For many candidate materials, constitutive models and their parameters are identified using uniaxial test data. Real components, however, generally operate in a multiaxial loading environment. Consequently, constitutive models deployed by uniaxial conditions may carry over to service conditions with inherent limitations. Research is proposed to determine the constitutive model constants for the creep and plasticity responses of a material via multiaxial fatigue testing which may contain ratcheting. It is conjectured that directly regressing data under conditions that favor those of actual service use will lead to more accurate modeling under these conditions, as well as a reduced consumption of model development resources. Application of observations of multiaxial loading in the determination of constitutive modeling constants and model selection represents a paradigm shift for material characterization. Numerical simulation and experimentation are necessary for material selection for application at high temperature. The candidate material used in this study is primarily applied for structural components in high-temperature environments for steam generating systems - 304 stainless steel. It confers an excellent balance of ductility, corrosion resistance, and creep resistance at moderate temperatures (i.e., up to 550°C). Under service conditions, both creep and cyclic plasticity can occur under either isothermal or non-isothermal conditions. Accurate deformation modeling and life prediction of these structures only achieved with an accurate understanding of how this and other key alloys behave under complex conditions. This research conveys a proposed methodology that can be used to apply creep and plasticity constitutive models that correlate with experimental data. Several creep and plasticity models are examined to augment the accuracy of the models. These results are presented to illustrate modeling performance. Based on this idea has been determined that novel methods of measuring the accuracy of modeling be needed, as well as methods for optimizing material response under multiaxial conditions. The models are applied under service-like conditions to gain an understanding of how this and other key alloys behave under complex conditions. This research will study the complex tensile-torsion loading to determine the constitutive constants for material, and thus will decrease the number of uniaxial experiments. Additionally, combined analytical and experimental methods will be used to establish the Bree diagram for elevated temperature tensile-torsion responses. This deformation mechanism map has been useful as a design tool for materials undergoing ratcheting.