Proposal of ultrasonic bolt axial force evaluation method using machine learning and signal processing

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Abstract

It has been confirmed that bolt axial force of high-strength bolted joints decreases due to various effects. Generally, evaluating the bolt axial force of existing bolts has been an important issue. In a conventional ultrasonic bolt axial force evaluation method, bolt length change due to the change of bolt axial force is evaluated. However, bolt length can include uncertainty due to manufacturing errors. Hence, in this study, attention was paid to the deformed shape of the bolt head, which has a little dependency on the bolt length, and application of signal processing and machine learning was attempted. It was shown that the waveform data obtained from the bolt head by ultrasonic testing included characteristic signals indicating the bolt axial force. The target characteristic signal was detected by the parasitic discrete wavelet transform (P-DWT). A highly accurate bolt axial force evaluation method was proposed by applying machine learning to characteristic signals.

Keywords: bolt axial force; ultrasonic test; machine learning; wavelet transform; initial time zone.

1 Introduction

It is known that the bolt axial force of high-strength bolted joints used in many structures decreases due to the effects of relaxation, vibration, earthquakes, and so on [1-2]. Therefore, as a maintenance technology to ensure the safety of structures, it is required to establish a method for accurately and quantitatively evaluating the axial force of existing bolts. Currently, many studies are being conducted to evaluate bolt axial force non-destructively. Among them, there is a method that utilizes the change of time-of-flight using ultrasonic waves. The method evaluates the bolt axial force by using the change of time-of-flight until the ultrasonic waves transmitted from the bolt head are reflected from the bottom surface and returned [3-4]. In the method using the change in time-of-flight, it is assumed that there is a high correlation between bolt elongation and bolt axial force, and the bolt axial force is also evaluated from the difference in ultrasonic propagation time between before and after the introduction of bolt axial force. In addition, work such as smoothing the tip of the bolt shaft is required, and it is difficult to use it for evaluating the bolt axial force of existing bolts.

In the conventional research for evaluating the bolt axial force in this way, problems and improvements remain in the quantification and applicability of the