Opponent's review of the dissertation thesis

By: Ing. Petr Straka, Ph.D.

Title of the dissertation thesis:
“Analytical and Computational Methods for Transonic Flow Analysis and Design“

Author: Ing. Jiří Stodůlka

Presented dissertation thesis deals with solving the parameters of near sonic two-dimensional flow. Main goal is combination of traditional analytical methods with nowadays numerical methods. In the final combination, the author sees very powerful and useful tool for flow-field analysis and for design process. This topic is repeated many times in the work.

After the introduction part, the author briefly deals with theory of the compressible flow, analytical solution at near sonic conditions and with numerical methods.

This is followed by chapter dealing with verification of numerical solution in case of two-dimensional inviscid flow in a channel with oblique shock waves. In this chapter the analytical methods are not used.

The following is a more comprehensive chapter comparing the numerical and analytical solution of flow around the profiles with sharp leading edge at near sonic speeds. The analytical solution is briefly described, but it is not done in this work but taken from the literature. For two cases the analysis using the heart polars was performed.

In the following key-chapter, the author shows usefulness of combination of analytical and numerical methods in case of design the symmetric supercritical nozzle. Proposed shape allows to reach the supersonic conditions followed by deceleration back to the subsonic regime without origin the shock waves.

Following chapter deals with application above mentioned methods for redesign the geometry of transonic blade profile in region near the sonic line. Resulting shape is compared with manually-performed modification and with optimization of parametrized profile.

The final part of the dissertation thesis contains discussion of results, summary and conclusions.

It can be stated that the objectives of the dissertation thesis were met.

An analysis of current state of art can be considered as sufficient.

The theoretical and practical benefit is obvious. The method of analytical solution of transonic flow field with both subsonic and supersonic domains was formulated. Transformation to the rheograph plane allows effective and illustrative flow field analysis in very sensitive domain near the sonic line. The combination with numerical methods makes the solution easier. Resulting linearized system of Beltrami equations can be simply solved using finite difference method. The power of combination both analytical and numerical approaches is useful particularly in the process of design.

The following opinions can be taken on the suitability of used methods, on the way they are applied and whether the author has demonstrated appropriate knowledge in the field:

Given the presented results and given the fact that the author has continuously presented obtained results at a number of international conferences, the author has demonstrated adequate knowledge in field of analytical and numerical solution of transonic flow fields. The way to solve this issue is correct.

However, some comments can be made about some parts.

It looks that some formulas contain little typos or some unclarity. In equation (2.60) there is no clear reason to change sign – to +. When deriving equations (2.62) to (2.64), it is unclear why a term of temporal derivation is omitted in comparison with equation (2.61). In a certain part of right hand side of equation (4.25) and index 'i–1/2' should be used instead of 'i+1/2'. The equation (5.18) basically says that $\beta_a < \beta_a$, similarly the equation (5.19).

It would be also appropriate in the introductory theoretical part of the dissertation thesis to mention the terms such as "limit characteristic", "neutral characteristic" or "polar".

The transformation of potential flow equations to the hodograph plane leads to the linear Beltrami system and subsequently to the Poison equation system that is then solved numerically in subsonic domain (eventually in extended subsonic region). This is the pivotal method of presented dissertation thesis. It would be useful briefly comment what is the effect of the space step of finite difference method with respect to the fact that the solution on the sonic line (s=0) is used as an input for the method of characteristic.

The need to averaging when taking the first step of the method of characteristic is mentioned. It would be appropriate to describe this in more details.

The above-mentioned example of the supercritical nozzle should serve as a new test case for validation of the numerical solution to the Euler equations system (similarly e.g. the Hobson's shock free transonic blade cascade [Hobson, 1974]). In such case, it would be more than appropriate to provide in appendix detailed coordinate table together with the Mach number distribution along the nozzle wall and along the nozzle centreline.

I have no comments on chapter 7. Perhaps only, in figure 7.19 there is visible the parasitic shock wave due to the interaction of wake with the outlet boundary, but this is not essential.

Please if the author could during the defense of the dissertation thesis in more details comment:

1. the averaging at first step of the method of characteristic,
2. choice of the similarity parameters A, B in equations (6.35) to (6.38).
3. Furthermore, please, if possible, perform the transformation of the parametric solution U, V, X, Y (fig. 6.2 to 6.5) from the working plane (s, t) to the physical plane (x, y) and this velocity field then compare with the numerical solution of the Euler equations (fig. 6.16) – at least for the subsonic domain.

The formal level of work is appropriate.

I recommend the thesis for defense.

In Prague, April 18, 2019 Petr Straka