FAX

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REMARKS: ☐ Urgent ☒ For your review ☐ Reply ASAP ☐ Please Comment

Dear Professor Van Aken:

Please find attached a report on the dissertation of Erasmus student Peter Van Cauwenbergh who is registered on our MSc. course in Thermal Power and Fluids Engineering.

Yours Sincerely,

Dissertation Report: Peter Van Cauwenbergh

1. Title

Review and Implementation of High-Resolution Upwind Schemes for Gas Dynamics

2. Abstract

The inviscid equations of gas dynamics can give rise to discontinuous variations in the variables characterising the flow due to the formation of shock-waves or contact surfaces. These features present a considerable challenge to numerical methods: First-order schemes produce relatively poor resolution of steep gradients, whilst second-order schemes with constant coefficients yield greater resolution but generate spurious oscillations. Much work, in the past fifteen years, has been directed towards designing oscillation-free second-order schemes using *non-linear* algorithms in which the coefficients are a function of the solution itself. The present work investigates the extension of Godunov-type schemes, which employ *Riemann solvers* to calculate the inter-cell fluxes, to higher-order accuracy using the *MUSCL* approach. This generic technique involves a piecewise-linear re-construction of the initial data within each cell and the subsequent *limiting* of the gradients of the gradients according to the *total variation diminishing* criterion

A variety of Riemann solvers were compared using Sod's shock-tube problem and one such scheme was selected and extended to second-order accuracy using the MUSCL approach. Several different limiters and time-stepping methods were coded, and the conventional approach of limiting using the conserved variables was compared with a 'wave-by-wave' limiter. The schemes were also compared with a space-centred (symmetric) TVD algorithm based on the two-step Lax-Wendroff method. The best scheme, in terms of accuracy, computational loading, and robustness was deemed to be the HLLC Riemann solver with wave-by-wave limiting and Hancock time integration.

Finally, the application of some of the Riemann solvers to pipes with varying area was investigated.

3. Use of Previous Work

The starting point for the project was a program written by myself which solved the shock-tube problem using several different first-order Riemann solvers.

4. Personal Contribution

Peter added another Riemann solver to the code mentioned above and found errors in the implementation of two of the methods already in the code. He then wrote a general extension to the code using the MUSCL approach to enable second-order accuracy to be achieved using any of the

Riemann solvers. This required a considerable amount of effort and was done in a very thorough and structured way.

5. Creativity

Although the work consisted mainly of implementing existing numerical methods, some of the techniques applied were very complex, not well documented, and required considerable understanding of the general field of numerical methods for gas dynamics. Peter showed much initiative in finding literature and also had the confidence to improve the efficiency of the algorithms contained in the literature. He coded the many different methods entirely on his own to create a code enabling different Riemann solvers, time integration methods, flux limiters, and types of limiting (ie. using conserved variables, or wave-by-wave limiting) to be compared for pipes with constant and varying areas.

6. Most Important Results

The most important results from the project were the comparisons of the different aspects (mentioned in 5) of the numerical methods studied and the creation of the computer program enabling this to be done.

7. Amount of Work Produced

Peter has worked extremely hard and the thesis represents what I consider to be a very large amount of work considering the very brief period allowed (a significant amount of which is taken up in the production of the thesis!), particularly since the taught part of the course touched only very briefly on the theory of a small part of the subject covered by this project.

Regarding points 5, 6, and 7, I should certainly rate Peter as in the best 5 % of the group.