Non-destructive evaluation of applied loadings level in mechanical components and structures constitutes a versatile tool to predict the behaviour of their materials in engineering industries and check services. Ultrasonic non-destructive techniques stand advantageously to allow predictions and diagnosis where other measurement methods are difficult or not possible. For analysing the effects of static uniaxial loads, the present work relates to the modification of waveforms of ultrasonic shear waves propagating in statically loaded materials. To predict the behaviour of waveforms of shear ultrasonic waves propagating in media under stress, an analytical method is proposed. The simulated waveforms are reconstructed by using parameters from an experimental signal measured on specimens free of any loading. Assuming the hypothesis of progressive ultrasonic plane waves and taking into account the elastic deformation and the stressed ultrasonic velocity, the time of flight calculation allowed the simulation of shear waveforms for each applied stress. To validate this method, some ultrasonic measurements have been carried out. A linearly polarised shear wave transducer is used for probing C35 steel and 2017A (AU4G) alloy samples of known macroscopic properties. Simulated and measured ultrasonic waveforms are partially in good agreement, in particular for the extra delay effect induced under compressive and tensile elastic loads