第 I 部門　　Post-fire fatigue performance of butt-welded joints by SBHS500

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1. Introduction

Fires are described as low-probability, high-consequence events such as earthquakes and ship collisions, which are instead common concerns in bridge engineering design. As a result, structural performance is reduced when the structure is exposed to fire accidents. In cases when the fires don't cause collapse or severe deflection, structural retrofitting can be performed to extend the bridge's service life. Such endeavors are especially possible in the case of steel structures due to their excellent ductility and workability. However, with increasing service life, structural fatigue becomes a relevant problem. H. Yin et al. [1] and R. An et al. [2] investigated the post-fire fatigue performance of S355J2W weathering steel and Q690 steel. Both studies considered the effects of cooling methods such as air- and water-cooling. Based on the results, both studies suggested that both temperature and cooling methods significantly affect fatigue performance.

This study experimentally investigated the post-fire fatigue performance of welded SBHS500 steel plates. The steel plates were exposed to 900 °C, after which they were air- and water-cooled. Subsequently, fatigue tests and Vickers hardness tests were conducted. Based on the results, the specimens exhibited sufficient fatigue performance when compared with Fatigue Design Recommendations for Steel Structures [3]. Additionally, through the hardness test, it was observed that the water-cooled specimen's hardness increased, while the air-cooled specimens decreased.

2. Test procedure

Heating was conducted in an electric furnace to gradually expose the plates using SBHS500 as the base metal and YM-60C as the weld metal to the target temperature of 900°C, which was chosen as the representative temperature of a severe fire. The temperature on the steel plate was measured using an identical plate, with a hole inside. After the heating stage, air- (900A) and water-cooling (900W) were performed. Subsequently, as seen in Fig. 1, the plates were cut into smaller 300x30x9 mm segments, which created a total of 4 test specimens per plate. Thus, four bending stress range test conditions were chosen to observe the post-elevated temperature fatigue performance: 250 MPa, 300 MPa, 350 MPa, and 400 MPa. When considering the room temperature plate (T20) as well, a total of 12 test specimens were produced. Additionally, on the leftover plate edges, a sample was cut out with the dimensions of 25x10x9 mm for each exposure condition; Vickers hardness tests were performed on the base metal and weld metal for each exposure condition.

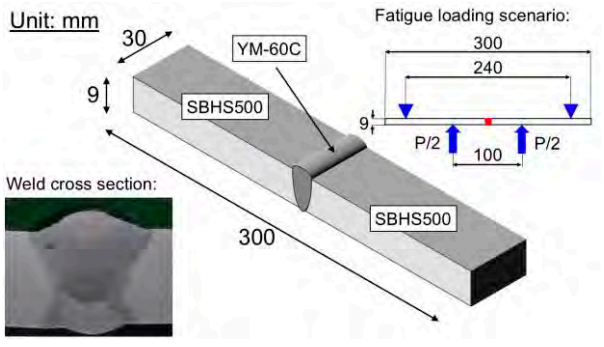


Fig. 1 Specimen dimensions

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3. Result discussion

Fig. 2 shows the results from the Vickers hardness test, where the exposed specimens were compared to the T20 specimen. The presented results show a clear increase in the hardness of the base metal when water-cooled, while also showing a substantial decrease in the overall hardness when air-cooled compared to the T20 results. These values were additionally validated by comparing the failure fatigue patterns, where 900W exhibited a more brittle behavior compared to 900A and T20 specimens.

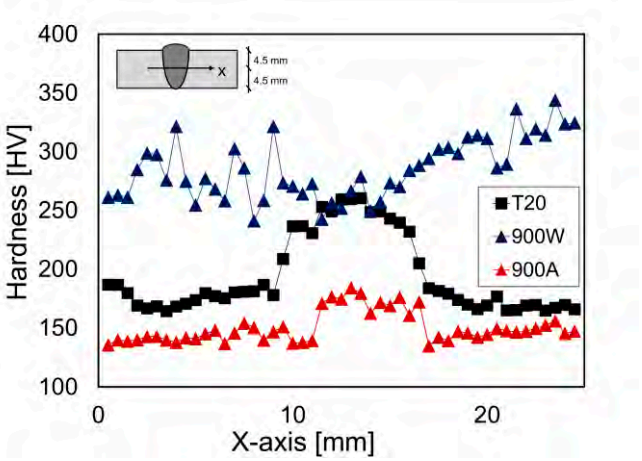


Fig. 2 Vickers hardness test results

Fatigued performance can be seen on Fig. 3, where the experimental data was plotted and compared with fatigue design recommendations [3]. All the observed specimens remained above the provided fatigue design curve, even though the fatigue life reduction was up to 79% when air-cooled and 78% when water-cooled. The obtained results also coincided with study [4], where a better strength recovery of SBHS500 could be observed by water-cooling. Additionally, it was observed that the specimens exposed to 350 MPa underperformed compared to 400 MPa, this poor performance was attributed to the low weld quality. Similar but opposite observation was done in case of 900W 250 MPa where the weld was well executed leading to better fatigue performance.

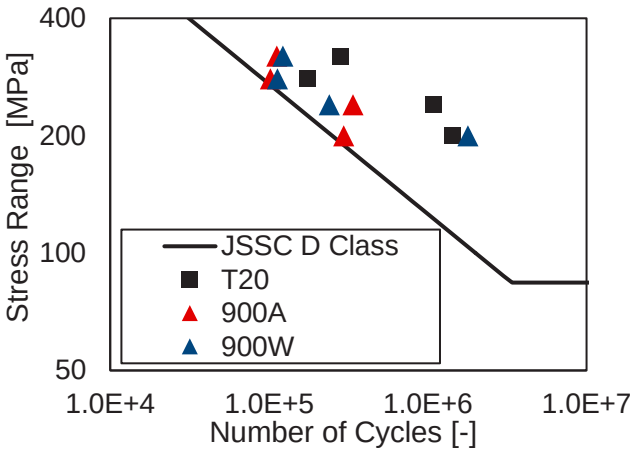


Fig. 3 Fatigue results

4. Conclusion

Based on the studies' observations, the design fatigue curve provides appropriate enough recommendations for the structure to sustain daily fatigue loads even post-elevated temperature exposure. However, it should be noted that fatigue performance decreases up to 79%, which should be considered if retrofitting is to be performed. Additionally, it is important to acknowledge the hardness results in post-elevated temperatures, which could lead to more brittle behavior in case of water-cooled elements.

4. Reference

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