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Study on Creep Rupture Properties of Welded Joints of Quenched and Tempered High Strength Steel

Isao OKANE (岡 根 功)

This paper describs creep rupture properties of welded joint of high strength steel and consists of eight chapters.

1. Introduction: Recently, high strength steels are often used for pressure vessels such as boilers and reactors for high temperature and pressure applications. The materials are exposed to high temperature for long duration in the application conditions. Therefore, it is necessary to understand the mechanical properties of the materials at high temperature for long period. Especially, in the case of welded joints, it is very difficult that the mechanical properties of the joints are exactly inferred from the results of conventional tests, because there are many metallurgical and mechanical factors which have influence upon the properties of welded joints, such as the different chemical composition between base and weld metals, the irregularity of structure at heat-affected zone (HAZ), the non-uniform stress distribution by the shape of groove and reinforcement, and moreover the structural change by exposure at high temperature for long period. Then, the test results by conventional small size specimens, cut off from welded joints, are scarcely used directly as design data. Accordingly, it may be desirable that the test results by large size specimens, having the cross section of as-welded joint, are used for design data.

In this study, the creep rupture mechanism for welded joints of high strength steel are discussed by the comparison of the results by large and small size specimens, and also by investigation of macro- and microscopic observations for the rupture region of welded joints.

2. Comparison with results by large and small size specimens: The results of creep rupture properties of large size specimens are compared with those of conventional small size specimens. Consequently, it becomes clear that the creep rupture properties of large size specimens are generally inferior to those of small size specimens, and this seems to be caused by formal and metallurgical stress concentration.

3. Creep rupture configuration of large size specimens: The large size specimens are ruptured at the HAZ near bond. The initiation of crack in rupture occurs at the toe of weld metal and the intersection of both side weld metal, and the crack grows along the austenite grain boundaries at the HAZ near bond.

4. Discussions on creep rupture configuration of large size specimens: The mechanism of creep rupture for large size specimens are investigated with results of high temperature tensile and creep rupture tests for synthetic HAZ specimens. The

specimens are synthesized the coarse grain part near bond, the fine grain part near base metal and the intermediate part in the HAZ. It becomes clear from the results of tests that high temperature tensile and creep rupture properties of coarse grain part are inferior to that of the other parts and the rupture occurs at austenite grain boundaries. Especially, the absorbed energy to rupture of coarse part is smaller than that of the other parts at 400°C over. Consequently, it is made clear that the creep rupture of large size specimens may occurr along the austenite grain boundaries at the HAZ near bond.

5. Influence of postheat treatment on creep rupture strength: The large size specimens are made under the following three conditions of postheat treatment: (a) 550°C×2.5 hr, furnace cooling, (b) 650°C×2.5 hr, furnace cooling and (c) 900°C×2.5hr, furnace cooling. The results are as follows: (1) The all specimens are ruptured at the HAZ near bond. (2) The creep rupture strength of specimens, treated at 650°C and 900°C after welding, are superior to that of the as-welded one. While, the postheat treatment at 550°C seems to decrease the creep rupture strength.

6. Discussion on the difference in rupture configuration between large and small size specimens: The large and small size specimens are ruptured at the HAZ near bond and base metal, respectively. The welded joints have to be made by multi-layer welding. So, it may be considered that the properties at welded joint of both size specimens are different. Then, the difference of rupture configuration may be caused by the aforesaid difference of properties of large and small size specimens. In this chapter, tensile tests at 450°C on synthetic HAZ specimens with respect to the coarse grain part near bond and the fine grain part near base metal in HAZ of small size specimen are carried out to measure the absorbed energy to rupture. The value of absorbed energy of fine grain part is less than that of coarse grain part. Consequently, it may be considered that small size specimens are ruptured at fine grain part near base metal, while large size specimens are ruptured at coarse grain part near bond in the HAZ.

7. Discussion on welding methods viewed from creep rupture configuration: The creep rupture configuration of large size specimens are discussed in various ways. As a result, it is believed to be desirable for improving the creep rupture strength of welded joint by making the penetration of final bead as shallow as possible.

8. Conclusion: It is confirmed that the design data for welded joints of high strength steel, using at high temperature and pressure, have to use the results of creep rupture tests by the large size specimens, having the cross section of as-welded joint, at least.