To improve the mobility of lower limb amputees, many modern prosthetic ankle-foot devices utilize a so-called energy storing and return (ESAR) design. This allows for elastically stored energy to be returned to the gait cycle as forward propulsion. While ESAR type feet have been well accepted by the prosthetic community, the design and selection of a prosthetic device for a specific individual is often experientially based design by the clinician and iterative feedback rather than engineering design. This is due to an incomplete understanding of the role of prosthetic design characteristics (e.g., stiffness, roll-over shape, etc.) have on the gait pattern of an individual. This cost of this iterative process can be extensive design time and material consumption; therefore, the focus of this work has been to characterize the design attributes of existing prosthetic devices through mechanical testing of existing designs and the development of a prototype prosthetic foot that has been numerically optimized for a specific gait pattern. The component stiffness, viscous properties, and energy return of commonly prescribed carbon fiber ESAR type feet were evaluated through compression testing with digital image correlation at select loading angles following the idealized gait from the ISO 22675 standard for fatigue testing. A representative model was developed to predict the stress within each of the tested components during loading and to optimize the design for a target loading response through parametric finite element analysis. This design optimization approach, along with rapid prototyping technologies, will allow clinicians to better identify the role the design characteristics of the foot have on an amputees’ biomechanics during future gait analysis.