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Finite Element Analysis of Ball Grid Arrays Subjected to Random Vibration Tests

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Over the past several years engineers at Raytheon's Surveillance & Reconnaissance Systems business unit have been studying the potential fatigue failure of Ball Grid Array (BGA) solder joints subjected to thermal cycling as well as exposure to random vibration environmental tests. In particular methodology has recently been developed to extend the capability of current finite element modeling and analysis tools so that accurate predictions of cumulative damage resulting from exposure to increased levels of random vibration can be made. Military electronic systems, such as radar units, must be capable of surviving exposure to vibration levels delineated in environmental test specifications without failure. However, the flexing of printed wire boards (PWBs) to which the packages were attached by BGA's, due to vibration normal to the plane of the modules, has been known to be a source of fatigue damage. This damage often results in cracks developing in the solder balls at the junction either with the packages or with the PWB's. These cracks, once developed, often grow in magnitude until either excessive signal noise or complete disruption of electrical conductivity occurs.

Prediction of the susceptibility of the BGA's to such fatigue damage, estimation of the fatigue life and development of measures to increase the fatigue life of these assemblies is essential to the successful employment of electronic assemblies in the field. In the present study, only BGA solder joint fatigue damage resulting from exposure to random vibration will be addressed**.** A chronology of procedures developed by the authors to address this issue, resulting in the methodology currently in use, is presented. This technology utilizes available software to create the solder ball geometry based on geometric and physical constraints. MSC.Patran is used for the creation of shell and solid finite elements, while MSC.Nastran is used for modal and frequency response analyses. Its "ishell" capability is employed to interrupt the analysis so that von Mises-Hencky equivalent strains across failure planes of the solder ball may be calculated. These strains are obtained from the correlated element strain tensor resulting from exposure to the random vibration process. Comparison of the results obtained through use of the methodology with test data results has been partially successful and a brief summary is presented. A discussion of desired extensions to the analytic tools to improve their capability, correlate better with test (particularly where underfill is employed) as well as to further automate the method is included.