THE ACOUSTIC ENVIRONMENT IN LARGE HTGRs

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SUMMARY

Well-known techniques for estimating acoustical vibration of structures have been applied to General Atomic high-temperature helium gas-cooled reactor designs. This paper presents results of general interest.

At high frequencies, internal loss factors are always larger than most radiation loss factors. (Most bending modes of thermal barrier cover plates have loss factors less than 10^{-4} at all frequencies of interest.) If internal loss factors were unknown, one would assume that structural modes achieve the same average energy as gas modes, and the principal advantage of helium at high frequencies would be lost.

Because of the high solidity of the core, it is convenient to treat it separately from the remainder of the helium circuit, for which internal loss factors of fluid modes are approximately given by $2.3\,f^{-1}+0.034\,f^{-1/2}$. Below 1000 Hz, this loss is significantly augmented by dissipation of acoustic power in thermal barrier assemblies. However, above 1000 Hz, the low radiation loss factors of bending modes prevent a major portion of the total acoustic power from being dissipated in structures, so acoustic levels are governed by internal loss factors only. Thus one must evaluate internal loss factors for both fluid and structural modes to avoid large errors in estimated structures response at higher frequencies.

The acoustic modal density (excluding core) is approximately $0.6+3\times10^{-3}f+$ $+1.0\times10^{-5}f^2$ modes/Hz. On the basis of this density, and the acoustic damping equation given above, one may distinguish two frequency ranges. Below 300 Hz, it is feasible to calculate acoustic mode shapes, because diffraction from shearing flow and turbulence can be neglected in helium. These mode shapes are needed to calculate some resultant structural stresses. Reliance on statistical averaging techniques to find total stresses in this frequency range is stymied by the fact that stresses at concentration points are often dominated by the contributions of only two or three structure modes. However, averaging techniques suffice to estimate the dissipation of acoustic energy in structural vibration.

At any frequency above 300 Hz, there are generally at least ten acoustic modes contributing to acoustic pressure, so statistical energy analysis may be employed to estimate stresses. But because the gas circuit consists mainly of high-aspect-ratio chambers, reverberant fields are nowhere established below 1200 Hz, and in some regions are not established at any frequency of interest. Where reverberant fields are not achieved, an alternative approximation has been developed: the one- or two-dimensional random field, which is defined to be statistically homogeneous in one or two dimensions, respectively, and uniform in the remaining dimension(s). In comparison with reverberant fields, these new fields enhance the radiation efficiencies of most structural modes. The acoustic efficiency of acoustic monopoles, such as fluctuations in mass flow from the core outlets, is always increased. The efficiency of quadrupoles (turbulent shear layers) is always decreased. The effect on dipole sources depends upon their orientations. Circulators radiate with increased efficiency into the modified fields, whereas vorticies shedding from most steam generator tubes have reduced acoustic efficiency.