Finite Element Method in the Engineering

Finite element method (FEM) is one of the most used methods by engineers. It's a necessity for each engineer to understand this method. FEM is now an integral part of most structural analyses. In fact, we not only use FEM in the daily analysis, we also use FEM to optimize our structural designs. FEM tools allow us to quickly test many design variations. And also optimize our design. What I mean by optimization is a mass reduction of our structures. These days, mass savings in our structures leads to lesser product cost, lesser transportation cost and so forth. FEM is very important for a structural engineer. It saves times, allows for quick variation in designs and is often used to bring out a lean product. We will analyze the FEM mathematically and then implement it in java with as goal to plot temperature distribution in profiles.

Calculate and plot the temperature distribution on the studied domain. For the 3 cases, we will trace the temperature distribution. Because of the symmetry around the y-axis, we can only have to the calculations for left or the right part, we have chosen the right part. Because the heat flux is only going in the x-direction (on the symmetry ax) we only have to do the calculations for the upper part. The heat flux goes from the right to the left (heat flux vector is proportional to the minus temperature gradient). Knowing that the flux is perpendicular to the isotherms, the results below are physically logical.

From the temperature distribution graphics, we can't conclude which profile has the highest thermal resistance. This is because the thermal resistance is a global parameter and this temperature distribution is local. Compute the thermal resistivity of the hollow wall for different configurations The goal of the profile is to isolate. The profile with the highest thermal resistance is by definition the best insulator. The best profile of the 3 cases is case C with a thermal resistance equal to R=2677 K/W.

But we also have to take into account the mechanical strength of the profile. The profile with the most airspace is the best insulator (air is a very good insulator in comparison with the profile material) but also the most fragile one. So we have to find an equilibrium between the insulation properties and the mechanical strength properties. For finding the best profile we can variate the dimensions a,b,c and d and stock every value for the thermal resistance in an array.

After the calculation, we look up the highest thermal resistance value in this array with the according to optimal dimensions. Make a study of convergence depending on the density of the finite element mesh and the time computation. We check to convergence with the value of the resistance: if the resistance doesn't change much if we higher the dichotomy, we can conclude we have reached convergence. We can't reach convergence because of the error

“OutOfMemoryError”. The reason is that our code isn’t efficient towards memory usage. But on the figures, we see clearly that the graphs reach a horizontal asymptote.

This value of this horizontal asymptote is the converged value of the thermal resistance. Draw the temperature profile inside the hollow wall between two points (for example, between both sides). This figure represents the temperature profile with a fixed y=1 for case c. The x-coordinate goes from 0 to 10. As the L profile is symmetrical the temperature for x=-10 to x=0 will also be symmetrical. Now we are interested in an electrokinetic problem. The studied problem is an electrical conductor in the shape of L. By using the developed code, calculate the electric resistance of the electrical conductor. On slide 10 we notice that the equations for the electrokinetic case are mathematically exactly the same as the thermal equations.

As the mathematics rest the same we can simply reuse our code. We can make a link between:

- Temperature and voltage
- Heat flux and current
- Thermal resistance and electric resistance

The finite element method (FEM) is a computational technique for solving problems which are described by partial differential equations or which can be formulated as functional minimization. The FEM is commonly used in the design and development of products, especially where structural analysis is involved. The simple object model of the Java programming language lends itself to efficient implementation of FEM analysis. The general conclusion is that an object-oriented approach to programming in Java allows developing well-organized finite element applications with acceptable computational efficiency.