The behavior of materials as they are subjected to combined thermal and mechanical fatigue loads is an area of research that carries great significance in a number of engineering applications. Power generation, petrochemical, and aerospace industries operate machinery with expensive components that undergo repeated applications of force while simultaneously being exposed to variable temperature working fluids. A case of considerable importance is found in steam turbines, which subject blades to cyclic loads from rotation as well as the passing of heated gases. The complex strain and temperature histories from this type of operation, combined with the geometric profile of the blades, make accurate prediction of service life for such components challenging. Development of a deterministic life prediction model backed by physical data would allow design and operation of turbines with higher efficiency and greater regard for reliability. The majority of thermomechanical fatigue (TMF) life prediction modeling research attempts to correlate basic material property data with simplistic strain and thermal histories. With the exception of very limited cases, these types of efforts have been insufficient and imprecise in their capabilities. Early researchers did not account for the multiple damage mechanisms that operate and interact within a material during TMF loads, and did not adequately address the extent of the relationship between smooth and notched parts. More recent research that adequately recognizes the multivariate nature of TMF develops models that handle life reduction through summation of constitutive damage terms. It is feasible that a modification to the damage-based approach can sufficiently include cases that involve complex geometry. The focus of this research is to construct an experimentally-backed extension of the damage-based approach that improves handling of geometric discontinuities. Smooth and notched specimens of Type 304 stainless steel were subjected to several types of idealized fatigue conditions to assemble a clear picture of the types of damage occurring in a steam turbine and similarly-loaded mechanical systems. These results were compared with a number of idealized TMF experiments, and supplemented by numerical simulation and microscopic observation. Two models were developed, including a model based on physically-measurable quantities, and a model based on observed phenomenological effects. Findings from this study will be applicable to other similar material and load cases, such as those encountered in gas turbine engines.