SUMMARY OF Ph.D. DISSERTATION

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Title

Expression for Load Transfer Paths in Structures

Abstract

In structural design, it is important to express the entire structure in terms of load transfer and load paths. In general, load transfer in structures has been investigated by examining the stress distribution. However, because of stress concentration, using the stress distribution to determine load paths is likely to cause errors. For example, a structure having a circular hole exhibits high stress values around the hole, but it is unreasonable to conclude from this fact that the hole is effective for load transfer.

In the present study, load path U* analysis is formulated and demonstrated to be an effective alternative to stress analysis. The parameter U* has intuitively been introduced representing the stiffness between a loading point and an arbitrary point. The author reformulate load path U* analysis by introducing internal stiffness tensors and decay vectors. Moreover, an effective calculation method is developed to reduce the U* computation time. Until now, it has not been possible to calculate the U* distribution for large-scale structures because of the huge computation times required. Using the present method, it is now possible to calculate U* values within a calculation time that is feasible for practical applications. Some examples of the application of load path U* analysis to vehicle body structures are also given.

Chapter 1 summarizes the background, the problems with previous studies, and the aims of this study.

Chapter 2 describes the conventional concepts of U* analysis and load path. The parameter U* is formulated using internal stiffness tensors.

In Chapter 3, the concept of the U* potential is introduced and an expression for stiffness lines that are orthogonal to the U* potential lines is given. The stiffness decay vector, which is the gradient of the stiffness line, is introduced, and the load path is defined as the line traced along the vectors.

Chapter 4 explains how to calculate U* for structures with multiple loading points or various types of supporting points. The parameter U* is reformulated for these complex boundary conditions and a procedure is introduced for calculating U* for each case.

In Chapter 5, a method is introduced that reduces the computation time for calculating the U* distribution using the finite element method. Multiple geometry conditions are converted to multiple mechanical boundary conditions and the U* distribution is obtained using a single stiffness matrix. The calculation time of this method is significantly smaller than that of the conventional method, and in some cases the ratio of the calculation times is almost 1:100.

In Chapter 6, load path U* analysis is applied to a structure of a heavy-duty truck cab. The present formulation of U* is calculated using the new calculation method. The global U* distribution and the local load transfer along the load paths are discussed. A modified cab structure with stiffer members is proposed based on this discussion. For a modified cab, an increase in stiffness of up to 30% can be achieved with only a small increase in mass.

Chapter 7 gives some examples for applying load path U* analysis to passenger car structures. The effects of stiffer members on load transfer are examined. Load transfer in a compartment structure during a frontal collision is discussed using a crash simulation, and the localization phenomenon of load paths is described.

Chapter 8 summarizes the conclusions of the present study.