Analysis of local failure modes and subsequent scenarios of global failures of complex technical systems

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Keywords: Complex technical system, load regime, local limit state, global failure scenario, quantitative risk assessment

Typically the functioning of a complex technical system (CTS) can be represented as a trajectory S_0 in its state space Ψ^N that determines the system's transfer from its initial state IS to the desired end state ES_0 (Fig.1). During their lifetime the components of the CTS are subjected to various combinations of damaging factors $\psi_k\ (k=1,2,...,M)$: mechanical loading, high/low temperatures, aggressive environments, etc. that determine the load regime $H_i\ (i=1,2,...n)$ and could lead to reaching local limit states $LS_j\ \ (j=1,2,...,m)$. Various limit states form a limit state surface in the component's state space $\psi^M\ \ (\psi^M \subset \Psi^N)$.

The fact that a component of CTS has reached a limit state does not necessarily mean instantaneous failure of the entire system. Due to the presence of redundancy, alternative load pathways, protection barriers after the occurrence of the component's failure loads can be redistributed and carried by some other components. These additional loads on the remaining components may trigger the sequence of components' failures deflecting the system from the success scenario S_0 to various failure scenarios S_l leading to damaged end states $ES_l\ \ (l=1,2,...,q)$.

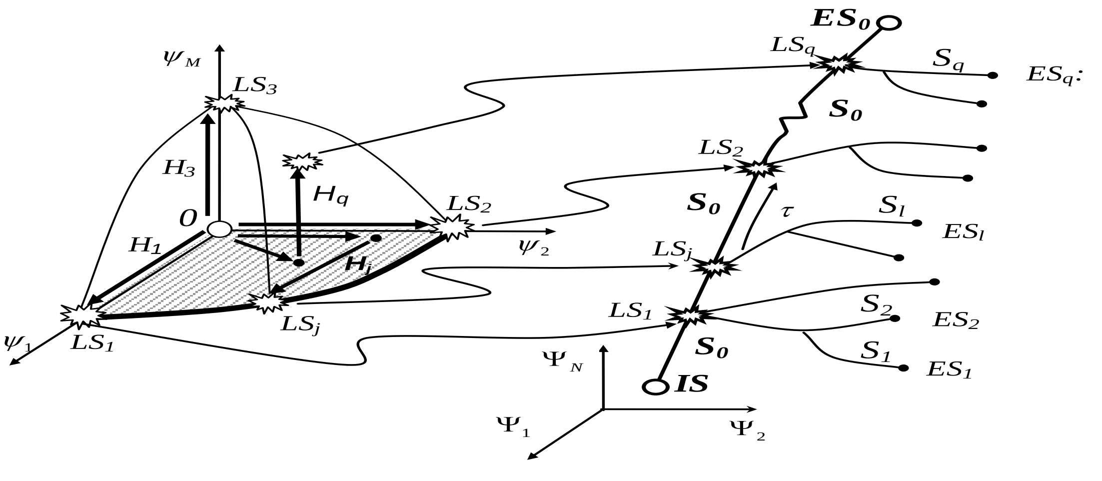

Fig. 1. Local limit states and failure scenario tree

Thus the complex probabilistic event $\langle ES_l \rangle$: 'the system reaches the limit state ES_l ' could be considered as a sequence of interrelated probabilistic events: (1) $\langle H_i \rangle$: 'the system is subjected to load regime H_i '; (2) $\langle LS_j \mid H_i \rangle$: 'the system component reaches the local limit state LS_j provided that it is subjected to H_i '; (3) $\langle ES_l \mid LS_j, H_i \rangle$: 'the system reaches the damaged end state ES_l provided that the system is subjected load regime H_i and its component reached the limit state LS_j '.

The paper presents a matrix-based approach to analyzing local limit states mechanisms and subsequent global failure scenarios that is then used in quantitative risk assessment.