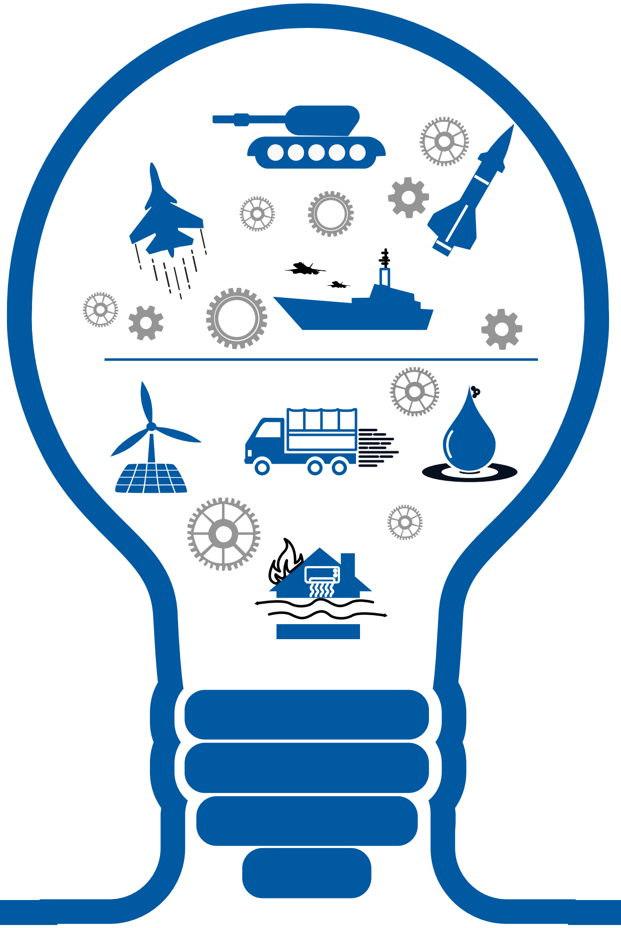
ZEUS NUMERIX

Charring Ablation of Liner for Plume Management System.

REFERENCE MANUAL

http://labs.zeusnumerix.com/



Contents

Introduction

- Based on literature survey, it was evident that liner erosion of deflector plate is driven mainly by thermal effects & erosion is directly proportional to total heat load during launch.
- High heat transfer from plume ablates the upper layer of liner.
- Methodology was based on 1D transient heat conduction with moving boundary. The non-linear governing equations were transformed for varying mesh & implemented using finite difference scheme.

Governing Equations

- The governing equation and corresponding boundary condition is:

$$\rho C_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial x}\left(k \frac{\partial T}{\partial x}\right) \qquad \text{for } 0 < x < s(t); t > 0$$

BC: $\frac{\partial T}{\partial x}|_{x=0} = 0 \,, \quad T_{x=s(t)} = T_M$

- Here, ρ, Cp & k are density, specified heat capacity and thermal conductivity of liner material.
- Thickness of liner at any time instant is represented by s(t). At x = s(t), i.e. liner surface boundary facing plume is maintained at Tm, melting point of liner. The opposite liner face, i.e. x = 0, exhibits adiabatic boundary condition.

Web App - Usage

- User needs to upload input file containing the name, properties and thickness of liner material. Other data related to plume properties and discretization should also be provided.
- Upon execution, following output is generated:

1. Plot of Nozzle location, Heat flux onto liner, Erosion depth, Rate of interface movement, thickness, plume plate temperature, ablation interface temperature vs. time.
2. Summary report showing final erosion depth, liner surface temperature, heat flux onto liner and heat content of liner.

- User can download the raw output data (textual format) for future reference

Input File Description

Parameter	Default Value	Unit	Description
LinerProperties			
name	VIRGIN	-	Primary Liner material
thickness	10E-3	m	Thickness of primary liner material
layer_nodes	10000	-	Number of nodes for discretization for primary liner material
name	CHAR	-	Secondary Liner material
thickness	10E-6	m	Thickness of secondary liner material
layer_nodes	10000	-	Number of nodes for discretization for secondary liner material
GeneralVariables			
gravity	9.806	m/s^2	Acceleration due to gravity
num_nodes	1	-	Number of location where erosion depth is to be found.
UserTimeStep	0.001	s	Time step for discretization

Input File Description

Parameter	**Default Value**	**Unit**	**Description**
DeflectorLength	1.0	m	Length of deflector plate.
AmbientPressure	101300.0	Pa	Ambient Pressure
InitialTemperature	300.0	K	Initial Temperature
InitialNozzleLocation	1.0	m	Initial distance between nozzle and deflector plate.
InitialBuildupDuration	0.1	s	Initial build up duration of missile.
NumLaunches	1	-	Number of launches of missile.
CanisterLength	1.0	m	Canister length
NumLayers	2	-	Number of layers of liner
ThrustWeightRatio	5.0	-	Thrust to Weight Ratio
LaunchDuration	1.0	s	Launch duration of missile.

Input File Description

Parameter	Default Value	Unit	Description
NozzleExitDiameter	0.1	m	Exit diameter of nozzle
ChamberPressure	50E5	Pa	Chamber pressure in PMS
ChamberTemperature	3000	K	Chamber temperature in PMS.
ExitMach	3.0	-	Mach number of plume at nozzle exit.
PlumeProperties			
AluminiumPercentage	10.0	%	Aluminium percentage in plume.
PlumeSpecificHeatRatio	1.2	-	Specific heat ratio of plume
PlumeGasConst	320.0	J/kg/K	Gas constant of plume.
PlumeDynamicViscosity	1E-4	Pa-s	Dynamic viscosity of plume
PlumeThermalConductivity	0.5	W/m/K	Thermal conductivity of plume
AccoCoeff	0.1	-	Accomodation coefficient of plume particle.

Input File Description

Parameter	Default Value	Unit	Description
ImpingeAngle	0.0	rad	Impingement angle of plume on deflector.
ParticleSpecificHeat	850.0	J/kg/K	Specific Heat of plume particle

Output File Description

- outfile1.txt presents the time date of Nozzle location (m), Heat flux onto liner (MW/sq. m), Erosion depth (mm), Rate of interface movement (m/s), thickness (mm), and ablation interface temperature (K).
- First column is time (sec)
- Each of the next column show the Nozzle location (m), Heat flux onto liner (MW/sq. m), Erosion depth (mm), Rate of interface movement of virgin (m/s), Rate of interface movement of char (m/s), thickness of virgin (mm), thickness of char (mm), and ablation interface temperature (K).

Summary File Description (outfile2.txt)

Parameter	Default Output	Unit	Description
LINER SURF. TEMPERATURE	800.0	K	Surface temperature of primary liner after erosion.
HEAT FLUX ONTO LINER	4.615	MW/sq. m	Total heat flux onto liner
HEAT CONTENT OF LINER	2.430	MW/sq. m	Heat conducted through liner
HEAT LOST IN EROSION	2.122	MW/sq. m	Heat lost in erosion
HEAT LOST IN PYRO	0.089	MW/sq. m	Heat lost in pyrolysis
HEAT IN PYRO GASES	-0.016	MW/sq. m	Heat in pyrolysis gases.
EROSION DEPTH	1.860	mm	Total depth of erosion.
LAYER THICKNESS OF VIRGIN	9.862	mm	Final thickness of virgin layer
LAYER THICKNESS OF CHAR	1.065	mm	Final thickness of char layer

References

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Thank You !

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