A Global-Local Strategy for the Elastoplastic Analysis of Complex Metallic Structures via Component-Wise Approach

E. Carrera, I. Kaleel, M. Nagaraj and M. Petrolo

Politecnico di Torino, Italy

The current work involves the non-linear analysis of complex metal structures considering elastoplastic material behaviour, which is modelled via the isotropic von Mises constitutive law with piece-wise linear hardening. The analysis is performed within the framework of the Carrera Unified Formulation (CUF), where refined beam elements are developed using higher order structural theories. In such a formulation, expansion functions based on Taylor and Lagrange polynomials are used across the beam cross-section to enrich the kinematics of the finite element. This process removes the assumptions associated with classical 1D FE formulations, and results in 3D-like accuracy of the solutions at a significantly reduced computational cost [1]. Another feature of CUF is the Component-Wise (CW) approach, where elements based on Lagrange polynomials are used to define the beam cross-section, resulting in a physically based finite element model. A consequence of such an approach is that all the unknowns of the system are purely based on displacements.

The computational efficiency of the numerical analysis is further increased by considering a global-local approach, where a coarse analysis is performed over the entire structure and a refined analysis is reserved for a smaller region where material non-linearity occurs. In the current work, the global analysis can be performed in either a commercial software (ABAQUS) or CUF, and the resulting displacements are used as boundary conditions to drive the local analysis, performed using CUF. The extent of the local region is determined using a 'plasticity index', which is the ratio of the von Mises stress to the initial yield stress. Two types of global-local techniques are presented, where – (a) elastoplasticity is considered for both the global and local analyses, and (b) a linear elastic global analysis is followed by an elastoplastic local analysis. It is shown that the second type of the global-local technique is valid when the plastic zone is extremely localised and does not significantly influence the overall structural response.

A combination of the global-local strategy and refined beam models via CUF results in accurate results which approaches that of a full 3D FEA, at a reduced computational cost. Such an approach is therefore ideal for the non-linear analysis of complex metallic structures in an efficient manner.

References

[1] Carrera E, Cinefra M, Petrolo M, Zappino E. "Finite element analysis of structures through unified formulation", John Wiley & Sons (2014).