出國報告（出國類別：參加研討會）

參加 2016 年工程及資訊科技國際研討會心得報告

服務機關：國防大學理工學院機械及航太工程學系
姓名職稱：上校副教授李峻溪
派赴國家：日本京都
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摘要

2016 年工程及資訊科技國際研討會(Annual Conference on Engineering and Information Technology , ACEAIT 2016)，為年度性之國際學術會議，本次會議由 ACEAIT 主辦，結合 GLSBE (Global Conference on Life Science & Biological Engineering), ISFAS (International Symposium on Fundamental and Applied Sciences) 及許多世界一流大學的學者於 3 月 29~31 日假日本京都研究園（Kyoto Research Park），進行一系列學術研究成果發表及新知討論。

本次研討會共有來自五大洲等數十個國家及地區之多位學者專家及研究人員參與為期三天之學術討論會，發表之論文包括自動控制技術，工業工程，機械設計與工程，計算機和資訊科技等領域之相關文獻，均深獲與會學者之興趣及討論。此外，藉由參與大會各國專家學者之交換研究心得及吸取他人寶貴之研究經驗，將可做為日後教學及研究之參考。

個人有幸執行科技部計畫參與此一重要國際會議，於會場實施海報論文發表，發表題目為” 不同熱邊界條件對光學側窗表面溫度的影響 Study of Aero-Thermal Effects of Two Heat Conditions on Optical Side Window”，會議期間達到與世界各國學者交流的目的，獲益良多。

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壹、會議目的

2016 年工程及資訊科技國際研討會(Annual Conference on Engineering and Information Technology , ACEAIT 2016)，其會議宗旨在於結合世界各國有關自動控制技術，工業工程，機械設計與工程，計算機和信息工程技術等研究領域之學者專家，進行一系列學術研究成果發表及新知討論，本次會議近 20 個不同國家和地區的投稿。會議結合 GLSBE (Global Conference on Life Science & Biological Engineering), ISFAS (International Symposium on Fundamental and Applied Sciences) 及世界各國一流大學之學者於 3 月 29~31 日在日本京都研究園（Kyoto Research Park）主辦。筆者的研究成果有幸能被接受並受邀發表報告。ACEAIT 學會歷年所主辦之學術研究年會、研討會及專題討論會，皆對該學術領域有深遠的影響及貢獻。個人有幸參與此一重要國際會議，尤其感謝科技部專題計畫經費補助以及本院各項研究和教學設施之支持，方使個人能在有限時間內完成研究並彙整成果發表，未來將秉持持續研究創新的研究態度，廣泛參與各項學術會議，期能拓展專業領域，精進個人教學與研究品質。

貳、會議過程

(一)本屆年會共有來自歐洲、美洲、澳洲及亞洲等數十個國家及地區之多位學者專家及研究人員參與為期三天(3月29日-3月31日)之學術論文發表及討論會。會議地點在日本京都舉行。此次為Annual Conference on Engineering and Information Technology , ACEAIT 2016及許多世界一流大學的學者共同協助舉辦，包括GLSBE (Global Conference on Life Science & Biological Engineering), ISFAS (International Symposium on Fundamental and Applied Sciences)，共計128場次口頭論文發表，海報論文發表134篇，大會邀請演講計三場，與會者多為各國在該領域學有專精之教授與學者，與各國學者相互交流之下獲益良多。

(二)本屆議程計有3場主題講演(Plenary Lecture)，29 日下午開幕典禮於京都研究園報到及參加歡迎茶會。30日上午同時有二場大會主題演講在京都研究園會議廳舉行。筆者

選擇參加由德國明斯特大學(University of Muenster)資工系教授 Sergei Gorlatch所發表的講演，題目是雲端運算應用現況與發展趨勢，講者介紹隨著雲端運算的日益普及，許多大廠也都開始引進和開發雲端運算相關技術，以提升自己的資訊運算效率，同時節省企業成本，創造更高的利潤。然而，雲端運算不僅是資訊技術上的進步，也是一種商業模式的創新。綜觀雲端運算對資訊和商業造成的影響和轉變，分別從技術面、商業面、應用面、行動終端裝置面以及生活面探討雲端運算的未來發展，搭配多篇論文引導實際講解說明。30日下午的大會演講是由日本立命館大學經濟系教授 Michelle Kawamura主講，題目是多元文化教育的前瞻發展，是他長期貢獻的領域，講述如何在平等、瞭解、尊重之中，建立起自我文化和他者文化之間的交流平台，如何讓不同文化的學生在大學中同中求異、異中求同，避免造成教育不平等現象，實現真正具有文化相對主義的平等教育。Michelle Kawamura分享了不同的案例，說明最終如何學生了解與認同自己的文化，並能欣賞及尊重他人的文化。

(三)筆者此次發表的論文，題目為”不同熱邊界條件對光學側窗表面溫度的影響 Study of Aero-Thermal Effects of Two Heat Conditions on Optical Side Window”，此為執行 104 年度科技部計畫的成果發表，其內容主要是以計算流體力學研究光學側窗在飛行速度 6 馬赫，模擬 20~60 公里高度，探討在暫態，DES 紊流模式，比較絕熱、熱通量兩種熱邊界條件對光學側窗表面溫度的影響。模擬結果顯示當飛行時間至 60 秒時，在熱通量條件，其光窗表面溫度較絕熱條件低約 100~200K 較接近真實情況。在 20~40 公里高度，光窗表面溫度均超過 500K 的安全工作溫度，須加裝冷卻機制。飛行高度 50 公里以上，光窗表面溫度在 500K 以下，則無須加裝冷卻機制。會場多位學者對筆者發表的報告亦提出見解與問題討論，學者除對本研究光學側窗表面溫度之研究方法深感興趣，也對本研究對光窗設計的的貢獻採高度肯定，另筆者也藉由交流獲得諸多良好之設計建議，獲益良多。

(四) 3 月 31 日的場次，聽了 8 場在應用力學及自動控制應用的論文發表。其中韓國首爾大學的 2 篇針對大數據資訊應用及燃料電池尖端發展現況介紹之論文最具代表性，Prof. Dung 團隊展現在燃料電池領域的前導地位和豐碩成果，其研究現已應用於新產品

研發上，可說是該領域發展的佼佼者。筆者與多位來自世界各國教授交換此次會議心得及經驗分享，也藉此達到與世界各國學者學術交流之目的。

參、會議心得

近年來，亞洲國家參與本會議程度較往年呈明顯增加趨勢，顯見亞洲知名大學藉由參加重要研討會以提升國際知名度之重視。由接受論文得知，南韓與日本兩國學者參與最多，中國大陸知名大學也有近10 餘篇發表，國內參與學校則包括台大、清大、交大、師大、中山及本校。

本次會議由ACEAIT主辦，結合GLSBE (Global Conference on Life Science & Biological Engineering), ISFAS (International Symposium on Fundamental and Applied Sciences)及許多世界一流大學的學者共同協助舉辦，有幸參與此次會議可說是獲益匪淺，也藉此一窺世界各國在機械領域發展的學術現況，於各場次論文發表過程中，瞭解各國學者不同領域的思考模式，並藉由問與答之間各取所需，達到智識精進功效。此次學術研討會的議程中，在各場次發表後皆有另外安排短暫的休息時間，讓眾多參與者可以在此時針對場次中的研究成果進行更多的對談、交流和討論，筆者積極把握此機會與各國學者交換演講意見，達到此次研討會學術交流之目的，希冀對爾後研究交流有所助益，也藉此建立各國學者之關係鏈。

此次能夠在國際研討會發表本人的研究成果，並與來自世界各國的學者們互動是難能可貴的經驗，能夠藉由此研討會進一步了解到目前最新的研究發展趨勢，同時啟發個人未來研究的方向和靈感，實屬難能可貴。

經過此次研討會歷練，使本人對未來之研究更具信心，將持續於此領域探討研析，並且對於後續之研究將會秉持精益求精的精神戮力完成，盡已所能將學術研究之成果呈現於各大期刊並貢獻於我國國防工業之上。

肆、建議事項

針對此次於日本京都舉辦之工程及資訊科技國際研討會，筆者有三點個人心得在此提出供本院教學施政之參考：

一、定期參加國際研討會以提升整體國防科技研究能量。在軍事院校資源有限之狀況下，憑藉個人研究能量實難以擴展研究領域，本院目前已建立各領域之專業研究群可整合學校研究資源，惟囿於部分貴重儀具、設備與研究生人力逐年下滑，期盼本院可加強校際合作，藉由定期研討交流，逐步發展跨領域研究，以提升整體研究能量。

二、鼓勵軍校教師及研究生多參與國際學術研討會。在政府研究預算縮減下，研究計畫案經費獲得不易，但仍應鼓勵軍校教師及研究生參加國際學術研討會，加強與國際學者學術交流，此舉不僅有助於瞭解國際最新研究趨勢，另也可以藉此提升個人國際觀與增加本校知名度。

三、藉由課程引導逐步訓練研究生具備良好學術及外語表達能力。本次會議許多議程均由研究生擔任主講者，其表達能力與外語嫻熟度令人印象深刻。在本院研究所課程規畫方面，應加強研究生外語口說能力與學術寫作、報告等相關課程，藉由課程引導，逐步訓練研究生具備良好學術表達能力，達到與世界接軌之目標。

伍、附件

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Annual Conference on Engineering and Information Technology
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Chun Chi Li
Chung Cheng Institute of Technology, National Defense University

Has attended the conference and presented a paper entitled

Study of Aero-Thermal Effects of Two Heat Conditions on Optical Side Window

Chief Executive Committee

研討會紀念狀

於會場報到處留影

和與會學者合影

報到處電子顯示板

Study of Aero-Thermal Effects of Two Heat Conditions on Optical Side Window

Li Chun-Chi [a,*]
[a]Department of Mechanical and Aerospace Engineering, Chung Cheng Institute of Technology, National Defense University,
No.75, Shiyuan Rd., Daxi District, Tauyuan City 33551, Taiwan, ROC
E-mail address: davidli560607@gmail.com

Abstract

Under hypersonic flow environment, the optical side window of optical guidance missile triggers aerothermal heating effects that create high heat and cracks in optical windows, leading to optical windows failure. This study adopted computational fluid dynamics to compare the effects of two types of thermal boundary conditions (i.e., adiabatic and heat flux conditions) on the surface temperature of an optical side window at a flight speed of Mach 6, simulated altitude of 20–60 km, and under a transient detached eddy simulation (DES) turbulence model. The simulation results revealed that after a flight time of 60 seconds, the surface temperature of the optical side window was 100–200 K cooler in a heat flux condition compared with that in an adiabatic condition. This temperature range approximated more closely to that observed in reality. At an altitude of 20–40 km above sea level, the surface temperature of the optical side window exceeded the safe working temperature of 500 K, indicating that the optical side window requires a cooling mechanism. When the flight altitude exceeded 50 km or more, the surface temperature of the optical side window was less than 500 K, suggesting that no cooling mechanism is necessary.

Keyword: Hypersonic Flow, Aerothermal Heating Effect, Aero-Optics, Optical Window, Computational Fluid Dynamics

1. Introduction

When interceptor missiles are flying at high speeds in the atmosphere, complex flow-fields form between the optical windows and the airflow. This results in high heat, thermal radiation, and interference with image transmission in the seeker, leading to target image offsets, jitter, and fuzziness. This is called the aero-optical effect. The aero-optical effect includes the high-speed flow-field optical transmission effect, shock waves, the window aerothermal radiation effect, and the optical window aerothermal heating effect, as shown in Fig. 1[1].

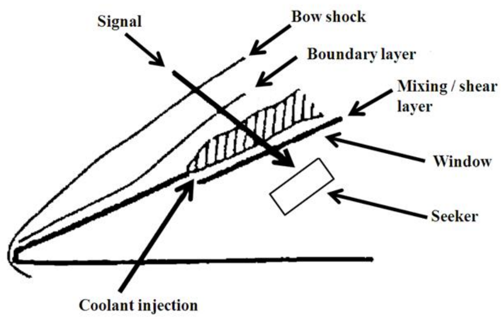


Fig. 1. Schematic diagram of aero-optical effects [1]

The aerothermal heating effect of an optical window is generated when high-speed airflow approaches the optical window. Due to the viscous effect of the inner boundary layer and the no-slip condition on the surface of the optical window, the kinetic energy of airflow is converted into heat energy, heating the optical window and exposing the optical window and infrared seeker to an adverse aerothermal environment.

Bertin and Cummings[2] indicated that during hypersonic flight at altitudes of 30 to 50 km, the aerothermal effect impacted the reliability of the material structure of optical windows, forcing the installation of a temperature protection system (TPS) on the flying body. In general, cooling technology must be used for protection and for lowering temperatures. Two methods are primarily adopted for optical window cooling, external jet cooling and internal convection cooling. The external cooling method is simple and easy to implement, but cooling gas and the gas boundary layer mix, forming a shear/mixed layer. Thus, complex turbulence flow fields and the aero-optical effect easily occur. The internal cooling mechanism of an optical window is extremely complex. However, inappropriate cooling mechanism and quantity of coolant will engender problems related to missile payload. Therefore, accurately calculating the surface temperature of an optical window is a crucial issue in aero-optics.

Li et al. [3-4] simulated Terminal High Altitude Area Defense (TAAD) missiles at angles of attack from 0° to 30°. The turbulence method used was the Spalart-Allmar (SA) model. At a flying altitude of 30 km with a flight speed M = 6, by using active external cooling jet controls, when cooling air mass flow reached 0.15 kg/s, the entire optical window could be cooled to 500 K or less, protecting the function of the optical window. However, Li found that the surface temperature of optical windows is typically overestimated. Previous studies generally use a steady state simulation condition, in which the viscous effect of the boundary layer and the no-slip condition cause kinetic energy to be completely converted into heat. The surface of optical windows features adiabatic heat that cannot be dissipated. Therefore, the surface temperature of optical windows continues to rise, resulting in overestimated results. By contrast, transient simulation considers time step calculations and involves a slow heat transfer rate, which more closely reflects real-life situations.

In this study, the optical side window of an interceptor missile was composed of a single-crystal sapphire with a safe working temperature below 500 K. The effects of two types of boundary condition (adiabatic and thermal flux conditions) on the surface temperature of the optical side window were investigated under the following simulation conditions: an altitude of 20–60 km, flight speed of Mach 6, transient time of 60 seconds, and DES turbulence. Subsequently, this study aimed to determine the flight altitudes that would cause an optical window to require or not require a cooling mechanism to maintain a safe working temperature.

2. Problems and Methods

2.1 Governing Equation and Numerical Methods

The governing equations are the Reynolds averaged Navier-Stokes equations, the conservation can be expressed as follows

$$\frac{\partial U}{\partial t}+\frac{\partial F}{\partial x}+\frac{\partial G}{\partial y}+\frac{\partial H}{\partial z}=\frac{\partial F_{v}}{\partial x}+\frac{\partial G_{v}}{\partial y}+\frac{\partial H_{v}}{\partial z} \quad (1)$$

In solving equation (1), convection terms (F,G,H) are calculated by $AUSM^{+}$ scheme, while viscosity and diffusion flux terms (F_v, G_v, H_v) are calculated using the central difference method. Discrete space terms are to form a group of ordinary differential equations followed by time integration to obtain the numerical solution. Turbulence model adopted the DES equation.

2.2 Boundary Conditions

Inlet boundary condition should be set to pressure-far-field condition, outlet boundary for the pressure-outlet condition, projectile and the optical window is set to no-slip, and added the real gas equation modified specific heat ratio. The adiabatic and heat flux conditions were adopted the thermal boundary on the surface temperature of an optical side window. Regarding the settings for heat flux boundary condition, the thickness of the optical window was assumed to be 0.5 cm; the thermal conductivity coefficient was defined according to the physical properties of the sapphire; and the convection heat transfer coefficient h was set as 100 $W/m^2.K$.

2.3 3-D Physical Model and Grid Configuration

This paper assumes the optical window to be rectangular for ease of modeling and prediction of flow field. Besides, the former configuration shows a groove tilt with a deep front and shallow end. Schematic model of missile is shown in Fig. 2. The domain is divided into many sub-domains, yielding a grid number of approximately 800,000 grids. Adopted in this study three-dimensional computational grid of structural grid configuration shown in Fig. 3. All the results presented in this study are grid insensitive.

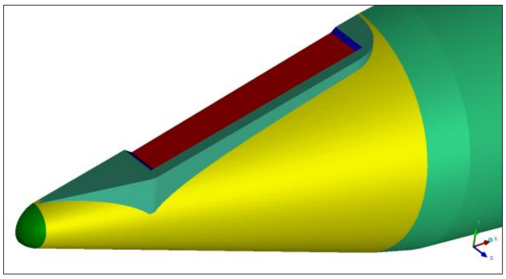


Fig. 2 Guidance section model diagram

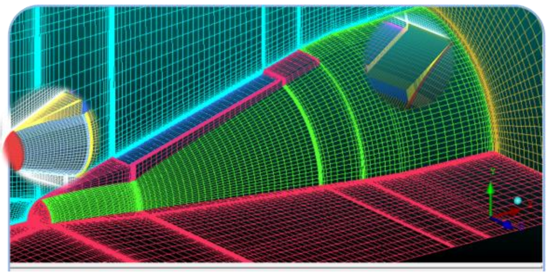


Fig.3 Optical window grid diagram

3. Results and Discussion

3.1 Numerical Code Validation

In order to verify the accuracy of numerical programs, this paper compared with the experimental and theoretical solution three-dimensional blunt body by Rakich & Cleary [5] shown in Fig. 4-5. Simulate conditions under the conditions of Mach number = 10.6. Simulation results show that the cone at different azimuthal angel 0° , 90°, 180° of the surface pressure values are very good agreement, indicating that this program can be used for hypersonic flow simulation.

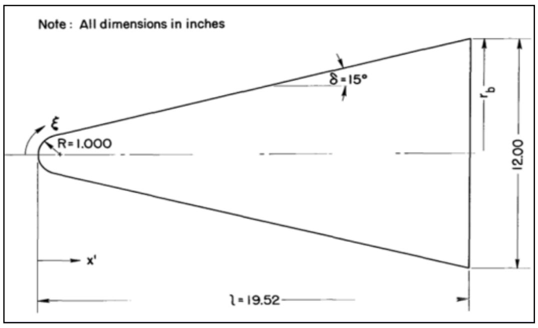


Fig. 4. 3-D blunt body configuration diagram

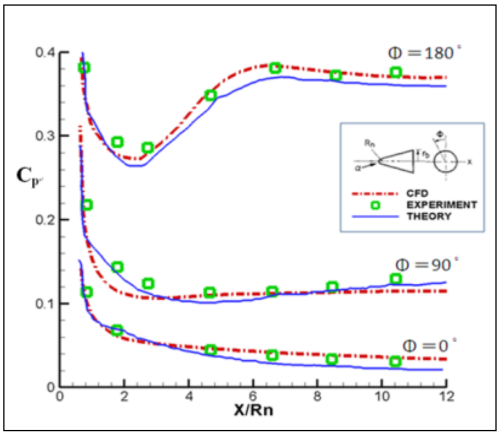
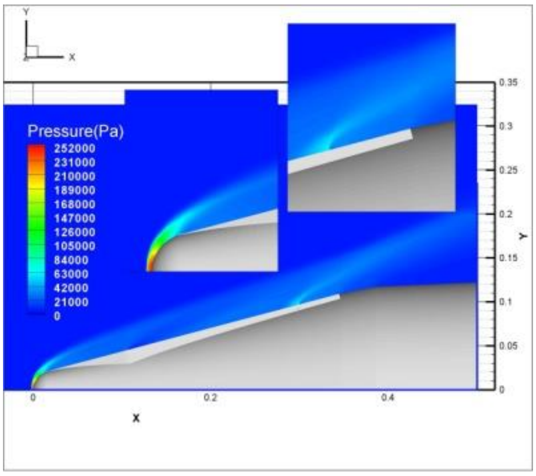


Fig. 5. Comparison the C_p values of computation with the experimental and theory of Rakich and Cleary.

3.2 Hypersonic Flow Characteristics

The hypersonic flow characteristics of the optical side window at a flight speed of Mach 6 were simulated. Using a flight altitude of 20 km as an example, the pressure, density, and Mach contours were compared shown in Fig. 6. The front end of the nose cone clearly produced a bow shock wave, and within the sonic line range, a strong shock with high pressure, high temperature, and a Mach number of <1 was observed. The intersection of the nose cone and optical side window exhibited characteristics of expansion waves. The optical window groove produced expansion fan at the front and oblique shock waves at the back.



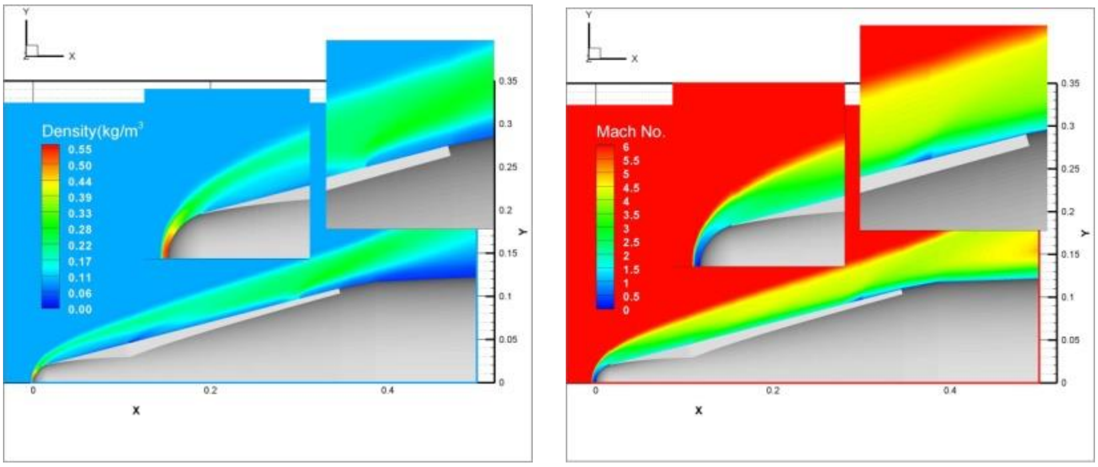


Fig. 6. Pressure, density and Mach number contour respectively.

Because of viscosity and friction, the airflow in the boundary layer produces heat and thus increases the temperature of the boundary layer. The boundary layer was substantially thinner than the shock wave layer. However, the speed distribution from the boundary layer to the shock wave layer still exhibits hypersonic flow, which quickly transfers the heat in the boundary layer. Under the two boundary conditions, the pressure, density, and speed distributions in the shock wave layer are nearly identical, and only the temperature in the boundary layer differed significantly, as shown in Fig. 7-10.

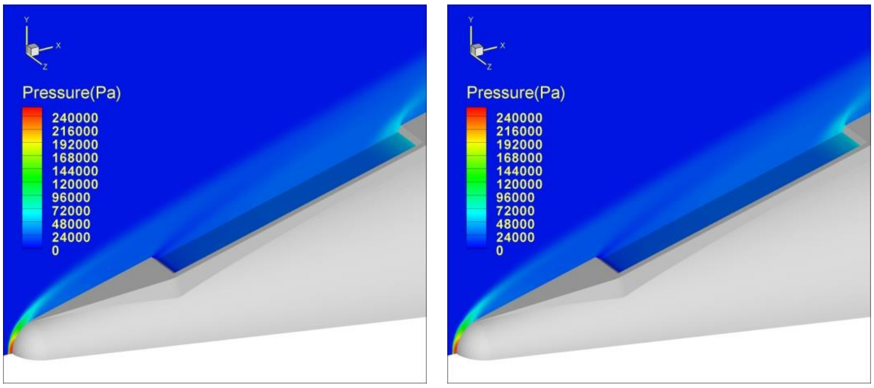


Fig. 7. 20km, 60sec, pressure contour in adiabatic, heat flux condition respectively.

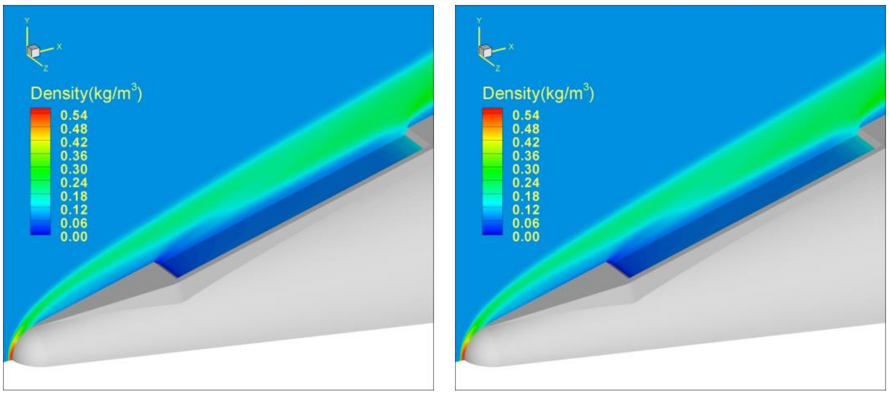


Fig. 8. 20km, 60sec, density contour in adiabatic, heat flux condition respectively.

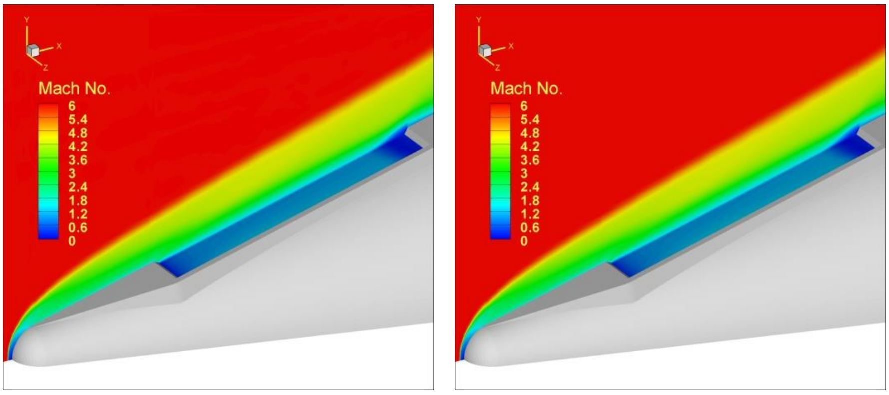


Fig. 9. 20km, 60sec, Mach No. contour in adiabatic, heat flux condition respectively.

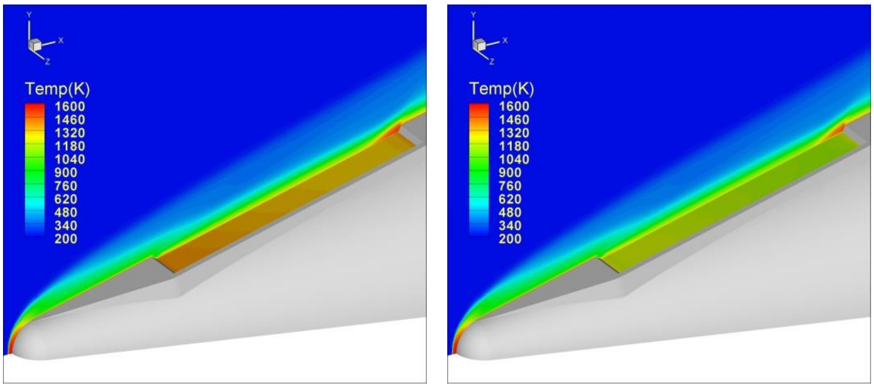


Fig. 10. 20km, 60sec, Temp. contour in adiabatic, heat flux condition respectively.

3.3 Analysis of Optical Window Surface Temperature

The surface temperatures of the optical side window at flight altitudes of 20–40 km and 60 seconds of open-cover flight were compared, as shown in Fig. 11-13. At an altitude of 20 km, the surface temperature of the optical window reached approximately 1400 K in an adiabatic condition, whereas the temperature reached approximately 1200 K in a thermal flux boundary condition. At 30 km (40 km), the air density decreased with increasing altitude, the surface temperature of the optical window reached approximately 1000 K (680 K) in an adiabatic condition, whereas the temperature reached approximately 830 K (580 K) in a heat flux boundary condition. Thus, at a constant flight speed, an increase in flight altitude decreased air density and decreased surface temperature of the optical window.

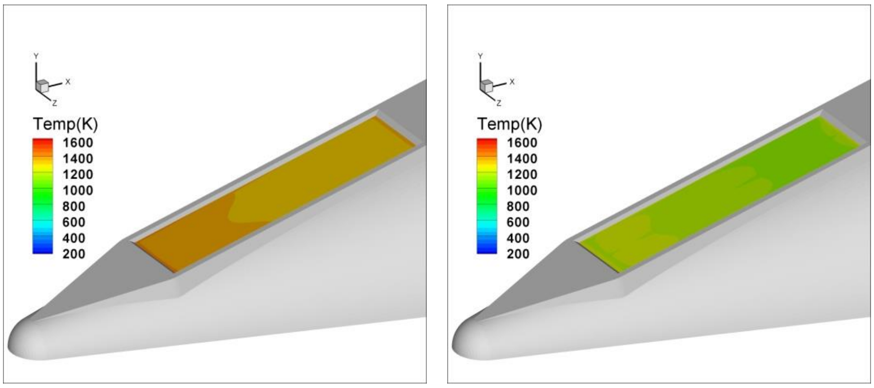


Fig. 11. 20km, 60sec, optical window Temp. in adiabatic, heat flux condition.

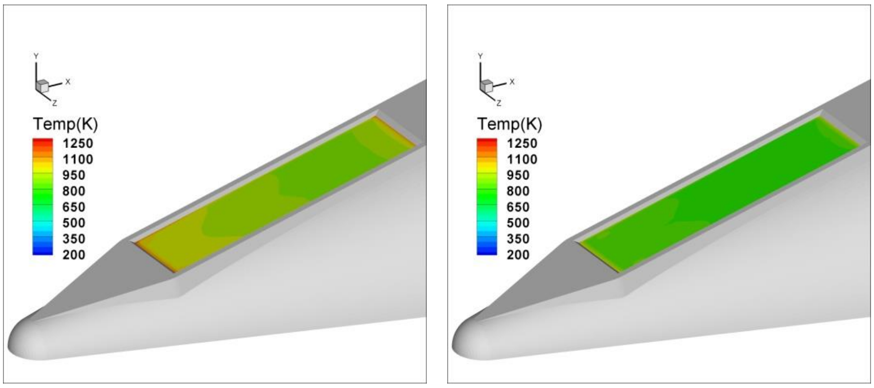


Fig. 12. 30km, 60sec, optical window Temp. in adiabatic, heat flux condition.

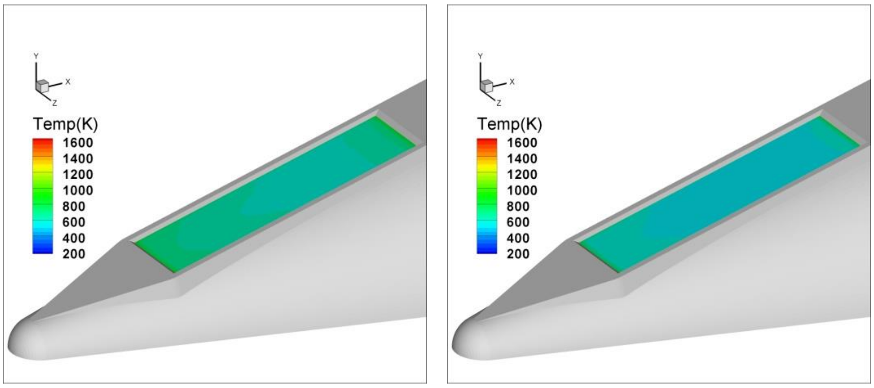


Fig. 13. 40km, 60sec, optical window Temp. in adiabatic, heat flux condition.

The surface of the optical window was assumed to exhibit an adiabatic condition, in which heat flux cannot dissipate when the external wall surface of the optical window is heated, causing the temperature of the optical window to rise. Although experimental data on the true convection heat transfer coefficient of optical windows are lacking, this coefficient can be defined on the basis of the missile body's speed flight condition. Therefore, air convection heat transfer coefficient was assumed to be 100 $W/m^2.K$. The transient simulation results of the optical window subjected to aerodynamic heating at flight altitudes of 20–60 km were compared with those generated under adiabatic conditions. This study then analyzed the maximum temperatures of the optical window surface in a 60-second flight process at flight altitudes of 20–60 km under adiabatic and heat flux conditions, as shown in Fig. 14.

At a flight altitude of 20 km, the air density was high. For both types of boundary conditions, the maximum temperatures of the optical window surface exceeded the safe working temperature of 500 K when the optical window was subjected to aerodynamic heating for 4 seconds . At a flight altitude of 30 km and exposure to 12 seconds of adiabatic condition and 14 seconds of heat flux condition, the maximum temperatures of the optical window surface exceeded the safe working temperature of 500 K. At a flight altitude of 40 km and exposure to 24 seconds of adiabatic condition and 34 seconds of heat flux condition, the maximum temperatures of the optical window surface exceeded the safe working temperature of 500 K. At a flight altitude of 50 km and exposure to 50 seconds of adiabatic condition, the maximum temperatures of the optical window surface exceeded the safe working temperature of 500 K. Under the heat flux condition, only the maximum temperature of 450 K conformed to safety regulations. At a flight altitude of 60 km, the maximum temperatures of the optical window surface fell below 500 K for both types of boundary conditions.

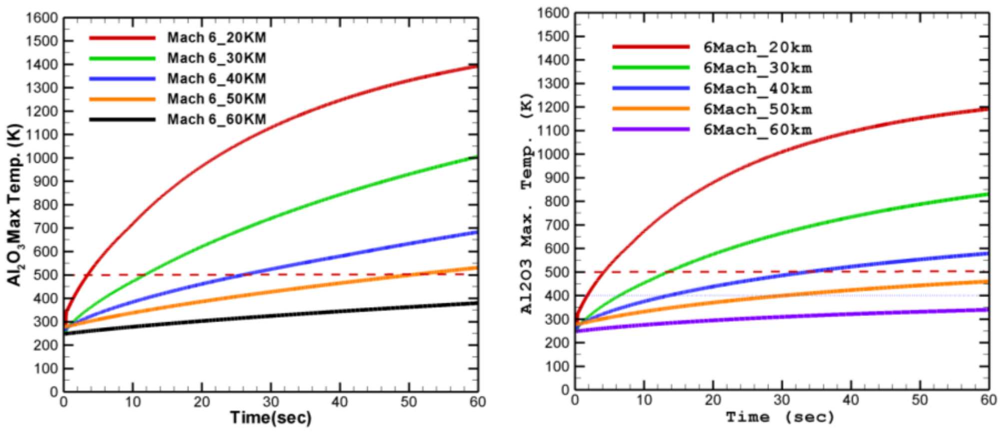


Fig.14. 20~60km, optical window T_{max}-Time in adiabatic, heat flux condition.

4. Conclusion

Accurately calculating the surface temperature of optical windows in a high-temperature, low-pressure hypersonic flow environment is difficult. Particularly, an adiabatic condition yields overestimated surface temperature. Although a thermal flux condition more closely reflects real-life conditions, its high-temperature, low-pressure hypersonic flow field poses difficulties in determining the correct convection heat transfer coefficient. Nevertheless, regardless of convection heat transfer coefficient, the surface temperature of optical windows must not exceed adiabatic temperature. Therefore, a comparison of the simulation results for the two types of heating conditions provides a basis for assessing the characteristics of interceptor missiles (e.g., interceptor altitude) to determine whether to install cooling mechanisms. At a flight speed of Mach 6 and altitudes of 20–40 km, optical windows require a cooling mechanism. When the cover is opened at an altitude of 50 km or more, the optical windows do not need a cooling mechanism. Using computational fluid dynamics to simulate the aero-optics of a hypersonic flow environment facilitates the reduction of ground testing costs.

5. References

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