 63.

P53 A clear wave length could be observed “what does this mean”

This wavelength refers to the observed waviness of the wakes in figure 4.14. This wave length reduces as PI\_1 is increased.

The summary of this chapter was rewritten.

**Chapter 5- Frequency response of the system**

Kindly refer to the responses made in section 1 of this document under this chapte .

**Chapter-6 Influence of Fluid Dynamics of the System on the Extracted Power**

The definitions of “top” and “bottom” shear layers were added using a schematic in section2.13 (page 12) and is referred to in this section. The selection process of the cross section was added, refer page 99-81.

P 70 “mean power PI\_2 vs .mean power ”

Typographical error was corrected (page 84).

“P72 figure caption not clear”

Caption of figure 5.4 was updated.

p.73 Figure 6.5: the direction of the flow was indicated.

The figure was made clearer by indicating direction of the flow. (refer page 88)

P75 figure 6.7 was changed. The plots of stream traces were changed to contour plots of the magnitude of the shear strain rate which provided a better explanation for that section kindly refer to figure 5.7 (page 90).

Overall this chapter was rewritten to provide a clear explanation of the arguments and the findings.

**Chapter 7-Conclusions**

The conclusions chapter was re written to highlight the key findings of this study and all the other amendments made in this thesis. Kindly refer to Chapter 6 of the amended thesis (pages 99-102).