Note

Effect of Pearlite Banding on Mechanical Properties of Hot-rolled Steel Plates

Pearlite banding in hot rolled steel plates is a phenomenon known for a long time but it is still a matter of some concern.¹⁻³⁾ It is manifested by the formation of dark lines in polished and etched sections aligned parallel to the rolling direction. Although normally a microscopical examination is required for their identification, sometimes they occur on a level visible to the naked eye, with features quite reminiscent of delamination. Whatever its level, an aspect which is always relevant concerns the macroproperties of the plates. With clear separation of phases into bands of ferrite and pearlite, it is certain that the local properties in the plates will be affected, but whether or not this would lead to gross changes in the macroproperties, such as tensile and impact properties, is not at all certain. This note reports results from a study aimed at clarifying this aspect.

Materials studied were hot rolled steel plates with nominal composition 0.21% C, 0.85% Mn, 0.028% S, 0.016% P, 0.2% Si, 0.015% Al. In all, 14 different coils were studied all conforming to the same specification. The coils, 1400 mm in width and 5.5 mm in thickness, were produced from continuously cast slabs by 97.25% hot rolling reduction. Initial examination showed that the majority of the coils had banded structure. A structure which is typical of these plates is reported in Fig. 1. The initial examination also showed that the banding was more frequent and relatively more pronounced in the middle portion of the plates, presumably due to preferential segregation of elements such as Mn and lower cooling rates experienced in these regions.

Hardness values taken in the centerline at 50 mm intervals along the width direction obtained for all plates gave an average value of 178 VHN. The values differed somewhat from plate to plate and also within the individual plates, but this scatter was only slight and not

more than 5 VHN units. More importantly there was no obvious correlation with banding. The same was also true for yield and tensile strengths measured in full thickness samples prepared parallel to the rolling direction. The average values were 378 and 550 MPa, and the scatter was within ± 24 and ± 15 MPa for the yield strength and the tensile strength, respectively. The ductility as measured by percent elongation over 50.8 mm gage length, however, exhibited a slight correlation with pearlite banding. Samples from heavily banded plates or from heavily banded regions gave systematically lower values of elongation. With heavily banded samples, *i.e.* those with structure similar to Fig. 1, the elongation was about 36% which compares with 39% obtained in slightly banded or unbanded samples.

Impact properties, on the other hand, correlated quite well with banding. Charpy V notch (CVN) tests with subsize samples (5 × 5 mm in section) gave consistently lower impact energies for banded samples, as shown in Fig. 2. A gross feature in these results is that the impact energy is highly anisotropic irrespective of banding. In unbanded plates the impact energies of longitudinal specimens is more than three times that of transverse specimens in crack arrester geometry, *i.e.*, notch in the plane of the sheet, and more than two times in crack divider geometry, *i.e.*, notch perpendicular to the plane of the sheet. With banding the impact energies of longitudinal specimens increase to six times and to three times that of transverse specimens for crack arrester and crack divider geometries, respectively.

In order to check this point further, a heavily banded sample with a structure similar to that given in Fig. 1 was heat treated to unbanded condition by accelerated cooling through the ferrite transformation region, and impact tests were carried out for the two notch geometries both in longitudinal and transverse directions. This enabled a direct comparison to be made between impact energies of the same plate in banded and unbanded conditions. The values for unbanded sample, *i.e.* after

Fig. 1. Typical banded microstructure of the plates.

Fig. 2. Effect of the extent of banding on Charpy V notch impact toughness for various specimen geometries.

the treatment, were 11 and 35 J for transverse and longitudinal samples, respectively, for the crack arrester geometry. The corresponding values in heavily banded samples were 4 and 28 J, which confirm the conclusion that the banding enhances the anisotropy.

A point of further technological significance in Fig. 2 is the relatively rapid reduction of the impact energy (by about 50% of the range of reduction) for all geometries upon slight banding which may go undetected or ignored in production stage. Also, the more pronounced effect of banding on impact energy in transverse samples, *e.g.*, 50–80% reduction in transverse samples comparing to 20–40% reduction in longitudinal samples, deserves some consideration remembering that most of the material specifications use the longitudinal impact energy as the acceptance criteria.

In conclusion it appears that the banding as is encountered in hot rolled steel plates exerts no significant

effect on strength properties. Thus yield strength and tensile strength in the material are little affected. There is some adverse effect on ductility. The effect on impact properties is however more significant, in which the level of anisotropy already present in the material is worsened with the evolution of banded structure.

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