ABSTRACT

A theoretical/numerical study is undertaken to elucidate the vaporization, ignition, and combustion characteristics of a LOX droplet exposed to hydrogen gas contained in a concentric spherical shell of finite radius. The concentric spherical shell of gas is believed to represent the sphere of influence of a droplet in a spray and, with appropriate boundary conditions at its outer boundary, is expected to reflect the interaction effects of the neighboring drops on the droplet under consideration. The mathematical model adopted for the analysis is comprised of the unsteady continuity, species, and energy conservation equations in the gas phase and the energy equation in the liquid phase, the phases being linked across the interface through appropriate energy balance and phase change conditions and takes a realistic account of the various thermophysical and transport properties of a multicomponent gas undergoing chemical reaction. A versatile FORTRAN code has been developed based on the above model to obtain numerical solutions for various limited environment conditions.

Results show that for LOX drops vaporizing in limited atmospheres, the vaporization exhibits an unsteady behavior with continuously decreasing vaporization rate with time, especially with small shell to drop radius ratios. Both the condensed phase and gas phase processes are unsteady during the entire vaporization process. For limited atmospheres the burning rate exhibits a strong dependence on time, decreasing with the progress of combustion unlike in the case of a drop in an infinite atmosphere which exhibits a quasi steady behavior insofar as the burning rate is concerned. The burning rate becomes lower with decreasing values of shell to drop radius ratios. Further the ignition delay increases with decreasing shell to drop radius ratio and below a threshold value does not even take place indicating a transition from individual drop combustion to group combustion. The denseness of a spray as judged by the shell to droplet radius ratio for which the combustion mode is one of group combustion appears to be a strong function of pressure, initial gas phase temperature, and the individual droplet size itself.

The thesis is organized into six chapters as follows:

Chapter 1: Introduction

This chapter starts with a general introduction to Rocket propulsion followed by a description of the processes occurring in the combustion chamber of a Liquid Rocket engine. The importance of the present investigation from both practical and academic research point of view is discussed and the objective of the current investigation is outlined.

Chapter 2: Literature Review

This chapter is concerned with a detailed review of the published literature relevant to the current research work and is grouped into the following categories:

(a) Droplet vaporization and combustion in an atmosphere of infinite extent

(b) Droplet vaporization in limited environments

(c) Droplet combustion in limited environments

Chapter 3: Mathematical Formulation

This chapter describes the model for the numerical simulation of droplet vaporization and combustion in limited extents of environment along with the assumptions made and outlines the development of the theoretical formulation for the spherico-symmetric problem of vaporization and combustion of drops in the finite extent of environment.

Chapter 4: Method of Solution

This chapter describes the numerical methodology adopted to solve the system of equations for obtaining numerical solution to the above problem which is complex and highly non linear.

Chapter 5: Results and Discussion

The transient combustion code developed for analysis of the vaporization and combustion phenomena is used to study the entire droplet behavior at limited and infinite surroundings including the vaporization, ignition, drop burning, group to isolated combustion mode, transition and extinction process.

Chapter 6: Summary and Conclusions

This chapter contains the major conclusions drawn from the current investigation .