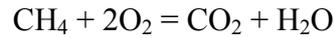


**A STUDY ON SUPERSONIC COHERENT JET  
CHARACTERISTICS USING COMPUTATIONAL FLUID  
DYNAMICS**

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Supersonic gas jets are widely used in BOF and EAF steelmaking for refining the liquid iron inside the furnace. Supersonic gas jets are preferred over subsonic jets because of high dynamic pressure associated with it which results in higher depth of penetration and better mixing. Laval nozzles are used to accelerate the gas jets to supersonic velocities of around 2.0 Mach number in steelmaking. When a supersonic gas jet exits from a Laval nozzle, it interacts with surrounding environment to produce a region of turbulent mixing. This process results in an increase in jet diameter and decrease in jet velocity with increasing distance from nozzle exit. During oxygen blowing, the higher the distance between liquid surface and the nozzle exit the more is the entrainment of surrounding fluid which in turn decreases the impact velocity as well as momentum transfer to the liquid. Hence, it is desirable to locate the nozzle close to the liquid metal surface. But the disadvantage of this is the sticking of slag/metal droplets on the lance tip which results in poor tip life. In order to solve the problem, coherent jet technology has been introduced in the EAF steelmaking process at the end of last century. The potential core length (the length up to which the axial jet velocity is equal to the exit velocity at the nozzle) of a coherent supersonic jet is about 40 nozzle diameters compared to 10 nozzle diameters in case of normal supersonic jet. Coherent gas jets are produced by surrounding the normal supersonic jet with flame envelope [1]. The flame envelope is created using a fuel and oxidant. Due to the flame, the entrainment of the surrounding gas into the supersonic jet is reduced, leading to a higher potential core length of the supersonic jet. Although the steelmaking industries have been using the coherent supersonic jet for last one decade, not much research work has been done to investigate the physics involved in supersonic coherent jet. In this study, Computational fluid dynamics (CFD) simulations of supersonic jet with and without shrouding flame were carried out and validated against experimental data [2]. The numerical results showed that the potential core length of the coherent supersonic jet is 4 times longer than that of a supersonic jet without flame shrouding which were in good agreement with experimental results. The CFD model results were then used to analyse the flame shrouding effect on the central supersonic jet.

A 2D computational grid was used for the simulation. The numerical simulations were carried out by solving the unsteady continuity, momentum and energy equations. For each species separate scalar equation has been solved. Temperature corrected  $k-\epsilon$  turbulence model was used for the modelling of turbulence. The fuel and oxidizing agent used in the present study is  $\text{CH}_4$  and  $\text{O}_2$ . Nitrogen and Oxygen were used as the central supersonic jet. Only one step of reaction has been considered. The equation of reaction is given by,



Eddy break up combustion model has been used for the modelling of the combustion flame.

Figure 1 shows the velocity distribution of the supersonic jet with and without shrouding effect. The potential core length of the supersonic oxygen jet with shrouding flame is approximately 4 times higher than that without shrouding flame. Again the potential core length of the shrouded supersonic oxygen jet is higher than the potential core length of the shrouded supersonic nitrogen jet. Figure 1 also shows the axial velocity distribution of the shrouded supersonic N<sub>2</sub> jet with flame deflector. Although the CFD results shows that potential core length of the jet increases when flame deflector is used but it still underpredicts the experimental results [2]. Study is going on to understand the reason for this difference.

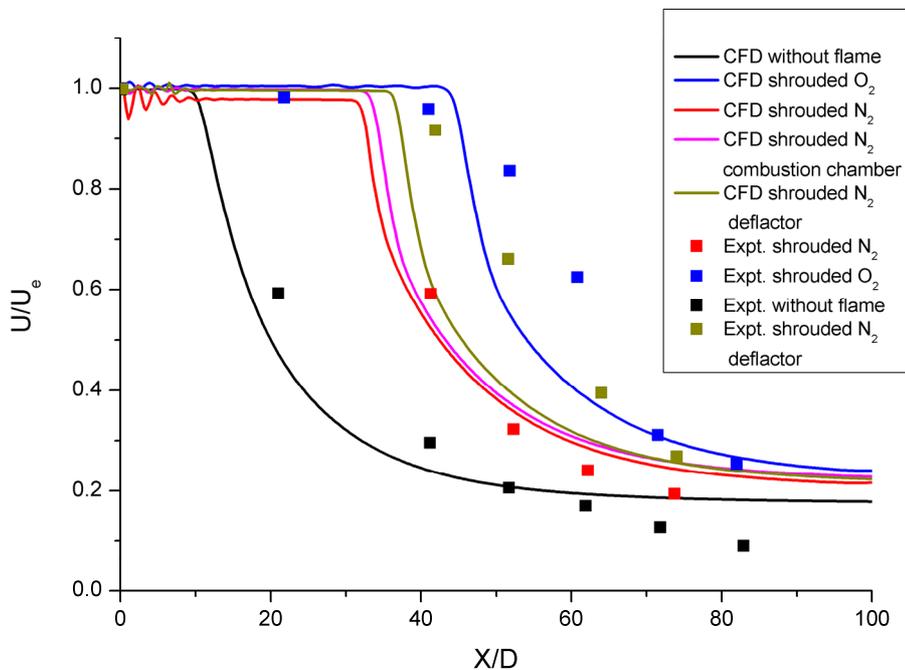


Figure 1

In summary, it can be said that shrouded supersonic jets are very important for steelmaking because it allows the injector to be installed at a distance from the liquid surface which in turn protects the lance tip from corrosion. The present study should allow improved design for shrouded supersonic jet in more effective way.

## Reference

1. Sarma *et al.* "Fundamental Aspects of Coherent gas Jets", Proceedings of the electric furnace conference, ISS, Vol. 56, 1998
2. Anderson *et al.* "Coherent Gas Jet" US patent No. 5823762, Oct 20, 1998.