Fatigue Strength Improvement Using the Weld Metal Transformation Expansion

1. Introduction

It is said that when the strength of steel is increased, the fatigue strength of the steel itself also is increased, but that fatigue strength of a welded joint of steel remains the same even when the strength of the steel is increased. Because of this, there has been considered that in the case of steel structures whose fatigue strength matters, increasing the strength of their steel structural members is not an effective solution. This paper describes technology for improving the fatigue strength of welded joints by utilizing the weld metal expansion that accompanies the transformation of weld metal.

2. Results and Conclusion

The mechanism of this technology for improving the fatigue strength of welded joints is that steel constrains the weld metal transformation expansion and thereby the compressive residual stress is introduced in the part in which fatigue occurs. Ordinarily, when a weld metal transforms , it expands. However, because the transformation takes place and is completed under high temperatures, a tensile residual stress sets in due to thermal shrinkage after the transformation. In this technology, the weld metal composition is adjusted to lower the transformation start temperature and to reduce the amount of thermal shrinkage after the transformation, whereby the compressive stress that occurs during the transformation/expansion can remain even after the weld metal is cooled down to room temperature.

Fig. 1 shows the shape of a fatigue test piece. The test piece shown is called a corner boxing welded joint. In this joint, there is a severe stress concentration and it can be considered that this joint determines the fatigue strength of the whole welded structure. All the test pieces used are the same, except for additional weld beads. By varying the compositions of the additional weld beads, their influence on the fatigue strength of joints was studied. Three types of welding materials were used for the additional weld beads: ordinary 570 MPa class welding material (L62EL), 10% nickel-added material (N19) and 15%Cr-7%Ni material (C15N). The reason why additional weld beads were adopted is that the cost of welding materials would become very high if N19 and C15N were used over the entire weld bead line. In order to eliminate the influence of the difference in shape of the weld bead, ordinary welding material was also used for the additional weld beads. According to the results of a Formaster test, the transformation start temperature of weld metal was 350℃ for N19 and 230℃ for C15N.

Fig. 2 shows the fatigue test results. The fatigue test was carried out under the condition of a stress ratio of R = 0.1. In the test, the load under which no fatigue cracks had occurred in the test piece after 5,000,000 cycles was assumed as the fatigue limit of that test piece. The points where cracks had occurred were the weld toe of additional beads. The test pieces that were free from cracks in those points are indicated by an arrow in Fig. 2. The test pieces that are indicated by an arrow even though they had not been subjected to 5,000,000 cycles of loading are those which revealed cracks in part A (lap of bead) in Fig. 1. Testing of those test pieces was stopped halfway.

According to the test results shown in Fig. 2, both N19 and C15N improve the fatigue strength of welded joints significantly. A comparison between N19 and C15N shows that by lowering the transformation point to about 350℃, it is possible to improve the fatigue limit to the same degree as when the transformation point is lowered to about 230℃. The Charpy absorbed energy at 0℃, for example, was about 100 J for N19 and about 30 J for C15N. (At -80℃, N19 secured an absorbed energy of 50 J or more.) Thus, because N19 and C15N are nearly the same in terms of their effectiveness in enhancing fatigue strength, it is considered more practical to focus on securing other desired properties than to lower the transformation point excessively.

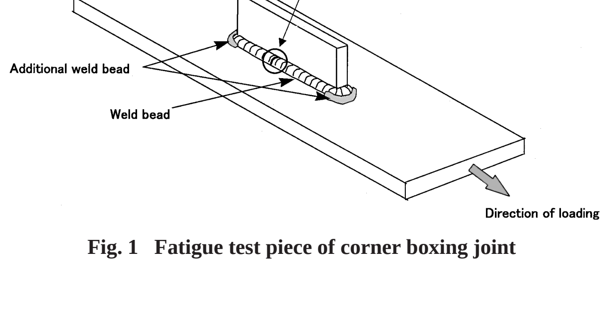

Fig. 1 Fatigue test piece of corner boxing joint

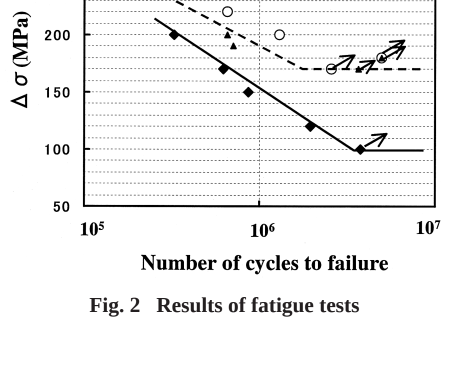

Fig. 2 Results of fatigue tests