significant strain accommodation. Both variants 10 and 23 help accommodating the strain resulting from the transformation of variant 1. Variant 23 was not experimentally observed to be intimately associated with variant 1, consistently with previous literature results on upper bainite [18]. It is worth noting that the misorientation relationship between variants 1 and 23 slightly departs from the twin relationship, so that the transformation eigenstrains of variants 1 and 23 do not cancel each other. On the other hand, low-angle misorientation between groups of laths having highly misoriented habit planes, such as variant 10 with variant 1, were most frequently observed in the investigated microstructures. The model indicates that this particular spatial and crystallographic arrangement is able to partly accommodate the transformation strain by limiting plastic deformation in the austenite phase. This could in turn help growth of the bainite phase, which is known to be hindered or eventually stopped by increasing plastic strain in the mother austenite phase [50]. Thus, the model shows how self-accommodation can be at least partly achieved thanks to the experimentally observed configuration. Further work is still in progress to more accurately describe interactions between neighbouring bainite variants during the phase transformation.

5. Summary and conclusions

The present study was devoted to the formation of upper bainite in a high strength, low alloy steel under simulated welding conditions. No particular hypothesis was made concerning the actual transformation mechanism at the interface. Multi-scale crystallographic and metallographic investigations together with simple analytical micromechanical modelling led to the following results:

1. The EBSD technique is able to give detailed crystallographic features of the phase transformation, including orientation relationships with the mother austenite phase even if no retained austenite is analysed. The proposed method can thus be used for any steel chemical composition. In this study, the orientation relationship between parent and product phases is well within the Bain zone, and close to the KS or NW relationships.
2. Upper bainite packets of the fully transformed microstructures consist of highly intricate, non-parallel sets of plate-shaped groups of laths. These groups have a low angle misorientation relationship but highly misoriented habit planes.
3. The bainite phase transformation appears to occur in two stages. In the first stage, discrete, non-parallel, highly intricate, straight groups of laths form. The second stage is thickening of these groups, leading to coarse crystallographic packets containing both elongated and equiaxed M–A constituents.
4. Simple analytical micromechanical modelling of accommodation mechanism was carried out by solving an Eshelby inclusion problem using a self-consistent scheme. Results indicate that the intricate configuration described above could be able to limit the plastic strain in austenite, and thus to enhance growth of the bainite phase.

Acknowledgements

Financial support and constant interest from Dillinger Hütte are gratefully acknowledged.

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