AE608A - Computational Project

Due on April 18, 2023, 5 pm

Note: *The last date of computational project submission is April 18, 5 pm. Submission after the said time will be marked as late submissions. Get the required thermophysical properties of the materials from a standard reference data book. Please submit your project as a single zipped file (containing code and project document pdf), with the name of the file in the format: Name_Rollnumber_CP*

Problem: Develop a Finite Volume (FV)/Finite Difference (FD), 1D/2D code for designing the thermal protection system (TPS) for a base plate (as shown in the schematic figure on the next page) subjected to uniform heating on the exposed side as shown in the figure. Total time of exposure is 12 min, with heat flux, q_s'', variation on front (exposed) surface through the duration of exposure, as shown in Fig. 1 on the next page. Initial temperature of the sample through the thickness is 300 K.

Use the **explicit approach,** as discussed in the class to solve this problem. Consider surface radiation from the exposed end of the TPS surface to space at a temperature of 0 K with an emissivity of 0.9. Come up with the thickness, material of TPS and its thermal response during the time of exposure. Please select an appropriate material by doing some literature survey. Also note that though structural considerations form an important component of TPS design, the same is not considered in this sample TPS design problem in order to keep the problem tractable.

The following criteria should be met for TPS to be qualified for use on the system.

(1) Temperature of TPS material cannot exceed its melting temperature.
(2) Temperature on the backend of TPS (see the schematic figure on the next page) cannot exceed 310 K, so that the base plate can always be found to be nearly at room temperature.
(3) Total weight per square meter of frontal surface needs to be minimized. The assignment will be evaluated based on how good you can do with respect to this number, i.e., the lower the weight, the more marks you earn.

For simplicity, you may use the following assumptions:

a) The mesh is uniform.

b) No internal heat generation.

c) The material composition is homogeneous, however thermal conductivity and specific heat capacity may change with temperature. You may first do the problem by considering constant properties, and the variation of properties with temperature in the second stage.

d) Temperature at the backend of the TPS can be considered to be same as that of the base material (see the schematic figure in the next page).

Write your code in fortran/C/matlab preferably or any language of your choice. Include a README text file that states:

i. How to compile the code: the line command necessary to compile.
ii. How to execute the code: the line command necessary to execute.
iii. Status of your code: operational/compiles-doesn't-run/doesn't compile.

Note: Your code should function for general input values not just the above; the sample input serves only as a check of your successful completion of assignment. This is a very simple problem to code using the explicit formulation. Start early to avoid last days hassles.

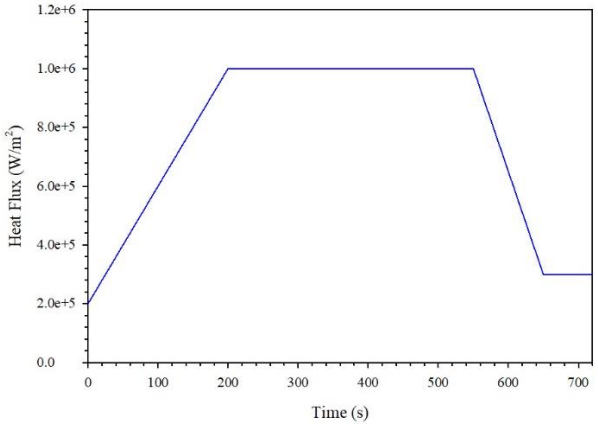

Fig. 1 Surface heat flux on exposed TPS surface

Answer the following:

a. Material selected for the sample problem, showing its density, specific heat capacity, thermal conductivity, thermal diffusivity, melting temperature.
b. Thickness and weight per square meter of the TPS.
c. Show the sensitivity of your results with respect to grid used. Essentially you should be able to show grid independence.
d. Plot the temperature variation with time at the exposed and back ends at any y location (essentially, the problem is one-dimensional in nature).
e. Plot the temperature distribution through the TPS material along x coordinate at any y location at the following instants: 100 s, 200 s, 300, 450, 550, 650, 720 s.
f. Plot the results with and without the consideration of variation of thermal conductivity and specific heat capacity with temperature.
g. Show the effect of surface radiation on thermal response by turning it off.

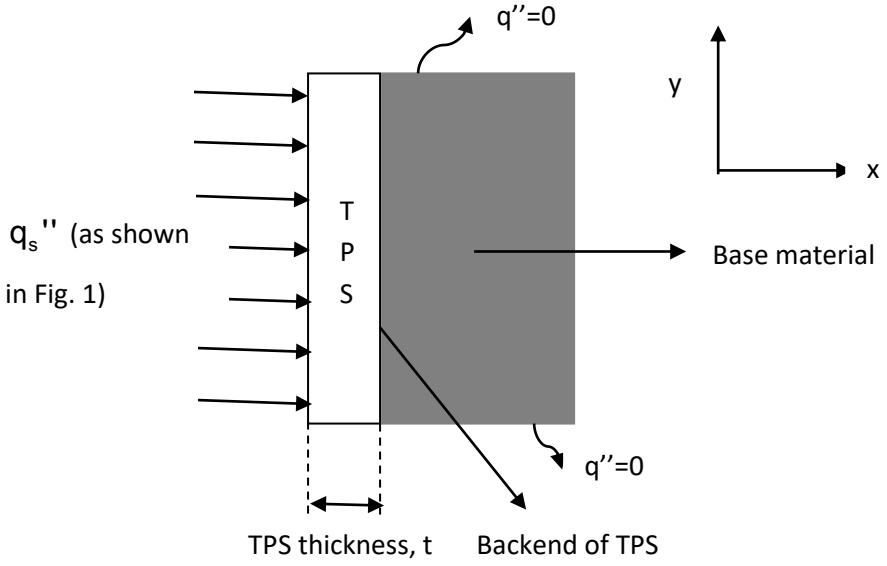

Fig. 2 TPS and back-up substrate with boundary conditions