Acceleration of the Time-Dependent Radiative Transfer Calculations using Diffusion Approximation

Taewan Noh

Hongik University
Seoul, Korea

Abstract : An acceleration technique combined with the discrete ordinates method which has been widely used in the solution of neutron transport phenomena is applied to the solution of radiative transfer equation. The self-adjoint form of the second order radiation intensity equation is used to enhance the stability of the solution, and a new linearization method is developed to avoid the nonlinearity of the material temperature equation. This new acceleration method is applied to the well known Marshak wave problem, and the numerical result is compared with that of a non-accelerated calculation

Introduction : The field of radiative transfer provides scientists in various fields with the foundation for the analysis of stellar atmospheres, planetary illumination, and sky radiation. Through radiative transfer has been investigated chiefly as a phenomenon of astrophysics, in recent years it has attracted the attention of engineers as well, since essentially the same problem arise in the theory of neutron transport or diffusion, fire simulation, internal combustion, space ship design, etc. Although the time dependent radiative transfer equations in which the photon intensity and the material temperature exist as unknowns are very complicated in terms of the total number of variables including space, angles, time-dependency, and nonlinearity of temperature behavior, the solution techniques are very similar to the well established ones in the neutron transport fields In this study we focused to develop a new acceleration technique which is similar to the diffusion synthetic acceleration(DSA) in the field of neutron transport.

Methodology : For the solution of radiative transfer equations with the assumption of 1 dimensional and 1 group Grey model we used the self-adjoint form of photon intensity equation along with the corresponding spatial differencing and the standard discrete ordinates(S_N) scheme which have been developed for the solution of neutron transport equations. We derived an acceleration equation which is an approximation to the angle dependent photon intensity equation. The procedure is more complicated than the one for the neutron transport because the scalar intensity is also coupled with the temperature equation. We obtained the acceleration equations by integrating the radiative transfer equation over the angle domain not only at interior nodes but also at boundary nodes. Multistep linearization method was used to avoid the nonlinear property of the temperature equation.

Result : The developed scheme is applied to various problems to confirm accuracy and reduction in the number of source iterations. One of the final results is the comparison between accelerated and non-accelerated calculations for the Marshak wave problem. The problem is a radiative transfer, which corresponds to an initially cold at 0.01 kev, homogeneous, infinite, and purely absorbing medium with a constant boundary source at the left face of the slab at a black-body temperature of 1 kev. The curves in Fig. 1 shows an exact agreement in accuracy between two methods. The number of source iterations in Table 1 shows a constant ratio of faster convergence by the proposed acceleration scheme. More reduction is expected for the medium with higher scattering ratio.

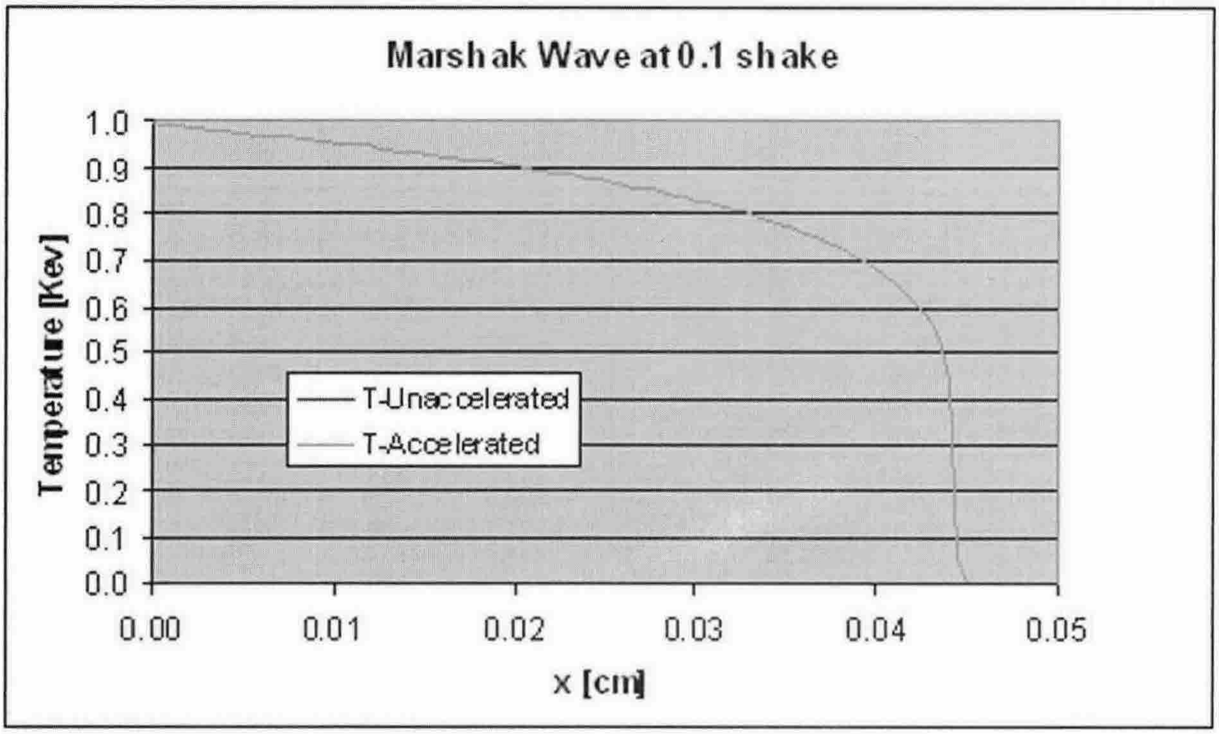

Fig. 1 Temerature Change by Black-Body on Left Boundary

Table 1 Comparison of Number of Source Iterations

Order of Angular Qudrature		# of Time Steps	# of total Source Iterations	Average # of Source Iterations per Time Step
S2	None	10,000	57,933	5.79
	Accelerated	〃	22,870	2.29
S4	None	〃	57,920	5.79
	Accelerated	〃	22,986	2.30
S8	None	〃	57,907	5.79
	Accelerated	〃	22,988	2.30
S16	None	〃	57,910	5.79
	Accelerated	〃	22,999	2.30