LETTERS TO THE EDITOR

On the Cleavage Plane of Tempered Martensite*

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The main characteristic of cleavage is the orientation relationship between the plane of the crack and the crystal structure through which the crack passes. It has already been proved that cleavage occurred along the {100} plane in the ferritic steel⁽¹⁾. The most evident fracture surface features associated with cleavage are the flatness of the facet and the formation of river patterns. A large number of tempered martensitic steels fracture along transgranular paths producing fracture surfaces similar to those caused by cleavage of the ferritic steel. For this type of fracture in tempered martensitic steels "the quasi-cleavage" has been proposed, since the fracture path has not yet been related to the orientation of the crystal structure through which the cracks passed⁽²⁾.

The present investigation was carried out to prove directly the relationship between the fracture facets and the crystal lattice planes of a low carbon tempered martensite. The chemical compositions of the material used are shown in Table 1, which was prepared in a vacuum induction furnace. After austenitizing for 30 min at 1300°C, specimens were quenched into iced-brine and tempered for 1 hr at 600°C. The orientation was determined by forming etch pits on large brittle fracture facets. The etchants used are tabulated in Table 2⁽³⁾. By the use of these etchants and etching processes, sharp etch pits composed of {110} planes were developed.

Photo. 1 is a typical example of etch pits formed on a large brittle fracture facet of the low carbon tempered

Photo. 1 An example of {001} etch pits formed on a large brittle fracture facet of the low carbon tempered martensite. Two-stage replica.

Photo. 2 A large brittle fracture facet without etching. Two-stage replica.

Table 1 Chemical composition of the material used (wt%)

C	Si	Mn	Ni	Cr	Mo	Fe
0.12	0.2	0.5	2.4	1.0	0.4	Balance

Table 2 Etchant and etching time

Etchant A		Etchant B		Etchant C	
Reagent	Time	Reagent	Time	Reagent	Time
HCl 1 cc H ₂ O ₂ 20 cc H ₂ O 20 cc	<5 sec	FeCl ₃ -6 H ₂ O 20 cc HCl 10 cc H ₂ O 100 cc	<50 sec	HCOOH 25 cc H ₂ O ₂ 25 cc C ₂ H ₅ OH 25 cc H ₂ O 25 cc	<5 sec

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(2) J. Srawley : NRL Research report.

(3) J. Imamura et al. : *Practical Metallography*, 5 (1968), 22.

(4) S. Matsuda, T. Inoue and M. Ogasawara : *Trans. JIM*, 9 (1968), 343.

(5) T. Inoue, S. Matsuda, Y. Okamura and K. Aoki : *Trans. JIM*, 11 (1970), 36.

martensite. For reference, the feature of a fracture facet without etching is shown in Photo. 2. As is clearly seen from Photo. 1, all the pits show that the fracture facet is cracked along the {001} plane. This means that the brittle fracture mode of the low carbon tempered martensitic steel is cleavage and the cleavage plane is equivalent to that of the ferritic steel. This result supports the concept of the effective grain size which has been applied to the tempered martensitic steel⁽⁴⁾⁽⁵⁾.

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