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IMPLEMENTATION OF MULTI-PARAMETER LOADING WITH THE SIMPLIFIED THEORY OF PLASTIC ZONES

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In case of over-elastic and cyclic loading, strain may accumulate due to a ratcheting mechanism until the state of shakedown is possibly achieved. Load history dependent numerical investigations by a step-by-step analysis are rather costly in terms of engineering time and numerical effort. In the case of multi-parameter loading, where various independent loadings affect the final state of shakedown, the computational effort becomes an additional challenge. Therefore, direct methods like the Simplified Theory of Plastic Zones (STPZ) are developed to solve the problem with a few linear elastic analyses.

The STPZ is based on estimates of a transformed internal variable, which can be used to perform modified elastic analyses, where the elastic material parameters are modified and initial strains are applied as modified loading, resulting in residual stresses and strains. The STPZ already turned out to work well with respect to cyclic loading between two states of loading. Usually, few linear elastic analyses are sufficient to obtain a good approximation to the post-shakedown quantities such as strain ranges and cyclic accumulated strains.

This method aims to approximate the post-shakedown quantities by disregarding the load history. However, solutions of multi-parameter loaded systems can vary in dependence of the chronological order of the cyclic loads. The additional challenge is to estimate the transformed internal variable with respect to the order of cyclic loads, which is solved with a successive calculation algorithm.

In a multi-dimensional load domain, the approximation of the transformed internal variable transforms from a plane problem into a hyperspace problem, where time-consuming approximation methods need to be applied. Therefore, a solution restricted to structures with four stress components was developed to estimate the transformed internal variables by means of three dimensional vector algebra.

This paper presents the extension to cyclic multi-parameter loading, so that a large number of load cases can be taken into account. The theoretical basis and basic presumptions of the Simplified Theory of Plastic Zones are outlined for the case of elastic shakedown. The extension of the method to many load cases is explained and a workflow of the procedure is illustrated. An example, adopting the FE-implementation of the method into ANSYS and considering multilinear hardening is given which highlights the advantages of the method compared to incremental step-by-step analysis.

REFERENCES

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