UCRL-16161

University of California

Ernest O. Lawrence Radiation Laboratory

FACTORS DETERMINING TWINNING IN MARTENSITES

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

Berkeley, California

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Letter to Editor -
Acta Metallurgica

UCRL-16161

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

FACTORS DETERMINING TWINNING IN MARTENSITES

O. Johari and G. Thomas

May 1965

FACTORS DETERMINING TWINNING IN MARTENSITES

O. Johari and G. Thomas

Department of Mineral Technology, College of Engineering,
University of California, Berkeley, California

In a recent investigation[1] of substructures and strength of ausformed steels, it was found that the extent of twinning in martensite decreased with increasing amounts of deformation of the metastable austenite prior to transformation to martensite. It was shown that the precipitation of carbides in austenite occurred after a critical amount of deformation. Since the extent of twinning in ausformed martensites was extremely low, twinning was not regarded as a strengthening parameter. The strength of ausformed steels was thus explained on the basis of dislocation density and precipitation. Here the factors influencing the presence or absence of transformation twinning will be considered.

Transmission electron microscopy investigations of the transformation substructure in Fe-C alloys by Kelly and Nutting[2] and in Fe-Ni alloys by Speich and Swann,[3] showed that the amount of transformation twinning increased with solute concentration. The change in transformation substructure from dislocations to twinning is not a sharp one. The steels we investigated were based on a composition Fe-28%Ni-0.3%C with or without Cr, Mo, V (see Table I) so that in all these alloys, after conventional heat treatment the martensites were twinned.

Table I

Heat No.	%C	%Ni	% Alloying Element
1410	0.3	27.94	---
1398	0.28	24.92	4.50 Mo
1541	0.32	16.40	4.72 Cr
1402	0.29	24.73	1.85 V

Two reasons have been proposed for the occurrence of twinned martensite in steels containing C or Ni.

a. M_s Temperature

Since both C and Ni lower the M_s temperature and promote twinning it has been suggested[2] that low M_s temperatures favor twinned martensites (for review see ref. 4). This is in agreement with results on both F.C.C. (Cu for example[5]) and B.C.C. (iron for example[6]) metals where plastic deformation takes place by twinning at low temperatures, suggesting that at these temperatures the critical resolved shear stress for twinning is lower than that for slip. On this basis low M_s temperatures would be expected to favor transformation twinning in martensites. Thus all alloying elements which lower M_s temperatures should favor twinning.

b. Stacking Fault Energy

Little is known about the influence of stacking fault energy on transformation substructures, although Kelly and Nutting[7] postulated that twinning in martensite is favored by austenites of high stacking fault energy. This result agrees qualitatively with the observation of twinning in Fe-Ni steels by Speich and Swann,[2] as Ni is known[8,9,10] to raise the stacking fault energy of austenite. This effect of stacking fault energy is opposite wo what is found for mechanical twinning in F.C.C. metals, where the lower the stacking fault energy the higher is the tendency for deformation by twinning.[5,11] This would suggest that as far as transformation twinning is concerned the effect of solutes on M_s temperatures is more important than their effect on stacking fault energy.

It has been clearly established from our work on ausformed steels[1]

that increasing deformation of metastable austenite favors precipitation and reduces the extent of transformation twinning. The deformation of austenite and the removal of alloying elements from solid solution by the formation of precipitates both raise the M_s temperature of steels. On the other hand the solutes* present in the present steels are known to lower the stacking fault energy[8,9,10,12] and hence their depletion from solid solution as carbide precipitates should raise the stacking fault energy of austenite. According to Kelly and Nutting[7] this should favor twinning. However, since this is not the case it further suggests that M_s temperature rather than stacking fault energy of austenites is the important factor in determining twinning.

It is also worth noting that transformation twinning occurs in body centered martensites and since the body centered structures in general have high stacking fault energies, the latter parameter cannot be very important in determining twinning in steels which undergo the martensitic transformation. Also, there may be no direct correlation between stacking fault energy of austenite and twinning in martensite. No observations of faulted martensites have been reported for steels, but in Cu-Al alloys of low stacking fault energy, the lattice invariant shear in martensite occurs by faulting.[13]

These considerations strongly suggest that the M_s temperature determines the occurrence of transformation twinning in martensitic structures, rather than the stacking fault energy of austenites.

---

*No data are available on the effect of V on stacking fault energy of austenites, but observations on the effect of other solutes suggest that V also lowers the stacking fault energy.

ACKNOWLEDGMENTS

This work was supported under the U.S. Atomic Energy Commission through the Inorganic Materials Research Division of the Lawrence Radiation Laboratory.

REFERENCES

1. O. Johari and G. Thomas, submitted for publication to Trans. of ASM. Also UCRL-11861 Rev., March (1965).
2. P. M. Kelly and J. Nutting, Proc. Roy. Soc. London A 259, 45 (1961).
3. G. R. Speich and P. R. Swann, Journal of Iron and Steel Institute, 203, 480 (1965).
4. A. S. Keh, W. C. Leslie and G. R. Speich, Symposium on the Role of Substructure in Mechanical Behavior of Metals, Technical Documentary Report No. ASD-TDR-63-324, Wright Patterson Airforce Base, Ohio, p. 393, April (1963).
5. J. A. Venables, Deformation Twinning, Gordon and Breach, New York, p. 77, (1964).
6. E. Bull Simonsen and J. M. Dossin, Journal of Iron and Steel Institute, 203, 380 (1965).
7. P. M. Kelly and J. Nutting, Journal of Iron and Steel Institute, 197, 199 (1961).
8. P. R. Swann, Corrosion, 19, 102t (1963).
9. D. L. Douglass, G. Thomas and W. R. Roser, Corrosion, 20, No. 1, 15t (1964).
10. A. J. Goldman and C. N. J. Wagner, Acta Met., 11, 405 (1963).
11. O. Johari and G. Thomas, Acta Met., 12, 1153 (1964).
12. S. Barnartt, R. Stickler and D. Van Rooyen, Corrosion Science, 3, 9 (1963).
13. P. R. Swann and H. Warlimont, Acta Met., 11, 511 (1963).

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.