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Influence of Zr on Characters of Welding Joint of Low Alloy Heat–Resisting Steel

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To estimate operation of weld joint of steam pipes in service at both high temperature and high pressure is significance for safety of thermal power station and economic efficiency. Long–term exposure of heat–resistant steel at high temperature leads to changes in microstructure. It causes the deterioration in mechanical properties. Alloying elements and microstructures have an important influence over the heat resistance in weld of low alloy heat–resisting steel using at the high temperature. Mechanical properties (R_m, δ, φ, HB,) of pipe materials and its welding joint have been investigated with respect to content of elements in carbide, their morphology and microstructural transformation to explain characteristics in change of heat–resistance. Also, researchers have done experiment using Zirconium in the coating of electrode to measure microstructure of deposited metal, mechanical properties at room temperature, metallic structures analysis, carbide analysis, scale resistance, short–term creep strength and long–term creep strength.

All kinds of experiments and analyses were carried out cyclically according to the annual record.

In detail, ten boilers were selected as object for acquiring data. The welding joints of steam pipes was prepared from 12Cr1MoV steel with dimension of 377×50mm. The operation conditions are as follows; 1.7×10^6h service time, 540~560°C, 14MPa working pressure. Based on the experimental results and analysis, the heat resistance of pipelines was weakened in five processes according to operation period. Its mechanism follows as below.

In the maintenance process, the primary carbides in matrix maintain its original features quantitatively and morphologically. There is no change in mechanical properties at this time. In the precipitation, the new carbides begin to precipitate. In other words, the alloying elements which never form primary carbides precipitate secondary carbides with carbon in grain boundary. And the cementite–type carbides convert into complex ones simultaneously. Therefore, in which the strength value is increased slightly, but value of plasticity is decreased a little. At this time, the regular creep action continues with strain hardening and recovery. In the first cohesion, both the primary and the secondary carbides are concentrated and then transfer as the complex precipitations, so the zone of ferrite is increased but bainite base and pearlite base is decreased gradually. In the mechanical properties, there are strength value decreased and values of plasticity increased. In the second cohesion process, the carbide concentration gets in grade Ⅸ or Ⅹ at the end of this process. Process of graphitization from carbides, which has large size, concentrated in grain boundary could slightly progress if carbides are holds are grade Ⅹ. Then grain boundary is widened and individual creep defaults is generated and then grow. In this process, strength and plasticity is inferior. Finally, in the graphitization process, carbides are decomposed and graphitized. Because carbides already–cohered are graphitized, ferrite base increases as much as possible. Also carbides are almost disappeared and individual pores convert into strip–holes. When these are linked with each other, cracking occurs. Thus, mechanical properties are getting worse.

From the metallographical observation, it is found that Zr series has less migrant tendency of grain boundary than V series at high temperature for a long time. And the results of hybrid carbides and mechanical properties show that the Zr series is superior to the V series in all.

There is no such precipitation in Zr series because melting points of its compounds are higher than that of V and thus, primary crystal nuclei came into with short primary crystallization interval being at higher temperature.

It shows that mechanical properties at room temperature and hot temperature mechanical properties in deposited metal of Zr series could be superior to that of V. And it could be found that zirconium has more carbide–forming ability than vanadium.

VC, Cr_7C_3, Mo_2C carbides were occurred in the case of up to 75h and $(Fe, Cr, Mo)_{23}C_6$ was produced in the case of up to 100h in V series from the result of qualitative analysis. ZrC, Cr_7C_3, Mo_2C carbides were precipitated in the case of up to 75h and complex carbides precipitation was never produced in the case of up to 100h in Zr series. Change in total amount of special carbides in Zr series was less than that of V series; increment of special carbides in V series is 2.05%, which of Zr series is 0.07% at 700°C for 100h.

The results of experiment for oxidation inclination at the high temperature show that the value of scale oxidation of Zr series is 1.4 times greater than V series. It shows that Zr series has kept steady–state at high temperature.

Zr series has the higher scale resistance because its compounds including zirconium carbides are more robustness against the heating than V series. In contrast, it was proved that the heat resistance of V oxidation (V_2O_3, V_2O_5) is lower in V series

Next, to evaluate the short–term strength, the experiment was performed at temperatures of 200, 400 and 570°C, respectively. It was found that the tensile strength of Zr series is 1.2 times greater than V series. This is because the primary crystalline structure in welding joint of Zirconium series is refiner than Vanadium series and no heterogeneous.

The experiment for measuring long–term strength is performed by evaluating the service time of heat resistant steel pipes.

The experimental conditions are as follows: stress; 170MPa, temperature; 560°C. Here, the average values of fractural terms are as follows, repectively:

$$\text{Zr series;}\quad \tau_{170}^{560} = 910\text{h}\ ,\ \text{V series;}\quad \tau_{170}^{560} = 697\text{h}$$

From these results, we could prove that serve time in Zr series is 1.4 times longer than that in V series.