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流體控制、量測及可視化國際研討會報告書

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赴義大利參加第七屆流體控制、量測及可視化國際研討會

主辦機關:

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分類號/目: G6／機械工程　G6／機械工程

關鍵詞:

內容摘要: 流場可視化是研究上一項相當重要的工作，藉由可視化技術，可將研究成果明顯且具體地呈現出來，電腦與雷射兩種技術在流場可視化應用上已相當的進步而且也相當成熟，是流場可視化主要的應用技術。8月25日~28日於義大利於蘇連多所舉辦的第七屆流體控制、量測及可視化國際研討會，發表論文範圍涵蓋相當廣，包含微流場可視化(Micro Flow Visualization)、多相流(Multi-phase)、分子追蹤可視化、高速與超音速流場、壓力與溫度感應塗料、先進PIV(particle Imagine Velocimetry)技術、電腦可視化、紊流等等，本次會議總共發表論文三百餘篇。個人在此次研討會中發表國科會補助專題研究成果論文一篇，由於主題爲CFD之工業應用類，因此產、學界參與者、聆聽者眾多，期間有些學者提出問題詢問，皆能加以詳細答覆，可說是圓滿達成任務。

本文電子檔已上傳至出國報告資訊網

摘要

流場可視化是研究上一項相當重要的工作，藉由可視化技術，可將研究成果明顯且具體地呈現出來，電腦與雷射兩種技術在流場可視化應用上已相當的進步而且也相當成熟，是流場可視化主要的應用技術。8 月 25 日~28 日於義大利於蘇連多所舉辦的第七屆流體控制、量測及可視化國際研討會，發表論文範圍涵蓋相當廣，包含微流場可視化(Micro Flow Visualization)、多相流(Multi-phase)、分子追蹤可視化、高速與超音速流場、壓力與溫度感應塗料、先進 PIV(particle Imagine Velocimetry)技術、電腦可視化、紊流等等，本次會議總共發表論文三百餘篇。個人在此次研討會中發表國科會補助專題研究成果論文一篇，由於主題為 CFD 之工業應用類，因此產、學界參與者、聆聽者眾多，期間有些學者提出問題詢問，皆能加以詳細答覆，可說是圓滿達成任務。

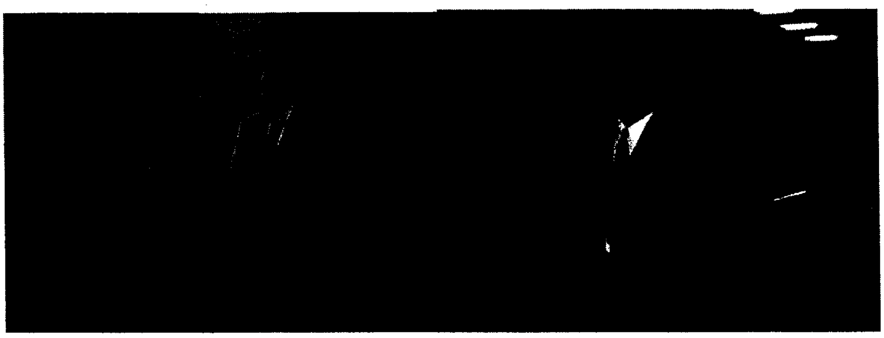
目　　次

一、 目的

本次出席第七屆流體控制、量測及可視化國際研討會之目的有二：其一爲發表研究論文一篇，題目爲[Flow Visualization and Film Cooling Effectiveness over a Flat Plate with Various Expanded Cooling Hole Geometries(經不同冷卻展開孔形狀之平板流之可視化與簿膜冷卻效應)]，另一爲學習流體控制、量測及可視化之 CFD 相關新知與學術交流。此次出國參加國際學術研討會，承蒙教育部給於補助，甚感榮幸。

二、 過程

本人於八月 25 日~28 日至義大利，參加在蘇連多所舉辦的第七屆流體控制、量測及可視化國際研討會(如圖一)。大會主席由 Napoli Federico 大學 Carlomagno 教授擔任。國內方面，有逢甲大學航空系宋齊有教授參與本次研討會的論文審查等相關工作。



圖一、作者出席蘇連多研討會會場剪影

本次會議共計接受發表來自世界各地有關流場可視化技術將近三百篇論文。本人於92年8月25日由高雄小港國際機場搭乘中華航空公司CI192 班機於台北時間07：10 起程，然後於中正國際機場轉機，搭乘中華航空公司CI067班機於台北時間08：55 起飛前往義大利。途中於泰國曼谷機場轉機停留，再搭乘原班機起飛，於義大利當地時間21:00時抵達羅馬機場，途中因遇羅馬天候不佳，雷雨交加，飛機三次盤旋與二次落地才安全落地；稍事休息後，隨即於當日轉搭火車前往大會所在地辦理報到。

本次研討會乃於 8 月 25 日(週一)開始正式進入議程，每天於上午安排一場全體參加之 invited lecture，然後緊接著於每個 session 之口頭報告(Parallel OralSessions)。此外，於 27 日之下午時段(14：00~18：00)則安排海報論文展示(poster session)。會議期間並同步進行廠商儀器展覽。論文口頭報告部分，分為四個場地(Room A、B、C、與 D)同時

進行。大會指定語言爲英語，每位演講者分配之報告及討論時間爲二十分鐘，本次會議總共發表論文三百餘篇，其間每個場次皆選擇感興趣之議題加以聆聽及研討。

個人在此次研討會中共計發表國科會補助專題研究成果論文一篇，題目爲：經不同冷卻展開孔形狀之平板流之可視化與簿膜冷卻效應(Flow Visualization and Film Cooling Effectiveness over a Flat Plate with Various Expanded Cooling Hole Geometries)。流場可視化是研究上一項相當重要的工作，藉由可視化技術，可將研究成果明顯且具體地呈現出來，電腦與雷射兩種技術在流場可視化應用上已相當的進步而且也相當成熟，是流場可視化主要的應用技術。本次發表論文範圍涵蓋相當廣，包含微流場可視化(Micro Flow Visualization)、多相流(Multi-phase)、分子追蹤可視化、高速與超音速流場、壓力與溫度感應塗料、先進 PIV(particle Imagine Velocimetry)技術、電腦可視化、紊流等等。會中並邀請在流場可視化方面學有專精的學者作演講，後續將依照時間順序，將參與研討會的心得說明如後：

92.8.26. 由美國佛州大學，工學院奈米生技中心的 Ching-Jen Chen 教授，發表奈米技術、微米技術及生醫應用之方向，演講重點如下：描述應用磁奈米粒子於醫療和診斷探查生物組件於微系統方面的一些發展。內容包括有三(1)奈微米生物技術的歷史發展，(2)在微生物

組件之微系統中流動特性，(3)如 micropumps 之微裝置的發展。

92.8.27 由西班牙 Industrie Pininfarina 的 Cogotti A.教授，發表 PININFARINA 洞由穩態至非定常狀態空氣動力與氣動聲學之效能測試評估，演講重點如下：以汽車道路上運行之空氣動力與氣動聲學現象測評一個機動全尺度風洞能否達最好的水準。以該機構第一個生產型機動風洞在過去十年間產生一些局限，無法真實表現運動中之汽車，特別是氣流之擾動及影響。 爲了真實模擬道路條件，在 1995 年 Pininfarina 結合"滾動道路"，使汽車行駛之風洞測試仿真，並分析噪音之影響與分佈。

92.8.28 由美國喬治亞理工學院的 Binn 教授，發表斜外吹預混式燃燒室減少氮化物氣體瞬持控制限制，演講重點如下：探討斜外吹預混式燃燒室使用即時控制方法減少氮化物排氣，針對控制系統發現對燃燒室和飛行員注射器主要的預混流動氣流之間會使燃氣流動分佈均勻且穩定，研究內容探討各種控制方法以比對氮化物排氣之比例。

本人之議程被安排於 8 月 26 日(週二)，12：00~12：20，Room D 第四位口頭報告(Oral Presentation)。經由大會所安排之 Chairmen 介紹後，開始本人之口頭報告。由於主題爲 CFD 之工業應用類，因此產、學界參與者、聆聽者眾多，期間有些學者提出問題詢問，皆能加以詳細答覆，可說是圓滿達成任務。口頭報告後有一位來自印度之學者對

於本人之研究深感興趣，想進一步瞭解研究之過程。

於 8 月 28 日下午議程結束之後，參加會後之參訪行程，瞻仰義大利之藝文古物與建築;8 月 30 日行程結束後隔日隨即搭火車回羅馬旅館休息一晚，隔日(9 月 1 日)搭乘中華航空公司 CI068 班機於羅馬時間 22：00 起程，於本地時間大約 9 月 2 日(週二)20：30 抵達中正國際機場，再轉搭接泊機華航 CI197 班次於 21:50 起飛 22:50 抵達高雄，結束本次義大利之行。

三、 心得

本次之研討會論文包含流體之實驗與計算之可視化相關探討，內容大多工業應用、生醫工程、微機電居多，同時中國大陸及日本之學者近乎 1/3，可見亞洲人之活躍於此領域；亦另一方面，參與本次會議最大的感觸是，大會中雖以英語爲報告之主要語言，然義大利人平時不常使用之，一般人大學時才修習英語相關課程，對國際化恐有商榷之處。

四、 建議

由於義大利生活費水平頗高，本次行程承蒙國科會補助機票費用，希望下次行程能在經費許可下，亦再能另補助部份生活費。

附錄一

FLOW VISUALIZATION AND FILM COOLING EFFECTIVENESS OVER A FLAT PLATE WITH VARIOUS EXPANDED COOLING HOLE GEOMETRIES

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Keywords: *computational fluid dynamic, impingement cooling, film cooling, lateral diffused hole*

ABSTRACT

Computations have been conducted on a flat, three-dimensional discrete-hole film cooling geometries that included the mainflow, injection tubes, impingement chamber, and supply plenum regions. The geometrical shapes of the vent of the cooling holes are cylindrical round, simple angle (CYSA) 、forward-diffused, simple angle (FDSA) and laterally diffused, simple angle (LDSA). Diameter of different shape of cooling holes in entrance surface are 5.0mm and the injection angle with the main stream in streamwise and spanwise are 35^o and 0^o respectively.

The governing equation is the fully elliptic, three-dimensional Reynolds-averaged Navier-Stoke's equations. Four other two-equation turbulence models, i.e. standard k-ε, low Reynolds number k-ε, RNG k-ε, and low Reynolds number k-ω, have been tested. The simulated streamwise distribution of spanwise-averaged film cooling effectiveness exhibited that low Reynolds number k-ε model gives the best fit to the experimental data of the previous investigators. Present study discovered that the geometrical shape of the cooling holes has great effect to the adiabatic film cooling efficiency especially in the area near to the cooling holes. When the blowing ratio is increased to 1.0 and 1.5, the LDSA has shown a better cooling performance than other shapes. It is due to the structure of the FDSA and LDSA is capable of reducing the momentum of the cooling flow at the vent of the cooling holes, thus reduced the penetration of the main stream. Moreover, the structure of the LDSA can increase the lateral spread of the cooling flow, thus improves the span wise average film cooled efficiency.

1 INTRODUCTION

In pursue of higher thrust and heat efficiency of a turbo engine, the proper and effective protection for the turbine blades working under a high temperature and pressure environment has been an inevitable task. External film cooling was widely used to reduce the heat stress. The working principle of the film cooling is to let the lower temperature passes through the holes on the surface of the blades, in order to form an air film with lower temperature between the surface of the blade and the main stream to protect the turbine blade Figure 1 [1] shows the diagram of the internal cooling system for a turbine blade. The cooling stream flow will eject through the impinging holes into the impinging chamber when it enters the blade and achieves the cooling purpose by flowing through the film cooling holes to the surface of the blade.

Film cooling and impingement cooling are two of the main studies in this topic. Some of the film cooling flat-plate studies with cylindrical holes are carried out by Ammari et al. [2], Goldstein et al. [3] and Baldauf et al.[4,5]. While Loftus and Jones [6] as well as Ligrani et al. [7] has applied various working fluid to the cooling flow in order to study the film cooling efficiency under different density ratio.As the authors' knowledge, one of the systematic researches that concerned about the film-cooled problems with three-dimensional computational approach was accomplished by Leylek and Zerkle [8] who used a flat-plat model with one row of five cylindrical holes to analyze the effects of blowing ratio and hole length-to-diameter ratio on film cooling performance. They have adopted the wall function of standard k-ε turbulent model to treat the near-wall quantity of turbulent profile. In spite of flow passage of mainstream, the computational domain also included the cooling flow at the supplying plenum, and coolant pipes. The flow structure of the velocity vectors on different streamwise planes normal to cross-stream is very complicated and they have also concluded that there is also a pair of counter-rotating vortex which dominated the interaction of individual coolant jet and cross mainstream. The local jetting effect occurred within the coolant pipes will significantly affect the distributions of film cooling effectiveness on the near-hole field. Later Hyams and Leylek [9] have focused on the detailed analysis in physics of film cooling process for five kinds of shaped, streamwise-injected, inclined jets. This study suggested that the crucial flow mechanisms downstream of discrete-cooling hole could be clarified from a vorticity point of view. It can be observed from their results that the shape of the cooling holes has great effect to the downstream film cooling performance.

Gritsch et al. [10] has used infrared thermal-photographic system to analyze the heat transfer coefficients in the near-hole region of various shapes of the cooling hole with a flat-plate model. The results show that fan type design with laterally expanded hole will have a lower heat transfer coefficient distribution when the blowing ratio is higher.

In order to improve the heat transfer in the advance turbine blade, the cooling stream is being cooled twice where the cooling stream will complete the internal cooling inside the impingement chamber before blowing out from the cooling pipes beneath the surfaces of the blade to perform the external film cooling. Behbahani and Goldstein [11], Huang et al.[12], and Azad et al.[13] have literatures on the study of heat transfer of the impingement cooling in the turbine blade. Downs and James [14] has suggested that the factors that affect the heat and mass transfer of the impingement cooling are: geometrical structure, temperature, the interaction between the cooling stream and the lateral stream, strength of the turbulent and the structure of the hole of the cooling jet. Viskanta and Huber [15] also pointed out that the factors that affect the performance of the impingement cooling are: interaction between of the jet and wall, separation distance, distance between the adjacent jets, diameter of the hole of the jet, characteristic of the main stream and the surface topology of target plat. All the above studies focus on the heat transfer of a physical flat plat impingement cooling with several effusion holes

One of the major conclusions in a review article of Schiele and Wittig [16] is that there is very close relationship between the supply type of the cooling flow and the film cooling performance due to the variation of discharge coefficient and local jetting effect within coolant pipes. However, most of the studies nowadays still focus in experimental simulations, and there is no literature so far has systematically investigated both the internal impingement cooling and external film cooling together with numerical approach. Therefore, the main features of this study are: (1) Realistic, dual function of internal impingement cooling and external film cooling geometries have been used that included the mainstream, two rows of staggered injection coolant pipes, impingement pipe-plate, and the supply plenum regions, (2) the effects of shape of hole and blowing ratio on film cooling effectiveness have been studied, and (3) the underlying reasons for these effects have been discussed using velocity contours and velocity vectors at centerline of each of coolant pipes and at several cross-stream planes downstream of holes.

2 NUMERICAL MODEL

Figure 2 shows the numerical model of the impingement cooling and film cooling flat plate used in this paper. The path can be separated into the rectangle shaped path for the upper mainstream and the path for the lower cooling stream from the two rows of staggered cooling holes, while an impingement region is set in the path of the cooling stream. That is, a three dimensional computational domain is formed by the rectangle mainstream, the collocated cooling holes and the supplying path of the cooling stream, while an impingement chamber with array of holes is setup in the cooling flow supplying path located beneath twice the diameter of the cooling hole from the entrance of the cooling holes to simulate the internal impingement cooling effect. The size of the path of the mainstream is 100mm $\times$ 100mm $\times$ 800mm (width $\times$ height $\times$ long), while the size of the path of the cooling stream is 45mm $\times$ 90mm $\times$ 185mm (width $\times$ height $\times$ long). The area with an "A" mark in Figure 2 included the impingement cooling holes array, impingement chamber and the two rows of film cooling holes array.

The close view of the area can be seen in Figure 3. There are two rows of film cooling holes where the first row from the upper stream has five holes order in equal distance, and the second row will have four holes. The two rows are staggered with each other. The streamwise angle between the axis of each cooling hole and the main stream is 35°, and the spanwise angle between the axis and the crossflow direction is 0°. The diameter of the entrance of the cooling hole (D_c) is

5mm, where the ratio between the diameter of the entrance of the cooling hole and the length of the cooing hole is 3.5, and is 3.0 with the distance to the center of the next parallel row as well as the longitudinal row. Where the impingement hole arrays are nine holes in three row or 8 holes in 2 rows, with a total of 43 impinging holes, where the nine holes are arranged interlace with the eight holes. The diameter (D_i) and the length of the impingement holes are 5mm and 10mm respectively, and the distance between holes is $2xD_i$, while the impingement distance (distance from the exit of the impingement hole and entrance of the cooling hole) is also $2xD_i$.

We have studied three kinds of geometrical shapes of hole in this paper, which are:

(1) Cylindrical round, simple angle hole (CYSA), as shown in figure 4(a)

(2) Forward-diffused, simple angle hole (FDSA), where a taper angle of 15° is applied to the trail edge of exit, as shown in figure 4(b)

(3) Lateral diffused, simple angle hole (LDSA), where a taper angle of 15° is applied to both lateral sides of exit, as shown in figure 4(c).

3 GRID SYSTEM

A lot of studies, Schiele and Wittig [16], have stated that the performance of the film cooling for the surface of the sample is highly related to the flow physics of distinct jet within the cooling pipe and the feed path of the supplying cooling stream. In order to present the characteristic of the heat flow field by the dual effects – internal impingement cooling and the external film cooling, we have included the supplying area of cooling stream, impingement-pipes plate, impingement chamber, cooling pipe array and the main stream as the computational areas.

Because of the geometrical complexity of impingement cooling/film cooling problems, the physical model and structured multi-block grid system will be generated by the HEXA module in software package ICEM/CFD. Grid sensitivity studies study that with the low Reynolds number κ-ε turbulence model using wall function, grid-independent results can be obtained with 87x47x117 nodes in x-, y- and z-directions. The nodes were considered refined in the near-wall regions of tested plate and in the vicinity of the injection hole. The y^+ value in the first cell adjacent to the sample walls was set always below 1 with respect to the criteria required for the individual near-wall treatment. Figure 5 shows the grids system of the exit of the LDSA cooling holes and region near the surface of the sample plate. The multi-block topology and high quantity of grid system can be clearly observed.

4 GOVERNING EQUATIONS

The numerical solver is a package of software, CFX-4.4, which was developed by AEA to solve the conservation governing equations, i.e. three-dimensional Reynolds-averaged Navier-Stoke's equations. While the scalar advection-diffusion in conservative form is written as:

$$\frac{\partial}{\partial t}(\rho\Phi) + \nabla\cdot(\rho\bar{U}\Phi - \Gamma\nabla\Phi) = S \qquad (1)$$

The continuous equation, momentum equations and the energy equation can be expressed as below:
Continuous equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \bar{U}) = 0 \qquad (2)$$

Momentum equation:

$$\partial \rho \bar{U} / \partial t + \nabla \cdot (\rho \bar{U} \otimes \bar{U}) = B + \nabla \cdot \sigma \qquad (3)$$

where σ is the stress tensor, stated as below:

$$\sigma = -\mathrm{p}\delta + (\zeta - \tfrac{2}{3}\mu)\nabla \bullet \bar{\mathrm{U}}\delta + \mu(\nabla \bar{\mathrm{U}} + (\nabla \bar{\mathrm{U}})^{\mathrm{T}}) \qquad (4)$$

Energy equation:

$$\partial \rho H / \partial t + \nabla \cdot (\rho \bar{U} H) - \nabla \cdot (\lambda \nabla T) = \partial p / \partial t \qquad (5)$$

where H is total enthalpy defined as below:

$$H = h + (1/2)\bar{U}^2 \qquad (6)$$

where h is static enthalpy, ρ is the density of the fluid, $\bar{U} = (U,V,W)$ is the velocity, P is the pressure, T is the temperature, t is the time, B is the body force, μ is the dynamic viscosity, and ζ is the bulk viscosity.

Numerically, the transport equation will be discretized with the conservative finite volume method. The advection term will be approximated with the Hybrid difference scheme, while all others will use the Central difference scheme. The coupler between the velocity and the pressure will use the SIMPLEC algorithm.

5 TURBULENCE MODEL

Since the characteristic of the thermal-flow field downstream of cooling holes is strongly affected by the interaction between the cross mainstream and the two rows of inclined cooling jet, the accuracy of simulated results by different turbulence models should be validated in advance. Present study started with a simpler model in Ai et al.[17], and used the one row of round discrete-hole flat-plate model from their experiment for the numerical simulation. Four runs with each of turbulence models, i.e. k- ε [18], Low Reynolds number k- ε [19], RNG k- ε [20], and Low Reynolds number k-ω[21], are conducted in order to come out with the most suitable turbulence model for the present grid system and numerical methods of this kind of heat flow field. Generally, some of the above turbulence models for the viscous laminar sublayer within the developing boundary layer flow can be process by introduced the logarithmic wall function. The complete mathematical theory and the associated boundary conditions for solving of turbulent kinetic energy and rate of dissipation energy can be referenced to [21].

6 BOUNDARY CONDITIONS AND STUDY MATRIX

The normal speed of the mainstream is uniform set as 10 m/s, therefore the corresponding Reynolds numbers with the diameter of the cooling holes at entrance surface as the characteristic length is 3400. For simulation of film cooling effect, the temperature of the mainstream is maintained as 333K, and temperature of the cooling stream is lower as 293K. In addition, the turbulence intensity and dissipation length at the inlet boundary of mainstream are 4% and 15 % of hydrodynamic diameter, respectively. The same turbulence intensity is set at inlet boundary of coolant but the dissipation length is changed to D_c value. The mass flow rate of coolant will be determined by the tested flow parameter, which is blowing ratio defined as below:

$$B_r = \frac{\rho_c u_c}{\rho_m u_m} \qquad (7)$$

Where ρ and u are the density and speed respectively, the subscript c and m are the coolant flow and mainstream respectively. The blowing ratios being used in this paper are 0.5, 1.0 and 1.5 with the density ratio of 1.14. The surface boundary condition of the solid walls are all defined to be non-slip and adiabatic. Pressure boundary condition is specified at the exit of mainstream flow passage. The study matrix is listed in Table 1, including of information on applied blowing ratio and shapes of the cooling hole.

In spite of the velocity contours and velocity vectors shown at different cross planes, the computational results are displayed and compared by introducing an important non-dimensional quantity- local adiabatic film cooling effectiveness, defined as:

$$\eta = \frac{T_{aw} - T_m}{T_c - T_m} \qquad (8)$$

Where T is the absolute temperature, the subscript aw is the adiabatic wall, c is the cooling stream, and m is the main stream.

7 RESULTS AND DISCUSSIONS

7.1 Turbulence Model Selection

Since there is a lack of experimental data to validate the computational results when using film-cooled flat plate models with internal impingement cooling chamber, a prior numerical study with a simpler geometrical model was achieved. In literatures, a lot of studies investigation on effects of flow several parameters on thermal-flow structure and film cooling performance of one-row of discrete-hole cooling plate to reference. Figure 6 shows the simulated streamwsie distributions of spanwise-averaged film cooling effectiveness results with different turbulence models as the turbulence enclosure. The blowing ratio is 0.5. The experimental result conducted by Ai et al. [17] is also included in Figure 6 for comparison. It should be noted that present simulated geometrical model and the proper boundary conditions are set as the same as those of Ai et al. [17].

Figure 6 shows that the numerical results from laminar, standard k-ε and RNG k-ε have a greater deviation with the experimental result of Ai et al. [17], while the results from the Low Reynolds number k-ε and Low Reynolds number k-ω are all closer to the experimental data. Owing to the restrictions of study period and computer memory, this study will adopt the Low Reynolds number k-ε turbulence model to deal with all the Reynolds stress items in further runs.

7.2 Sensitivity test of the grids system

One of the aims of present study is to setup a complex flow domain for simulation, where the computational areas include the supplying tank for the cooling stream, impinging holes array, impinging chamber, film cooling holes array and the main stream. Three sample grid systems being used are named M1, M2 and M3, where total numbers of grids are 772068, 966614 and 1040604 respectively. Since the total computational area is very complicated and the main issue being considered is the distribution of the film cooling effectiveness for different blowing ratios, the major difference among the three grid systems would be the number of nodes close to intersection regions of coolant pipes and mainstream duct. Moreover, the thickness of the grid system M2 and M3 at the first layer of cell above the sample surface is ensured the Y^+ value less than 1. When the blowing ratio is set to 1.5, the distribution curve for the spanwise-averaged adiabatic film cooling effectiveness is shown in Figure 7. Grid sensitivity tests using M2 and M3 grid systems show that the deviation in $\overline{\eta}$ results is minor for most portions of tested sample. Consider the time cost and efficiency for computing; the M2 grid system is selected for all further runs.

7.3 Distribution of the local film cooling efficiency

Figure 8 shows the top view of the exit of the cooling-pipes array, where the main stream is flowing to the right. The cooling holes at the left side are marked as the first row, where the cooling holes at the right side are marked as the second row. The first row contains five cooling holes marked as H1~H5, while the second row have four cooling holes marked as H6~H9. The first and second rows are arranged staggered. The location of the central of the first row of the cooling holes of the main stream is defined as $Z/D_c=0$, while the location of the central of the second row of the cooling holes of the main stream is referred as $Z/D_c=3$. The contours of the local adiabatic film cooling effectiveness for different shapes of cooling holes when the blowing ratio is 0.5, 1.0 and 1.5 respectively are shown in Figures 9(a)~(c). Different shapes of cooling holes will result in a remarkably difference on laterally spreading of higher local adiabatic film cooling effectiveness under same blowing ratio especially at the area near the exit of the cooling stream. Basically, the area covered by the cooling stream for all tested three kinds of shapes of hole is larger with increasing of the blowing ratio.

Figure 9(a) shows that only downstream regime that next to the exit of the cooling hole has a higher η value. Further downstream, because of the jetting effect within path of cooling pipes and the strong turbulence shear flow structure as meeting with the cross mainstream, the visible protection region which is relating to the streamwise movement of discrete-hole ejected coolant stream will obviously diminish and present as a triangular-like shrink profile in η distribution. In area of adjacent holes for each row, simulated results displayed that periodic lower η value would cover the mainly section, which indicates that the CYSA structure is not able to provide a cooling effect at the lateral direction. The distribution of η for FDSA cooling holes can be seen in Figure 9(b). The main difference between Figure 9(a) and Figure 9(b) is the longer distance of high η

value distributed at the downstream trailing edge of the FDSA cooling holes. The taper anger of 15° at the trailing edge has successfully reduce the momentum of the cooling stream at the exit of the cooling hole and reduce the penetration effect into the main stream, thus would provide a better cooling performance at the surface of the sample.

Figure 9(c) is the distribution of η value for the LDSA cooling hole structure at various blowing ratios. LDSA cooling hole has a remarkably wider area of surface of the sample that is being protected by the cooling stream compare to both FDSA and CYSA at the same blowing ratio. This is due to the extended 15° taper angle consideration at both lateral sides of the exit of the cooling hole will increase the flow area of the cooling stream, therefore a reducing in momentum ratio for prevention of penetration effect and weakly the strength of shear flow at high blowing ratios. Figure 9(c) also shows that a remarkably reduce of low η region between two LDSA cooling holes compared to CYSA and FDSA cooling holes structure due to the lateral flow spreading effect. Generally, the lateral spreading effect of the cooling jet in LDSA has a relatively even cooling protection effect on the surface of the sample.

7.4 Characteristic of the flow field

Walters and Leylek [22] stated that the distribution of the film cooling effectiveness on the surface is controlled by two primary mechanisms. The first is concerned with the jetting flow structure within the film hole itself. The second mechanism is due to the interaction of individual coolant jet and the cross mainstream. Pairs of counter-rotating vortex dominate the developing of thermal-flow structure over the surface of discrete-hole film cooling plate. When the blowing ratio is equal to 1.5, Figures 10 shows the velocity contour plot of H3 at centerline cross plane for CYSA, FDSA and LDSA types of holes. When the cooling streams pass through the impingement pipes and flow into the cooling pipe, inspection on Figures 10 reveals that part of cooling streams may encounter a larger turning angle near the leeward side of cooling hole in lower section. Moreover, the cooling stream would pass more smoothly into the windward side of cooling hole. A major feature of "jetting flow" which is caused by the non-uniform velocity distribution at the entrance of cooling hole can be observed from present numerical results.

Generally, the structure of the flow field at the lower part of the cooling pipe is basically displayed with uneven fork in the curl region, which shows a higher momentum at the leeward slope but shows a lower momentum at the windward slope at tested range of blowing ratio. That is, the four parts of jetting flow, i.e. the separated/back flow area near the cooling hole entrance, the re-attachment area, developing area and the area at the tail end downstream near the cooling hole which affected by the main stream can be demonstrated from the velocity contours. In addition, a highly shear layer downstream of jet exit produced by the cooling stream penetrating into the mainstream can be observed which will cause the local film cooling effectiveness to be reduced rapidly at the near-field of jet-crossflow intersection (Figure 10(a)). Figures 10(b), and 10(c) are the results from FDSA and LDSA types of hole, respectively. The forward-expanded hole structure can effectively moderates the degree of lift-off phenomena occurs in a high momentum cooling stream. When the structure of the hole is to be replaced by a LDSA type of hole, the lateral expanded hole will increase the cross section of the exit and perform a lateral spreading effect. Thus characteristics of the flow fields for CYSA and FDSA are quite different. Figures 10(c) has clearly show the location that show a high momentum cooling stream is focus on the half way to the exit of the pipe instead of the region closer to the exit of the hole, where each cooling streams are interacting evenly with the mainstream and given a highest local film cooling effectiveness.

Downstream of two rows of staggered holes at cross-stream plane Z/Dc=6, Figure 11(a)~(c) show the velocity vector for CYSA, FDSA and LDSA respectively when the blowing ratio is equal to 1.5. The counter rotator vortex pairs generate by the cooling stream ejected from the second row of cooling holes H6~H9 can be observed clearly from Figures 11(a) and 11(b). The expanding angle at the exit of FDSA has resulted in a closer attach of the vortex to the wall of the sample. This also indicates that the expanding angle can effectively reduce the lift-off of the jet from a cylindrical hole under high blowing ratio. Figure 11(c) shows a lateral expanded angle of the LDSA type of hole that can avoid CRVP. Since the high temperature mainstream will impact on the wall due to the downwash effect of CRVP and breakup the complete and equilibrate development of the cooling film, LDSA shows the best performance in high blowing ratio (Figure 12(c)).

7.5 Distribution of the Spanwise-Averaged Film Cooling Effectiveness

The effect of different types of cooling holes can be observed from Figure 12(a) under fixed blowing ratio of B_r=0.5. In the near-field jet-crossflow region of $Z/D_c \leq 6$, a visible difference in spanwise-averaged film cooling effectiveness for different shape of hole is existed. At Z/D_c=1 and 4, i.e. locates next to the downstream of the cooling hole, FDSA gives the highest value of $\bar{\eta}$, then CYSA, while LDSA type of hole shows the lowest value. At Z/D_c=2, FDSA still gives the highest value of $\bar{\eta}$, then LDSA, and CYSA type of hole shows the lowest value. The distribution of $\bar{\eta}$ for the three types of holes are very close to each other between Z/D_c=6 to 25. The FDSA structure still exhibits the highest spanwise-averaged film cooling effectiveness when the blowing ratio is 1.0, shown in Figure 12(b). The $\bar{\eta}$ value for LDSA is higher than that of CYSA downstream of cooling holes. When the blowing ratio further increases to 1.5, Figure 12(c) shows that the $\bar{\eta}$ value of LDSA structure in region of $0 \leq Z/D_c \leq 12$ is the highest among the three types of holes, while CYSA shows the lowest value of all. We can also discover that the $\bar{\eta}$ values do not change much for FDSA and CYSA near the cooling hole by comparing Figures 12(b) and 12(c), however, still maintain a higher $\bar{\eta}$ value farther at the downstream. Figure 12(c) also shows that, in between Z/D_c=20~25, the $\bar{\eta}$ value of LDSA is slightly lower than CYSA and FDSA, which is due to part of the cooling stream produce a stronger lateral spreading effect by LDSA structure.

8 CONCLUSION

This paper has performed a systematic numerical simulations on the characteristic of the 3-D thermal-flow field of a impinging cooling/film cooing dual effect sample flat plate with different kinds of hole shapes under three blowing ratios (B_r = 0.5, 1.0, and 1.5). The cooling holes are distributed in two rows that interlace between each other in pitch of three times of diameter of hole. The types of holes being used in the study are: cylindrical round, simple angle hole (CYSA), forward diffused, simple angle hole (FDSA) and lateral diffused, simple angle hole (LDSA). Some major conclusions are drawn out from the numerical results and listed as below:

(1) The present paper accomplished a realistic cooling study on turbine blade with numerical approach. The tested sample is a film-cooled flat plate with internal impingement cooling chamber. Using ICEM/CFD as the preprocessor, the multi-block and body-fitted computational grid system that includes the mainstream duct, two-rows of cooling pipes, impingement chamber, and supply plenum regions is successfully constructed.

(2) The simulated velocity contours clearly displayed that the structure of the flow field within cooling hole tube can be separated as the windward high momentum area at the entrance, the contrariwise low momentum at split of the curl, central developing area and the exit region that directly affected by the main stream. The structure of jetting flow is under the influence of both geometrical shape of hole and blowing ratio. Further, CRVP are observed clearly in both shapes of CYSA and FDSA. Simulated results also exhibits that CRVP no longer exist for LDSA hole, especially for high blowing ratios. Thus, LDSA will provide better protection on sample surface.

(3) The geometrical shape of cooling hole plays a significant effect to the adiabatic film cooling effectiveness. Near field of jet-crossflow intersection, LDSA hole would give a better later coverage of the cooling stream on the surface of the sample flat plate. Far downstream, CYSA and FDSA are able to provide a longer cooling distance for the film cooling effect.

(4) The FDSA shape has shown a higher value in distribution of spanwise-averaged film cooling effectiveness when B_r=0.5. However, as blowing ratio is increased to 1.0 and 1.5, the LDSA has shown a better cooling performance than other shapes. It is due to the structure of the FDSA and LDSA can reduce the momentum of the cooling flow at trailing edge of cooling holes, thus reduced the penetration of the main stream. Moreover, the structure of the LDSA can increase the lateral spread of the cooling flow, thus improves the spanwise-averaged film cooling effectiveness.

ACKNOWLEDGEMENT

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NOMENCLATURES

B	body force, kg
Br	blowing ratio
D_i	diameter of the impinging hole, m
D_c	diameter of the film cooling hole, m

H total enthalpy
h static enthalpy
k kinetic turbulence
L thickness of the sample
p pressure, Pa
S source
T_{aw} adiabatic temperature of the wall, K
T_c temperature of the cooling stream, K
T_m temperature of the main stream, K
t time, s
$\vec{U}$ velocity vector of x, y, z direction
U,V,W velocity of x, y, z direction, m/s
u_c velocity of the cooling stream, m/s
u_m velocity of the mainstream, m/s
x,y,z coordinates

Greeks

Γ diffusion coefficient
ε dissipation rate
η adiabatic film cooling efficiency
ρ_c density of the cooing stream, kg/m^3
ρ_m density of the main stream, kg/m^3
σ stress tensor, N/m^2
Φ dependent variable

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TABLES AND FIGURES

Table 1 、Study Matrix

Numerical Model	Blowing Ratio	Turbulence Model
One row CYSA (Ref. Ai et al. 2001)	0.5	k- ε ,Low Re k- ε ,RNG k- ε ,Low Re k- ω
Two row CYSA	0.5,1.0,1.5	Lo Re k- ε
Two row FDSA	0.5,1.0,1.5	Lo Re k- ε
Two row LDSA	0.5,1.0,1.5	Lo Re k- ε

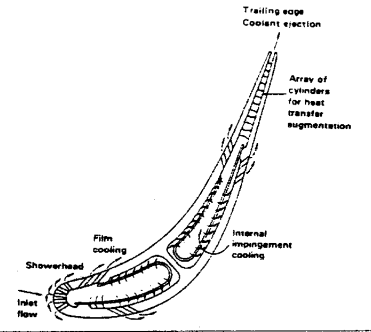


Fig. 1-Schematic of cooling arrangement in a turbine blade, Taylor [1980]

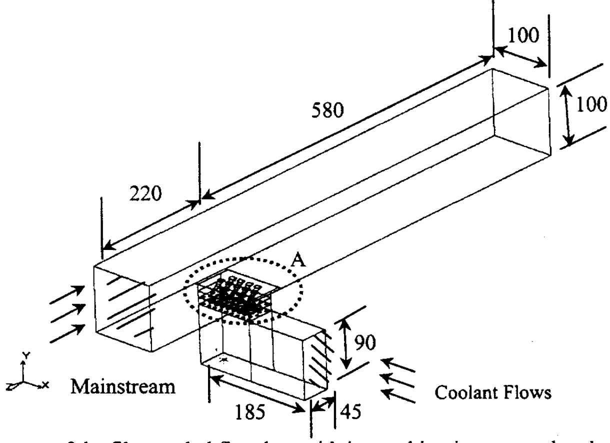


Fig. 2-The geometry of the film-cooled flat plate with internal impingement chamber, unit: mm

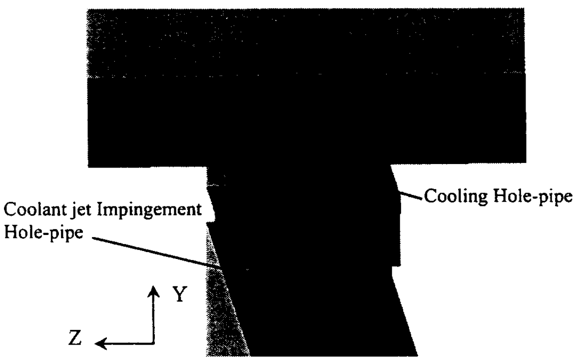


Fig. 3-The close view of two-rows of cooling tubes and internal impingement regions

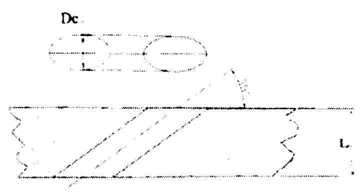


Fig. 4(a)-Schematic geometry of film cooling hole, CYSA

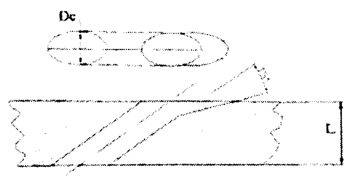


Fig. 4(b)-Schematic geometry of film cooling hole, FDSA

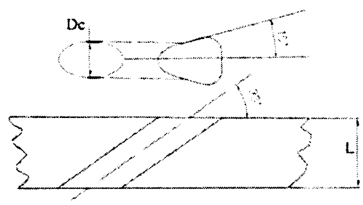


Fig. 4(c)-Schematic geometry of film cooling hole, LDSA

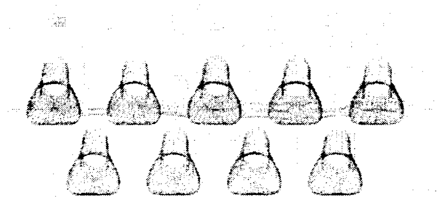


Fig. 5-The grid features on both of inner surface and the surface perpendicular to the axial of LDSA cooling hole

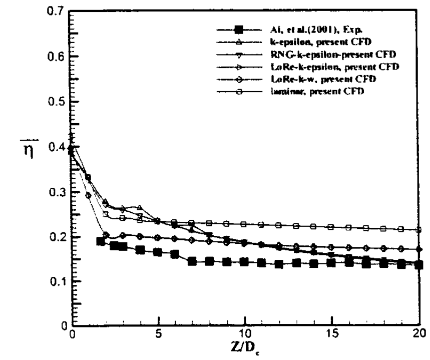


Fig. 6-The distribution of spanwise-averaged adiabatic film cooling effectiveness over film-cooled plate with one row of discrete-holes

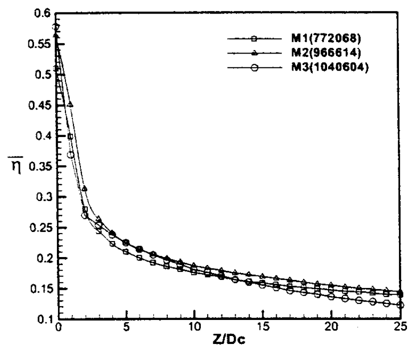
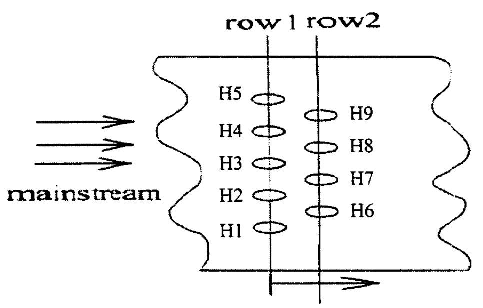
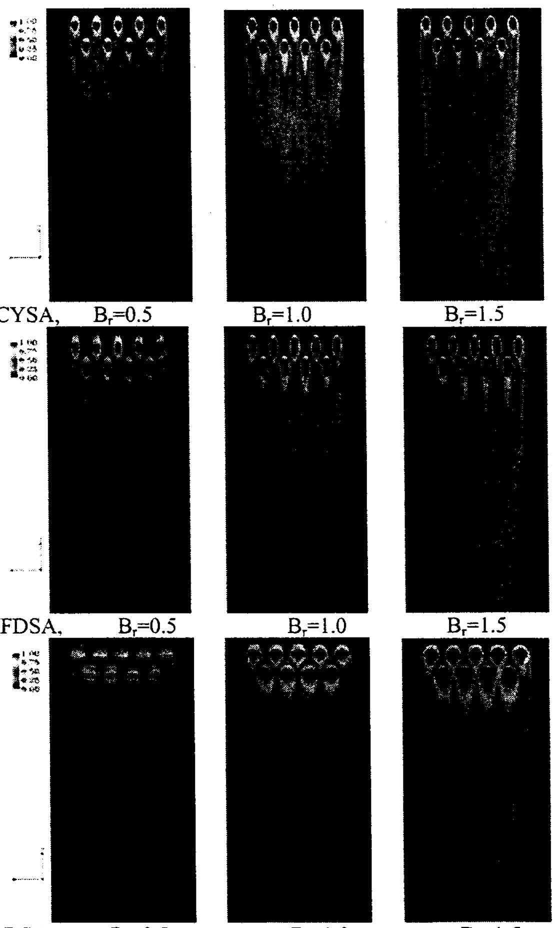


Fig. 7-The distribution of spanwise-averages film cooling effectiveness at three grid system



Z/Dc=0, Z/Dc=3

Fig. 8-Top view around cooling hole exit area

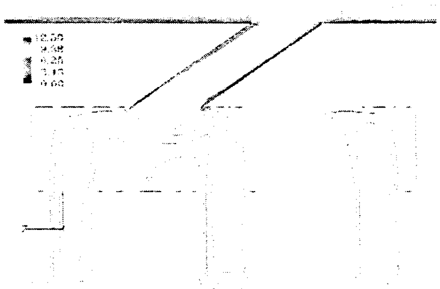


(a)CYSA, B_r=0.5 B_r=1.0 B_r=1.5

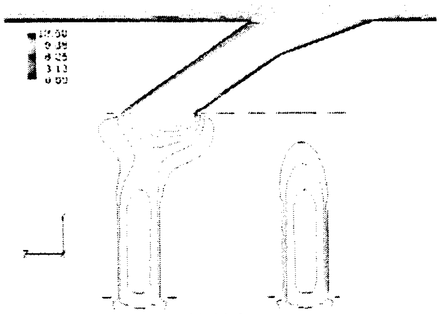
(b)FDSA, B_r=0.5 B_r=1.0 B_r=1.5

(c)LDSA, B_r=0.5 B_r=1.0 B_r=1.5

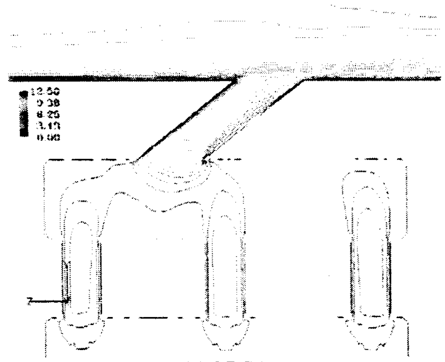
Fig. 9-Contour plots of local film cooling effectiveness for different shapes of hole



(a)CYSA

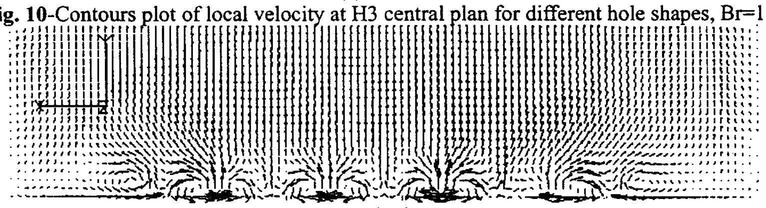


(b)FDSA

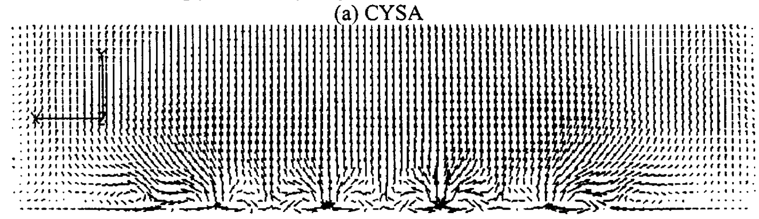


(c) LDSA

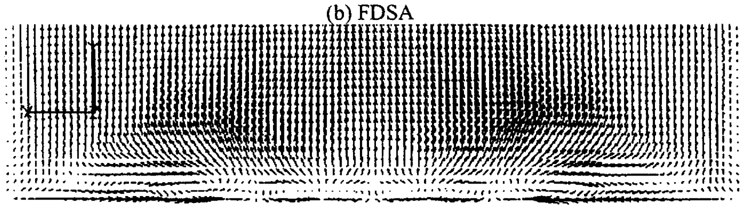
Fig. 10-Contours plot of local velocity at H3 central plan for different hole shapes, Br=1.5



(a) CYSA

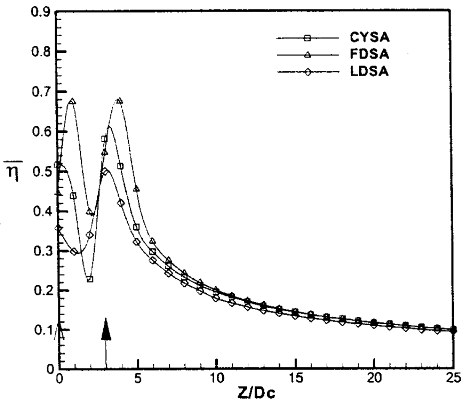


(b) FDSA

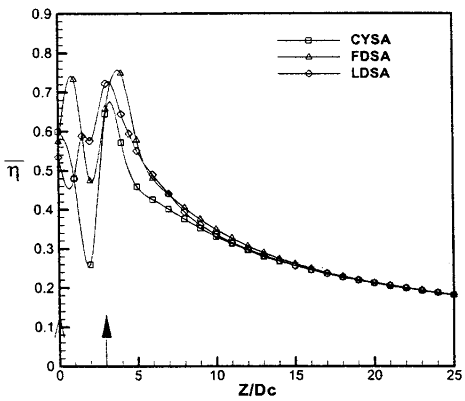


(c) LDSA

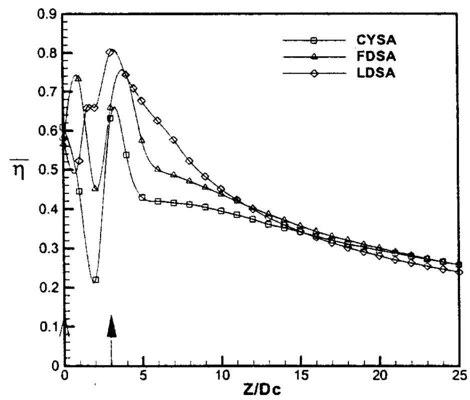
Fig.11 Velocity vectors in the spanwise plane at Z/Dc=6, Br=1.5



(a) B_r=0.5



(b) B_r=1.0



(c) B_r=1.5

Fig.12 Streamwise distributions of spanwise-averaged film cooling effectiveness for different hole shapes

附錄二

Sunday, August 24, 2003

16:00-19:00
Registration desk opens

19:00-21:00
Welcome Reception
(free of charge)

Monday, August 25, 2003

7:30-17:00
Registration desk opened

8:00-8:20 (Room *A*)
Opening ceremony

8:20-9:00 (Room *A*)
Invited Lecture:
Fluid Mechanical Problems in Flow Metering
Speaker: *W. F. Merzkirch*

9:10-10:30

Technical Sessions	Room
Synthetic Jets	*A*
Fluidics I	*B*
Jets I	*C*
Micro Flows I	*D*

11:00-12:40

Technical Sessions	Room
Aerodynamics	*A*
Fluidics II	*B*
Jets II	*C*
Micro Flows II	*D*

14:00-15:40

Technical Sessions	Room
Unsteady Aerodynamics	*A*
Pneumatics I	*B*
Separated Flows I	*C*
Flow Measurements	*D*

16:00-17:40

Technical Sessions	Room
Tunnel Testing	*A*
Pneumatics II	*B*
Separated Flows II	*C*
Flow Control	*D*

Tuesday, August 26, 2003

8:00-17:00
Registration desk opened

8:10-8.50 (Room *A*)
Invited Lecture:
Some Aspects of Nanotechnology, Microtechnology and Biomedical Applications
Speaker: *C.J. Chen*

9:00-10:40

Technical Sessions	Room
PIV I	*A*
CFD Methods	*B*
H. T. External Flows	*C*
Flow Metering I	*D*

11:00-12:40

Technical Sessions	Room
PIV II	*A*
CFD Applications	*B*
H. T. Internal Flows	*C*
Flow Metering II	*D*

14:00-15:40

Technical Sessions	Room
Cylinder Flows I	*A*
Two Phase Flows I	*B*
Combustion I	*C*
Machine Flows I	*D*

16:00-17:40

Technical Sessions	Room
Cylinder Flows II	*A*
Two Phase Flows II	*B*
Combustion II	*C*
Machine Flows II	*D*

Wednesday, August 27, 2003

8:00-17:00
Registration desk opened

8:10-8:50 (Room *A*)
Invited Lecture:
From Steady-state to Unsteady Aerodynamics and Aeroacoustics. The Evolution of the Testing Environment in the Pininfarina Wind Tunnel
Speaker: *A. Cogotti*

9:00-10:40

Technical Sessions	Room
Turbulence I	*A*
Two Phase Flows III	*B*
Optical Methods	*C*
Hydraulics I	*D*

11:00-12:40

Technical Sessions	Room
Turbulence II	*A*
Two Phase Flows IV	*B*
Jets III	*C*
Hydraulics II	*D*

14:00-16:00
Poster Session

20:00-on
Social Banquet
(free of charge)

Thursday, August 28, 2003

8:00-13:00
Registration desk opened

8:10-9:00 (Room *A*)
Invited Lecture:
Real Time Control of the Lean Blow Out Limit in Pre-Mixed Combustors for Reduced NOx Emissions
Speaker: *B. Zinn*

9:00-10:40

Technical Sessions	Room
Compressible Flows I	*A*
Flow Visualization I	*B*
Natural Convection	*C*
Bioengineering I	*D*

11:00-12:40

Technical Sessions	Room
Compressible Flows II	*A*
Flow Visualization II	*B*
Mixed Convection	*C*
Bioengineering II	*D*

14:00-14:30 (Room *A*)
Plenary Lecture:
The Interaction Between Art & Science: from Mona Lisa to Einstein
Speaker: *A. Tamir*

14:40-16:20

Technical Sessions	Room
Compressible Flows III	*A*
Flow Visualization III	*B*
Pneumatic Components	*C*
Bioengineering III	*D*

Friday, August 29, 2003

9:30-18:00
Mini-Cruise in the bay
A delightful day spent cruising in the Bay of Naples and Salerno. Comfortable yachts for sun bathing and relaxing will depart from Sorrento harbour. Stops will be made for swimming at Faraglioni rocks of Capri and "li Galli" islands. Optional landing at Positano beach for shopping, strolling around or swimming. A "marinara Neapolitan surprise lunch" will be served onboard.

Room	Name
A	***Sala Sirene***
B	***Sala Ulisse***
C	***Sala Tritoni***
D	***Sala Nettuno***

Technical Program Schedule
Monday morning, August 25 2003

Time				
8.00	***Opening ceremony***			
8.20	Invited Lecture: **FLUID MECHANICAL PROBLEMS IN FLOW METERING** Speaker: ***W. MERZKIRCH***			
9.00				
9.10	**Session: Synthetic Jets** **THE BEHAVIOUR OF SYNTHETIC JETS IN A LAMINAR BOUNDARY LAYER** *S. ZHONG, F MILLET, N J WOOD* **PIV STUDY OF SYNTHETIC JETS** *G.M. DI CICCA, G. IUSO, A. VIVIANO, M. ONORATO, P.G. SPAZZINI, R. MALVANO* **FLOW VISUALIZATION OF AN AXISYMMETRIC SYNTHETIC JET** *Z. BANGASH, A. AHMED* **SYNTHETIC JET CONTROL OF A CONFINED FLOW THROUGH A WIDE-ANGLE DIFFUSER: FLOW CONTROL MECHANISMS** *M. BEN CHIEKH, J.C. BERA, M. MICHARD, M. SUNYACH*	**Session: Fluidics I** **PROSPECTIVE OF MICROCHANNEL FLOW CONTROL BY THE ELECTRIC DOUBLE LAYER EFFECT** *S. TARDU* **MICROHEATER-TRIGGERED MICROPUMP BY THERMAL ENERGY RECYCLING** *K. TAKAHASHI, T. IKUTA, K. NAGAYAMA* **AUTOMATED CHARACTERISTIC TEST BENCH OF PNEUMATIC SERVO VALVE** *T. FUNAKI, K. KAWASHIMA, T. KAGAWA* **PIV ANALYSIS OF FLOW IN FLUIDICS-TYPE SPRINKLER** *M. NAKASHIMA, T. NOZAKI, T. TABATA*	**Session: Jets I** **VISUALIZATION OF UNDEREXPANDED RADIAL JET** *Y. SAKAKIBARA, M. ENDO, J. IWAMOTO* **FORMATION OF SHOCK IN VORTEX RING INDUCED BY COMPRESSION WAVE** *M. ENDO, J. IWAMOTO* **SKIN FRICTION AND HEAT TRANSFER IN THE IMPINGEMENT REGION OF A SLOT JET** *A. ORTEGA, R. WESTPHAL, WODRICH, J.* **EXPERIMENTAL STUDY ON THE FLOW FIELD NEAR THE PLATE SHOCK OF UNEXPANDED IMPINGING JET** *Y. YASUNAGA, J. IWAMOTO*	**Session: Micro Flows I** **APPLICATION OF MICRO PIV TO MEASUREMENT OF FLOW IN VARIOUS DESIGNS OF MICROCHIP** *H. KINOSHITA, M. OSHIMA, S. KANEDA, T FUJII, T SAGA, T. KOBAYASHI* **MICRO VISUALIZATION AND PTV MEASUREMENT OF FERROMAGNETIC PARTICLES** *H. KIKURA, J. MATSUSHITA, M. ARITOMI, Y. KOBAYASHI, K. NISHINO* **AN APPLICATION OF MICRO FLOW SENOR IN MACRO HYDRAULIC SYSTEM** *ZHANG HONGPENG, SUN YUQING, CHEN HAIQUAN*
10.30	***Coffee Break***			
11.00	**Session: Aerodynamics** **FLOW VISUALIZATION EXPERIMENTS FOR HELICOPTER BODY AERODYNAMICS** *M.C. TOPAL, H. ACAR* **FLOW CHARACTERISTICS AROUND A RIGID AIRSHIP IN CROSS FLOW** *H. KAWASHIMA, Y. SOGO, H. ENNOJI, T. IIJIMA* **FLOW AROUND A BODY OF L-TYPE CROSS SECTION** *Y. SUZUKI, H. ENNOJI, T. IIJIMA* **CFD ANALYSIS FOR REAL 2-D FLOWS** *P. CACCAVALE, C. DE NICOLA, B. MELE, A. PICCOLO* **NUMERICAL AND EXPERIMENTAL SIMULATION OF THE FLOW AROUND COMPLEX GEOMETRIES** *W. FRANK, J. ALKEN*	**Session: Fluidics II** **MONOSTABLE IMPINGING-JET NOZZLES WITH FLUIDIC CONTROL** *V. TESAR* **SUBDYNAMIC BEHAVIOUR OF PRESSURE-DRIVEN MICROFLUIDIC VALVES** *V. TESAR* **FLUIDIC NEGATIVE RESISTANCE DEVICES APPLIED TO LEVEL CONTROL** *J. R. TIPPETTS, G. H. PRIESTMAN* **WATER DISPLAYS USING FLUIDIC VORTEX VALVES** *J. R. TIPPETTS, G. H. PRIESTMAN* **EXPERIMENTAL AND NUMERICAL STUDY OF VORTEX FLUIDIC DIODES** *L. BALDAS, R. CAEN, S. COLIN*	**Session: Jets II** **CIRCULAR AND PLANAR JETS IN CROSS FLOW AT VERY LOW REYNOLDS NUMBER** *R. CAMUSSI, G. GUJ, G. MURGIA* **THE FLOW FIELD ASSOCIATED WITH A CONFINED JET IN A CROSSFLOW** *P. J. DISIMILE, C. COLE, N. TOY* **CONFINED JET FLOW CONTROL: AN INVESTIGATION USING 2D AND 3D CFD AND 2D LDA** *M. P. ARRUDA, N. LAWSON, M. DAVIDSON* **CONTROL OF THE BEHAVIOR OF VORTEX TUBES IN A PLANE JET BY ACOUSTIC EXCITATION** *H. MAKITA, N. SEKISHITA, K. SASSA* **IMPINGEMENT HEAT TRANSFER ISSUED FROM ISOSCELES TRIANGLE ORIFICE JET** *M. HIWADA, J. MIMATSU, S. SAKAI, K. TANAKA, K. OYAKAWA*	**Session: Micro Flows II** **A LASER-INTERFEROMETRIC MOLECULAR TAGGING METHOD FOR MICROFLOW VISUALIZATION** *F. MIKAMI, N. KOJIMA, N. NISHIKAWA* **A MICROACTUATOR USING ECF-JET WITH NEEDLE-TYPE ELECTRODES** *S. YOKOTA, R. ABE, W. UEDA, K. EDAMURA* **CRYOSTATIC MICRO-CT IMAGING OF EXTRAVASCULAR TRANSPORT IN VARIOUS TISSUES** *M. GÖSSL, P. E. BEIGHLEY, S. M. JORGENSEN, E. L RITMAN*
12.40				

Time				
14.00	**Session: Unsteady Aerodynamics** DRAG MAXIMIZATION FOR A FLAT PLATE OSCILLATING IN A SINGLE DIRECTION *M. MILANO, M. RINGUETTE, M. GHARIB* VORTICAL PATTERNS OF A PITCHING AND HEAVING AIRFOIL *C.J. YANG, K. TANAKA, M.S. CHOI* FLOW VISUALIZATION OF 2-FREEDOM FLAP OF FOIL *GUANG KUN TAN, GONG XIN SHEN* EXPERIMENTAL AND NUMERICAL ANALYSIS OF UNSTEADY SEPARATION AROUND AN UNSTEADY AIRFOIL *M. FUCHIWAKI, K. TANAKA*	**Session: Pneumatics I** A NEW FLEXIBLE PNEUMATIC FINGER FOR A FRUIT-HARVESTING HAND *M. CARELLO, C. FERRARESI, C. VISCONTE* SOFT ROBOT HAND CONSTRUCTION WITH PNEUMATIC RUBBER MUSCLE AND TACTILE SENSOR *T. NORITSUGU, D. SASAKI* CONSTRUCTION MACHINERY OPERATING ROBOT USING PNEUMATIC ARTIFICIAL RUBBER MUSCLES *K. KAWASHIMA, T. MIYATA, T. FUNAKI, T. KAGAWA* DEVELOPMENT OF ANTI-PERSONAL LANDMINES DETECTING AND DEMINING VEHICLE *K. ICHIRYU, T. YAMASHITA, H. KARKI* CURRENT CONDITIONS AND ISSUES OF ENERGY SAVING IN PNEUMATIC SYSTEM *M. SENOO, H. ZHANG,N. ONEYAMA*	**Session: Separated Flows I** DEVELOPMENT OF HIGH-PERFORMANCE TWO-WAY DIFFUSER SYSTEM BY LOCALLY CONCENTRATED FLUID ENERGY *T. SETOGUCHI, N. SHIOMI, T. NAKANO, K. KANEKO* VISUALIZATION OF LARGE-SCALE STRUCTURES IN SEPARATED-REATTACHED TRANSITIONAL FLOW ON A BLUNT PLATE *I. E. ABDALLA, Z. YANG* EXPERIMENTAL AND THEORETICAL INVESTIGATION OF FLOW AROUND A BODY WITH ELLIPTIC CROSS-SECTION *R. TAGHAVI-ZENOUZ, P. J. LAMONT* THE PASSIVE FLOW CONTROL BEHIND A PAIR OF CYLINDERS AT INTERMEDIATE SPACING RATIO *Y. LIU, R.M.C. SO, Z.D. SU* A STUDY OF COMPLEX FLOW INDUCED BY TRANSVERSE JET AT SUPER/HYPERSONIC SPEED *S. X. LI, Z.Y. NI*	**Session: Flow Measurements** COLOR-CODED TOMOGRAPHY *B. RUCK* THREE-DIMENSIONAL VORTEX BEHAVIOR OF LEX DELTA WING BY DYNAMIC STEREO PIV *H. LEE, J.W. CHOI, M.S. CHOI, Y. KADOOKA, Y. TAGO, Y.H. LEE* OPTICAL INVESTIGATION OF NATURAL CONVECTION IN VERTICAL CHANNELS *D. AMBROSINI, D. PAOLETTI, G. TANDA, G. GALLI* 3-D FLOW RECONSTRUCTION WITH ELECTROMAGNETIC FLOWMETER *T. KATOH, S. HONDA* FLOW CHARACTERISTICS IN SEPARATOR OF A POLYMER ELECTROLITE FUEL CELL *C. HUANG, H. ENNOJI, T. IIJIMA*
15.40	***Coffee Break***			
16.00	**Session: Tunnel Testing** FLOW VISUALISATION AND FORCE AND MOMENT CORRELATIONS IN A WATER TUNNEL *C. MUNRO, C. JOUANNET, P. KRUS* A PHYSICAL MODEL OF ASYMMETRIC VORTICES STRUCTURE AT REGULAR STATE OVER SLENDER BODY *D. XUEYING, W. YANKUI, L. PEIQING, C. XUERUI, W. GANG* A VISUALIZATION STUDY OF THE VORTICAL FLOW OF A DOUBLE-DELTA WING WITH AND WITHOUT SIDESLIP *M. H. SOHN, K. Y. LEE* DESIGN, DEVELOPMENT AND CALIBRATION OF A LOW SPEED WIND TUNNEL *A. GRINSPAN, U. K. SAHA, P. MAHANTA*	**Session: Pneumatics II** INTELLIGENT CONTROL OF PNEUMATIC ACTUATOR USING ON/OFF SOLENOID VALVES *K.-K. AHN, S.-M. PYO, S.-Y. YANG, B.-R. LEE* DYNAMIC CHARACTERISTICS ON AN ELECTRO-PNEUMATIC HYBRID POSITIONING SYSTEM *Y. SAKURAI, K. TANAKA, T. NAKADA.* MODELLING OF PNEUMATIC SYSTEMS UTILIZING DIFFERENT MASS FLOW MODELLING METHODS *P. PESSI, A. ROUVINEN* ENERGY SAVING CIRCUIT OF POSITIVE OR NEGATIVE PRESSURE SUPPLY SYSTEM *N. YAMAMOTO, K. KAWASHIMA, T. KAGAWA, T. FUNAKI, K. OHTANI* DEVELOPMENT OF CALCULATION PROGRAMS FOR ENERGY SAVING IN PNEUMATIC SYSTEM *H. ZHANG, M. SENOO, N. ONEYAMA*	**Session: Separated Flows II** MEAN AND FLUCTUATING VELOCITY FIELDS IN THE NEAR WAKE OF A WAVY CYLINDER *K. LAM, F. H. WANG, G. D. JIANG, R. M. C. SO* THERMOGRAPHIC APPROACH TO THE STUDY OF LAMINAR SEPARATION BUBBLE *F. D'AMICO, S. MONTELPARE, R. RICCI, E. SILVI* INVESTIGATION OF THE FLOW PROPERTIES ON THE WAKE OF A MODEL CAR BY SIMULATING THE GROUND EFFECT *B.A. SEN, Z.D. COLAKEL, E.O. KOZAKA* THE EFFECT OF THE SHAPE OF THE FOREBODY ON THE FLOW BEHIND THE ROCKET BODY *O. DOLEK, I.B. OZDEMIR* CONSTRUCTION OF A DATABASE ON THE WAKE OF A SPHERE WITH A 3D-PTV *D.H. DOH, T.G. HWANG, T. SAGA, T. KOBAYASHI*	**Session: Flow Control** MASTER-SLAVE SYSTEM CONSISTS OF HYDRAULIC AND PNEUMATIC PARALLEL MECHANISMS *H. YAMADA, T. MUTO, N. BANDO* ACTIVE CONTROL OF FLOW-INDUCED VIBRATION ACTING ON A SQUARE CYLINDER BY MICRO-EXCITATION OF SIDEWALL SURFACES *M. ODA, Y. YAMAMOTO, A. TAKAKI, M. FURURKAWA, M. INOUE* DEVELOPMENT OF SIMULATOR FOR CRITICAL LABORATORY ENVIRONMENT USING VARIABLE AIR VOLUME VALVE *H. ARAI, T. FUNAKI, K. KAWASHIMA, T. KAGAWA, T. SAEGUSA* ROBUST VELOCITY CONTROL OF WATER HYDRAULIC SERVOMOTOR SYSTEM WITH LOAD FLUCTUATIONS *K. ITO, S. IKEO* PERFORMANCE IMPROVEMENT OF DIGITAL POSITIONER FOR PNEUMATIC CONTROL VALVE WITH LARGE HYSTERESIS *T. WAKUI, T. HASHIZUME, T. NISHIJIMA*
17.40				

Time				
8.10	Invited Lecture: **SOME ASPECTS OF NANOTECHNOLOGY, MICROTECHNOLOGY AND BIOMEDICAL APPLICATIONS**			
8.50	Speaker: *C.J. CHEN*			
9.00	**Session: PIV I**	**Session: CFD Methods**	**Session: H.T. External Flows**	**Session: Flow Metering I**
	DEVELOPMENT OF A NEW DYNAMIC PIV SYSTEM *H. HAYAMI, K. OKAMOTO, S. ARAMAKI, T. KOBAYASHI* CHARACTERIZATION OF VORTICES IN A CAVITY AT LOW SPEED *E. OZSOY, P. RAMBAUD, A. STITOU, M.L. RIETHMULLER* AIRCRAFT WAKE VORTEX DETECTION IN LARGE TOWING TANK *F. DE GREGORIO, A. RAGNI, F. ALBANO, F. DI FELICE AND F. LA GALA* PARTICLE DRAG UNDER VELOCITY GRADIENT *R. RODRIGUES, F. VAN DER LAAN, A. ELBERN* USE OF PARTICLE IMAGE VELOCIMETRY (PIV) IN THE STUDY OF CONICAL ROOF EDGE VORTICES *M. GAMBOA-MARRUFO, C.J. WOOD, R. BELCHER*	A CFD APROACH TO FLOW CONTROL OF TRANSONIC SHALLOW CAVITIES *P.GERALDES, D. BRAY* TIME-DOMAIN SIMULATION OF FLOATING PIER AND MULTIPLE-VESSEL INTERACTIONS BY A CHIMERA RANS METHOD *H.C. CHEN, E.T. HUANG* NEW NUMERICAL METHOD FOR SOLVING COMPRESSIBLE FLUID FLOWS BASED ON AN ANALYTICAL SOLUTION OF LINEAR AND NONLINEAR ADVECTION-DIFFUSION EQUATIONS *I. KIMURA, K. SAKAI, T. ADACHI, H. HISHIDA* NUMERICAL ANALYSIS OF FREE SURFACE BEHAVIOR IN SIPHON TUBE *F. SHIMIZU, K. HATAKENAKA, K. TANAKA, H. SHIGEFUJI* NUMERICAL ANALYSIS OF UNSTEADY INCOMPRESSIBLE FLOWS *S. GOKALTUN, H. SAYGIN, M. MURADOGLU*	TRANSIENT HEAT TRANSFER MEASUREMENTS ON A BLUNTED CONE-FLARE MODEL IN A SHORT DURATION HYPERSONIC FACILITY USING QUANTITATIVE INFRARED THERMOGRAPHY *F.F.J. SCHRIJER, F. SCARANO, B. VAN OUDHEUSDEN* VARIABILITY EFFECT OF THE AIR FLOW ON CONVECTIVE DRYING OF UNSATURATED POROUS MEDIA *A. MOBARKI, N. BOUKADIDA, S. BEN NASRALLAH* CALIBRATION OF HEAT FLUX MEASUREMENT AND DEVELOPMENT OF DATA ACQUISITION SYSTEM FOR ICP WIND TUNNEL *D. CAIMANO, O. CHAZOT, C.O. ASMA* FLOW FIELD VISUALIZATION AND HEAT TRANSFER ASSESSMENT DUE TO PULSED JET IMPINGEMENT ENHANCEMENT *M. ANGIOLETTI, R.M. DI TOMMASO, E. NINO, G. RUOCCO* EFFECTS OF A DOWNSTREAM CYLINDER ON THE FLUCTUATING SURFACE TEMPERATURE OF A HEATED CYLINDER IN CROSS FLOW *Z. J. WANG, X. W. WANG., Y. ZHOU*	VELOCITY PROFILES IN THE PIPE WITH AN ORIFICE UNDER PULSATING FLOW CONDITIONS *E. TAMURA, J. IWAMOTO* DEVELOPMENT OF DYNAMICALLY CALIBRATED QUICK RESPONSE FLOW SENSOR AND ITS APPLICATION TO PRESSURE SERVO CONTROL SYSTEM *T. KATO, K. KAWASHIMA, M. CAI, T. FUNAKI, K. TAKAYAMA, T. KAGAWA* EXPERIMENTAL INVESTIGATION OF A PNEUMATIC PROPORTIONAL FLOW VALVE *G. FIGLIOLINI, M. SORLI* DESIGN AND ANALYSIS OF THE DIRECT DRIVE-TYPE PNEUMATIC SERVO VALVE *D.S. KIM , W.H. LEE* STATIC AND DYNAMIC CHARACTERISTIC ANALYSIS OF PITOT TYPE FLOW METER *K. NUKUI, T. FUNAKI, K. KAWASHIMA, T. KAGAWA, S.NAKAZAWA*
10.40	***Coffee Break***			
11.00	**Session: PIV II**	**Session: CFD Applications**	**Session: H.T. Internal Flows**	**Session: Flow Metering II**
	QUANTITATIVE VELOCITY AND VORTICITY FIELD MEASUREMENTS OF SECOND TAYLOR VORTEX FLOW *K. D. VON ELLENRIEDER, J. SORIA, T. T. LIM, Y. T. CHEW* TAYLOR VORTICES BETWEEN TWO ROTATING CYLINDERS WITH AXIAL GROOVES *M. NOMA, A. MORI* SPARSE VECTOR VIDEO COMPRESSION TECHNIQUES FOR PIV IMAGE ANALYSIS *H. YEZZA, A. AROUSSI* A SIMPLE AND EFFECTIVE 3D PTV AND LAGRANGIAN TRACKING TECHNIQUE FOR FLUIDS FLOW STUDIES *K. CHEUNG, W.B. NG, Y. ZHANG* COMPARISION BETWEEN OPEN-LOOP AND CLOSED-LOOP CONTROL OF RESONANT FLUID-STRUCTURE INTERACTION IN A CROSS FLOW *M.M. ZHANG, L. CHENG, Y. ZHOU*	WHEEL ARCH AERODYNAMICS OF A MODERN ROAD VEHICLE *S, APSLEY, A. AROUSSI, I. GRANT* DETERMINATION OF EMPIRICAL EROSION CONSTANTS USING A SAND-BLAST TYPE EROSION RIG *A. P. O'MAHONY, C.A. MARSH, J. NIVEN, P.J. FRAWLEY* TEMPERATURE STRATIFICATION CONTROL IN PASSENGER VEHICLES *A ZEID, A. AROUSSI* FLOW VISUALIZATION AND FILM COOLING EFFECTIVENESS OVER A FLAT PLATE WITH VARIOUS EXPANDED COOLING HOLE GEOMETRIES *C. H. TAI, J. M. MIAO, A. F. KAO, J. W. LIU* PIV STUDY OF VORTICAL FLOW BEHIND TOWING MODEL AND CFD APPROACH *F. MIKAMI, N. NISHIKAWA, H. TOYODA*	TRANSIENT RESPONSE OF PLATE HEAT EXCHANGERS UNDER FLOW MALDISTRIBUTION AND VISCOSITY VARIATIONS *H. SHOKOUHMAND, N. KHAREGHANI* HEAT TRANSFER FOR PULSATING LAMINAR DUCT FLOW PARTIALLY FILLED WITH POROUS MEDIUM *H. DHAHRI, A. BOUGHAMOURA, S. BEN NASRALLAH* EXPERIMENTAL STUDY OF HEAT AND MASS TRANSFER INTENSIFICATION IN ADSORPTION AIR CONDITIONING DEVICE *M. JASKOLSKI, M. WIERZBOWSKI* EXPERIMENTAL DETERMINATION OF HEAT TRANSFER AND PRESSURE LOSSES IN CHANNEL FLOWS USING LIQUID CRYSTAL THERMOGRAPHY *J. STASIEK, M. WIERZBOWSKI* PRESSURE DROP, MASS TRANSFER AND WAVY DUCTS *P. GSCHWIND, V. KOTTKE*	EFFECT OF DIAMETER RATIO ON THE SWIRLING ORIFICE PLATE *A. AHMAHDI, S, BECK, R.STANWAY* CORIOLIS MASS FLOWMETERS: STATE OF THE ART AND INNOVATIONS *W. DRAHM, H. LINNARTZ* A NEW ALGORITHM FOR THE EVALUATION OF THE PNEUMATIC VALVES FLOW CHARACTERISTICS USING THE CHARACTERISTIC UNLOADING TIME METHOD *S. DE LAS HERAS* 3-D PARTICLE TRACKING VELOCIMETRY WITH AN IMPROVED GENETIC ALGORITHM *K. OHMI* DETERMINATION OF FLOW RATE CHARACTERISTICS OF SMALL PNEUMATIC VALVES USING ISOTHERMAL CHAMBER BY PRESSURE RESPONSE *T. KAGAWA, T. WANG, Y. ISHII, Y. TERASHIMA, T. MOROZUMI, T. MOGAMI, N. ONEYAMA*
12.40				

Technical Program Schedule
Tuesday afternoon, August 26 2003

Time				
14.00	**Session: Cylinder Flows I** MEASUREMENTS OF STROUHAL NUMBERS IN THE WAKE OF TWO TANDEM CYLINDERS *G. XU, Y. ZHOU* FLOW CHARACTERISTICS AROUND A CIRCULAR CYLINDER WITH TRIANGULAR GROOVES *Y. YAMAGISHI, S. AKAIKE, M. OKI* EFFECT OF FLOW CHANNEL SHAPE AND SEPARATION DISTANCE ON STROUHAL FREQUENCY AND INTENSITY ASSOCIATED WITH DRAG AND LIFT ON SQUARE-PITCHED CYLINDER ARRAY ELASTICALLY SUPPORTED IN CROSS FLOW *H. HISHIDA, T. ADACHI, H. HISHIDA* NUMERICAL ANALYSIS ON FLOW CHARACTERISTICS AROUND A CIRCULAR CYLINDER WITH GROOVES *S. TAKAYAMA, H. OKANAGA, K. AOKI* QUALITATIVE AND QUANTITATIVE CHARACTERISTICS OF STEADY HORSESHOE VORTEX SYSTEM AT A RECTANGULAR CYLINDER-BASE PLATE JUNCTURE *C. LIN, T.C. HO, C.CH. KUO*	**Session: Two Phase Flows I** EXPERIMENTAL ANALYSIS OF BUBBLE BEHAVIORS IN CIRCULAR TUBE *H. S. KO, Y.-J.KIM* MIXING PROCESS OF PARTICLES INTO WATER JET *A. MIZUSAKI, R. OGISO, H. MONJI, G. MATSUI* LOCAL AND AVERAGED EVOLUTION OF AN INTERMITTENT TWO-PHASE FLOW IN A DUCT WITH A SUDDEN EXPANSION *S. AROSIO, M. GUILIZZONI* EFFECT OF FLOW ORIENTATION ON GAS-LIQUID INTERFACIAL STRUCTURE IN NARROW RECTANGULAR CHANNEL *T. SAWAI, M. KAJI, Y. KATO, T. SHOJI* THE NOVEL VELOCITY PROFILE MEASURING METHOD IN BUBBLY FLOWS USING ULTRASOUND PULSES *G. YAMANAKA, H. MURAKAWA, H. KIKURA, M. ARITOMI*	**Session: Combustion I** PDA AND APPLICATION IN SOOT INSPECTION *Z. ZENG, Y. YU, Q. OUYANG* EXPERIMENTAL TESTS ON A HYBRID ROCKET WITH A COOLED TWO-DIMENSIONAL PLUG NOZZLE *C. CARMICINO, A. RUSSO SORGE* THE PIV-LDA STUDY FOR THE ANALYSIS OF UNSTEADY COMBUSTION IN AN INDUSTRIAL BURNER MODEL *GUJ G., CAMUSSI R., GIULIETTI E., GIACOMAZZI E.* VISUALIZATION OF A CONSTANT VOLUME MICRO COMBUSTOR FOR ANALYSIS OF FLAME PROPAGATION *S. KIM, H. NA, D.HOON LEE ,S. KWON* SIMULTANEOUS PLIF AND TOMOGRAPHY MEASUREMENTS FOR STRATIFIED CHARGE COMBUSTION *B. RENOU, O. DEGARDIN, E. SAMSON, A. M. BOUKHALFA*	**Session: Machine Flows I** DESIGN OF THE VOLUTE CASING OF A SIROCCO FAN *T. ADACHI, N. SUGITA* UNSTEADY WAKE EFFECTS ON A FILM COOLED LEADING EDGE *F. MONTOMOLI, P. ADAMI, F. MARTELLI* A NEW APPROACH TOWARDS THE UNDERSTANDING OF THE FLOW IN SMALL CLEARANCES APPLICABLE TO HYDRAULIC PUMP PISTONS WITH PRESSURE BALANCING GROOVES *J. M. BERGADA, J. WATTON* NUMERICAL FLOW VISUALIZATION IN A TRANSONIC AXIAL COMPRESSOR *R. TAGHAVI-ZENOUZ, M. KHORSAND*
15.40			*Coffee Break*		
16.00	**Session: Cylinder Flows II** FLOW AROUND CYLINDERS - VISUALIZATION *J. W. HOYT* STUDY ON THE THREE DIMENSIONAL VORTICAL STRUCTURE OF THE FLOW AROUND A CIRCULAR CYLINDER *T. SAGA* FLOW STRUCTURE OF A CIRCULAR CYLINDER BEHIND AN AIRFOIL *H.J. ZHANG, L. HUANG, Y. ZHOU* CONTROL OF THE WAKE BEHIND A CIRCULAR CYLINDER USING A FLEXIBLE V-GROOVED MICRO-RIBLET *S. J. LEE, H. C. LIM* CONTROL OF THE FLOW AROUND A CIRCULAR CYLINDER BY USING BOUNDARY LAYER SUCTION *J. TENSI, S. BOURGOIS*	**Session: Two Phase Flows II** A STUDY OF PULVERISED FUEL MIXING IN PNEUMATIC CONVEYING ELBOWS PRIOR TO SPLITTING *P. ROGERS, A. AROUSSI, A. ROBINSON, E. MOLLOY, T. WILD , J. ROBERTS, I. GRANT* CHARACTERISATION OF A QUADRAFURCATOR IN A POWER STATIONS PF CONVEYING PIPELINES *J. ROBERTS, A. AROUSSI, P. ROGERS, I. GRANT* APPLICATION OF STATE TRANSITION MATRIX TO PARTICLE FLOW CT IMAGES *M. TAKEI, M. OCHI, Y. SAITO, K. HORII* VISUALISATION AND CONTROL OF PULVERISED COAL CONVEYING. *D. GIDDINGS, A. AROUSSI, E. MOZAFFARI, S. PICKERING, J. ROBERTS, P. ROGERS* RECOGNITION OF FLOW STRUCTURE FOR TWO PHASE GAS-SOLID MIXTURE WITH THE USE OF DIGITAL IMAGE ANALYSIS TECHNIQUE *S. ANWEILER, R. ULBRICH*	**Session: Combustion II** EXTINCTION AND IGNITION OF OPPOSED AND DUCTED PREMIXED FLAMES *E KORUSOY, P LINDSTEDT, D LUFF AND J H WHITELAW* INFLUENCE OF OSCILLATINNG BOUNDARY LAYER ON VOLUME PROCESSES AT COMBUSTION OF GASES IN FLOW CONDITIONS *G. SARGSYAN* TEMPERATURE FIELD MEASUREMENTS IN A COUNTERCURRENT CONTROLLED AXISYMMETRIC JET FLAME *E. KOC-ALKISLAR, L. LOURENCO, A. KROTHAPALLI* INFRARED ANALYSIS OF FUEL SPRAY INJECTED IN A THERMAL CONVECTIVE COUNTER FLOW *A. AMORESANO, C. ALLOUIS.* VISUALIZATION OF FLOW PATTERNS AND SIMULATION OF COMBUSTION PROCESS USING PHYSICAL AND NUMERICAL TECHNIQUES *BARANSKI J., STASIEK J.*	**Session: Machine Flows II** FLOW VISUALIZATION AND LDV MEASUREMENTS THROUGH DARRIEUS ROTOR *I. PARASCHIVOIU, L. SURUGIU* VISUALIZATION OF OIL-WATER SEPARATION ON BOARD AN AIR-DRIVEN CENTRIFUGE *J. R. TIPPETTS, G. H. PRIESTMAN, T. POBLETE, J. DJUVE* VISUALIZATION OF THE INTERNAL FLOW OF CYLINDERS FOR SMALL TWO-STROKE ENGINES *P. STUECKE, C. EGBERS* EFFECT OF CROSS-ANGLE ON FLOW PULSATIONS AND INTERNAL FORCE DYNAMICS IN AXIAL PISTON PUMPS *A. JOHANSSON, J. ANDERSSON, J.-O PALMBERG* WALL SHEAR STRESS UNSTEADY CHARACTERISTICS AT THE TRAILING EDGE OF A TURBINE BLADE *M. UBALDI, P. ZUNINO, TH. SCHROEDER*
17.40				

Time				
8.10 – 8.50	Invited Lecture: **FROM STEADY-STATE TO UNSTEADY AERODYNAMICS AND AEROACOUSTICS. THE EVOLUTION OF THE TESTING ENVIRONMENT IN THE PININFARINA WIND TUNNEL** Speaker: *A. COGOTTI*			
9.00 – 10.40	**Session: Turbulence I** VISUALIZATION OF TURBULENT WEDGES UNDER ADVERSE PRESSURE GRADIENT *B. GULACTI, S. ZHONG* THE INERTIA OSCILLATIONAL NIGHT LOW LEVEL JET OF THE BOUNDARY LAYER AND A METHOD OF THE AIRPLANE TURBULENCE PREDICTION NEARBY IT *Y. WANG* THE VIBRATING SPIRE METHOD FOR WIND TUNNEL SIMULATION OF ABL *Q.-D. WEI, W.-T. BI, K. CHEN* STATISTICS MEASUREMENTS OF TEMPERATURE IN A TURBULENT JET AND GRID TURBULENCE USING COMPENSATED COLD WIRES *A. BENAISSA, J. LEMAY* EFFECTS OF REYNOLDS NUMBER ON THE TURBULENT STRUCTURES OF DIFFERENT SCALES *H. LI, Y. ZHOU, M. NAKANO*	**Session: Two Phase Flows III** SPRAY AND SPLASH GENERATED BY HEAVY VEHICLES: ROAD TEST MEASUREMENTS AND WIND-TUNNEL MODELLING *J. LEMAY, G. DUMAS* X-RAY TOMOGRAPHIC FLOW VISUALIZATION OF MULTIPHASE FLUID MIXTURE IN POROUS MEDIA *E.I. PALCHIKOV, S.V. SUKHININ, A.YU BURLEV, E.R. BARTULI, D. YU MEKHONTSEV, M.A. ROMANJUTA AND K.S. SELEZNEV* AN OBSERVATION OF FILM THICKNESS AND LOCAL PRESSURE IN UPWARD AND DOWNWARD ANNULAR TWO-PHASE FLOW IN MICROGRAVITY, HYPERGRAVITY AND NORMAL GRAVITY *K.S. GABRIEL, D. MANZ* FREE SURFACE TIME EVOLUTION OF A GRANULAR MATERIAL CONTAINED IN A BOX *A. D. FERREIRA, A.C.M. SOUSA, P. J. A. VAZ* MEASUREMENTS OF GAS-LIQUID FLOW IN BUBBLE COLUMN USING IMAGE PROCESSING METHOD *D. ZAJ, C. W. SUCHECKI, R. ULBRICH*	**Session: Optical Methods** SCHLIEREN AND OH EMISSION VISUALIZATION OF THE PRIMARY IGNITION PROCESS OF A COAXIAL GH2/LOX SPRAY *V. SCHMIDT, H. CIEZKI* BLAST WAVE AND ITS FLOW FIELD RESEARCH *H. YANG, Z.G. TANG, L.D. GUO, J.L. LUO, N.P. MENDE, A.B. PODLASKIN, V.A. SAKHAROV* COMBUSTION STUDIES IN A SI ENGINE USING NATURAL GAS TIMING INJECTION BY OPTIC FIBER SPARK PLUG *A. GHEDDACHE, B. RENOU, D. PUECHBERTY, A. BOUKHALFA* COMBINING WOLLASTON PRISM INTERFEROMETRY WITH DIGITAL PARTICLE IMAGING VELOCIMETRY *R.L. COGNION, C.T. LANT* EJECTOR RESEARCH USING SCHLIEREN PHOTOGRAPHY *T. CARPENTER*	**Session: Hydraulics I** TRAJECTORY TRACKING CONTROL OF LOW-PRESSURE WATER HYDRAULIC CYLINDER DRIVE WITH PROPORTIONAL VALVE *H. SAIRIALA, K. T. KOSKINEN, M. VILENIUS* CHARACTERISTICS OF A DIGITAL FLOW CONTROL UNIT WITH PCM CONTROL *A. LAAMANEN, M. LINJAMA, M. VILENIUS* MOTION CONTROL OF ANIMATRONIC SYSTEM USING WATER HYDRAULIC DRIVE *Y. TANAKA, J. ISHIBASHI, T. SAWADA, T. ITO* RESEARCH ON HYDRAULIC CYLINDER DRIVING SYSTEM USING HYDRAULIC TRANSFORMER *W. D. MA, S. IKEO* DEVELOPMENTS IN LIFETIME ENGINEERING OF FLUID POWER BASED SYSTEMS *G.M MADS, G.V HAUGEN*
10.40 – 11.00	***Coffee Break***			
11.00 – 12.40	**Session: Turbulence II** REYNOLDS NUMBER EFFECTS ON 3-D VORTICITY IN A TURBULENT WAKE *M. W. YIU, Y. ZHOU AND T. ZHOU* QUANTITATIVE EXPERIMENTAL AND COMPUTATIONAL MASS FLUX DETERMINATION FOR TURBULENT SCALAR MIXING *X.H. ZHANG, Z.S. ZHANG, M. AYRAULT, S. SIMOENS* EFFECT OF COHERENT STRUCTURES IN A TURBULENT FLOW BEHIND A GRID AND FORCES ON AN AIRFOIL *A., BENAISSA, D. FAUX, D. POIREL, L. LEMAY.* TURBULENCE MEASUREMENTS WITHIN A CYCLIC FLOW USING STEREOSCOPIC PIV *E. SUK, P. SULLIVAN* EFFECT OF ROUGHNESS ELEMENTS ON TURBULENT BOUNDARY LAYERS UNDER PRESSURE GRADIENTS *G.-K. KEREVANIAN, A. SIDORENKO*	**Session: Two Phase Flows IV** EXPERIMENTAL STUDY OF FLOW PATTERNS FOR R134A BOILING IN A MICRO-FINNED HELICALLY COILED TUBE *W. CUI, M. XIN* THE DESIGN OF ACOUSTIC CHAMBERS FOR THE STUDY OF BUBBLE DYNAMICS *S. CANCELOS, F. MORAGA, R.T. LAHEY, JR* INTERFACIAL WAVE CHARACTERISTICS OF ACCELERATED AIR-WATER TWO-PHASE FLOW IN HORIZONTAL AND VERTICAL RECTANGULAR CHANNELS *M. KAJI, T. SAWAI, K. MORI* FLASHING FLOW PAST ORIFICE PLATES *C. A. MARSH, A. J. NIVEN, P. FRAWLEY* EXPERIMENTAL AND NUMERICAL INVESTIGATION OF ACTIVE HEAT EXCHANGE FOR FLUID POWER SYSTEMS *Y. TANAKA, R. SUZUKI, T. YOSHIDA, K. KOIKE*	**Session: Jets III** AN EXPERIMENTAL TECHNIQUE FOR STUDYING LARGE-SCALE MOTION USING IMAGE PROCESSING *N. TOY, P.J. DISIMILE* PIV MEASUREMENTS IN NEAR FIELD ELLIPTIC JET: EFFECT OF SAMPLE SIZE, GRADIENT AND SPATIAL RESOLUTION ON TURBULENCE *G. RAMESH, L. VENKATAKRISHNAN, K. T. MADHAVAN* STEREOSCOPIC VISUALISATION OF THE LARGE-SCALE STRUCTURES IN AN AERODYNAMICALLY EXCITED TURBULENT JET *S. ZHANG, K. BREMHORST, J. T. TURNER* CONTROL OF JETS BY THE SMALL JET *N. OGAWA. R. SAITO* AN EXPERIMENTAL INVESTIGATION ON THE STRUCTURE OF COFLOWING JETS *J. PILALIS, D.R. HONNERY, J. SORIA*	**Session: Hydraulics II** WATER HYDRAULIC SPOOL VALVE - LEAKAGE FLOW THROUGH ANNULAR CLEARANCE DUCT *M. LAKKONEN, KARI T. KOSKINEN, M. VILENIUS* STUDY ON LOCAL HYDRAULIC STRUCTURE OF THE FLOW AROUND VEGETATIVE GROINS *T. ABE, A. AIHARA, T. OIKAWA, Z. L. ZHU* INSTABILITY OF FREE-SURFACE JETS BY GLOBAL ANALYISIS *L. DE LUCA, C. CARAMIELLO, L. MONGIBELLO* RESEARCH ON FLUID COLUMN SEPARATION OF ANTI-LOCK BRAKING SYSTEM *H. OGINO* EFFECTS OF HARTMANN NUMBER IN OSCILLATING RADIAL FLOW *A. ZALOGLU, G.YALCINKAYA*

Poster Session

Time				
14.00	**NUMERICAL STUDY OF OSCILLATORY FLOW PAST A PAIR OF CYLINDERS AT LOW KEULEGAN-CARPENTER NUMBERS** *P. ANAGNOSTOPOULOS, A. KOUTRAS, S. SEITANIS* **DIFFUSION AND MIXING IN THE WAKE OF A CYLINDER NEAR A FREE WATER SURFACE** *E. ALYGIZAKIS, V. BONTOZOGLOU, A. EZERSKY, P. PAPANICOLAOU, H. STAPOUNTZIS* **FLOW VISUALIZATION OF NATURAL CONVECTION IN ASYMMETRIC CHANNEL - CHIMNEY SYSTEMS** *A. ANDREOZZI, B. BUONOMO, O. MANCA, M. MUSTO* **VISUALIZATION OF COHERENT THERMAL STRUCTURES IN A TURBULENT CHANNEL FLOW** *T. ASTARITA, N. MARATI* **NUMERICAL AND EXPERIMENTAL VISUALIZATION OF NATURAL CONVECTION IN A VERTICAL CONVERGENT CHANNEL** *N. BIANCO, O. MANCA, S. NARDINI, V. NASO* **A FLOW CONTROL FOR THE WING OF ATRA (ADVANCED TECHNOLOGY REGIONAL AIRCRAFT)** *P. EDI* **FLOW VISUALIZATION IN HIGH ENTHALPY HYPERSONIC FLOWS** *A. ESPOSITO, G. P. RUSSO, M. D'ANGELO, R. RENIS, A. PINTO, C. PURPURA* **AIR CONSUMPTION IN PNEUMATIC SERVO SYSTEM** *T. FUJITA, K. SAKAKI, K. KAWASHIMA, T. KIKUCHI, K. KUROYAMA, T. KAGAWA* **CHAOTIC MIXING OPTIMIZATION FOR 3D PIPE FLOWS BY MAPPING METHOD** *S. GIBOUT, Y. LE GUER, E. SCHALL* **STUDY ON A NEW MECHANISM OF A SILICON OUTER FENCE MOLD ACTUATOR** *Y. HAYAKAWA, K.MORISHITA, M. AICHI*	**THREE-DIMENSIONAL SCHLIEREN VISUALIZATION OF THE PATH, SHAPE, AND WAKE OF SINGLE AIR BUBBLES RISING IN STAGNANT FLUID** *V. HEINZEL, A. JIANU, H. SAUTER* **FLOW VISUALIZATION AND VORTICITY MEASUREMENT IN A TRANSONIC CAVITY FLOW** *H. HIRAHARA, M. KAWAHASHI, M. U. KHAN* **SELF-SUSTAINED OSCILLATION NECHANISM OF TARGET TYPE FLUIDIC OSCILLATOR** *F. HIROKI, A. YUMOTO, K. YAMAMOTO* **STEREOSCOPIC PIV MEASUREMENTS OF A JET MIXING FLOW WITH VORTEX GENERTAING TABS** *H. HU, T. SAGA, T. KOBAYASHI, N. TANIGUCHI* **COMPUTER AIDED AERODYNAMIC DESIGN OF AXIAL FLOW COMPRESSORS** *H. B. KADAM, U.K. SAHA, M. K. DAS* **ROTATING FLOWS IN A SCROLL CASING** *J. W. KIM* **POSITION AND FORCE SIMULTANEOUS CONTROL OF A PNEUMATIC CYLINDER DRIVING SYSTEM** *K. W. KIM, J. S. JANG* **NEURAL-NET BASED ESTIMATION OF AIR FLOW DISTRIBUTION IN A HOSPITAL ROOM** *I. KIMURA, H. FUKUI, T. ITOH, A. KAGA, Y. KUROE* **NUMERICAL VISUALIZATIONS OF THE 3-DIMENSIONAL WEAK SHOCK DISCHARGED FROM AN OPEN END OF DUCT** *Y. H. KWEON, H. D. KIM, D.H. LEE, T. AOKI, T. SETOGUCHI* **CHARACTERISTICS EVALUATION OF RESONATOR HOSE FOR AUTOMOTIVE POWER STEERING SYSTEM** *I.-Y. LEE, I.-S. LEE, J.-H. LEE*	**THE INFLUENCE OF THE SUPPLY CHAMBER CONFIGURATION ON A SONIC/SUPERSONIC, SWIRLING JET** *K.H. LEE, T. SETOGUCHI, S. MATSUO, S.YOSHIOKA, H.D.KIM* **MIXED CONVECTION IN A CHANNEL WITH AN OPEN CAVITY BELOW** *O. MANCA, S. NARDINI, R. PITZOLU, V. NASO* **VISUALISATION OF HORSE-SHOE VORTEX FORMATION ON WALL MOUNTED CYLINDERS** *K. MARRAKOS, J. T. TURNER* **VISUALIZATION OF MOIST AIR FLOW WITH NON-EQUILIBRIUM CONDENSATION THROUGH LUDWIEG TUBE** *S. MATSUO, M. TANAKA, R. NIINO, T. SETOGUCHI, H.-D. KIM* **SPEED CONTROL OF HIGH-SPEED MOTOR DRIVEN BY FLUID ENERGY** *Y. NAKAO* **STEPWISE DRIVE OF A PNEUMATIC CYLINDER USING A PZT ON-OFF VALVE** *H. OHUCHI, N. MARUYAMA, T. OSADA* **DEVELOPMENT OF GAS METER WITH THERMAL FLOW SENSORS ARRANGED ON THE SURFACE OF THE RECTIFIED FLUID PATH** *K. OTAKANE, M. SETO* **PERFORMANCE IMPROVEMENT OF WATER HYDRAULIC HIGH SPEED SOLENOID VALVE** *S.-H. PARK, A. KITAGAWA* **SELF-SUSTAINED OSCILLATIONS OF A TURBULENT PLANE JET IN THE CAVITY** *A.C.S. ROLAND, S. ABDELAZIZ* **TRANSIENT BEHAVIOUR OF A SALT GRADIENT LAYER HEATED FROM BELOW** *M.J. SAFI., K. CHOUBANI, P. PRINCIPI*	**ULTRASONIC METHOD OF A MEASUREMENT OF VISCOSITY OF A LIQUID** *V. SHARAPOV, Ò. Y. KISIL* **EXPERIMENTAL STUDY OF METHANE/AIR LAMINAR FLAME QUENCHING: HEAT FLUX AND QUENCHING DISTANCE MEASUREMENTS** *J. SOTTON, M. BELLENOUE, S. A. LABUDA, B. RUTTUN* **A NUMERICAL MODEL FOR SIMULATION OF COMBINED ELECTROOSMOTIC AND PRESSURE DRIVEN FLOW IN MICRODEVICES** *D. SOUDERS, G. FA YAO, A. INCOGNITO, M. CORRADO* **TWO-DIMENSIONAL MEASUREMENT OF THE WATER VAPOR USING NEAR-INFRARED ABSORPTION** *Y.TAKAHASHI, K. KITAGAWA* **DETERMINATION OF THE FLOW-RATE CHARACTERISTICS OF SPEED CONTROL VALVE** *Y. TERASHIMA, T. MOGAMI, N. ONEYAMA* **STUDY AND IMPROVEMENT OF PEAK LOCKING DEVIATION IN PTV ANALYSIS** *T. UEMURA, Y. AKAMATSU, Y. YAMAMOTO, N. YONEHARA* **STUDY ON APPLICATION OF ELECTRORHEOLOGICAL TECHNOLOGY TO FLUID POWER TRANSMISSION** *K.-X. WEI, S.-S. ZHU, Q.-X. WANG* **DEVELOPMENT OF WEARABLE POWER ASSIST SUIT** *K. YAMAMOTO, M. ISHII, K. HYODO, T. YOSHIMITSU, T. MATSUO* **EXPERIMENTAL AND NUMERICAL INVESTIGATION OF A SUPERSONIC FLOW OVER THE LEE-SIDE OF A DELTA WING** *A. V. ZABRODIN, A. E. LUTSKY, M. D. BRODETSKY, A.M. KHARITONOV, A.M. SHEVCHENKO*
16.00				
20.00	***Social Banquet***			

Time				
8.10–8.50	Invited Lecture: **REAL TIME CONTROL OF THE LEAN BLOW OUT LIMIT IN PRE-MIXED COMBUSTORS FOR REDUCED NOX EMISSIONS** Speaker: ***B. ZINN***			
9.00	**Session: Compressible Flows I**	**Session: Flow Visualization I**	**Session: Natural Convection**	**Session: Bioengineering I**
	APPLICATION AND ANALYSIS OF DYNAMIC CHARACTERISTIC OF PRESSURE TRANSDUCER *T. YAMAZAKI, M. ENDO, J. IWAMOTO* **AN EXPERIMENTAL STUDY OF THE SUPERSONIC PETAL EJECTOR SYSTEM** *H.D. KIM, J.H. LEE, J.B. KIM, T. SETOGUCHI* **THE ROLE OF INFRARED THERMOGRAPHY IN THE STUDY OF CROSSFLOW INSTABILITY AT M=2.4** *S. ZUCCHER, W.S. SARIC, H.L. REED, L.B. MCNEIL* **ACCURACY ASSESSMENT OF VELOCITY MEASUREMENT TECHNIQUES VIA FILTERED RAYLEIGH SCATTERING** *J. GUSTAVSSON, C. SEGAL* **AN EXPERIMENTAL STUDY OF THE SONIC/SUPERSONIC, COAXIAL, SWIRLING JETS** *K.H. LEE, H.D. KIM, S.YOSHIOKA, S. MATSUO, T. SETOGUCHI*	**IMAGE PROCESSING IN KARMAN VORTEX STREET IDENTIFICATION** *G. L. PANKANIN, A. KULINCZAK, J. BERLINSKI* **RESPONSE OF A CONFINED VORTEX BREAKDOWN TO AN IMPOSED ASYMMETRIC CONDITION IN A LOW ASPECT RATIO CONTAINER** *T. T. LIM, Y. D. CUI* **REPRODUCTION OF TWIN & KÁRMÁN VORTICES VISUALIZED BY JOMON-PEOPLE BEFORE 4500 YEARS** *Y. NAKAYAMA, M. OKI, K. AOKI, H. MARUOKA* **FLOW STRUCTURE AND LOADING DUE TO AN OSCILLATING CYLINDER IN STEADY CURRENT** *M. SARITAS, O. CETINER* **CONTROL OF VORTEX BREAKDOWN-FIN INTERACTION ON A DELTA WING** *S. OKAMOTO*	**VISUALIZATION OF NATURAL CONVECTION FROM ISOTHERMAL L-SHAPED HEATED PLATE** *K. ICHIMIYA, H. TAKIGUCHI,* **TOWARDS ELECTROMAGNETIC CONTROL OF THERMAL CONVECTION** *J. VERDOOLD, L. ROSSI, M. TUMMERS, K. HANJALIC* **EXPERIMENTAL STUDY OF NATURAL AND MIXED CONVECTION INDUCED BY HOT SOURCE IN CONFINED CAVITY** *M.-L. TOULOUSE, P. REULET, P. MILLAN* **STUDY ON NATURAL CONVECTION IN A RECTANGULAR ENCLOSURE WITH A UNIFORMLY HEATED BOTTOM SURFACE. PART 1: FLOW FIELD MEASUREMENT WITH PIV SYSTEM** *J. ONISHI, A. NAKATA, S. KUWABARA, K. MORI, Y.H. CHUNG, M. MIZUNO* **STUDY ON NATURAL CONVECTION IN A RECTANGULAR ENCLOSURE WITH A UNIFORMLY HEATED BOTTOM SURFACE. PART 2: MEASUREMENTS OF FLOW AND TEMPERATURE DISTRIBUTIONS NEAR WALL REGIONS** *A. NAKATA, J. ONISHI, S. KUWABARA, K. MORI, Y.H. CHUNG, M. MIZUNO*	**NUMERICAL SIMULATION OF NONINVASIVE BLOOD PRESSURE MEASUREMENT BY PARTIALLY PRESSURIZED COLLAPSIBLE TUBE MODEL** *S. HAYASHI, M. MARUYAMA, T. HAYASE, A. SHIRAI* **COMPUTER MODELING OF OPENING AND CLOSURE MOTION OF A PROSTHETIC HEART VALVE** *H. G. KANG, K. S. CHANG, BYUNG-GOO MIN* **HEMODYNAMIC AND CYTOKINETIC STUDY FOR THE TREATMENT OF THE CORONARY ARTERIAL DISEASES** *S.-H. SUH, H.-W. ROH, H. MOON KWON, B. KWON LEE* **A CAROTID ARTERY BIFURCATION MODELLING FOR BLOOD FLOW** *S. PISKIN, M.S. CELEBI*
10.40	***Coffee Break***			
11.00	**Session: Compressible Flows II**	**Session: Flow Visualization II**	**Session: Mixed Convection**	**Session: Bioengineering II**
	THE STABILIZATION FEATURE OF THE SUPERSONIC STREAMLINE OF THE BODIES WITH CAVITIES IN THE PRESENCE OF THE ENERGY SUPPLY AREA IN THE INCIDENT GAS FLOW *L. A. BAZYMA, V. M. RASHKOVAN* **BOOSTING EFFECTS FOR DOWNSTREAM OF SUPERSONIC CAVITY** *H. KIM, S. KIM, S. KWON* **PRESSURE DISTRIBUTION AND INJECTED GAS CONCENTRATION MEASUREMENTS ON A MACH 2 CAVITY USING MULTI-LUMINOPHOR PRESSURE SENSITIVE PAINT** *S. FONOV, J. CRAFTON, L. GOSS, K.-Y. HSU, G. JONES, F. FERRIGNO, A. AULETTA, M. GRUBER, J. DUNBAR* **EXPERIMENTAL RESEARCH OF INTERACTION OF BLAST WAVE AND SHOCK WAVE** *L.D. GUO, Z.F. ZHOU, H. YANG, J.L. LUO, N.P. MENDE, A.B. PODLASKIN, V.A. SAKHAROV*	**DELIF MEASUREMENT OF PH DISTRIBUTION INDUCED BY CO2 DISSOLUTION IN HIGH PRESSURE VESSEL** *S. SOMEYA, S. BANDO, J. SAKAKIBARA, K. OKAMOTO, M. NISHIO* **VISUALIZATION OF JUNCTION FLOW OF TWO RECTANGULAR BLOCKS** *J. CHEN* **FLOW VISUALIZATION OF FLOW PAST A CIRCULAR CONCAVITY** *T.H. NEW AND T. T. LIM* **CONTROL OF WAKE BEHIND A CIRCULAR CYLINDER USING A FLEXIBLE V-GROOVED MICRO-RIBLET** *S.J. LEE, H. C. LIM* **ENVIRONMENTAL FLOW MAPPING USING ULTRASONIC DOPPLER METHOD** *S. WADA, H. KIKURA, M. ARITOMI*	**UTILIZING 2D-AIRFLOW PATTERNS IN PD-INDEX EVALUATION IN NON-UNIFORM THERMAL ENVIRONMENT OF SINGLE-ZONE SPACE** *L. HACH, Y. KATOH, J. KURIMA* **MIXED CONVECTION FLOW VISUALIZATION IN AN INCLINED ISOTHERMAL TUBE** *T. MARE, A. G. SCHMITT, M. HELLOU* **BUOYANCY EFFECTS ON MIXED CONVECTION HEAT AND MASS TRANSFER IN CHANNELS** *S. EL ALIMI , J. ORFI, S. BEN NASRALLAH* **EFFECTS OF THERMAL RADIATION, THERMAL DISPERSION AND VARIABLE VISCOSITY ON NON-DARCY CONVECTION HEAT TRANSFER IN A FLUID SATURATED POROUS MEDIUM** *M. F. EL-AMIN* **HEAT TRANSFER IN AN AXISYMMETRIC BOTTOM HEATED CAVITY IN A CROSS FLOW** *H. STAPOUNTZIS, G. RUOCCO*	**NUMERICAL AND EXPERIMENTAL STUDY OF SPATIAL PERIODICITY OF STATIONARY AIR FLOWS IN PULMONARY BIFURCATIONS** *C. RAICK, A. RAMUZAT, P. CORIERI ,M.L. RIETHMULLER* **COMPUTATIONAL FLUID DYNAMICS SIMULATIONS OF THE AIRFLOW IN THE HUMAN NASAL CAVITY** *F. CASTRO, A. DELGADO, C. MENDEZ, P. CASTRO, C. CENJOR* **STUDY OF A HAPTIC FINGER ACTUATED BY PNEUMATIC MUSCLES** *C. FERRARESI, W. FRANCO, A. MANUELLO BERTETTO, F. PESCARMONA* **STUDY ON A PHEUMATIC ROBOT HAND** *T. SHINOHARA, S. DOHTA, H. MATSUSHITA* **EFFECTIVE CONTROL OF VORTEX SHEDDING BY AN ARTIFICIAL MUSCLE** *M. FUCHIWAKI, K. TANAKA, S. SEWA, K. ONISHI*
12.40				

Technical Program Schedule
Thursday afternoon, August 28

14.00

Plenary Lecture: **THE INTERACTION BETWEEN ART & SCIENCE: FROM MONA LISA TO EINSTEIN**
Speaker: ***A. TAMIR***

14.30

14.40

Session: Compressible Flows III	Session: Flow Visualization III	Session: Pneumatic Components	Session: Bioengineering III
FLOW MEASUREMENTS AT THE PERFORATED WALLS OF A TRANSONIC WIND TUNNEL *M. MOKRY, Y. MEBARKI* **STUDY OF THE UNSTEADY EFFECTS ON THE GAS FLOW THROUGH A CRITICAL NOZZLE** *H. D. KIM, J. H. KIM, K. A. PARK, S. MATSUO, T. SETOGUCHI* **VISUALIZATION OF TRANSONIC FLOW FIELDS CONTROLLED BY NON-EQUILIBRIUM CONDENSATION AND POROUS WALL** *T. NAKANO, S. MATSUO, M. TANAKA, T. SETOGUCHI, K. KANEKO, H.D. KIM* **QUANTITATIVE PLANAR VELOCIMETRY OF A TURBULENT SEPARATED WAKE FLOW AT TRANSONIC AND SUPERSONIC FLOW REGIMES** *F. SCARANO, B. VAN OUDHEUSDEN* **DETERMINATION OF TRANSONIC FLOW PROPERTIES OF A TRISONIC WIND TUNNEL FOR ITS USE IN MISSILE AERODYNAMICS** *A. SAYIN, K.B. YUCEIL, O. CETINER*	**PROFILE MEASUREMENT AND FLOW VISUALIZATION OF SESSILE DROP THROUGH LASER SHADOWGRAPH** *N. ZHANG, D.F. CHAO* **FLOW VISUALIZATION INSIDE AN OIL HYDRAULIC BALL VALVE DURING CAVITATION** *T. TSUKIJI, G. MATSUMOTO, K. NAGATA AND F. YOSHIDA* **INVESTIGATION OF FAST, REPETITIVE EVENTS BY MEANS OF NON-STANDARD VIDEO TECHNIQUES** *B. STASICKI* **EXPERIMENTAL STUDY OF THE INTERACTION OF DISTURBANCES INDUCED BY THE FINE MESH GRID WITH THE STRAIGHT WING BOUNDARY LAYER** *G.M. ZHARKOVA, B.YU. ZANIN, V.N. KOVRIZHINA, D.S. SBOEV, A.P. BRYLYAKOV* **ON UPWELLING INDUCED BY MAN-MADE V-SHAPED STRUCTURE PLACED ON SEA BOTTOM** *T. NAGAMATSU*	**DEVELOPMENT OF OPTO-PNEUMATIC ON-OFF VALVE AND ITS APPLICATION TO POSITIONING** *S. DOHTA, T. AKAGI, H. MATSUSHITA* **DEVELOPMENT OF A FLEXIBLE PNEUMATIC CYLINDER WITH A FLEXIBLE TUBE** *T. AKAGI, S. DOHTA AND K. OKABE* **STUDY ON TEST METHOD OF FLOW CHARACTERISTICS OF PNEUMATIC COMPONENTS EXHAUSTING DIRECTLY TO ATMOSPHERE** *K. KUROSHITA, M. AKASHI, T. TAKAHASHI, N. ONEYAMA* **STUDY AND SUGGESTIONS ON FLOW-RATE CHARACTERISTICS OF PNEUMATIC COMPONENTS** *N. ONEYAMA, T. TAKAHASHI, K. KUROSHITA, K. KAGAWA* **DEVELOPMENT OF A PHOTO-FLUIDIC CONTROL VALVE USING FLUIDICS** *T. AKAGI AND S. DOHTA*	**HYDRODYNAMICS OF CEREBROSPINAL FLUID IN THE HUMAN CENTRAL NERVOUS SYSTEM** *L. HOWDEN, A. AROUSSI, M. VLOEBERGHS* **VISUALISATION OF DRUG DELIVERY TO THE HUMAN BRAIN** *S. AMMOURAH, A. AROUSSI, M. VLOEBERGHS* **INVESTIGATION OF THE FLOW IN AN ARTERIAL BLOOD FILTER USING PIV AND DYE INJECTION** *R. HUEBNER, M. PINOTTI, P. CASTELLINI* **VELOCITY MEASUREMENTS IN THE VICINITY OF A BIOPROSTHETIC HEART VALVE USING DPIV** *V.M.S. SANTOS, P. CASTELLINI, L. SCALISE, D. BRAILE, E.P. TOMASINI, M. PINOTTI* **THERMOBIOSENSOR FLUID CONTROL OF CONTAMINATED WATER BY SURFACE ACTIVE SUBSTANCES** *N. STARODUB, O. SHMIROVA*

16.20

附錄三

Symposium Chairman

G. M. Carlomagno,
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