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MIXING OF AIR AND CO2 STUDY ON A TURBINE BLADE

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ABSTRACT

Effects of the inclination angles on the mixing process and the film cooling is presented for a rectangular two-dimensional (2-D) domain. For this purpose five different inclination angles are taken into account. Computational solution is performed by using Re-Normalized k-epsilon (RNG) turbulence model with near-wall treatment. Additional transport equations for different species to analyze the mixing process of air crossflow and CO_2 cooling jet are also solved. Effects of the blowing ratios are also investigated by taking two different blowing ratios, M=0.15 and 1.20.

1. INTRODUCTION

Jet in crossflow (JICF) is a natural flow phenomenon and has many engineering applications such as blade cooling in the turbo machinery, chimney flows, and fuel injection and piping systems. When a jet issuing into a cross flow, the jet bends quickly over in the direction of the cross flow and there is a complex interaction between these two flows. There are a lot of parameters affect the mixing phenomena in the JICF of transverse jets such as blowing ratio, inclination angle, jet exit geometry, inlet and outlet conditions such as uniform or parabolic profiles, laminar and turbulent flow, etc. Although there are many experimental studies could be found in the literature, some computational works are cited here such as Pathak et al. [2006], Taslim and Khanicheh [2005], Priere et al. [2004], Iourokina and Lele [2005] and Roy [200]. Effects of turbulence model, velocity ratio, inclination angle and hole spacing are reported by these papers.

In this study, blowing ratio, M, is defined as follows: $M = \frac{r_j}{r_{cf}} \frac{V_j}{U_{cf}}$ where ρ and V, represent density and velocity. Subscripts j and cf stand for jet and crossflow, respectively. Effect of density difference between two different fluids is approximately 1.6

2. COMPUTATIONAL MODEL

Computational domain used in this paper is taken as two-dimensional (2-D). The crossflow channel covered the area extending from 2D upstream and 16D downstream from the leading edge of the jet nozzle and 6D above the bottom flat plate. The height of the nozzle is 2.5D where D=40mm. As can be seen from the Figure 2, the origin of the rectangular coordinate system is located at the leading edge of the jet nozzle. The computational domain is decomposed into 210×280 structured non-uniform grid in the x- and y-directions. After the generation of the domain and mesh structure, all the governing equations are solved iteratively using SIMPLEC algorithm of Patankar [1980] who stated that there is no need to specify pressure at the outlet because of given velocities at the channel and slot inlets. In this paper, simulations are performed for two different blowing ratios; M=0.15 and 1.20. Reynolds number based on the U_{jet}=2.3 m/s and 18.4 m/s is Re_{jet}=12000 and 96000. Crossflow

Reynolds number is calculated as $Re_{crossflow}$=19300 for $U_{crossflow}$=23 m/s. Jet and crossflow inlet temperatures are 300 K and 373 K for both cases.

2. RESULTS AND DISCUSSION

Effects of the inclination angle between the jet slot and crossflow channel is showed in Figure 1 for blowing ratio off 1.20. In these figures main flow (crossflow) is assumed from left to right while jet flow is obtained from upward.

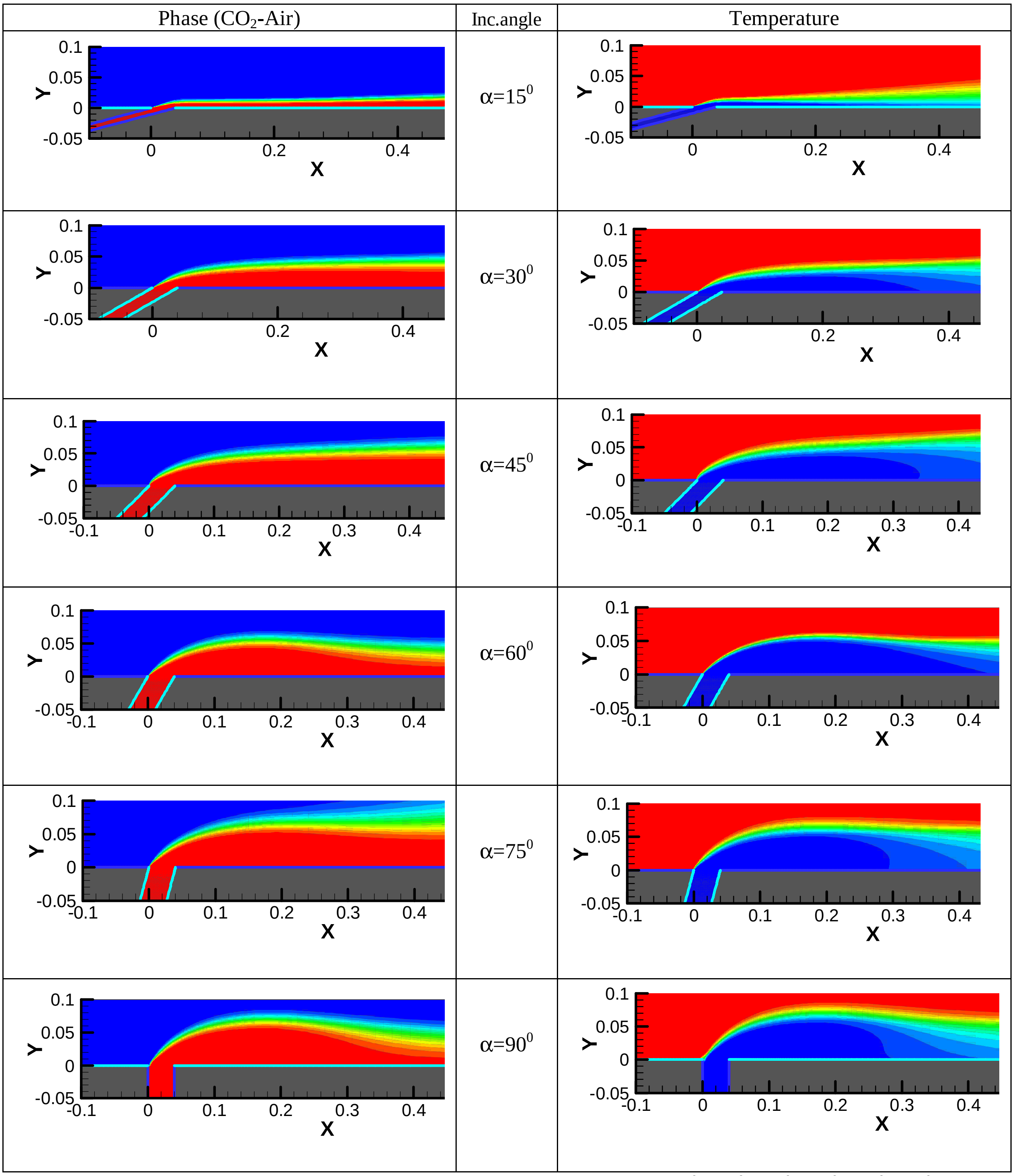

Figure 1. CO_2-air and temperature contours for M=1.20 at $\alpha=15^0$, 30^0, 45^0, 60^0, 75^0, 90^0.

Temperature and CO_2-air distribution is showed in Figure 1 for the higher blowing ratio (M=1.20). Comparing to Figure 2, it is seen that due to increment in the vertical momentum, the injectant starts to lift off from the wall so that, temperature regions are detached from the upper wall of the hot turbine blade. In the left columns, red color stands for CO_2 (phase=1) and blue shows air (phase=0). The penetration of the coolant fluid (CO_2) into the crossflow shows the effects of these two different fluids's density. Film cooling is also revealed by tracking the CO_2 on the upper wall of the turbine blade. From the left and right column comparison it can be concluded that, the higher the inclination angle, the higher the jet penetration into the channel which result the lower film cooling effectiveness due to low coverage on the blade surface.

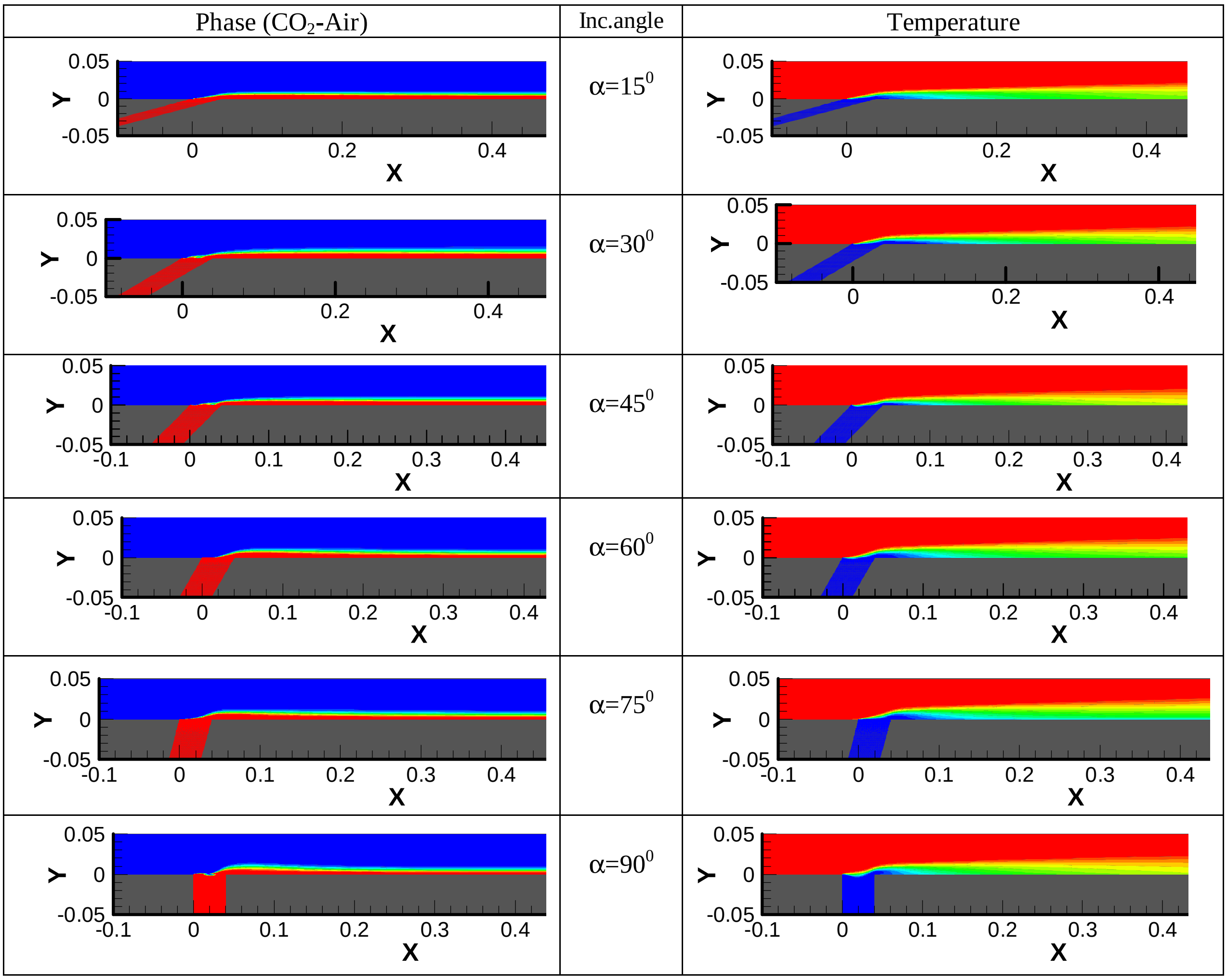

Figure 2. CO_2-air and temperature contours for M=0.15 at $\alpha=15^0$, 30^0, 45^0, 60^0, 75^0, 90^0.

CONCLUSION

In this paper, mixing process in a 2-D domain is investigated numerically. Two different fluids have been used to show film cooling. CO_2 and air have been used as coolant and freestream, respectively. Simulations were performed for five different inclination angles between the slot and channel and two different blowing ratios. It is observed the higher the blowing ratio, the more penetrate into the channel upper wall that indicates lower film cooling effectiveness.

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