UNUSUAL STRESS SERRATIONS AND PLC BANDS IN HIGH MANGANESE AUSTENITIC Fe-Mn-C TWIP STEEL

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Abstract
Deformation twinning and dynamic strain aging (DSA) are two major phenomena occurring in Fe-Mn-C twinning-induced plasticity (TWIP) steels. DSA is manifested with serrated plastic flow, with stress serrations appearing on stress-strain or stress-time curves. TWIP steels, especially Fe-Mn-C TWIP steels, show apparent serrated plastic flow. However, the stress serrations and associated Portevin-Le Chatelier (PLC) band behavior of such steels reported in several publications, especially at very low strain rates, are not consistent. This paper is to investigate the serrated plastic flow and the spatio-temporal behaviors of PLC bands in a Fe-Mn-C TWIP steel at very low strain rates, by means of in-situ tensile tests, in conjunction of digital image correlation (DIC) technique.

1. Introduction

High manganese austenitic TWIP steels exhibit extradinarily high strain-hardening rate and excellent mechanical properties. A large volume of research has been conducted to investigate the deformation twinning behavior in these steels, and its role in enhancing strain-hardening rate. Alternatively, DSA was also claimed to contribute significantly to the strain-hardening rate of Fe-Mn-C TWIP steels. DSA is typified by stress serrations on stress-strain curves, which are often accompanied by the occurrence of PLC bands or strain localization on specimen surface. Different types (types A、B and C) of stress serrations have been reported in TWIP steels. It was shown that PLC bands associated with type A serrations propagate continuously and type B ones propagate in a hopping way. A limited number of studies have been conducted on type C bands, showing that PLC bands related to type C serrations are nucleated randomly on specimen surface. The purpose of this study is aimed to investigate the serrated plastic flow behavior and spatio-temporal characteristics of PLC bands in Fe-18Mn-0.6C TWIP steel at very low strain rates and compare them with those at a higher strain rate, using DIC technique to measure the full-field strain distributions and using water transfer printing method to prepare digital speckle patterns for accurate and reproducible DIC data analyses.

2. Results

It is observed that, at high strain rate of $5.5\times10^{-3}s^{-1}$, stress serrations are typical of type A ones, which take the shape of an upward spike, featured by a stress rise and a stress drop to or slightly below the general stress level. At low strain levels, serrations are single or separate; however, at higher strain levels, serrations become clustered. Furthermore, at very low strain rates of $6.9\times10^{-5}s^{-1}$ and $4.1\times10^{-5}s^{-1}$, stress serrations are typical of type C ones, which take the shape of a downward spike, featured by stress falling below the general envelope of the stress–time curve. At low strain levels, serrations are also single or separate; however, at strain levels, serrations are type C serration clusterings, as shown in the circled areas in the upper part of Fig. 1.

At low strain levels, single serrations prevail, regardless of strain rate. PLC bands that are formed at single, type A serrations have a stagnation time before band propagation; however, PLC bands that are formed at single, type C serrations propagate instantly after formation, with no stagnation time. At higher strain levels, serration clusterings are prevalent, regardless of strain rate. In the serration clustering time, PLC bands tend to be formed during stress drops and disappear during stress rises, showing an alternating band appearance and disappearance phenomenon. Propagable bands are formed at the ends of serration clustering time and propagate during the smooth portions of the stress-time curve, as shown in the lower part of Fig. 1.

At both high and very low strain rates, PLC bands propagate persistently at either low or high strain level: i.e. PLC bands, whether they are formed at single serrations or at the end of serration clusterings and whether the serrations are of upward-spike type A or downward-spike type C, all propagate continuously along the specimen length.

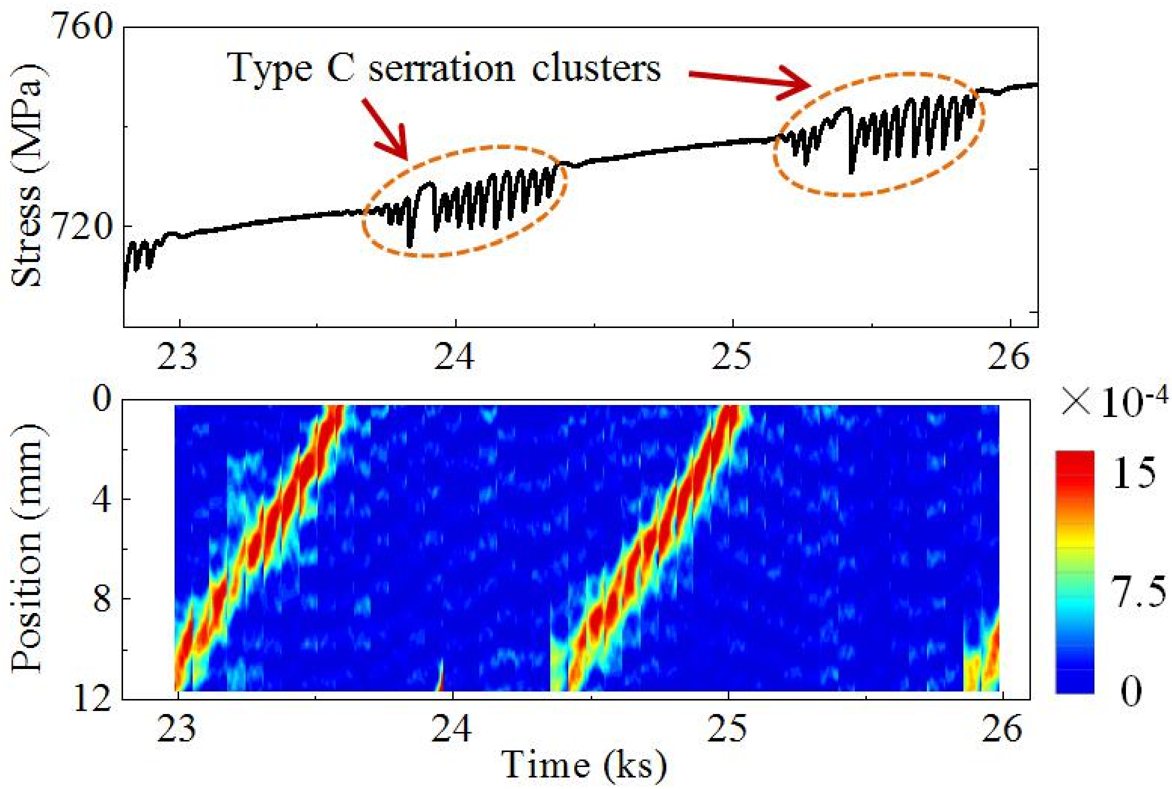

Fig.1 –An portion of enlarged stress-time curve (upper) and corresponding axial incremental strain distribution map (lower) measured at strain rate of $4.1\times10^{-5}s^{-1}$.

3. Conclusions

The findings that the stress serration morphology changes from single serrations to serration clusters with increasing the strain level, and the PLC bands propagate continuously independent of associated serration morphology (type A or type C) are unusual, as compared with the results on other TWIP steels reported in literature. Further studies are required to clarify the underlying mechanisms associated with different morphologies of stress serrations and PLC band behaviors in Fe-Mn-C TWIP steels.

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