# Weakly ionized plasma effects on mitigation of shock waves

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In this work, shock wave modification by a DC glow discharge was investigated, theoretically. Numerical results showed that the electric field distribution has significant effects on shock front. Also, the electron temperature and their diffusion were found to be effective parameters on the plasmaaerodynamic. It was found that the plasma can deflect the incoming flow and modifies the structure of shock waves. The effect of the electric field strength was also examined in this work. Equilibrium and non-equilibrium assumptions for the plasma were examined to demonstrate heat and momentum transfer contributions in supersonic flow control.

## 1. Introduction

Since non- thermal plasmas generated in relatively low power input, therefore they are the appropriate discharges for use in aeronautic. Some authors believe that thermal effects [1] and transfer momentum to the incident fluid particles (neutrals) can modify the flow properties, locally [2]. Therefore, we will use a theoretical model to examine the physical mechanisms governing the plasma flow control for supersonic incident flow. We took a wedge geometry in which the plasma was created in front of the wedge by electrical discharge. The cathode electrode and anodes assumed to be positioned on the front and the side walls of the wedge, respectively. The DC voltage on the cathode was -10 kV. Here we assumed the electric field components as

$$E_X = \frac{E_0}{1+(a\xi)^2}, \qquad E_Y = \frac{\xi E_0}{1+(b\xi)^2} \qquad (1)$$

Where $E_0$ is electric field amplitude and $\xi = y/L$. Here L is cathode length and dimensionless parameters a and b are constant. a and b are either 1 or 0.7 depending on the cathode configuration such as flatness or sharpness.

## 2. Basic equation

We assumed a weakly ionized plasma that produced by the external electric field. Also, we assumed that the incoming flow having Mach number M=2.5 and p=0.175 atm. We used momentum transfer equation for electrons, ions and neutrals with taking into account of collision frequencies for electron-neutral, electron-ion, and ion-neutral interactions. We also employed the energy equation for each species. Some of our numerical analysis are as follows:

1- Thermal effect does not play a major role in the weakly ionized glow discharge.
2- The distribution of the electric field has more effect on the shock front position than the electric field strength
3- For higher values of the electric field, the electron temperature has not any significant effect on deflection angle of flow.
4- Incoming flow is deflected after interacting with the plasma.

Figure 1, shows the effect of the different electric field distributions on the shock wave angle. In figure 2, the change in attached shock by electric field distributions is seen. From figure 2, one can conclude that the electric filed distribution affects the shock properties significantly. It is also seen that the electric field strength has minor effect with respect to the field distribution.

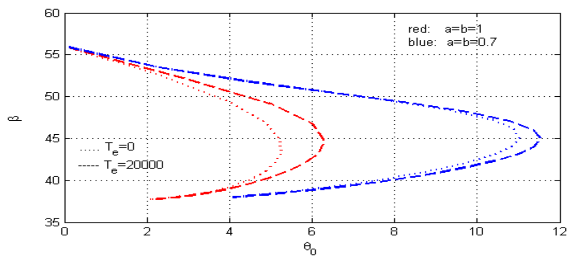


**Figure 1.** Shock wave angle $\beta$ versus deflection angle by plasma, doted line with no electron density gradient and dashed line for $T_e$=20000 K for both electric field distributions a=b= 1 and a=b=0.7

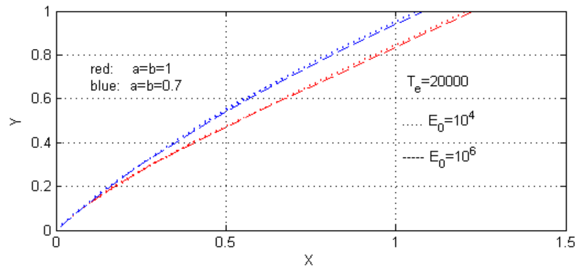


**Figure 2.** Attached shocks in the supersonic flow over a 15° wedge for different electric field distributions(red line: a=b=1 and blue line a=b=0.7), dot line $10^4$V/m and dash line $10^6$ V/m.

## 3. References

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[2] S.P. Kuo, Steven S. Kuo, Physics of Plasmas, 12 (2005) 012315.

[3] M. Moisan, J. Pelletier, Physics of Collisional Plasmas, Springer, (2012).