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NASA TECH BRIEF

Determination of Permissible Applied Load Stress in Structural Elements

Changes to structural design temperatures occur frequently during design development, making it necessary either to select structural materials compatible with the new temperatures or to determine the temperature above which insulative protection to structure becomes advisable. Other such temperature-related data as time at temperature to failure or the maximum temperature allowable may be needed. Thus, the evaluation of changes to design temperatures in terms of allowable and applied stresses in critical structural members becomes necessary.

A graphic method for selecting allowable stresses in thermally loaded structures has been developed. In this method, the results of equations are used for determining the mode of failure for specific materials in order to plot a range of stress curves. In previous methods of calculations, the effect of temperature was assumed to be linear. This assumption led to large errors over relatively small changes in temperature, necessitating lengthy iterative calculations to estimate the maximum permissible applied temperature. In the graphic method however, linear assumptions and iterative calculations are eliminated resulting in comparatively high accuracy. The stresses produced by a change in the maximum temperatures, applied to a structure while the original temperature distribution remains essentially unchanged, can be predicted. The effects of material properties, induced thermal stresses, and structural restraints are included. With this method, a value of the permissible applied load stress and the maximum allowable applied temperature for specific failure modes can be determined. A capability for evaluating structural materials with respect to dominant modes of failure may also be possible.

Under conditions where structural test information including thermal influence data are available, and where design changes involve the maximum temperature value but not the relative temperature distribution, an accurate evaluation may be obtained from a set of curves. The set of curves is constructed from an equation that is derived by equating the allowable to the applied stress. A term that accounts for temperature-induced stresses is added, and the terms of the equation (where applicable) are modified to include the thermal influence on the physical and mechanical properties of the structural material; a factor of safety may be included. Equations can be developed for each specific material and other modes of failure.

Similar sets of curves for the structural members of elements subjected to any mode of failure encountered in stress analysis can be constructed to evaluate changes arising from variations of the maximum temperature. In addition, curves may be constructed for the purpose of comparing different structural materials to find those most suitable for use at elevated temperatures for some dominant mode of failure. These comparisons can be accomplished by superposing transparencies of curve sets for each material under consideration. From such graphical displays under identical design conditions, the material yielding the highest value of stress or allowable temperature is selected. The selected material should possess superior characteristics for elevated temperature applications under loadings that induce the specified failure mode.

(continued overleaf)

Notes:

1. This method may be of potential value for (a) adapting completed structural designs to new applications and (b) constructing design charts for selecting structural materials that can be used at elevated temperatures for specific mode of failure.
2. Information concerning this innovation may be of interest to the manufacturers of semiconductors and products that require long heat treatments.
3. No additional documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Marshall Space Flight Center
   Huntsville, Alabama 35812
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Patent status:

No patent action is contemplated by NASA.

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North American Rockwell Corporation
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