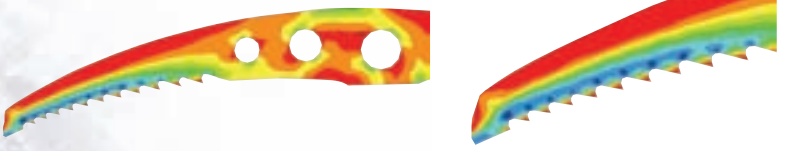
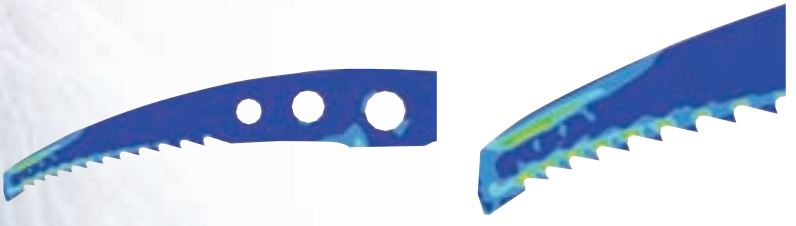


The above two figures show the third principal stress 1.6ms after impact in a transient FEA analysis and depict the most compressive stresses at the root of the axe teeth; the stress shown is above the yield stress of the material, so any tensile stress present at a later time is a residual stress.



The first principal stress 4.6ms after the initial impact in a transient FEA analysis; the highest tensile stress is apparent at the root of the teeth.

Ice Axe Impacts

Finite element analysis is used to study crack initiation on a serrated blade.

By Rae Gordon and Kathryn Franklin
Faculty of Advanced Technology
University of Glamorgan, Wales

Ice climbers scaling a frozen waterfall use two ice axes, one in each hand, and crampons on their feet. The ice axe consists of a shaft with a spike at the bottom and a head at the top. The head consists of an adze (or hammer) on one side and a pick on the other side. The adze is used for removing loose ice and the pick is used to help the climber advance up the face of the icefall. To improve the pick's grip in the ice, the bottom edge is serrated with a row of teeth. In operation the ice axe is subjected to various load conditions but primarily to the impact of the pick with the ice, the weight of the climber pulling up on the pick and "torquing" where the pick is placed in a fissure and twisted to achieve purchase.

There have been a number of recorded failures of ice axes, most of which involve fracture brought on by fatigue [1,2]. Typically, fatigue cracks grow from the serrated edge, particularly from the root of a tooth. An initial finite element study using ANSYS software revealed that a steady-state load applied normal to the end of the pick results in a compressive stress along the serrated edge of the pick with the teeth acting as stress raisers. Fatigue cracks, however, are not normally initiated in areas of compressive stress, but more often are initiated if a tensile stress is present. This can occur if the compressive yield stress for a material is exceeded, resulting in a residual tensile stress. If a residual tensile stress is present at the root of the ice axe teeth, subsequent impact cycles would repetitively expose the tooth area to alternating compressive and residual tensile stresses, ideal conditions for crack initiation and growth. The majority of fatigue literature reports on cracks that are initiated at the site of impact loading, though some also focuses on the phenomena of cracks that are initiated at stress concentrations remote from the impact site.

A transient finite element study using ANSYS Mechanical software subsequently was performed to study how fatigue cracks not normally initiated in areas of compressive stress develop at the root of the teeth. A worst-case scenario was considered in which the pick strikes against rock. The results examined the effect of cyclic impact loading at the root of the ice axe teeth. This analysis revealed that the compressive stress resulting from the impact load exceeds the yield stress and, hence, results in a residual tensile stress at the root of some of the teeth. The results indicate that the conditions required for a crack to be initiated and fatigue failure to occur on subsequent load cycles are present. Further work is required to determine if fatigue would actually occur. ■

References

[1] http://www.thebmc.co.uk

[2] Hellen, T.: The Engineering Stability of Metallic Climbing Equipment, in The Science of Climbing and Mountaineering: Chapter 15, Human Kinetics. Messenger, N.; Patterson W.; Brooks D.: Editors, 1997.