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Ablating and Charring of Heat Shield Materials For 1-D & 2-D Geometry

Mohammad Hassan Rahimian *rahimyan@ut.ac.ir*
Mohammad Reza Shabani *shabani@me.ut.ac.ir*
Mechanical Engineering Department
University of Tehran Tehran, Iran

Abstract

The objective of this research is to estimate ablating and charring of heat shield materials in severe aero thermal / erosive environments. This requires an accurate and rapid technique for many practical aspects such as suitable thickness design, selection of materials and so on. Quasi-steady state model is poor for this object and finite difference method in spite of good accuracy, is too slow to use in large parametric studies, because of its need to many grids. To get rid of this problem one should use an effective technique in finite difference methods. In this work VOF method accompany with finite difference algorithm is used. This couses redaction of necessary nodes about 75%. Therefore running time of the code reduced about 70%. In VOF method a matrix F is defined in the whole solution domain. F is equal to one in non-ablated cells and equal to zero in ablated cells. F is between one and zero in the surface cells. In this paper phenomenological study of charring and ablating of heat shield materials is considered too. The charring ablator considered to be composite of carbon-phenolic.

Results and conclusion

VOF and regrid finite difference method is used in the computer code that is run on a pentume 3 with 900 MHz. The schematic of heat shield is shown in figure 1. It is containing of virgin, pyrolysis, charring and heat surface zone. Energy balance is applied to heat surface zone and the ablated area is eliminated from the computational domain.

Figure 2 displays the wall temperature distribution versus time. It is obtained by VOF, regrid, HBI and quasi-steady methods. It is observed that all the above methods except quasi-steady are in good agreement.

Fig. 3 denotes pyrolysis gas flux from the surface versus time. Regrid and VOF methods agreed well together and quasi-steady model shows poor predication.

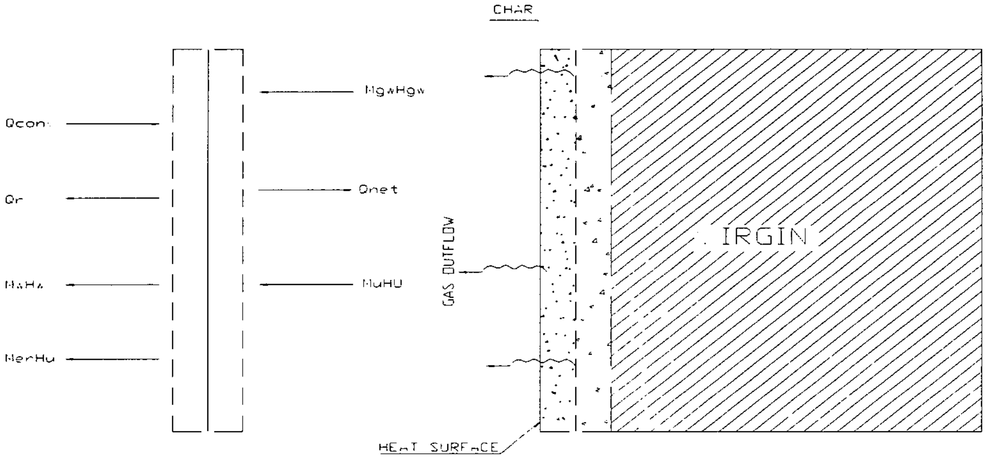
Fig. 4 indicates the convection heat flux on the external surface. This is an input of the code, which is used for stagnation point and is obtained from standard aerodynamics relations.

The net heat flux conducted into the surface and heat flux re-radiated away from the surface is shown in Figures 5 and 6 respectively. Because of increasing wall temperature the re-radiation increases and net heat flux decreases.

Fig. 7 demonstrates regression of surface while figures 8, 9 and 10, 11 explain temperature and density profile in the heat shield. Since VOF method uses a fixed mesh and the surface retreated so ablated cells eliminated from the solution filed therefore fig 9 and 11 don't show the relevant curves in the ablated length (0-0.4 cm) but in regrid method the origin of coordinate started from regression surface and it is reduced from the end of heat shield. Thus fig 8 and 10 are agreed with figs 10,11 completely.

It is observed that VOF methods compared with regrid finite difference method and heat balance integral (HBI) scheme are in good agreement. This method is able to simulate moving boundary of ablator surface and solve non-linear conservation energy, mass and decomposition equations for unsteady state situation. It is completely reliable for prediction of charring and ablating materials to severe aero thermal / erosive environments, with moving surface and change phase by changing density reduces about 75% of nodes and 70% in time consuming.

Result of 1-D :



(a) (b)

Fig. 1: (a) Surface Energy Balance (b) Schematic of Heat Shield for Ablatoon

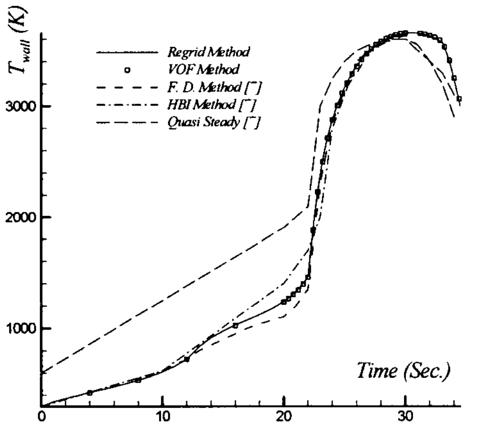


Fig 2- Comparison of surface temprature prediction

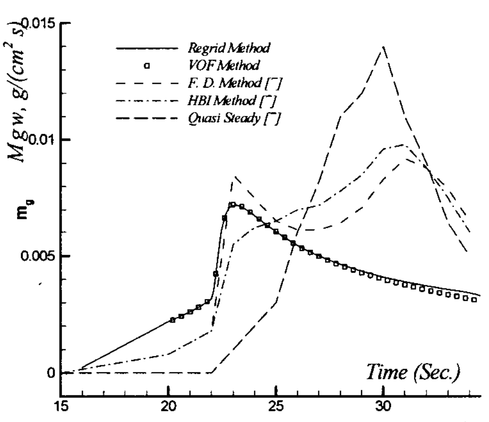


Fig 3- Comparison of pyrolysis gas flux m_g prediction

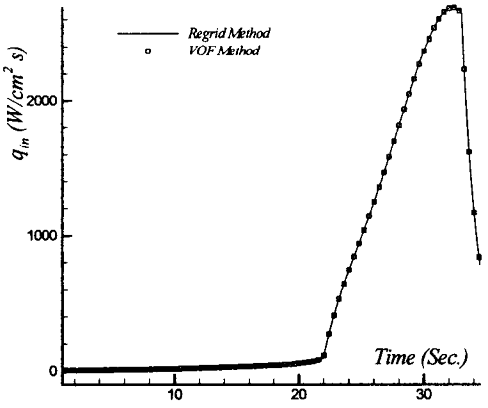


Fig 4-Convective input heat flux

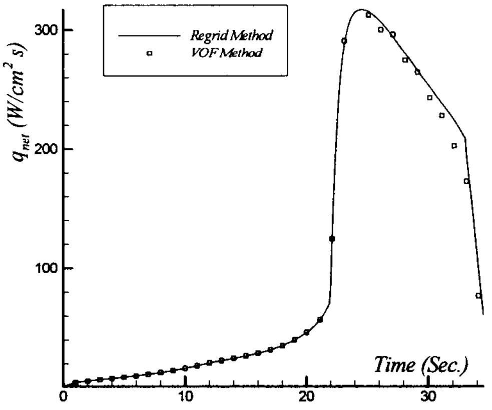


Fig 5- Net input heat flux

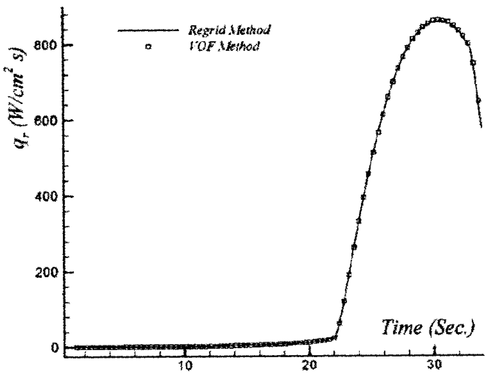


Fig 6- Radiation output heat flux

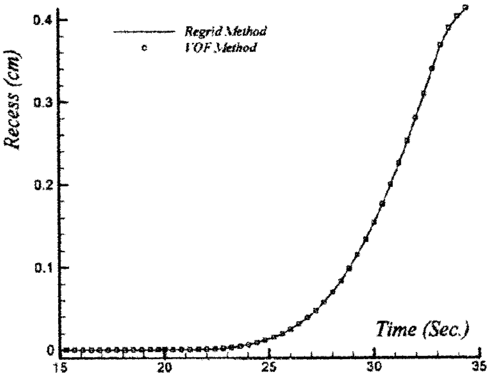


Fig 7- Comparison of surface recession

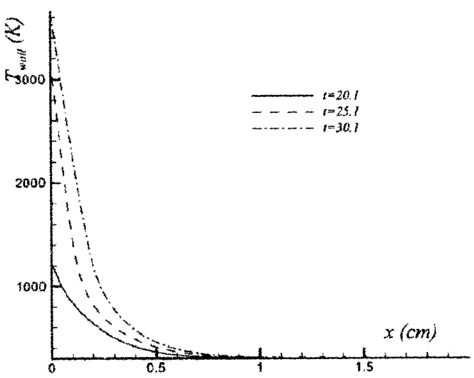


Fig 8- Profile of temprature by F.D. method

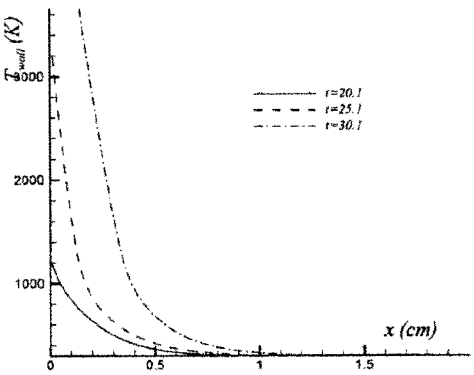


Fig 9- Profile of temprature by VOF method

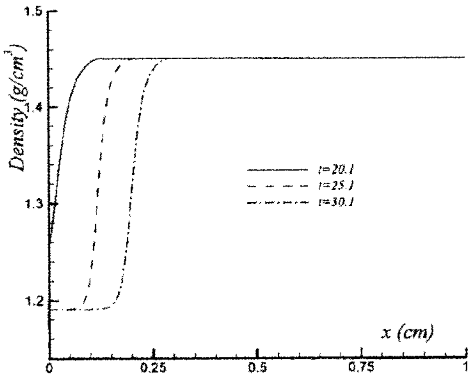


Fig 10- Profile of density by F.D. method

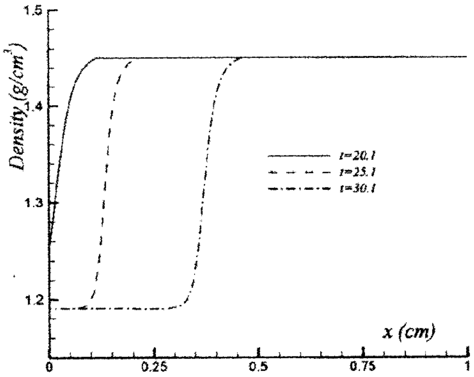


Fig 11- Profile of density by VOF method

Note: Result of 2-D coming in full paper