COMPUTATIONAL ANALYSIS OF TWO-DIMENSIONAL INVISCID FLOW AROUND TURBINE CASCADE USING GAS KINETIC *BHATNAGAR-GROSS-KROOK* (BGK) SCHEME

B$_y$

SALEH NASER ABDUSSLAM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

June 2004

DEDICATED

TO

My Parents, Mona, and Abdalmalk
For all their love and understanding

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

COMPUTATIONAL ANALYSIS OF TWO-DIMENSIONAL INVISCID FLOW AROUND TURBINE CASCADE USING GAS KINETIC *BHATNAGAR-GROSS-KROOK* (BGK) SCHEME

By

SALEH NASER ABDUSSLAM

June 2004

Chairman: Associate Professor Megat Mohamad Hamdan, Ph.D.

Faculty : Engineering

Fluid flows within turbomachinery tend to be extremely complex. Understanding such flows is crucial to improve current turbomachinery designs, and the computational approach can be used to great advantage in this regard. This study presents a gas kinetic Bhatnagar-Gross-Krook (BGK) scheme to calculate the flow within a turbine cascade.

The two dimensional Euler equations with a numerical method based on the gas kinetic Bhatnagar-Gross-Krook (BGK) scheme was developed to simulate the flow around a turbine cascade configuration. The grids around the select model are efficiently generated using a multi-zone structure technique.

Computed results for the even studied cases were compared with experimental data in terms of Mach number distribution. Comparisons of these results with experimental data were made wherever possible and the agreement between the two is found to be good. In addition the gas kinetic Bhatnagar-Gross-Krook (BGK) scheme as the numerical procedure has been tested for its accuracy in solving the two-dimensional compressible inviscid flow fields. Analyzing the results in regular shock reflection revealed that the gas kinetic Bhatnagar-Gross-Krook (BGK) scheme is able to produce numerical results that are comparable, robust, and accurate as Roe's scheme. In addition, the gas kinetic Bhatnagar-Gross-Krook (BGK) scheme converges faster than Roe's scheme. For a given 1000 time iterations, the BGK scheme converges at 887 time iterations while the Roe's scheme converges at 906 time iterations. Therefore, the BGK scheme proved to be more efficient than Roe's scheme.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANALISIS BERKOMPUTER BAGI ALIRAN BOLEH MAMPAT 2-D DI SEKELILING LATA TURBIN DENGAN MENGGUNAKAN SKIM BGK (BHATNAGAR-GROSS-KROOK)

Oleh

SALEH NASER ABDUSSLAM

June 2004

Pengerusi: Profesor Madya Megat Mohamad Hamdan, Ph.D.

Fakulti : Kejuruteraan

Aliran bendalir dalam mesin turbo lumrahnya berkecenderungan untuk menjadi terlampau kompleks. Pemahaman tentang aliran sebegini sememangnya adalah suatu perkara yang mustahak bagi meningkatkan usaha reka bentuk mesin turbo pada masa kini. Untuk tujuan ini, kaedah pengiran mampu digunakan sejauh mana yang mungkin. Kajian ini akan membentangkan sejenis skim berangka yang dikenali sebagai skim gas-kinetik BGK untuk penyelakuan aliran dalam "lata turbin".

Persamaan dua dimensi Euler dengan kaedah berangka yang diasaskan kepada skim BGK gas-kinetik telah dibentuk untuk mengira aliran mengelilingi "lata turbin". Grid yang digunakan untuk model yang terpilih adalah berdasarkan kepada koedah struktur berbilang-zon.

Keputusan pergiraon untuk kes yang dikaji dibandingkan dengan data-data yang diperolehi daripada eksperimen. Pebandingan ini adalah berdasarkan kepada pengagihan nombor Mach. Hasil perbandingan ini menunjukkan bahawa persetujuan di antara keputusan pergiraon don eksperimen adalah memuaskan. Selain daripada itu, skim berangka BGK turut diuji

kejituannya dalam menyelesaikan medan aliran tidak likat boleh mampat dua dimensi. Hasil analisis dalan pemantulan kejutan biasa menunjukkan bahawa skim BGK mampu menghasilkan keputusan yang setanding, semantap dan sejitu skim Roe. Disamping itu skim kinetic Bhatnagar-Gross-Krook (BGK) menoapah lebih cepat dari skim Roe. Untuk 1000 kali iterasi, skim BGK menoapah pada 887 kali iterasi manakala skim Roe menoapah pada 906 kali iterasi. Oleh yang demikian skim BGK terbukti lebih etisyen dari skim Roe.

ACKNOWLEDGEMENTS

Every praise and thank are due to the Almighty Allah alone, the Merciful and peace be upon his Prophet who is forever a torch of guidance and knowledge for humanity as a whole. First, I would like to thank Allah for giving me this opportunity and patience to carry out this research.

I would like to express my greatest gratitude and deep appreciation to my supervisor, Associate Professor Dr. Megat Mohamad Hamdan Megat Ahmad for being so generous with his time and constructive criticism, his invaluable aid, and useful suggestions throughout the study. Thanks and appreciation are due to Dr. Ashraf Ali Omer for his genuinely intelligent guidance and useful criticism. I must gratefully acknowledge the help and critical interest of associate Professor Dr. Waqar Asrar. I strongly, believe that without their tremendous help and zeal, it would have been difficult to accomplish this task.

I would also like to thank the examination committee chairman Dr. Ahmad Shamsuri mokhtar for his comments and suggestions to reassure the success of the study. Iam most grateful to Libyan Higher Institute of Vocational Sabha, Libya for their co-operation and financial support conceded to my study. Iam also indebted to Universiti Putra Malaysia (UPM) for providing me with the necessary facilities to carry out this research. Great appreciation is also extended to all my colleagues and friends especially Mr. Ong Jiunn Chit, Omer Ali El-Sayed, and Mahmood K

Mawlood who have been wonderful in sharing their scientific knowledge and to all those who contributed directly and indirectly to the success of this study. However, acknowledgements will be incomplete if it had not been for my parents who have devoted their life and efforts to me, who have showered on me their love and moral support unconditionally and doubtless, prayed everyday for our success and prosperity.

Thanks also are extended to my brothers and sisters for their help and mutual understanding. Special thanks are extended to my wife Mona, and adorable kid Abdalmalk for being my family and best friends in Malaysia. I owe them my love and gratitude for their patience, understanding, support and continuous encouragement especially at times of hardship and difficulties. Last but not the least, I take great delight to seize this opportunity to express my thankfulness for those I havenot mentioned, their precious co-operative and guidance had made the period of my study at UPM an unforgettable chapter in my life.

I certify that an Examination Committee met on 4th June 2004 to conduct the final examination of **Saleh Naser Abdusslam** on his **Master of Science** thesis entitled **"Computational Analysis of Two-Dimensional Iviscid Flow Around Turbine Cascade Using Gas Kinetic Bhatnagar-Gross-Krook (BGK) scheme"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be award the relevant degree. Members of the Examination Committee are as follows:

Ahmad Shamsuri Mokhtar, Ph.D.
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ir. Mohd Sapuan Salit, Ph.D.
Associate Professor
Universiti Putra Malaysia
(Member)

Ir. Nor Mariah Adam, Ph.D.
Associate Professor
Universiti Putra Malaysia
(Member)

Ahmad Faris Ismail, Ph.D.
Professor
Faculty of Engineering
International Islamic University Malaysia
(Independent Examiner)

_____
GULAM RUSUL RAHMAT ALI, Ph.D.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science.
The members of the Supervisory Committee are as follows:

Megat Mohamad Hamdan Megat Ahmad, Ph.D.
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Waqar Asrar, Ph.D.
Associate Professor
Faculty of Engineering
International Islamic University Malaysia
(Member)

Ashraf Ali Omar, Ph.D.
Assistant Professor
Faculty of Engineering
International Islamic University Malaysia
(Member)

_____
AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotation and citations which have been duly, acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

_____

SALEH NASER ABDUSSLAM

Date:

TABLE OF CONTENTS