Image processing analysis of growth of carbide particles promoting SR embrittlement in HAZ of 2 1/4Cr-1Mo steel†

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KEY WORDS: (Image processing) (Carbide) (SEM image) (Heat affected zone) (2 1/4Cr-1Mo steel) (SR embrittlement) (Crack propagation) (Crack initiation) (Cleavage fracture) (Facet)

1. Introduction

SR treatment (stress relief annealing) improves the toughness of HAZ in 2 1/4Cr-1Mo steel and suppresses the temper embrittlement[1]. However, SR embrittlement occurs after long time heating at SR temperature[2]. Transition temperature rises when SR embrittlement occurs. Microstructure changes also through SR treatment. Especially, behavior of precipitation of the carbide particle cannot be evaluated easily by manual treatment, because a lot of particles exists in a microscopic area. Image processing may help systematic investigation of the dimension of the carbide particle.

Suitable image processing was developed to measure shape of the carbide particles in an image of the scanning electron microscope. The Shape of the carbide particles on the fracture surface differs from that in the cross section area when SR embrittlement occurs significantly. Peculiar phenomena were considered by SEM observation on both sides of the fracture surface in this study.

2. Specimen

2 1/4Cr-1Mo steel was used in this experiment. The synthetic HAZ specimen was produced by a weld thermal simulator and tempered at 975K. SR embrittlement occurs from 10h as shown in **Fig. 1.** The tempered specimen was fractured at very low absorbed energy with producing cleavage fracture. The fracture surface and the cross-section of each specimen were etched by 3% nital to reveal the contours of carbide particles.

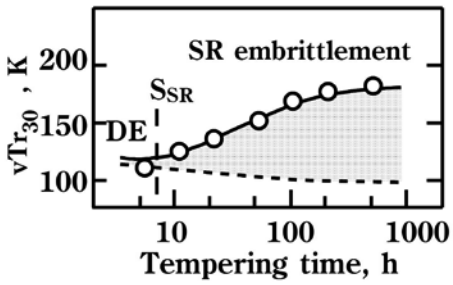

Fig. 1 Change of transition temperature vTr_{30}.

3. Image processing

Image processing was applied a SEM images of the cross section area and the fracture surface. Image processing was carried out by assembling Image dividing, Brightness&Contrast, Contraction and Expansion treatments. **Figure 2** shows an example of an original SEM image and image after image processing for the carbide particles on the fracture surface. Difference of the area between manual measurement and image processing for the

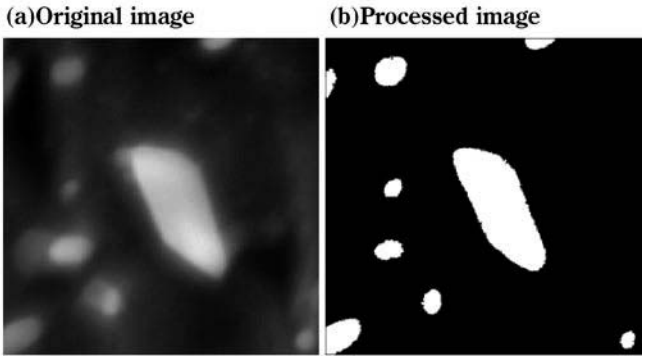

Fig. 2 Example of image processed image with some carbide particles on fracture surface.

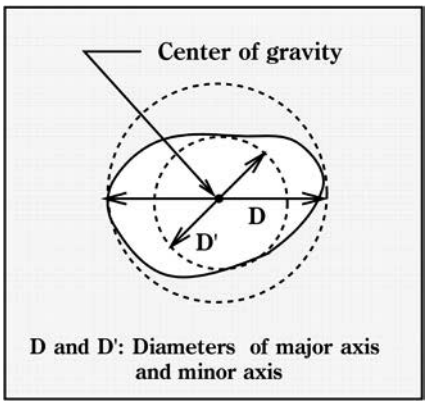

Fig. 3 Schematic diagram of shape of carbide particle measured after image processing.

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Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan

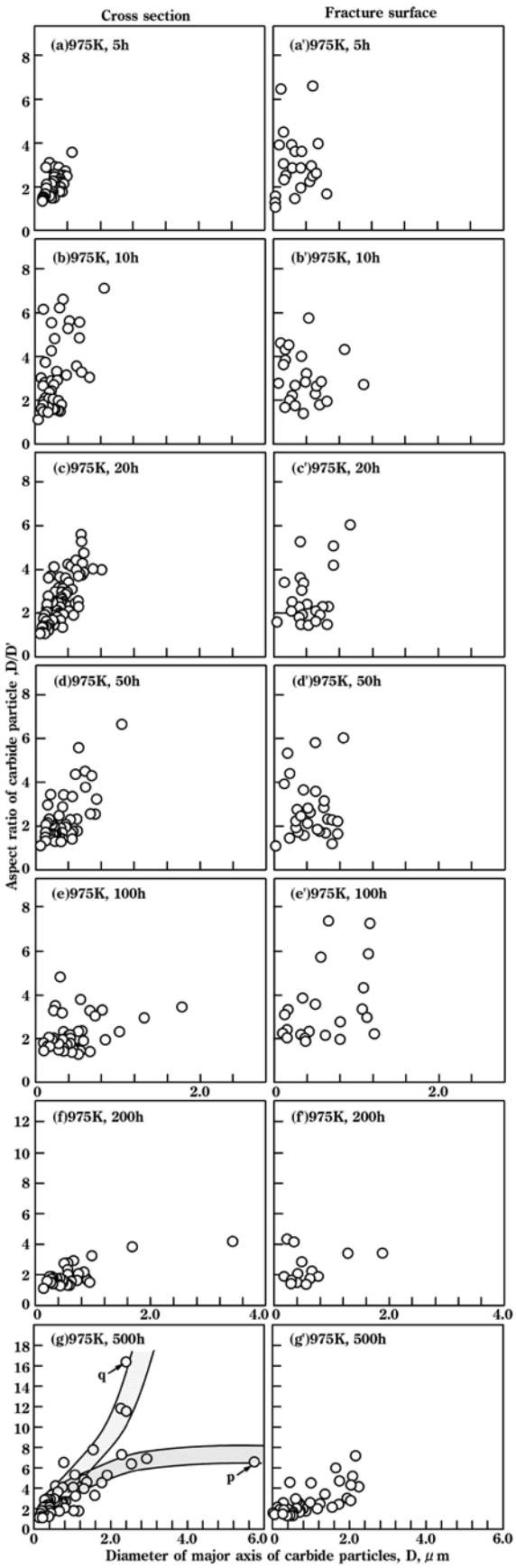

Fig. 4 Relationship between aspect ratio and diameter of major axis of carbide particle.

centered large carbide is below 1%. Major axis, minor axis and aspect ratio of the particle were measured by the digital image after image processing.

Major axis, minor axis and aspect ratio of the particle were defined as shown in **Fig. 3**. The particle with aspect ratio of 1 shows a spherical shape.

4. Experimental results

The relationship between aspect ratio and diameter of major axis of the carbide particle was measured by image processing as shown in **Fig. 4**.

The growth direction of the carbide particle is stable until 50h because gradient in these figures for cross section area does not change significantly. This result shows that the shape of the carbide particle retains the needle shape in short-time SR treatment. Moreover, the carbide grows as a polygonal type which has small aspect ratio against diameter of major axis after 100h. In case of 500h, "p" and "q" in Fig. 4(g) correspond with the polygonal type and the needle type, respectively. When SR embrittlement occurs significantly, coarse particles in the cross-section could not be observed on the fracture surface and aspect ratio on the fracture surface is lower than the cross-section. This result shows coarsened carbide particle promote SR embrittlement as a site of crack initiation or crack propagation as shown in **Fig. 5**[3].

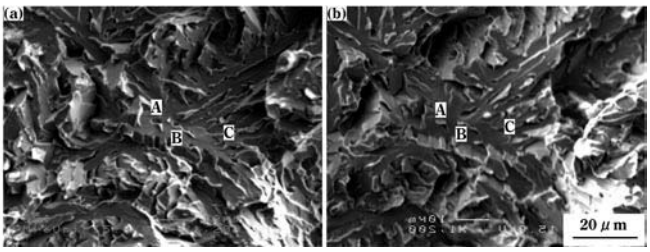

Fig. 5 Broken carbide particles at crack initiation site.

5. Conclusions

Image processing was developed to evaluate the shape of the carbide particle in a SEM image. Detailed analysis for the shape of the carbide particle by image processing shows that coarse carbide particles are broken during crack initiation and crack propagation.

References

[1] H. Kawakami, K. Tamaki, J. Suzuki, Y. Ichikawa.: Q. J. Japan Welding Soc., 16 (1998), pp.243-251.

[2] K. Tamaki, H. Kawakami, J. Suzuki, T. Niinomi: Q. J. Japan Welding Soc., 15 (1997), pp.502-508.

[3] H. Kawakami, K. Tamaki, J. Suzuki, K. Takahashi, Y. Imae, S. Ogusu: Doc. of IIW, IIW-2302-09(2009), pp.1-13.