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EVALUATION OF DUCTILE FRACTURE IN FERRITE–PEARLITE STEELS BY THE ELLIPSOIDAL VOID MODEL

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The ferrite–pearlite microstructure is fundamental for applications of carbon steels. Extensive studies have been conducted on the ductile fracture in ferrite–pearlite steels. These studies have demonstrated void nucleation due to the fracture of pearlite nodules and the propagation of macroscopic cracks due to the growth and coalescence of voids [1-3]. However, these previous studies are experimental; an analytical study is required to clearly understand the effect of material microstructure on ductile fracture. In our ellipsoidal void model for the evaluation of ductile fracture [4], circular voids are assumed to nucleate [5]. In other words, voids are assumed to nucleate owing to decohesion of inclusions from a matrix. However, voids nucleate owing to the fracture of pearlite nodules in the ferrite–pearlite microstructure. Hence, it is impossible to evaluate ductile fracture in ferrite–pearlite steels using our ellipsoidal void model in its current form.

In this study, we first improve our ellipsoidal void model to consider the nucleation of voids due to inclusion fracture. The shape of pearlite nodules before their deformation is assumed to be circular, and their deformation is assumed to be identical to that of a ferrite matrix. At the onset of the deformation of the material, it is assumed that pearlite nodules fracture and voids nucleate. The tangential direction of the fractured surface is assumed to be the direction of the maximum shearing stress of the material. The shape of voids is assumed to be ellipsoidal to simplify the analysis.

Second, we evaluate the ductile fracture in ferrite–pearlite steels in multi-pass drawing by using our improved ellipsoidal void model. A ferrite–pearlite steel, which is JIS S15C and equivalent to ISO C15E4, was used. A specimen is drawn multiple times using different dies until an inner fracture defect appears in the specimen. The multi-pass drawing experiment was performed with the reduction in area and die angle specified for each die. The inner diameter of the die at which the material fractures and the material density distribution in the radial direction after drawing through the die preceding the die at which the material fractures, both calculated from the analysis, were compared with those obtained from the experiment.

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