第 I 部門　Effects of hammer peening on improvement of fatigue life of out-of-plane gusset welded joint assessed by DIC strain and X-ray stress measurement

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## 1. Introduction

The out-of-plane gussets welded joints are prone to fatigue damage because of the inevitable local residual stress, stress concentration on the weld toe and welding imperfections [1]. The hammer peening is simple to operate and the tools are convenient to bring to the work field [2], thus it is widely used in prevention of the crack initiation and propagation in the steel structures. As the hammer peening is usually conducted around the weld with great stress concentration and residual stress, the Digital Image Correlation (DIC) method [3] is more favorable to analyze the local stress distribution after the hammer peening.

In this research, effects of hammer peening on the fatigue life of out-of-plane gusset welded joint made of high strength steel HT780 were studied. The residual stress and geometric deformation induced by the hammer peening were measured, and feasibility of DIC strain and X-ray stress measurement in fatigue life prediction of out-of-plane gusset welded joint was verified.

## 2. The experiment of hammer peening

The specimens of out-of-plane gussets were fabricated by high strength steel HT780 and welded by $CO_2$ gas metal arc welding. The geometric dimension of the specimens was shown in Fig. 1. Two specimens, namely AW (as welded) and HP (hammer peening), were designed for the experiment respectively. The geometric features of the specimens in the central axis were measured. It was shown that the radius of weld toe on the left increased from 1.5mm to 2.2mm while that on the right increased from 1.2mm from 2.5mm after the hammer peening, indicating great decline of stress concentration. Also, the residual stress of specimens was measured by X-ray and shown in Fig. 2. It could be observed that the welding residual tensile stress was obviously reduced by hammer peening and the maximum compressive stress could be greater than -600MPa.

## 3. The fatigue experiment after hammer peening

The nominal stress range $\Delta\sigma$ was 250MPa, the stress ratio $R$ was 0 and the loading frequency was 5Hz for the fatigue loading. The DIC method was used to monitor the change of strain until 1,000 loading cycles, and the stress distribution of specimen AW was shown in Table 1. The strain gauges were then used to measure the strain ranges since the loading cycle 1,001.

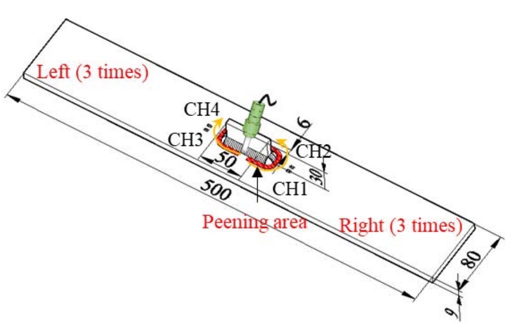

Fig. 1 The geometric dimension of specimens (mm)

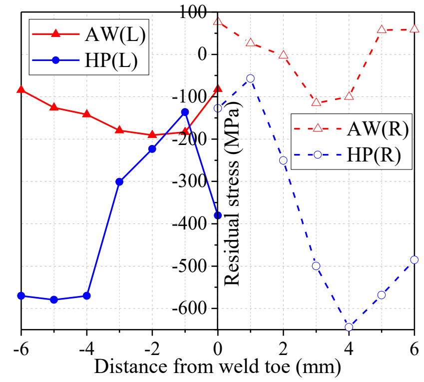

Fig. 2 Residual stress from the weld toe

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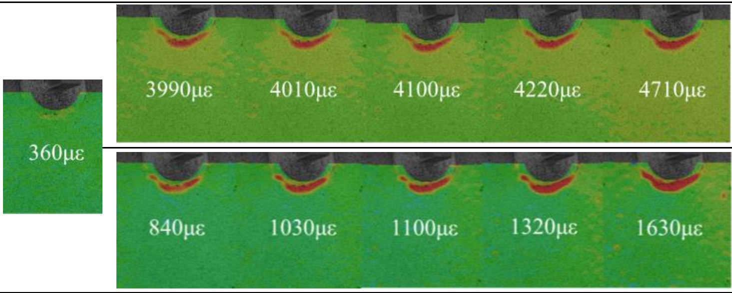
Table 1. Change of Strain by DIC method (Specimen AW)



| Cycles | $N=0$ | $N=1$ | $N=3$ | $N=10$ | $N=100$ | $N=1000$ |
|---|---|---|---|---|---|---|
| $\varepsilon_{xmax}$ | 360με | 3990με | 4010με | 4100με | 4220με | 4710με |
| $\varepsilon_{xmin}$ | | 840με | 1030με | 1100με | 1320με | 1630με |
| $\Delta\varepsilon_x$ | | 3150με | 2980με | 3000με | 2900με | 3080με |

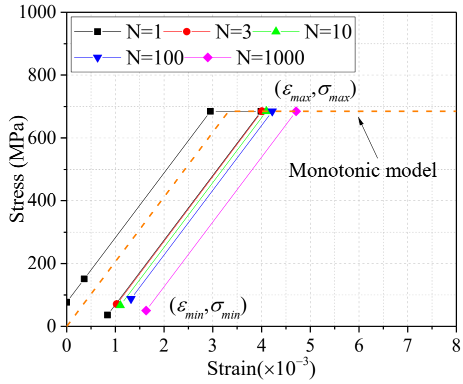



Fig. 3 The stress–strain curve (AW)

It could be observed that the $\varepsilon_{xmax}$ and $\varepsilon_{xmin}$ tended to increase with the increasing of loading cycles because the yield stress of steel was reached and plastic deformation was occurred to some extent. The strain range was stable and ranged from 2900 με to 3150 με. The peak strain $\varepsilon_{xmax}$ of the specimen HP remained unchanged generally with the increasing of loading cycles, indicating that the steel was in the state of elasticity after the hammer peening. Also, the peak strain $\varepsilon_{xmax}$ of the specimen HP was usually about half of that of the specimen AW, thus the local stress in the vicinity of the welding end was greatly reduced due to the effects of hammer peening.

## 4. Fatigue life predicted by the DIC strain and X-ray stress measurement

The strain range $\Delta\varepsilon_t$ and average stress $\sigma_m$ at $N$ = 1000 measured by the DIC strain and X-ray stress measurement was applied for the prediction of crack initiation life $N_c$[4]. It was assumed that the stress-strain response of HT780 was elasto-perfect plasticity with the yield stress $\sigma_y$=685MPa. The strain-stress relationship at $N$ = 1, 3, 10, 100, 1000 could be calculated considering initial stress measured by the X-ray and shown in Fig. 3. An obvious cyclic ratcheting could be observed for the specimen AW as the yield stress $\sigma_y$ was always achieved under the current loading condition.

Also, $N_c$ was assessed by the strain gauges at 5% decline of strain range to verify the feasibility of DIC strain and X-ray stress measurement with experimental strain-life curve in fatigue life prediction [4]. The $N_c$ of specimen AW assessed by the proposed method was 44,000 cycles which was close to that by the strain gauges (49,000 cycles). The errors might result from different definitions of crack initiation or elastic-plastic response of steel, *etc*. But it still could be concluded that the proposed method was reliable to assess the crack initiation life. The crack initiation was not occurred on the welded joint of specimen HP and the fracture happened at the base metal clamped by the loading jig. The fatigue failure life of the out-of-plane gusset welded joint was increased by more than 15 times after hammer peening.

## 5. Conclusion

The local stress in the vicinity of the welding end was greatly reduced due to the effects of hammer peening. The DIC strain and X-ray stress measurement was reliable to predict the crack initiation life by comparison of corresponsive results assessed by strain gauges.

## References

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