

## Jury Member Report – Doctor of Philosophy thesis.


**Name of Candidate:** Dmitry Smirnov

**PhD Program:** Engineering systems

**Title of Thesis:** Innovative technological pathway for new commercial applications of Stirling cycle-based systems

**Supervisor:** Assistant prof. Henni Ouerdane

**Name of the Reviewer:** Prof. Christophe Goupil

<p><b>I confirm the absence of any conflict of interest</b></p>	<p><b>Signature:</b></p>  <p><b>Date: 25-09-2019</b></p>
---	--

*The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.*

*If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.*

### Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

- **Brief evaluation of the thesis quality and overall structure of the dissertation.**

Mr Smirnov presents a thesis entitled "INNOVATIVE TECHNOLOGICAL PATHWAY FOR NEW COMMERCIAL APPLICATIONS OF STIRLING CYCLE- BASED SYSTEMS". This thesis is composed of six chapters and a conclusion:

1. Introduction
2. Bibliometric study of Stirling engines
3. Game theory in design optimization
4. Bibliometric study of Stirling refrigerators
5. Piston sealing in Stirling refrigerators
6. Modeling Heating load
7. Concluding discussion

This work is well presented and carried with great conviction by its author. The document is very structured and easy to read. This reflects a very good level of knowledge and maturity in the analysis. Starting from a subject that could lead to dispersion, Mr. Smirnov was able to keep a guideline throughout his work.

- **The relevance of the topic of dissertation work to its actual content**

This thesis work is the result of preliminary work already undertaken by the candidate before his thesis. It should also be noted that this work has been rewarded (Gazprom young specialist). Knowledge of the subject, both from a scientific point of view and in terms of economic developments, clearly demonstrates the relevance of this study in the current scientific and industrial context. It should be noted that Mr Smirnov does not forget to distinguish the properties of the working fluid from those of the machine that implements it. In this spirit, he is in the rightful filiation of Sadi Carnot.

- **The relevance of the methods used in the dissertation**

At first glance, this thesis may seem surprising due to the breadth of its spectrum and the originality of its methods. This originality is one of the strong points of this thesis, which takes the risk of putting the two ends of the TRL scale into dialogue. The proposed method is convincing, and the confrontation of the five approaches of analysis is fertile. The search for efficiency in the design process is a constant concern in this work.

- **The scientific significance of the results obtained and their compliance with the international level and current state of the art**

The results obtained by the bibliographic methods in Chapters 2 and 4 are quite convincing. However, it is regrettable that these results are not put in perspective in relation to their geographical origins. Indeed, if all the countries mentioned develop a Stirling activity for space applications, the development motivations for other applications are highly dependent on the country, and especially on its history. This is particularly true for the automotive sector, where Japan has long been a major innovator. Similarly, with regard to the domestic application targeted by this thesis, a critical study on the relevance of transposing a technological solution from one application to another would have been welcome. Nevertheless, the work is entirely in line with international standards, as also evidenced by the scientific production.

- **The relevance of the obtained results to applications (if applicable)**

The results obtained in the application part of the thesis, chapters 5 and 6, are essentially technological. In this sense, they respond very well to very applied problems. It may be regrettable that some more fundamental aspects have not been explored, in particular the question of the regenerator and associated thermal time constants. However, it should be

noted that the work applied was carried out on a machine at scale 1, i.e. in a completely realistic condition, which is not so common in this type of study.

- **The quality of publications**

Dmitry Smirnov is the first author of 3 articles,

1. Smirnov, D., Dvortsov, V., Saichenko, A., Tkachenko, M., Kukolev, M., Bisch, A. and Ouerdane, H., 2019. Experimental study of a high-tolerance piston-cylinder pair in the alpha Ross-yoke Stirling refrigerator. *International Journal of Refrigeration*, 100, pp.235-245. (Impact factor 3.18)
2. Smirnov, D. and Golkar, A., 2019. Design Optimization Using Game Theory. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*. Early access. (Impact factor 5.13)
3. Smirnov, D. and Golkar, A., 2015. Stirling engine systems tradespace exploration framework. *Procedia Computer Science*, 44, pp.558-567. (Impact factor 0.79)

This is a very reasonable scientific production for a technological thesis. Of particular note is the article published in the IEEE Review.

---

### **The summary of issues to be addressed before/during the thesis defense**

Some technical points need to be clarified:

- There is never really any mention of the specifications document of the system to be optimized. This is a little frustrating, especially since thermodynamic systems are sensitive to allometry issues, and a solution valid on one scale may be ineffective on another.
- It is never clear whether the strategy sought is one of maximum power or maximum efficiency. This point should be clarified.
- The question of a finite time approach is very rarely addressed. As a result, dynamics issues, including operating frequency, or regenerator optimization, are not part of the design process. It is likely that this would have considerably increased the workload of the thesis work.
- The question of boundary conditions of coupling to sources is addressed at the end of the thesis. It would have been interesting to specify to what extent there are really accessible degrees of freedom to optimize these coupling conditions in an already constituted system.
- The chapter III, which considers an approach based on game theory, has strong similarities with some microeconomic models. This is particularly true with regard to Nash optimization. It is known that this optimization method does not necessarily lead to the absolute optimum. This question could be considered.
- In the same spirit as the previous question, it seems that the inhibition of the optimization induced by too rigid specifications is not addressed. Indeed, in the presence of specifications defined too strictly, it appears that some optimal technological solutions are excluded, whereas a relaxation of the constraints of the specifications would have allowed access to them. This type of potential barrier to innovation should be addressed.

### **Provisional Recommendation**

*I recommend that the candidate should defend the thesis by means of a formal thesis defense*

*I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

*The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*