SYNOPSIS

Study of free convection in rectangular enclosures heated from below, is the subject of interest since long. This is because of its application in varieties of fields. Present status in the above subject is that bulk of experimental data at various orientations is readily available. Numerical investigations were also made for horizontally and vertically oriented enclosures. However, most of these studies, though some of them having suspected, did not include the effect of aspect ratio (i.e. the ratio of the width to gap height of the enclosure). Again, those who included this effect in their investigations, either choose very narrow range of inclinations (60 to 90 deg.) or aspect ratios (1 to 12), not practical for solar collector application.

It was thus decided to study the effect of aspect ratio on free convection in rectangular enclosures using constant strain triangle (CST) finite element method (FEM). It was planned to vary aspect ratio from 1 to 300, inclination from o to 180 degrees and gap height from 2 mm(Ra= 66) to 130 mm (Ra = 1.8×10^7).

The finite element method was tailored to suit the free convection problem which involves the solution of three, simultaneous, non-linear, elliptic, partial differential equations. The method was coded in FORTRAN and the code was tested for conduction. Sensitivity analysis was performed to test the resilience of the method. Mesh size and error tolerance levels were selected after careful study of several test runs.

Subsequently, horizontally oriented enclosures were studied exhaustively. Excepting hitches like numerical instability depending upon aspect ratio and numerical viscosity in a stray case, the code generated interesting results.

While the results show an encouraging trend for orientations in the second quadrant, the results tended to be incoherent for orientations

in the first quadrant, even after several revisions and re-runs. Zhong et al in 1985, observed similar trend in their numerical experiment.

The results of the present investigation, some of which being presented at the Ninth National Heat and Mass Transfer Conference, held at Indian Institute of Science, Bangalore during December 1987, are summarised as under :

i) Free convection in horizontally oriented rectangular enclosures, under adverse temperature gradients, is dependent upon aspect ratio, in which three distinctive convective flow regimes based on aspect ratio, are identified, e.g. low aspect ratio region, transitional aspect ratio region and high aspect ratio region.

ii) Two criticalities based on Rayleigh number are observed in high aspect ratio region. First criticality occurs when cellular convection begins to appear, replacing pure conduction while second criticality occurs when cellular convection is replaced by boundary layer convection.

iii) Both the critical Rayleigh numbers are strongly dependent upon aspect ratio while heat transfer in cellular and boundary layer convection is also aspect ratio dependent.

iv) Preliminary study on horizontally oriented enclosures under favourable temperature gradients, shows a departure from classical conduction behaviour into aspect ratio dependent cellular convection, at high Ra values for low aspect ratio enclosures.

v) Following correlations, for high aspect ratio, horizontally oriented, rectangular enclosures, under adverse temperature gradients, are obtained :

$$Nu = 1 \quad \text{for} \quad Ra \leqslant Ra_{c1}$$

$$Nu = 0.8463 \cdot Ra^{0.0675} . AR^{-0.125} \quad \text{for} \quad Ra_{c1} \leqslant Ra \leqslant Ra_{c2}$$

$$Nu = 0.6760 \cdot Ra^{0.125} . AR^{-0.25} \quad \text{for} \quad Ra \geqslant Ra_{c2}$$

$$Ra_{c1} = 10 \cdot AR^{2}$$

$$Ra_{c2} = 70 \cdot AR^{2}$$