Opponent review of Dissertation : "Performance Prediction Methods of Cascade Blades in Steam Turbines"

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a) The significance of the topic of Dissertation for the discipline of turbomachinery

Swift and precise prediction of losses is undoubtedly one of the key topics in turbomachinery. The tough competition among the turbomachinery producers does not allow them to apply any efficiency margins. Not fulfilling the guaranteed performance causes for the producers the risk of paying immense financial penalties to their customers.

Apart from that, better understanding of mechanisms of loss generation also enables a better optimization of the blade design.

Creation or revision of a complete loss model would be an extensive task even for a single Dissertation. That is why the author focuses the attention mainly on the aspects of profile losses and secondary losses. The other important types of losses, such as leakage losses, shock losses and moisture losses are not handled in the Dissertation and remain, as presented in the last chapter, a challenge for the future work.

b) The approach and methods used to meet the set targets

The approach of the author is based on a summary and critical review of all known loss models, both design and off design. After setting the targets in the first chapter, the author analyzes the losses in a general way in the second chapter and after that he compares in the third chapter the particular loss models published by various authors. He compares their strengths and weaknesses in a very clear way so that the third chapter may serve almost as a reference book for other researchers and specialists. As most methods used for fulfilling the target are based on CFD approaches, the author explains in the fourth chapter the utilized numerical analysis methods. The core of the Dissertation are the fifth and sixth chapters. In the fifth chapter the attention is cast to the topic of profile losses, both design and off design. The fifth chapter is in many aspects similar to the findings published already in the Doctoral Thesis, but the sixth chapter focused on secondary losses, which are handled using the entropy generation method, is completely new. My only reservation about the sixth chapter is, that it is, according to my opinion, too brief. As this part mainly extends the Dissertation when compared to the Doctoral Thesis, I wish more attention had been focused on that important topic. In the last, seventh chapter the work is concluded by highlighting the results and proposal of the future works.

c) The results of the Dissertation and the original research

The main objective of the Dissertation was to gain an understanding of the loss mechanism of profile loss, secondary loss, and to find the proper correlation for each loss. The simplified correlations shall aid design and lead to more reliable prediction by relatively simple techniques. I found that the objectives of the Dissertation were fulfilled, as its practical result are several simplified formulas (99,100,109,110) for calculating profile losses and secondary losses.

Concerning the original research, it shall be noted, that apart from the comparison and critical review of known loss models, the Dissertation incorporates creation of novel formulas based on approximation of results of many author´s own CFD calculations and moreover validation of

proposed formulas in terms of match and consistency with existing models, available CFD and measurement data form both internal and public available sources.

d) Other statements (systematic nature, clarity, formal arrangement and language level of Dissertation)

Compared to the previous Doctoral Thesis, the Dissertation was profoundly restructured (I would highlight e.g. Chapter 3.5 and Tables 22 and 24.). This restructuring shows author's better in-depth understanding of the studied subject. I appreciate that the particular loss models are now categorized basically by the authors and their concepts instead of the loss types. This change made the Dissertation better arranged and understandable.

The Dissertation exhibits good clarity and a precise formal arrangement. The language level of Dissertation is perfect.

e) Statement about the publications

Mr.Cheon is author and co-author of eight publications, which were presented over the past eight years in various conferences. Among them ASME Turbo Expo 2015 and 2016 are the most prestigious. All of the publications deal with the relevant topics of blade optimization, CFD modelling and blade loss predictions.

f) Final statement

I recommend the Dissertation for defense (according to law no. 111/1998 Coll., §47)

In Plzeň 20.11.2016

Reviewer: Ing. Jiří Kučera, Ph.D., Nad Dalmatinkou 2, 312 00, Plzeň

Doctor thesis review

Title: Performance Prediction Methods of Cascade Blades in Steam Turbines

Student: Ing. Junhong Cheon

Thesis content

The thesis is divided into 7 chapters. The introduction describes the definition of efficiency losses and flow phenomena related to each loss in order to identify and understand the losses in a blade cascade. There is also extensive related literature review. Then numerical methods are presented including governing equations, turbulence models, roughness model, computation model, boundary conditions and post-processing. The physics of profile loss mechanisms in various situations are described in detail in the next part. The sources of loses are divided in several types according to the region of theirs origin in space (inlet, inter-blade channel, outlet) and physical mechanism (profile loses, secondary loses, leakage loses, trailing edge loses, incidence loses). Numerous relevant quantities, conditions and factors are taken into account (Reynolds number, trailing edge thickness, Mach number, blade back radius and working regime). This analysis is followed with an attempt to quantify each loss mechanism associated with basic profile loss including the Reynolds number and roughness effects, trailing edge loss, and incidence loss. Correlations for the estimation of each loss are compared with the experimental data. A secondary loss mechanism is described based on entropy generation. A variety of factors affecting secondary loss are studied and discussed. In the end of the dissertation the overall conclusions and suggestions for future work are given. As the main result the complex method for evaluation resulting total losses of the turbine stage is presented. The thesis goals are clearly defined.

Thesis significance for the field

The thesis contains extensive survey of methods for evaluation losses in a turbine stage. The reviewed methods are critically evaluated.

As the main result, the new method of losses evaluation is proposed based on critical analysis of the existing methods and original research of losses sources using various methods including analysis of physical sources and CFD modelling. Such tool is of key significance for a turbine stage designers allowing for the design optimization from the point of view minimization of losses.

The main benefits of the work is development of good and reliable method of losses evaluation based on understanding to physical mechanisms behind the process of losses generation. In the same time this knowledge could give to turbine stage designers an efficient tool showing the efficient way, how the improvement in stage efficiency could be achieved.

Procedures, methods, fulfilment of the defined goals

The procedures and methods chosen to achieve the defined goals are adequate, well chosen, application of the method is proper. Most proposed methods are based on mathematical modelling, but the chosen methods have been validated against available experimental data.

The goals defined in thesis are completely achieved, in my opinion.

Achievements, original contribution of the doctoral student

The student subjected the chosen methods of losses prediction to deep analysis and validation against experimental data. Influence of many factors presented in real cases are taken into account using correction. Original contribution of the thesis I see in detailed analysis of effect of incidence losses, inlet blade angle, contraction ratio, leading edge diameter and inlet wedge angle on losses generated in the stage.

Attention is paid to of-design situations, the corrections are based mainly on empirical correlations. The corrections take into account the factors which could occur in real situations.

Formal aspects

The thesis is written carefully with minimum misprints. Figures and graphs are clear and of good quality. The thesis contains all obligatory parts. The thesis structure is logical and systematical.

Student's publications

In the short version of thesis (autoreferat) there are 8 publications of the student's participation. All of them are papers from conferences, 3 ASME papers and they are related to the thesis subject.

Conclusions

The student has shown a good orientation in the field of fluid mechanics and thermodynamics with application to turbomachinery. Within the subject of the thesis, which is related to losses in a turbine stage, he proceeded all available information from literature and other sources. He suggested a tool for evaluation and prediction of a turbine stage losses, which could be applied in the process of its design.

The student has shown good ability to apply the general knowledge to the special case and thus he has proved his ability of scientific work.

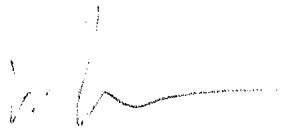
The submitted thesis meets all requirements according to the law no.111/1998 Sb§47, in my opinion.

I recommend acceptance of the thesis for defense.

Questions, notes

- Some theoretical considerations are very vague in description and thus not very clear (e.g. eq. 87, 88 – what is "characteristic area", L?)
- Some terms used in thesis are obsolete, not used in modern theory any more. E.g. the term "laminar sublayer" as a part of a turbulent boundary layer is misleading, the term "viscous sublayer" is standardly used instead nowadays.
- As for the secondary flow, only first kind is taken into account (i.e. those caused by the channel curvature). However also the second kind is present in reality due to interaction of turbulent boundary layers on perpendicular walls in corners. What error could be associated with this simplification?
- The individual losses are modeled according to theirs physical mechanism, total loss is evaluated as sum of them. This concept anticipate no interaction between the individual losses-generating mechanisms, which is not fully realistic. What could be effect of the losses-generating physical phenomena interaction?

In Plzeň, 14/11/2016



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