OPTIMIZATION OF GROOVE DESIGN IN THICK PLATES WELDING

Jia Liwei, Zhou Hongbin and Zhang Mingli

Civil Engineering and Mechanics Institute , YANSHAN University,
Qinhuangdao, Hebei province,P.R.China,066004
Tel: 0335-8067926
Fax: 0335-8057101
Email : joanajia@sohu.com

ABSTRACT: Groove design affects thick plates' residual stress distribution seriously. So optimization of groove design in thick plates' welding is an important work. In order to do this work better we use finite element method to quantitatively evaluate the effects of groove design. Groove design plays a very important role in residual stress distribution. Although we may butt weld two thick plates together by several kinds of groove design, the final residual stress distribution will be different.

In this paper we use three kinds of groove design to butt weld two same thick plates together. Thickness of the plate is 25mm. Finite element method has been employed to evaluate the final residual stress distribution. Utilizing of ANSYS code is efficient when we try to find the residual stress distributions by finite element method. Some functions of ANSYS such as "couple field" and "element birth and death" are adopted. Temperature related thermophysical material properties are considered. Some necessary measurements should be used to prevent convergence problems in this nonlinear analysis procedure.

The results suggest clearly that different groove design induces different residual stress distribution. We should take care of groove design before welding. Also numerical analysis of residual stress can help us to estimate residual stress distribution efficiently. At last we give some suggestions about thick plates groove design.
Keywords: residual stress(RS), finite element method(FEM), thick plate, groove design(GD), weld

INTRODUCTION

When steel structures are welded, RS is induced by the non-uniform temperature distribution. We have find GD has obvious effects on RS distribution especially in the through thickness dimension. But it is hard to measure the stress in through thickness dimension. FEM can help us knowing it better. We use a butt weld between two thick plates as an example. There are some forerunners in the early 1970s such as Kamichika[6] and Friedman[2].From1990, numerical simulation of weld process boomed. Goldak[4], Fricke[3],and Buchmayr ,Ping Dong [10]etc. have developed the process to a advanced level than before.[5]It has been accepted that FEM is more flexible than experiment methods. It is also accurate enough.

We choose a 25mm-thickness plate model because 25mm is relatively common thick in welding. Meanwhile 25mm thickness can not only present characteristics of thick plates welding but also save computing time than thicker plates such as 30mm. We make an assumption that the model is symmetric. Radiation and convection are considered. But we ignore the effects of phase transformation as they have relatively small effects on the final stress result. Three kinds of GD in this paper are: double Y, double V and single Y. Both first welded sides and second welded sides are in single pass in order to save computation sources. Checks have been implicated after thermal analysis to ensure the validity of thermal field. In order to make the RS comparisons equitable we try to make total heat input of each sample is same.

After FEM analysis we get all kinds of stresses, including longitudinal (Lon) stress, transverse (Tran) stress and perpendicular (Per) stress, in the specimen detailedly. RS' comparisons have been made between different types of GD. RS comparisons are shown clearly. From these results we can make an optimization of GD in thick plates welding.

FINITE ELEMENT MODEL

Geometry and Mesh

GD samples are shown in Figure 1.

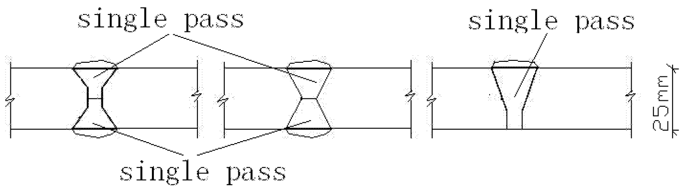


Figure 1: Three types of GD used to butt two plates together

It is accepted that temperature distribution is symmetrical about the weld center area. We also assume that the sample is constrained symmetrically about the weld center area. Using of symmetric model is reasonable. So only half of the model is analyzed. It is should be noticed that the real constrains of the sample should be symmetrical otherwise the half model should not be employed. In thermal analysis adiabatic condition can be used to describe symmetric area. In mechanical analysis ANSYS offer special symmetric boundary conditions. Magnitude of RS is distinctly higher in weld zone and heat affected (HAC) zone. In this example total extent of weld zone and HAC zone on either side of the weld is about 10mm~20mm. Division of the mesh in the weld zone and HAC zone should be fine enough to ensure convergence of the analysis. Of course the longer the distance from the weld zone the coarser the division can be allowable [9]. The FEM geometry and the mesh are shown in Figure 2.

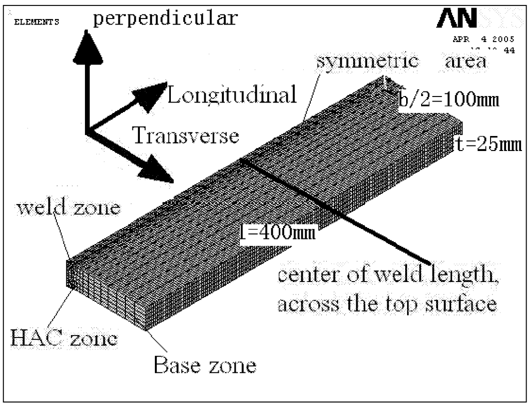


Figure 2: Geometry and the Mesh

Properties of Material

Materials in weld zone experience transient heating and cooling in a short time. Fig 3 shows temperature variation of point1.

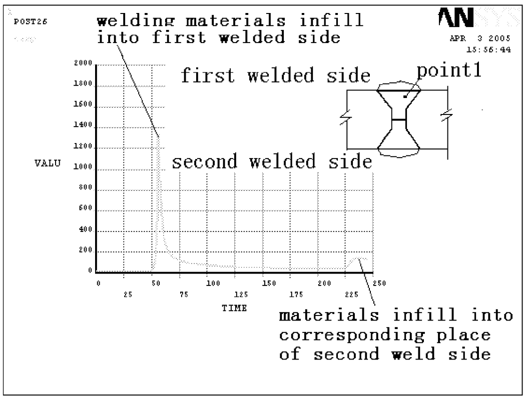


Fig3 Temperature Variation of Point1

Temperature rises instantaneously to the maximum value as soon as the welding materials infilling into this place. Then temperature reduces instantaneously to a lower level. When materials infilling into corresponding place of the second weld side, temperature of point1 rises. The stress release is usually approximated by specifying temperature dependent material properties [13].So properties of material are all temperature dependent. However, thermophysical material properties in high temperature are difficult to find. Thermophysical material properties used in this paper are according to David etc [1], except coefficient of convection is same as [8]. Von-Mises yield criterion and associate flow rule with kinematics' hardening were assumed to consider the Bauschinger effect. Materials in weld zone are evenly matched with the base material.

Other key techniques

This analysis involves heat analysis and mechanical analysis. A nonlinear transient thermal analysis is carried out as the first solving step. A stress analysis then developed. The results of thermal analysis are applied to the model as loading.

Function of element birth and death is used. All elements in weld zone of the FEM model are dead because materials in weld zone do not exist before welding. Activation of elements in the model simulates accumulating of materials in weld zone.

Time interval of every step and substep must be minimized otherwise the solution will not convergence. Maximum time interval of one substep should be less than 0.1s when heat source is moving on the weldment. It can be prolonged when cooling. [9]

RESULTS AND DISCUSSION

In thermal analysis a temperature field is obtained, and it is used as a thermal loading in the subsequent stress analysis. Distribution should be relatively stable and the isotherm obtained from thermal analysis should be in accordance with [11] and [12]. Fig4 shows an isotherm of a stochastic time.

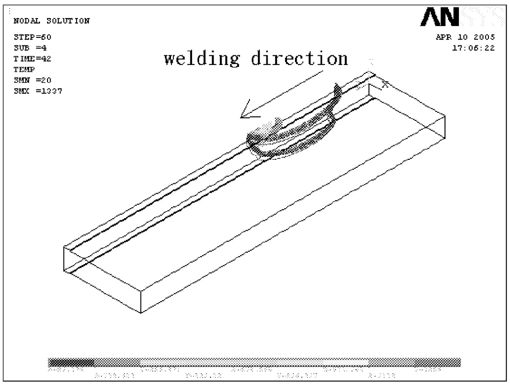
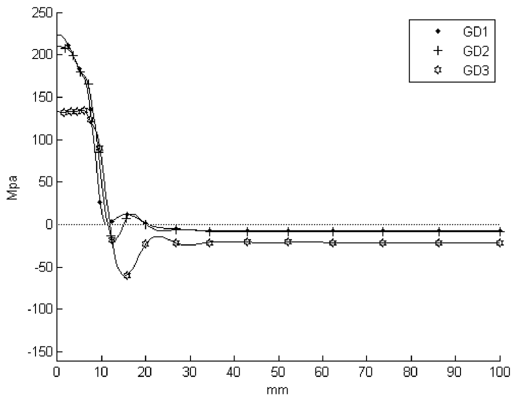
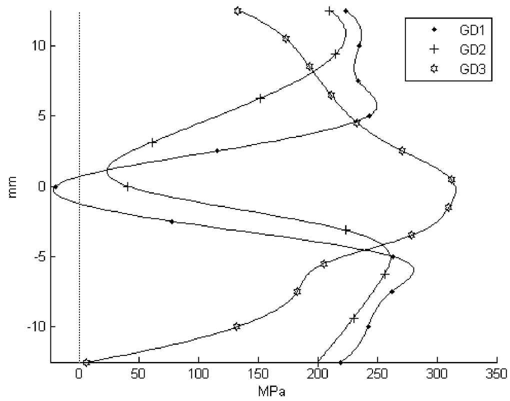


Fig4 .An Isotherm of a Stochastic Time

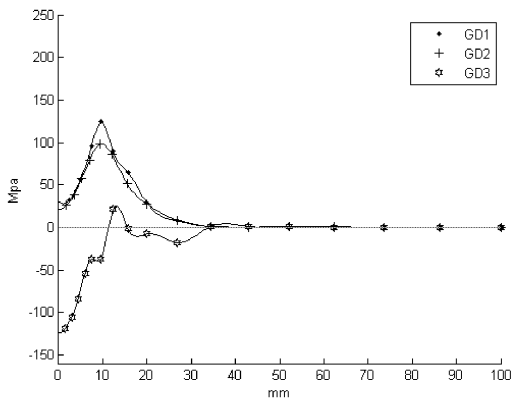
RS results proposed in this paper have the same trend line as provided by Hill, Michael R [5]. So it can be concluded that the FEM results are acceptable. Both surface RS and through thickness RS are shown in Fig.5.



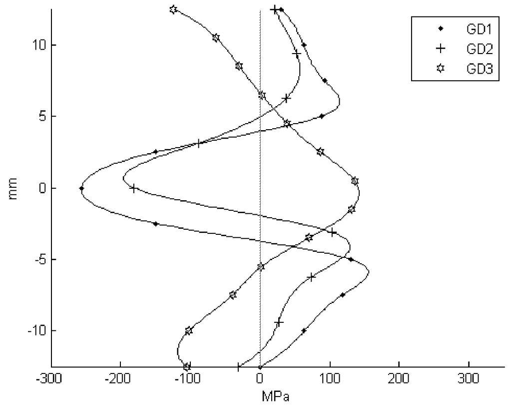
(a)



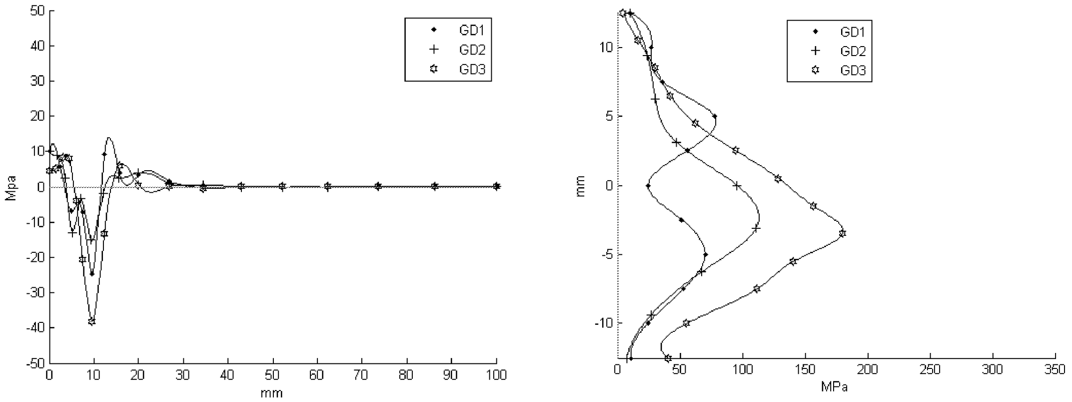
(b)



(c)



(d)



(e) (f)

Fig. 5 RS distribution

(a) Lon RS at the centre of the weld length, across the top surface

(b) Lon RS at the centre of the weld length, through the thickness

(c) Tran RS at the centre of the weld length, across the top surface

(d) Tran RS at the centre of the weld length, through the thickness

(e) Per RS at the centre of the weld length, across the top surface

(f) Per RS at the centre of the weld length, through the thickness

Fig5 shows that Lon stress is higher than other kinds of RS. It may be occurred in steel structure welding that a branch of stress even over yield stress [7] as it shows in Fig5.b.

Stresses across the top surface of GD1 and GD2 have similar trend lines. But Tran RS of GD3 in weld center is compressive which is different with GD1and GD2.

As far as Lon and Tran stresses through thickness are concerned, differences are remarkable. Lon and Tran stresses of GD1 and GD2 through thickness are large on the surface .And they reduce to a lower value even become to be compressive inside thickness. But there are obviously differences if we talk stresses quantitatively. GD1 has a thoroughly contradict trend line with GD1 and GD2.

Compared with the other kinds of RS ， Per stress is lowering. But there are some special requirements for thick plates' sustainable ability. The reason is thick plates' through thickness material properties are worse than thinner plates. So Per RS should be considered in thick plates welding. It is clearly that Per RS of GD3 is higher than Per RS of GD1 and GD2.Also stress gradient of GD2 and GD3 are hardener than GD1.

CONCLUSION

It is of fundamental importance for accurate and reliable structural integrity assessments of components and structures. While compressive RS may bring about some benefit to whole welding structure, tensile RS may induce some disadvantage to components. In this paper we investigate the GD effects on RS distribution.

There are many kinds of GD can be used to butt two same plates together. We should consider characteristic of loads and RS distribution simultaneously. It is better that stresses induced by loads and RS can offset each other. Multi-pass is better than single-pass for stress gradient can be reduced by it.

GD plays an important role in thick plate's RS distribution. It is better to simulate distribution of RS before welding and choose a suitable GD. We should take suitable GD in different engineering conditions.

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