出國報告（出國類別：其他\國際會議）

Twelfth International Conference on Flow Dynamics (ICFD2015)

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出國時間：104 年 10 月 26 日至 104 年 10 月 31 日

摘要

本人參加於 10 月 26 日赴日本仙台參加 Twelfth International Conference on Flow Dynamics (ICFD2015) 研討會，此會議由日本東北大學(Tohoku University)主辦會議舉行期間為 10 月 27 日至 10 月 29 日。會議主題涵蓋計算流體力學、流體力學、熱傳、燃燒學及火箭科學等研究論文發表, 計來自 20 幾個國家參與，共發表兩百餘篇論文。會中本人應邀發表論文*(Invited lecture)*及擔任會議主持人(session chair)。本次會議提供觀摩其他國家研究人員及學者在流體力學及數值計算上之最新發展之機會及藉參與此次國際會議增進國際交流，對於日後研究有非常多之幫助。

目次

一、目的

藉參與此次國際會議一方面觀摩其他國家研究人員及學者在流體力學及數值計算上之最新發展，增加新知, 促進研發靈感。二、呈現自己之研究成果，除展現能量外亦可吸收其他學者之建議。三、透過會議可觀摩其他各國大學在流體力學上之研究重點。四、藉參與此次國際會議增進國際交流，除藉由研究主題及成果互相認識來自其他國家研究人員及學者，也藉此進一步對彼此之研究機構及大學能有所瞭解，增進未來國際交流及合作之機會。

二、過程

(一) 10月27日9:30~12:00參加Plenary Lectures演講

1. Highlights from a University/Government Collaboration -
   Old Dominion University and NASA Langley Research Center Colin Britcher (Old Dominion University, USA)
2. Drop dynamics in complex fluids: Partial coalescence and self-assembly
   James J. Feng (The University of British Columbia, Canada)
3. Challenges in Photovoltaics
   Noritaka Usami (Nagoya University, Japan)

下午聆聽其他演講包括:

(1) 氣泡液滴複雜流體之實驗與模擬:

1. Numerical Study of the Collapse of a Bubble Cluster
2. Diffuse-Interface Approaches to Miscible and Immiscible Hele-Shaw Flows
3. Numerical Visualization of Nanobubble Behaviors at a Roughened Solid-Liquid Interface under Influence of Surface Charge Density
4. Numerical Simulations and Experiments of Single-Phase Fluid Loop
5. Surface Oscillations of Magnetic Fluid in Magnet-Magnetic Fluid Systems under the Alternating Magnetic Field

(2) 渦輪葉片流場:

6. Simulation of Unsteady Wet-steam Flow in Low Pressure Turbine Stages considering Blade Number
7. Hironori Miyazawa (Tohoku University, Japan), Satoshi Miyake (Mitsubishi Hitachi Power Systems, Ltd., Japan), Satoru Yamamoto (Tohoku University,Japan)
8. DDES Simulation of Turbine Blade at High Subsonic Outlet Mach Number Xinrong

Su, Xin Yuan (Tsinghua University, China)

9. Conjugate Heat Transfer Analysis on the Film-Cooling Effectiveness of a Flat Plate with Trench Configurations Inkyom Kim, Jinuk Kim (Hanyang University, Korea), Dong-ho Rhee (Korea Aerospace Research Institute, Korea), Jinsoo Cho (Hanyang University, Korea)
10. Performance Prediction of Axial Fan by using OpenFOAM

(二)本人於10月28日9:00參加 OS13: Complex Thermofluid System session ，應邀發表論文*(Invited lecture)* ，發表題目為〞Simulations of Flow past an Inclined Flat Plate with Adaptive Nonconforming Spectral Element Method”，如附件。此篇是關於動態計算網格於譜元素法之應用，獲不錯之回響，亦當場與許多國外學者交換心得及聯絡方式。隨即本人主持OS13: Complex Thermofluid System 10:40~12:00之 session，每個session有5篇論文發表。

(三) 本人於10月29日10:00~16:00參加 GS1: General Session Aerodynamics (空氣動力學)

1. Numerical Investigation of Aerodynamic Characteristics of a Roof from the point of Venturi Effect and Wind-Blocking Effect (Tokai University, Japan)
2. A Low Frequency Calibration Device for Pressure Sensitive Paint (Tohoku University, Japan)
3. Performance Evaluation of Flapping Flight of Elastic Wing Using Parallel Partitioned FSI Method
4. PIV Measurement of Flow Field around Tandem Flapping Wings (Nagaoka University of Technology, Japan)
5. Flow Measurement around a Straight Wing Vertical Axis Wind Turbine using PIV Method (Tohoku University, Japan)
6. Aerodynamic Design of a Tip-mounted Ducted Fan Propulsion System for the Small UAVs (Hanyang University,Korea)
7. Performance Prediction of an External Nozzle under Low Altitude Flight Condition (Tohoku University, Japan)
8. Curvature of Shocks at Regular and Mach Reflection (Ryerson University, Canada)
9. Investigations on Compressible Mixing Layers in Confined Ducts (Muroran Institute of Technology, Japan)
10. Numerical Simulations of Free Jets from Square Supersonic Nozzles (The University

of Kitakyusyu, Japan)

三、心得

(一) 大陸學術機構研究成果近年來水準提高非常多，無論其質與量均達國際水準，特別在氣渦輪機等國家重要研究方向直逼在此方面有穩固基礎的日本。

(二) 印度在數值模擬方面不斷挑戰並提出新的計算方法及物理現象之數學模型。

(三) 我國參與學校也相當活躍如交通、清華大學等除提出多篇論文外，亦擔任會議委員及主持人，亦有與日本東北大學學術合作。

(四) 國內交通、清華大學等學校除教授親自參與外也讓其多名研究生親自上台以流利英語簡報成果及回答問題，讓學生有參與國際會議及英語發表經驗，我想技職體系學生也加以訓練，應該可以加強之處。

(五) 主持國際會議除會前與演講者互動交換名片, 更需事先準備提問問題, 可使會議進行順利。此次會議增加不少經驗。

四、建議事項

(一) 鼓勵及贊助研究生參加國際會議，訓練學生有參與國際會議及英語發表經驗。

(二) 教師亦多參加國際會議， 可瞭解最新研究趨勢，增進國際研究人員交流，增進未來國際交流及合作之機會。

五、 附錄 (論文)

Simulations of Flow past an Inclined Flat Plate with Adaptive Nonconforming Spectral Element Method

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ABSTRACT

The spectral element method with vorticity error based adaptive meshes refinement schemde, namely, adaptive nonconforming method is used to simulate flow past a inclinded flat plate. Simulations of flow past a flat plate with an angle of attack of 20° to 50° are performed with conforming mesh method and the adaptive nonconforming method. The results show that the adaptive nonconforming method can reduce the global L^2 error dramatically with only 62% of the element number of the conforming method. The results of adaptive mesh method with respect to Strouhal number, drag and lift coefficients deviate less than 1% from those of the conforming method.

1. Introduction

Flow past a thin airfoil is an interesting topic for science and engineering because it abounds with rich physical phenomena such as shear layers, leading and trailing edge vortices, laminar separation, vortex shedding, etc. It is also important for micro-aerial vehicles design.

Lam [1] investigated experimentally the shedding of vortices from an inclined flat plate. The results showed the trailing edge vortex in the separated wake possesses more intense vorticity levels but a smaller vortex size than the leading edge vortex. Breuer [2] conducted a large eddy simulation (LES) for the flow past an inclined flat plate in Re=20000, at an angle of attack of 18°. His study revealed Kelvin–Helmholtz instability in the free shear layer behind the leading edge and a highly asymmetric wake with vortices of unequal strength in the wake region.

However, there have been few studies of flow past a flat plate in hundreds of Reynolds number. Taira et al.[3,4] studied the flow past an inclined thin flat plate with immersed boundary method to simulated a synthetic jet type actuator to modify the dynamics of wake vortices. Brunton and Rowley [5] further used the immersed boundary method and proper orthogonal decomposition/Galerkin projection to simulate stationary flat plate in Re=100, 300 flow and study the full dynamic wake structures of a pitching or plunging flat plate. Sun and Boyd [6] used a hybrid method which combines Navier-Stokes solver for continuum region and information preservation method for rarefied region to simulate flat plate in low Reynolds number (Re < 200) and extremely low Reynolds number (Re < 10) flow. Their results show low Reynolds number flows are viscous and compressible, and rarefied effects increase when the Reynolds number decreases.

The purpose of this study is to validate the adaptive nonconforming mesh scheme of spectral element method for the critical regions such as leading and trailing edges of extremely thin flat plate in high angle of attack.

2. Method

The incompressible Navier-Stokes equations are solved as the following manners.

$$\frac{\partial \bar{u}}{\partial t} + \bar{u}\cdot\nabla\bar{u} = -\frac{1}{\rho}\nabla p + \nu\nabla^2\bar{u} \quad (1)$$

$$\nabla\cdot\bar{u} = 0 \quad (2)$$

A time splitting scheme [7] is introduced to separate the nonlinear convective terms from the diffusion terms. The nonlinear convective term is treated explicitly by using a third order Adam-Bashforth scheme due to its low dispersion errors and relatively large part of the imaginary axis included within the absolute stability region [8]. The pressure and diffusion terms are modeled as Helmholtz problems which are discretized by the spectral element method as shown below.

$$(\nabla^2 - \lambda^2)u = g \quad (3)$$

The variational form of Eq. (3) is implemented by Gauss-Lobatto quadrature in integral and Lagrangian interpolation Contributions are summed from adjacent elements to from the global matrix equation as follows.

$$(A - \lambda^2 B)u = Bg \quad (4)$$

where A is the discrete Laplacian operator and B is the mass matrix.

The nonconforming spectral element introduced by Bernardi et al. [9] provides a technique which only requires minimum L^2 errors on the interfaces between elements. The corresponding nonconforming equation of Eq.(4) in the case is

$$Q^T(A - \lambda^2 B)Qu = Q^T Bg \quad (5)$$

Q is a global projection operator matrix which projects the solutions from mortars to the interior points of the local edge of elements, whereas Q^T projects solutions from the local edge of elements to mortars. The detailed can be referred in the previous works [9].

In this study, the estimated error of vorticity is used as the mesh refinement indicator.

3. Results and discussion

3.1 Validation

For validation, present results are compared with the

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Blasius solutions in boundary layer. An extremely thin two-dimensional flat plate with its leading edge at x=0, the trailing edge at x=30, is used to approach a horizontal flat plate. The upper surface is kept in absolutely flat. The lower surface begins from the leading edge to the trailing edge asymptotically with maximum thickness, 1×10^{-5} unit, at trailing edge. The uniform flow boundary conditions ($u=U_0$, v=0) are employed in the inflow, upper and lower boundaries so as to set flow conditions, Re=140. The outflow boundary condition is employed in the most downstream boundary. There are 95 conforming spectral elements (K), employed as the initial mesh with the 11 order (N) of Gauss-Lobatto-Legendre polynomial the basis function.

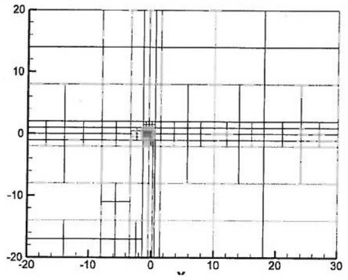

Fig.1 Nonconforming meshes (K=215) of zero degree of angle of attack after mesh refinement from a coarse mesh

After adaptive meshes refinement, the element number is increased to 215 as shown in Fig. 1. It shows mesh refinements are took place around the plate because viscous effect causes the large gradient in velocities. There are more vigorous mesh refinements at the sharp tip because the intersection between fluid and solid may cause the more difficulties in computation and generate larger errors. Fig. 2 shows the nondimensional velocity profiles at different stations (x=25 to 27) on upper surface agree well with Blasius solution. From these results, it demonstrates the adaptive nonconforming spectral element method can resolve the boundary layer problems with high accuracy.

3.2 Inclined flat plate

A length of the plate with only one unit at an angle of attack is employed to compare the accuracy and efficiency of the conforming and nonconforming method. There are 395 conforming spectral elements (K), employed for conforming approach. On the other hand, in the nonconforming approach, the initial coarse mesh with 95 elements. Fig. 3(b) shows the refined mesh after carrying out 50 times of mesh adaptation with the indicator based on the estimated error of vorticity. The mesh refinement regions are concentrated in the areas around the flat plate. The results from adaptive nonconforming meshes have good agreements with the counterpart done by conforming meshes as shown in Fig.3(a). This agreement also exists in α=20°, 40° as well as 50°.

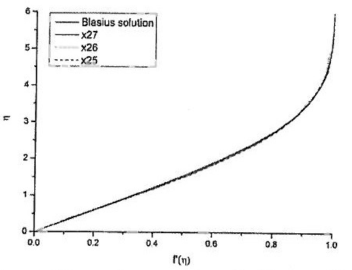

Fig.2 Comparison of present velocity profile with Blasius solution

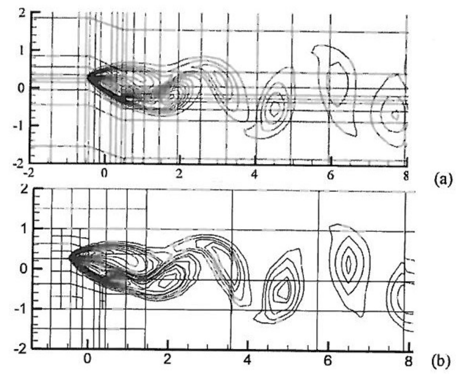

Fig.3 Vorticity contours of flat plate in α=50° (a) conforming method (b) Nonconforming method

4. Conclusion

This study shows the adaptive nonconforming method guided by vorticity error is a useful technique which performs the same or even better than the conforming method with respect to accuracy and computational cost.

References

[1] K.M. Lam, M.Y.H. Leung, *European Journal of Mechanics B/Fluids*, 24(2005)33–48.

[2] M. Breuer, N. Jovičić, *Journal of Turbulence*, 2 (2001)1–15.

[3] K. Taira, W.B. Dickson, T. Colonius, M.H. Dickinson and C.W. Rowley, *45th AIAA Aerospace Sciences Meeting and Exhibit*, (2007), 710.

[4] K. Taira and C. W. Rowley, *AIAA Journal*, 48 (8) (2010) 1785-1790.

[5] S.L. Brunton and C.W. Rowley, *47th AIAA Aerospace Science Meeting*, (2009) 1127.

[6] Q. Sun and I. Boyd, *Journal of Fluid Mechanics*, 502 (2004) 199- 206.

[7] S.A. Orszag and L.C. Kells, *Journal of Fluid Mechanics*, 96 (1980) 159-205.

[8] C. W. Gear, *Numerical Initial Value Problems in Ordinary Differential Equations*, 1971.

[9] C. Bernardi, Y. Maday, A.T. Patera, *Non-linear Partial Differential Equations and their Applications*, 11 (1994) 13-51.