Gesellschaft für Energie und
Klimaschutz Schleswig-Holstein GmbH

„Entwicklung eines Algorithmus-gesteuerten Optimierungsverfahrens für Windkraftanlagen “

Abschlussbericht von Robert Thomas Rudolf, Flensburg
EKSH-Promotionsstipendium 3/2015

Dauer des Stipendiums:
Oktober 2015 – Oktober 2016

Betreuer: Prof. Dr. Torsten Faber
Hochschule Flensburg

Dokumentation

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Scholarship Final Report
(Abschlussbericht: Anschlussstipendium EKSH-FuE-Förderprojekt)

Advisor (Betreuer):	Prof. Dr. Torsten Faber, Hochschule Flensburg
Theme (Thema):	Algorithmus-gesteuertes Optimierungsverfahren für WEA

Dear Dr. Wortmann,

The EKSH Anschlusspromotionsstipendium has allowed me to make substantial progress in converting my EKSH-sponsored technology-transfer research into a PhD. I have spent the 12 months of my scholarship on three main activities: completing required coursework, reproducing my industry results for academic use, and writing my dissertation. I have made substantial progress in these three tasks, and I hope to submit my Dissertation in the first half of 2017, dependent upon how much time I can spare next to my work. I am incredibly grateful to the EKSH for your scholarship support.

Considering that the average time to earn an engineering PhD in Germany is 5.4 years [1], I am pleased with my progress. In reflection, it is unrealistic that I could have finished my dissertation in only three years total time, especially considering the additional demands of my industry project. Specifically, three aspects of industry projects work against the requirements of a PhD. These are mentioned in the following paragraphs with examples from my own experience. They are not intended as excuses, rather, as considerations for subsequent prospective "Anschlussstipendiaten" so that they can structure their FuE research more efficiently.

I want to emphasize that I find industry-academic tech transfer projects such as the FuE program a wonderful means of spawning PhD research. It brings additional motivation to the tech transfer project and leverages that investment by allowing interested researchers to pursue a PhD with relatively little additional time and expense. The one-year scholarship is perhaps too brief to provide full funding for a typical engineering PhD student (or an equivalent timeframe to the standard EKSH 3 year PhD scholarship), however, it is certainly a tremendous help. Without the last year to concentrate solely on my PhD, I might have had to abandon my pursuit of the degree, spend and risk time trying to find further funding, or start over and seek a funded PhD position elsewhere on a new or revised topic. Now I am certain that I will be able to finish my Dissertation, even in my spare time.

My first point regarding the complications of using an industry project as PhD research is that many tasks required of industry projects demand time and effort that does not add value to a dissertation. This

[1] Forschung & Lehre: Erfolgreich zum Dr.-Ing., PDF, Juli 2011, Ausgabe 7/11, S. 534

includes project management and reporting, but also many technical work packages that are either too irrelevant or lacking in academic merit to be considered a part of one's PhD work. One example relevant to my experience is the level of detail required to design a prototype to industry standards (a requirement of my FuE project). Whereas just a handful of load cases are sufficient to validate my metamodel optimization methods for academic purposes, it was much more work to program and debug a tool that could design the guyed tower per industry certification guidelines.

Second, industry projects require a strict timeline with defined work packages. This inflexibility does not allow much time to explore and test new ideas. Only a certain amount of time and failure is tolerable within the budget of an industry project before a more conventional method must be pursued for practical purposes. As a result, the academic value of the research can suffer. For example, I was forced to work with the existing capabilities of my partner's in-house load simulation software which was (at the time) not state-of-the-art. Specifically, their code could not model the higher-order modal behavior of the structural dynamics, which are relevant to guyed towers and the behavior of other complex, next-generation structures. I wanted my design approach to account for this behavior and spent considerable time pursuing alternative solutions, which I eventually abandoned due to time constraints. One of these attempts included learning and validating an external code. This effort was eventually adopted by my industry partner at the end of the HWT project for their own purposes but unfortunately too late to be used in my research.

Lastly, industry projects require or at least favor some level of propriety. Academic activity, however, requires transparency so that results can be understood and replicated. This means that some of the work spent during an industry project may need to be duplicated using open-source methods before it can be used for a PhD. One example of how this delayed my PhD research is the in-house turbine model and aeroelastic code I used for my FuE project, and how I needed to duplicate my FuE project work using an open-source turbine model and software for my Dissertation.

My guyed tower industry project used an actual wind turbine model (the aeroMaster 2.5MW turbine with 117m rotor diameter on 140m tower). The use of an open-source "virtual" wind turbine model was not an option because the prototype tower design was intended to assess real-world material savings potential. This requires a production turbine model rather than a simplified open-source academic turbine (which exist only digitally, as they are never produced and sold). Additionally, the use of the aeroMaster 2.5MW (in combination with the aforementioned time constraints) necessitated that the guyed tower be simulated using aerodyn's proprietary aeroFlex software, adding to the concerns of transparency voiced by my Thesis advisor at KIT. As a result, I had to invest 6 months of time in learning the open-source FAST software, adapting my design tool to the new software and the simplified "NREL 5MW Reference Turbine" and replicating my results.

Despite these delays, I am happy to report solid progress toward earning my PhD during the scholarship period from October 2015-2016. In addition to replicating my EKSH research using open-source turbine model and software, I have also been able to improve the accuracy and efficiency of my metamodel optimization method. Specifically, I discovered that simple polynomial response surface surrogate models can more accurately predict extreme and fatigue loads versus the elliptical basis function neural network metamodels used in my FuE project. Additionally, I was able to achieve impressive "one-click" optimization capability using a well-known quadratic programming optimization algorithm. This is exciting

for the greater wind turbine structural optimization community, because it makes this advanced design method more practical and accessible to industry and academia.

In addition, I temporarily relocated to KIT from October 2015 through February 2016 and successfully completed the 12 "ECTS" credit points of coursework required by the KIT PhD rules. There I attended the lectures titled "Glas-Kunststoff und Seiltragwerke" and "Numerische Methoden in der Baustatik". The relevance of both courses to my research is obvious, and it was also very valuable to experience a German university environment first-hand. I greatly appreciate the additional travel budget provided by the EKSH to offset the additional rent and travel expense for this semester of work.

The last remaining task I have to earn my PhD is to prepare my dissertation and defend it. I have no set date for when I plan to submit my thesis, as I still have much to write and it is difficult for me to estimate how much free time I will have available in 2017. Fortunately, I have been able to compile a literature review within the last year (a required chapter in any dissertation) and I have also made good progress in understanding the theory behind the surrogate modeling techniques and optimization algorithms that I apply in my research. I could make much more progress in further improving the performance demonstrated in my open-source structural optimization of a guyed tower, however, I have run out of time. Now my focus is to document my work to-date and perform additional investigations only as required by my PhD committee. They seem satisfied with my quantity and quality of work so far and are waiting for me to submit drafts of my chapters before providing any additional feedback.

In closing, I would like to make a brief remark about conducting PhD research in a (Fach)hochschule environment versus a university. As anyone with experience in both systems is aware, earning a PhD as an external doctoral student situated at a Hochschule presents additional challenges. These are attributed to the vast differences in available material resources (library, software, hardware) as well as human resources. Specifically, the most challenging aspect that I have faced is the physical distance from my official PhD advisor at KIT and the lack of a local network of experienced colleagues in Flensburg. Proximity to a large, experienced research team not only accelerates learning, but also builds stronger networks and is helpful in less subtle ways such as suggestions for how to manage ones PhD research and understand and navigate the academic bureaucracy. For this reason, I think it is very important that the EKSH continues to financially support PhD students at (Fach)hochschulen with extra funds to spend time at their partner, degree-granting universities.

In closing, I thank the EKSH very kindly for your support and will do my best to make your investment in me a success.....by finishing my PhD as soon as possible and using it to continue researching ways to stem climate change.

Thank you,

Mit freundlichen Grüßen

Robert Thomas Rudolf, M.Eng., M.Sc.