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Mechanical behavior and microstructural evolution of nanostructured bainite under high-strain rate deformation

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ABSTRACT

To meet the demand for high strength and high toughness for advanced engineering application, nanostructured bainite was developed. A high Si content is required to hinder the detrimental formation of cementite in bainite and thereby produce a carbide-free structure. The concentration of carbon is usually fixed in the range of 0.8–1.0 wt% to ensure that the gap between the bainite-start (B_s) and martensite-start (M_s) temperatures is large enough to generate bainite, instead of martensite, at a low temperature. The resulting bainite microstructure mainly consists of nanometer-sized bainitic ferrite subunits with austenite thin films, wherein a high density of interfaces provides outstanding strength (in excess of 2 GPa). Furthermore, ductile austenite possesses exceptional toughness to retard crack propagation. The main advantage of nanostructured bainite over its competitors is the inexpensive thermal processing. Without sophisticated thermal mechanical processing, a bulk nanocrystalline structure can be produced simply by one-step isothermal heat treatment.

To explore the mechanical behaviour and microstructure evolution of nanostructured bainite under deformation at high strain rates ($>10^3 \text{ s}^{-1}$), split Hopkinson pressure bar experiments were conducted. It was found that nanometer-sized twinning occurred in both blocky austenite and film austenite. In the former case, the intersections of different twin variants brought about strain-induced α' -martensite, while in the latter case, the lamellar twinned structures were occasionally accompanied by a small amount of ϵ martensite. It is concluded that twinning occurs first in blocky austenite, enhancing the initial work-hardening; subsequent twinning takes place in film austenite, promoting further straining.