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Optimum Structural Design Based on Reliability Analysis

Thermomechanical properties of materials used in the structures of lightweight high-performance vehicles, particularly properties of composite materials, show considerable statistical variations. Moreover certain extreme environments (such as space) as well as loading conditions involve many obvious uncertainties. Both strengths of and loads on the structure should therefore be treated as random variables, and the notion of structural reliability should be incorporated in its optimum design. Many treatments of this subject have not considered the important fact that major structural components of such a vehicle are usually (proof-load) tested, individually or otherwise, under simulated environmental conditions before the vehicle goes into service.

A recent method (see ref.) of reliability-based structural optimization introduced the level of the proof load as an additional design parameter. It was emphasized that the proof-load test could significantly improve statistical confidence in the estimate of reliability; numerical examples indicated a definite advantage of the proof-load approach in terms of savings in structural weight.

Now the cost of establishing the statistical distribution of strength of the structural material is also introduced into the cost formulation. Examination of the effect of such cost, on the structural optimization, leads to the following conclusions:

As long as the cost of the specimen test is more significant than that of the proof-load test (i.e., $\beta > \gamma$), and as long as the constraint on the expected (total) cost is reasonably small, the optimum proof-load stress level is within a reasonable distance ($\pm 2\sigma$ range) from some central measure of location (e.g., the mean) of the strength distribution. Then it follows that use of a particular form of the distribution function, for the strength, is rather insensitive to the final optimum result. This fact implies that under usual circumstances a reasonable knowledge of the strength distribution, within the $\pm 2\sigma$ range, is sufficient for the purpose of optimum design.

Inclusion of the cost of the specimen test in the cost formulation does not alter the trend (see ref.) toward the optimum weight of proof-load-tested structures being less than that of structures not subjected to proof-load testing. The effect of βi (relative cost of the specimen test) on the improvement in reliability is complex. As βi increases, the improvement is more appreciable for smaller values of γi (relative cost of the proof-load test) and for smaller values of cost restraint. Moreover larger values of β appear to produce heavier (optimum) structures.

Reference:

Shinozuka, M.; Yang, J. N.: Optimum Structural Design Based on Reliability and Proof-Load Test. Ann. Assurance Sci., vol. 8, July 1969, pp. 375–391.

Note:

Requests for further information may be directed to:

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(continued overleaf)

Patent status:

Inquiries about obtaining rights for commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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