Thermal effects on fatigue behavior of cracked steel plates retrofitted with Fe-SMAs

Attributed to the remarkable shape memory effect (SME) activated by heating and cooling, iron-based shape memory alloy (Fe-SMA) can be conveniently used to introduce prestress in steel structures and to improve fatigue behavior of steel structures. Working temperature for steel structures ranges from −20 to 60 ℃. As Fe-SMAs were sensitive to temperature, the prestress may be affected by temperature variation. A comprehensive study is presented on stress recovery behavior of Fe-SMA materials and fatigue performance of Fe-SMA strengthened steel plates. Much attention was paid to the influence of temperature variation on both Fe-SMA materials and the retrofitting scheme.

Stress recovery behavior of Fe-SMAs for prestressed strengthening under high activation temperatures was first investigated. Effects of pre-strain levels, activation temperatures, and initial preloads on the recovery stress were carefully evaluated to propose the optimum activation strategy. The combination of the pre-strain of 8% and the activation temperature of 350 ℃ exhibited the highest recovery stress of 445 MPa. On this basis, a series experimental studies on the recovery stress of activated Fe-SMAs subjected to fatigue and thermal loading were conducted. Results showed that the recovery stress declined with fatigue cycles and the lost stress mostly occurred at the early stage of fatigue loading. After 2×10^6 stress-controlled fatigue cycles ($\Delta\sigma$ = 57 and 114 MPa), the recovery stress at RT decreased by 12% and 23%, respectively, whereas a higher temperature weakened such decline. Afterwards, fatigue behavior of cracked steel plates retrofitted with Fe-SMAs was assessed, focusing on the influence of different environment temperature, i.e., −20 ℃, 20 ℃, 60 ℃, and cyclic temperature from −20 to 60 ℃. Excellent strengthening efficiency promoted by Fe-SMA was witnessed regardless of environment temperatures. In comparison with bare steel plates, the fatigue life of strengthened specimens was extended by 223~352%. Eventually, considering the variation of recovery stress of Fe-SMA owing to fatigue, numerical and theoretical models of cracked steel plates retrofitted with Fe-SMA strips were established and validated by using the experimental results. The maximum deviation among numerical, theoretical, and experimental fatigue life was within 20%, indicating the reliability of numerical and theoretical models.