B. Fundamental Studies on the Relationship Between Plastic strains and Distortion in Fillet Welded T-Joints

G. Jung, Edison Welding Institute; and C. Tsai, The Ohio State University.

Introduction

The procedure of plasticity-based distortion analysis (PDA) directly mapping cumulative plastic strains into elastic models using equivalent thermal strains was developed and applied to the investigation of the characteristic relationship between cumulative plastic strains and angular distortion in fillet welded thin plate T-joints. PDA successfully demonstrated the validity of the unique relationship between cumulative plastic strains and distortion and the applicability of a linear elastic model in welding-induced distortion analysis. PDA procedure also provided the quantitative relationship between six cumulative plastic strain components and angular distortion of fillet welded T-joints, showing the importance of shear component in angular distortion.

Technical Approach

The characteristic relationship between cumulative plastic strains and angular distortion in fillet welded T-joints was investigated using the procedure of plasticity-based distortion analysis (PDA) that was developed to predict welding-induced distortion by direct mapping characteristic cumulative plastic strains into elastic models, instead of applying equivalent forces and moments. One of the advantages of this approach is to incorporate all cumulative plastic strain components in predicting distortion, and investigate the relationship between each cumulative plastic strain and a distortion type of concern. Especially, for fillet welded T-joints with a complex geometric configuration, PDA becomes a more powerful tool.

Results and Discussion

Cumulative plastic strains obtained from the thermal-elastic-plastic analysis were mapped into elastic models using equivalent thermal strains. Even though there were some differences in magnitude of plastic strains and mapped equivalent thermal strains, the general distribution patterns were close to each other.

From six elastic analyses, six individual deformed shapes related to each cumulative plastic strain were obtained. What was expected and previously believed based on the observation of butt welded joints was that transverse cumulative plastic strain (perpendicular to weld line) would cause bend-up angular distortion. However, PDA showed that the transverse cumulative plastic strain resulted in bend-down angular distortion. The vertical cumulative plastic strain (thickness direction) also generated bend-down angular distortion. A slight bend-up angular distortion was produced by the longitudinal cumulative plastic strain (weld line direction) which might be mainly related to longitudinal bending and buckling.

To date shear cumulative plastic strain components have never been highlighted in distortion analysis. xy-plane shear cumulative plastic strain (perpendicular to weld line) produced the most bend-up angular distortion. Other shear cumulative plastic strains were not related to angular distortion.

The accuracy of PDA was evaluated by comparing the total angular distortion calculated by the addition of six individual distortions with the angular distortion obtained from elastic-plastic analysis. The averaged total angular distortion from PDA was 0.99 mm at the free edge of T-joint, and the averaged angular distortion from elastic-plastic analysis was 1.02 mm. 98% of accuracy was achieved. This implies that the relationship

between cumulative plastic strains and angular distortion is unique, which means that angular distortion can be uniquely determined by the given cumulative plastic strains. It can also be said that the application of elastic models with material properties at room temperature and cumulative plastic strains associated is valid in engineering applications.

Conclusions

The relationship between cumulative plastic strains and angular distortion is unique.

PDA was proved as an effective tool to investigate the relationship between cumulative plastic strains and angular distortion.

New knowledge about the angular distortion mechanism for fillet welded T-joints using PDA procedure was addressed:

xy-plane shear cumulative plastic strain produces most bend-up angular distortion, and other shear components are not related with angular distortion.

Transverse and vertical cumulative plastic strains result in bend-down angular distortion.

Longitudinal cumulative plastic strain produces a slight bend-up angular distortion.