Experimental Study on Bearing Capacity of Straight Welded Pipe Used in Transmission Towers with Weld Defect

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Abstract—**A method for simulating welding defect of slags or incomplete fusion is raised in this research. Experiments on seven full-size members were conducted.The research shows that the length of the welding defect is related to the decrease of the ultimate bearing capacity of the members under the static axial load.In some case, it may be the main factor to reduce the bearing capacity, which mayeven be lower than the code limits so attention should be paid to engineering application.**

Keywords-weld defects; straight welded pipe; experimental study; ultimate bearing capacity; buckling

I. INTRODUCTION

In recent years, Transmission towers with large diameter steel tubes as the main members of the structure are a new type of towers with great development potential, which are widely used in large span transmission lines. In these structures, large diameter straight welded pipes are in application because of simple and efficient production process. The defects in welded pipe is inevitable and may induce brittle fracture of welded structure.

Defects such as crack, air hole, slag inclusion, incomplete fusion and so on exist because of Influence of various factors in welding process. Different types of welding defects have different geometry, contour, gray distribution, location, extension direction and other characteristics. The bearing capacity of the members with welded defects are studied extensively. Binnur Goren Kiral, SecilErim(2006) studied the bending bearing capacity of beam column connections with incomplete fusion weld defects and put forward five solutions of node strengthening[5]. K.K.Tang etc.(2010) considered that the existence of initial defects can significantly reduce the structural stiffness. Local defects tend to affect the weldment details and structural rigidity more appreciably than changes in the structural nominal strains [6]. Long Z.Y, Zhang G(1995) evaluated the influence of welding defects on the structural strength. It is considered that welding defect is the main cause of stress concentration. The stress concentration factor of the welding defect tip is deduced by the theory of fracture mechanics [8]. Based on the practical engineering, the types of welding defects in the welded joints of the steel tube truss joints are summarized by Ren Zhisen(2004). He simulated typical surface or internal defects and obtained the influence curves of different types and sizes of defects in the ultimate bearing capacity of the joints of different welds and the different positions of the same weld [7].

The mechanism of weld defects is complex, and the form is diverse. It has important influence on the mechanical properties of structures. In practical engineering, capacity reduction of steel pipe tower component containing weld defects is still difficult to quantify, so experiments on seven full-size members were conducted and the results were compared with the steel structure design code of China and the United States. The relationship between the bearing capacity of the steel tube member and the weld defect is defined.

II. TEST DESIGN AND IMPLEMENTATION

A. Specimen Design

The components are high frequency resistance welding seam welded pipes with diameter 168mm and wall thickness 6mm, the full-scale diagonal members on transmission steel tower.The designed slenderness ratio are 40, 50, 60 and the radius-thickness ratio is 28.According to GB50017-2003 "steel structure design code" terms 5.4.5: when the radius-thickness ratio of circular section, the local instability will not happen.In the middle part of the pipe section, the high temperature resistant ceramic plates are used to simulate the welding slag or the incomplete fusion defect, and the plates are fixed on the groove of welding through the instant dry heat glue.The size of the ceramic plate is 10mm×2mm×1mm. The length of the radial weld defect is simulated by the combination of the ceramic plate along the length direction. Considering the uncertainties of the simulated length in the actual welding process, after the welding is finished, the length of the measured defect is obtained by ultrasonic nondestructive testing. Specimen design is shown in Figure I and Figure II.
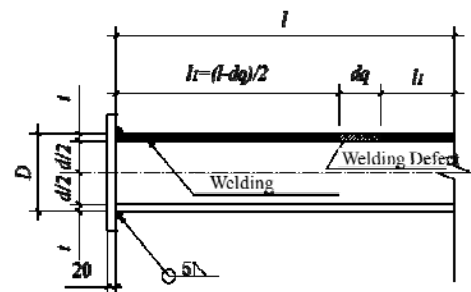

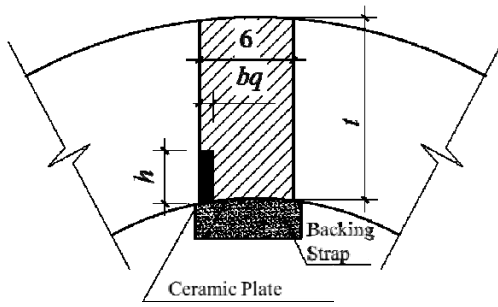FIGURE I. SCHEMATIC DIAGRAM OF SPECIMEN DESIGN.

FIGURE II. DEFECT SIMULATION SECTION

B. Experiment Plan

5000kN standard long column hydraulic test machine is used and the axial load is applied through the top hydraulic jack. In order to effectively simulate the constraint conditions of the two ends of the component and facilitate the installation of components, two-way blade hinges are installed in the both ends of the specimens. In the form of the combination of geometry and physics, the method avoids the eccentricity in the initial stage of loading.

The experiment objective is to obtain the ultimate load values of the specimens under axial compression. At the same time, in order to obtain the corresponding relationship between the stress and deformation in the weld defect position and other section, The 1/4, 1/2 and 3/4 cross sections along the longitude direction of each specimen are arranged in a total of 12 strain measuring points, which contains 8 bidirectional strain measuring points. At the same time the location of weld defects in radial and lateral direction of 90 degrees and a total of 4 orthogonal arrangement of cable displacement meter. 4 wire type displacement meters are arranged in the location of weld defects in longitudinal, transverse and orthogonal directions. Experiment is implemented with a continuous load system, loading speed is 10kN/min. Reduce the speed at 60% ultimate load. In the case of the total failure of the specimens, the readings of the measuring points under the ultimate load are acquired.

III. EXPERIMENTAL RESULTS

The measured values of the ultimate bearing capacity of each member in this test are listed in table I and compared with the suggested design value in "Specification Structural Steel Buildings"AISC360-2010 in USA and the GB50017-2003 "steel structure design code" in China. Ultrasonic nondestructive testing is carried out before experiment. The testing results show that in the introduction of ceramic chip simulation weld slag or incomplete fusion defects, other types of defects may also be introduced in. It leads to the actual defect length greater than the length of the design defect. At the same time, the small diameter welded pipe manufacture quality is poor, the initial defect itself contains will also affect the ultimate bearing capacity. Through experiment comparison, in the case of the same slenderness ratio and the same diameter thickness ratio, the ultimate bearing capacity of the member is related to the length of the actually contained defect. The greater the length of the defect, the lower the ultimate load.

Because of the initial eccentricity and residual stress of the actual structure, at the same time, considering the welding process may be introduced in addition to the design defects of other types such as porosity, not welded thoroughly, etc., in this experiment, the ultimate bearing capacity of the specimens is not only related to the length of the defect, and the relationship is not linear.

The stress state and failure modes of each specimen in the test are nearly the same.The load-lateral displacement curves are shown in Figure III, IV, and V. The strain and displacement are linearly growing at the initial stage of loading.The growth speed of displacement is very slow.When the load reached the limit of 80% or so, the lateral deformation velocity of the specimens began to increase. Nonlinear growth appears in the load displacement curve, until the overall instability in the limit state.At this point the displacement is far beyond linear stage. When the ultimate load is reached, the specimen is buckling, and the specimen is beginning to unload.
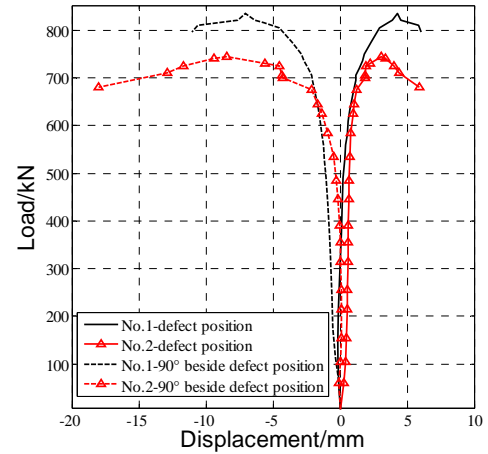

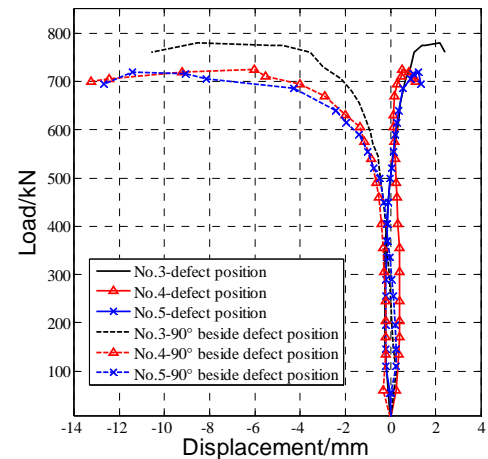FIGURE III. LOAD-LATERAL DISPLACEMENT CURVES –GROUP 1

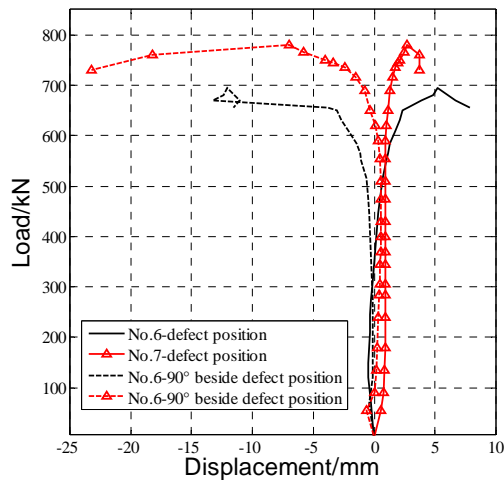FIGURE IV. LOAD-LATERAL DISPLACEMENT CURVES –GROUP 2

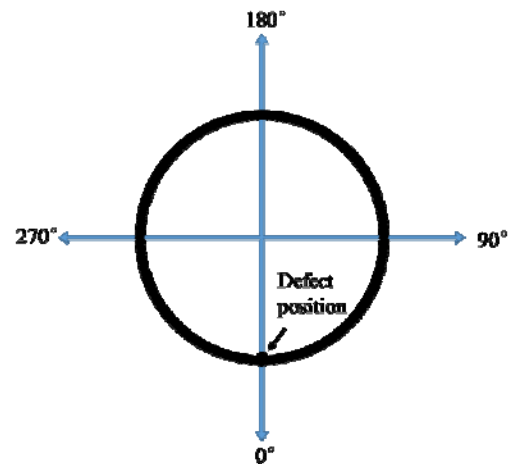FIGURE V. LOAD-LATERAL DISPLACEMENT CURVES –GROUP 3.
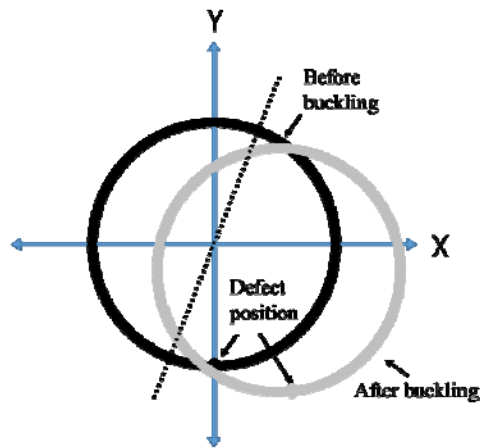

FIGURE VI. POSITION OF WELD DEFECT.

FIGURE VII. CROSS SECTION DEFORMATION DIAGRAM

FIGURE VIII. SCHEMATIC DIAGRAM OF THE OVERALL INSTALLATION OF SPECIMENS.

TABLE I. THE RELATIONSHIP BETWEEN THE LENGTH OF THE WELD DEFECT AND THE ULTIMATE BEARING CAPACITY

Group	No	Designed Length of Defect/mm	Detected Length of Defect/mm	Slenderness Ratio	Tested Ultimate Load/kN	GB50017-2003 Suggested value/kN	AISC360-2010 Suggested value /kN
1	1	50	65	40	825	872.2	789.0
	2	100	92		745	872.2	789.0
2	3	0	0		780	812.6	730.8
	4	50	64	50	725	812.6	730.8
	5	100	170		720	812.6	730.8
3	6	50	85	60	780	741.8	660.6
	7	100	133		695	741.8	660.6

As shown in Table 1, when the specimens are in the stable limit state, the bending degree of the cross section is more obvious, the load is continuously reduced and the strain gauge and displacement meter reading is increasing.In addition, figure VI and VII show when getting the ultimate load, the lateral displacement at the 90° position is obviously higher than the lateral displacement at the defect position.Combined with the experimental phenomenon, the whole instability of the symmetrical axis of the joint of the component is about 30 degrees.

Under the condition of static loading, the influence of the defect site on the bearing capacity is mainly reflected in the

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weakening of the section. As shown in Figure IX, at the same time taking into account the weld defect length and the length of the member, when the ratio is larger, the bearing capacity of the member is lower. When the ratio of defect length and specimen length is more than 0.025, the bearing capacity is increased. The reason is that on one hand the expansion of the area under the condition of static loading is difficult to appear, and the influence of the stability limit on the bearing capacity is limited in the area of the local area; On the other hand, the existence of weld defects causes the local geometry changes, resulting in the stress concentration and the inertia axis of the member cross section is also the factor of the instability of the component.
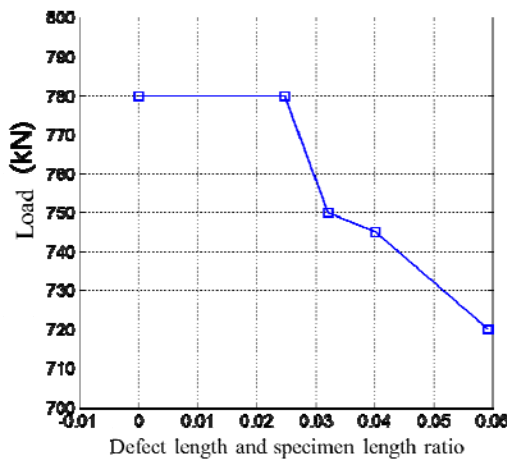

FIGURE IX. EFFECT OF DEFECT LENGTH ON DIFFERENT LENGTH OF SPECIMENS

IV. CONCLUSIONS

In this study, a method for simulating welding defect of slags or incomplete fusion is raised and experiments on seven full-size members were conducted, the following conclusions are obtained.

1) In the case of the same slenderness ratio and the same diameter thickness ratio, the ultimate bearing capacity of the member is related to the length of the actually contained defect. The greater the length of the defect, the lower the ultimate load.

2) Simulation of weld defects is not the only reason for the reduction of the bearing capacity of the specimens. The initial defects in the actual specimens such as initial eccentricity and residual stress should also be considered. However, in the same condition of initial imperfections, the reduction of bearing capacity caused by the length of simulated weld defect is more prominent.

3) When getting the ultimate load, the lateral displacement at the 90° position is obviously higher than the lateral displacement at the defect position.Combined with the experimental phenomenon, the whole instability of the symmetrical axis of the joint of the component is about 30 degrees.

4) Under the condition of static loading, the influence of the defect site on the bearing capacity is mainly reflected in the weakening of the section. At the same time taking into account the weld defect length and the length of the member, when the ratio is larger, the bearing capacity of the member is lower.

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