As with any variational or approximate method, one should approach the specification of expansion functions with care, and apply the results with a degree of caution. Our feeling is that enough diagnostics are provided by the fast critical experimental series that anomalous synthesis solutions, if they occur, should be readily identifiable. The benefits in computing time (22 min for a synthesis run on an IBM 360/75, compared with 14 min for a 2-D r-z computation) are indeed attractive, and investigations of more sensitive parameters, such as sodium-void coefficients, are now being done with synthesis. Our successes to date indicate synthesis can be a valuable tool in extending the realm of fast critical assembly analysis.

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9. Cylindrical Fuel Elements with Red-Blood-Cell-Shaped Cross Section, *Carlos C. Ching Tu (Univ São Paulo), Roberto Y. Hukai (IEA-Brazil)*

A preliminary evaluation pertaining to the heat transfer and thermal stress characteristics of a fuel rod with a cross section inspired by a red-blood-cell shape was made and the results were found to be very encouraging.

The human red-blood cell has a doughnut-like shape with a thin region in the middle, instead of a hole. It is thought that this particular shape optimizes the diffusion of oxygen through the cell into its innermost hemoglobin. Ponder[1] has estimated that if the cells were spherical it would need about nine times as many cells to feed the same amount of oxygen into the human body. Therefore, since the heat transfer and simple mass diffusion equation are analogous, it was thought that a fuel rod with a biconcave cross section could present less resistance to heat transfer than a pure cylindrical fuel rod.

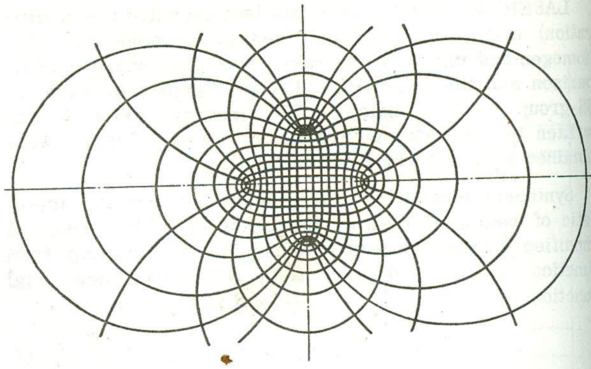

Fig. 1. Curves in the $\overline{z}$ plane resulting from the transformation $\overline{z} = a\ \mathrm{cn}(w)$ and m = 0.5.

On the other hand, Hartridge[2] first reported that biconcave shape of the red-blood cell allows some volume changes without stretching the cell membrane. This particular characteristic suggested a favorable distribution of the thermal stress inside the proposed fuel element. It was found that the biconcave shape can ideally be expressed by the curves deriving from the coordinate transform, defined by

$$\overline{z} = a\ \mathrm{cn}(w) \quad ,$$

where $\overline{z} = x - iy$ and $w = u + iv$ are complex variables; cn is the Jacobian Elliptic Function; $\underline{a}$ is the distance between the center and one of the foci of the transformed curves. Figure 1 illustrates these curves.

For preliminary purposes, by using qualitative arguments, the biconcave curve with m = 0.5, $v_0 = 0.7\,k'$, and y/y max = 0.70 (see Ref. 3) was chosen for further analysis. The heat transfer equation was then solved by using Prandtl's membrane analogy for typical BWR operating conditions and was compared with the results for the regular cylindrical fuel element with same cross-sectional area operating under similar conditions. The specific power was found to be about 30% higher.

The thermal stress distribution was also evaluated by assuming constant material properties for first estimate and by using a finite-difference stress analysis code for numerical computation. A definite advantage over the regular cylinder was also found. These stress characteristics may enhance the possibility of metallurgical bond between the oxide pellets and the Zircaloy cladding.

From the economic viewpoint, the fabrication cost of the new fuel element and its components appear worthwhile in view of the advantages; however, from the safety standpoint there is a definite possibility of cladding bowing due to inner gaseous fission product buildup during refueling and loss-of-coolant accidents. This fact makes it necessary to design built-in pressure suppression systems with vented fuels, which entails additional developmental and fabrication costs.

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