Determination of Deep Weld Penetration in Pressure Parts of Boilers

By
Imrich ANDREJÁK, Vladimír MODRÁK, Emil RAGAN
Faculty of Manufacturing Technologies, Slovakia

SUMMARY

The proposal of the determination method for deep weld penetration during repairs of the boilers pressure parts deals with a new concept of determination of the deep weld penetration. At the same time the previous state in this problem domain is analyzed. In the article the substances of the idea solution, as well as the theoretical models and results are introduced. Possible applications of proposed method can bring innovative approaches in boiler repair services.

Keywords: *weld joint symmetry, weld penetration, measuring hole*

INTRODUCTION

Existing boilers may continue to be operated according to actual operating conditions as long as they remain in good enough state to be issued with a certificate of inspection. In spite of that there have been a number of accidents due to lack of water, and other potential serious failures. A quality of repair work also counts among factors, which adversely affect a boiler's suitability. Proposed method is relating to determination of the factual penetration welds, which is aimed for construction of pressure parts subjected to high stresses. After following assumption specifications the description of the proposed manner of determination deep weld penetration will be performed and finally results and conclusions will be discussed.

BASIC ASSUMPTIONS

Preparation of welded materials, marking, dimensions and realization of the fillet welds are defined by the competent standards. The basic dimensions defining the size and the carrier dimensions of the fillet welds are (according to fig.1):

z (z_1,z_2) - height of the weld (non-symmetric weld z_1,z_2)

a - thickness of the weld

s - thickness of the weld with deep penetration

In the standards are the recommended methods of controls and inspection of the quality and carrier dimensions of the welds involved. They can be performed as destructive or non-destructive, and their global evaluation can be either obligatory or non-obligatory. All the methods are being applied on the samples used for the examination of the welders and for the technological inspection of the welds or details. In the following all the mentioned dimensions of the fillet weld are determined.

Expect the small welded parts; it is unable to perform a destructive test of the completed product. For the huge welded parts it is possible to perform just an obligatory visual inspection and to determine the dimension z (z_1,z_2) and then to count dimension $a = z / \sqrt{2}$. The size of value "a" is not guaranteed because the penetration of the point "0" is not known (Figure 1).

In order to get the thickness of the weld with deep penetration "s", molting of the weld until the P_x point, is needed. The P_x point has the coordinate X on the x-axis. According to the geometry of the dimensions "a" and "s", for the penetration "p" stands the following formula:

$$p = s - a \qquad (1)$$

Since the determination of the point of penetration, P_x, is impossible, determination of the values "p" and "s" is also impossible.

In addition it is impossible to use the value of eventual penetration "p" to determine the thickness of the weld with deep penetration "s" while

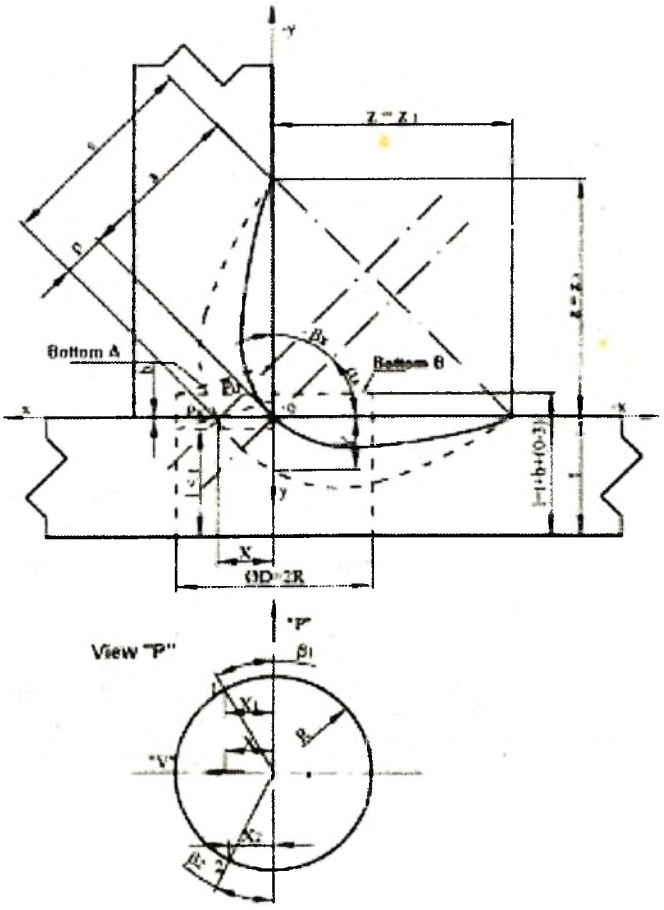

Figure 1 Characteristic dimensions of the filet weld

estimating the carrier dimension of the fillet. As the carrier dimension the non-obligatory value "a" is needed to be used.

DESCRIPTION OF THE PROPOSED SOLUTION

In order to get the accurate carrier dimensions of the filet welds (fillets) performed according to valid standards, and in order to use the real penetration value in calculation of the strength of the fillets, construction and repairs of the pressure parts of boiler, the following solution is suggested. Geometric characteristics and system of marking the dimension and the points are depicted in the figure 1.

Formula (1) determines the size of penetration using the dimensions "s" and "a" defined in the valid standards for the fillets. In the rectangular triangle O, P_x, P_o point O assigns gaining the full value of the parameter "a", point P_o – the start of the penetration, P_x – gaining the penetration "p" of the dimension "X". In the same triangle the abscissa P_xP_o is the size of the penetration "p", abscissa P_xO is the size of the dimension "X". Lines with the abscissas that determine the dimension "p" and "X" contain the angle $\pm_x$. Relation between the "p" and "X" values can be described by the following formula:

$$p = X \cdot \cos \pm_x \qquad (2)$$

Accurate size of the penetration can be determined using the calculated and measured values of the parameters $\pm_x$, X, b.

Angle $\pm_x$ can be estimated from the outer dimensions of the fillet, "z", or "z_1, z_2", using the goniometric function tan $\pm_x$ = z/z or tan $\pm_x$ = z_1/z_2.

Dimension "X" is determined by the abscissa P_xO and measuring of its length is real for the dimensional heights of fillet z > 4 mm or for the thicknesses of the fillet a > 2.8 mm.

It is suggested to measure the dimension "X" in the measuring hole ØD. The hole should be drilled from the available outer side of the continuous sheet created from the sheets that are joined by the fillet. Drilling should be done at the place estimated during the visual inspection of the weld. Axis of the hole is the normal to the continuous sheet and passes through the point "O" that is the edge of the normal sheet that is joined from the side of the weld. Diameter of the measuring hole can be estimated from the rated or expected (according to z_{1D}) size of the penetration "p_D" in the place of the measuring hole ØD. Minimal size of the measuring hole is $ØD_{min}$ = 5 mm. The bottom of the measuring hole ØD can be conic (figure 3 A), flat (figure 3 B), respectively.

Dimension X is being measured in the direction of view:

P – bottom A, for the value of depth 1 <t to 1 = t

P,V – bottom A, B for the value of depth 1 <t to 1 = t + b + (0 + 3) mm

Then the dimension "X" is estimated or the value of the parameter "$X_{1,2}$" is calculated using the value of the angle $^{2}_{1,2}$ and value of ØD. For X_1 '•X_2 the penetrations is irregular and for the carrier dimension of the weld the smaller value is valid.

Dimension "b" – is the gap between the welded sheets. Measuring is being realized in the measuring hole ØD in the direction of view:

V – bottom A,B, for the value of depth 1 e•t + b.

The average value of the measured values "b_1, b_2" is $b = (b_1 + b_2)/2$

From the measured and computed values: "z (z_1, z_2)", angle $\pm_x$, conjugate angle $^{2}_{x}$ and "X,b", it is possible to estimate the general dimensions "p_x, s_x" including the influence of the gap "b". Penetration "p_x" can be expressed by:

$$p_x = X \cdot \cos \pm_x - b \cdot \cos {}^{2}_{x} \quad (3)$$

The depth of the weld with a deep penetration, "s_x" will be:

$$s_x = (z_1 + X) \cdot \cos \pm_x - b \cdot \cos {}^{2}_{x} \quad (4)$$

The used proposal of the estimation of the parameter "X" in the measuring hole may be, completing the certain conditions, replaced by the proposals, which better suit the increasing quality and productivity requirements. These are the diagnostic methods of the non – destructive tests (so called NDT methods). According to the known parameters, the estimation of the hidden dimension "X" is possible using the radiological (RT) and ultrasonic (UT) methods. The NTD methods can use the suggested concept of the calculation of the penetration and the dimension of the fillet in the full scale.

Specification of the use of the dimensions estimated using the NDT methods (RT, UT) according to the figures 1,2,3 and 4:

- *X* – the measured abscissa is estimated by the marginal points O, P_x, calculation of the penetration according to formulas (2,3)
- *z (z_1) + X* – the both dimensions are lying on the same line and do have the common points O, P_x. IT is possible to calculate directly the thickness of the weld with deep penetration using the formula (4).

The method of determination and inspection of the fillets' penetration is shown at the figures 2 and 3. The preparation of the weld for

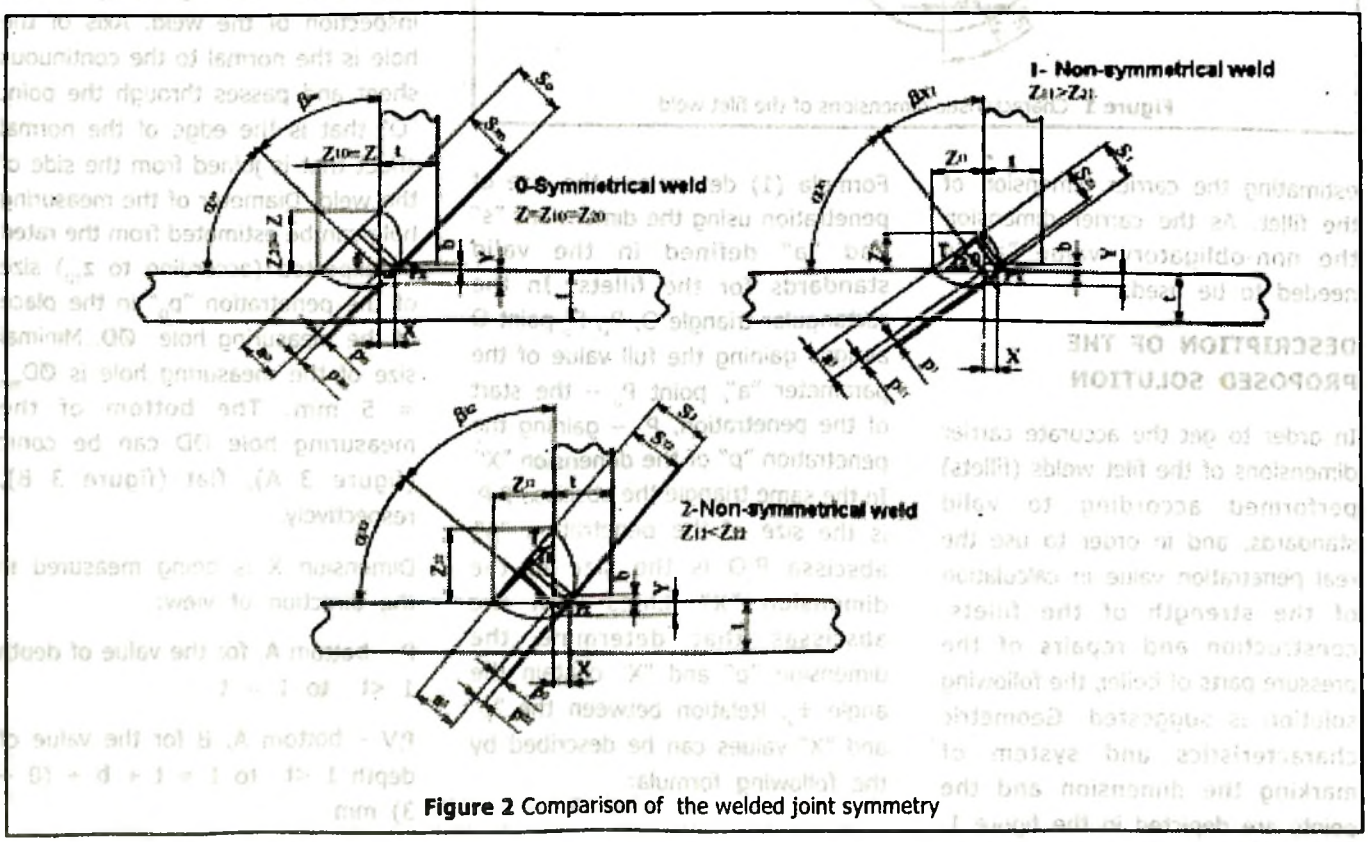

Figure 2 Comparison of the welded joint symmetry

determination of the realization of the fillet's root, the dimension that determine the basic penetration (point 0) and of the deep penetration (point P_x) are shown at the figure 1. In the x – y coordinate system the characteristic dimensions of the fillet with penetration, without penetration, the pre-melting dimensions of the welded materials, "X, Y" and symmetry of the weld, represented by the angle $\pm_x$, are presented. Using the geometrical data according to the figure 1, the dimension representing penetration "p" and the dimension with penetration, "s", are figured.

The figure 2 presents the dimensional welded joint symmetry rating –the outer, by the dimensions "z (z_1, z_2)" and symmetry of pre-melting rating – the inner, by the values X, Y (anchorage of the weld metal into the welded materials). There is a symmetric weld with the angle $\pm_x$ = 45° on the figure, and there also are the non-symmetric welds with the angles $\pm_x$ > 45° and $\pm_x$ < 45° imaged. Also the influence of the gap "b" is shown.

In the figure 3 the view at the bottom of the measuring hole and the assessment of the measuring hole are presented. The meaning of symbols is following:

a – drilling of the measuring hole ØD and the depth of drilling for the bottom:

A: l_{1A} – l_{5A}

B: l_{1B} – l_{4B}.

The characteristic depths of drilling, for the dimensions X, $X_{1,2}$ determination, are marked.

b – characteristic dimensions in the direction of the view P for the

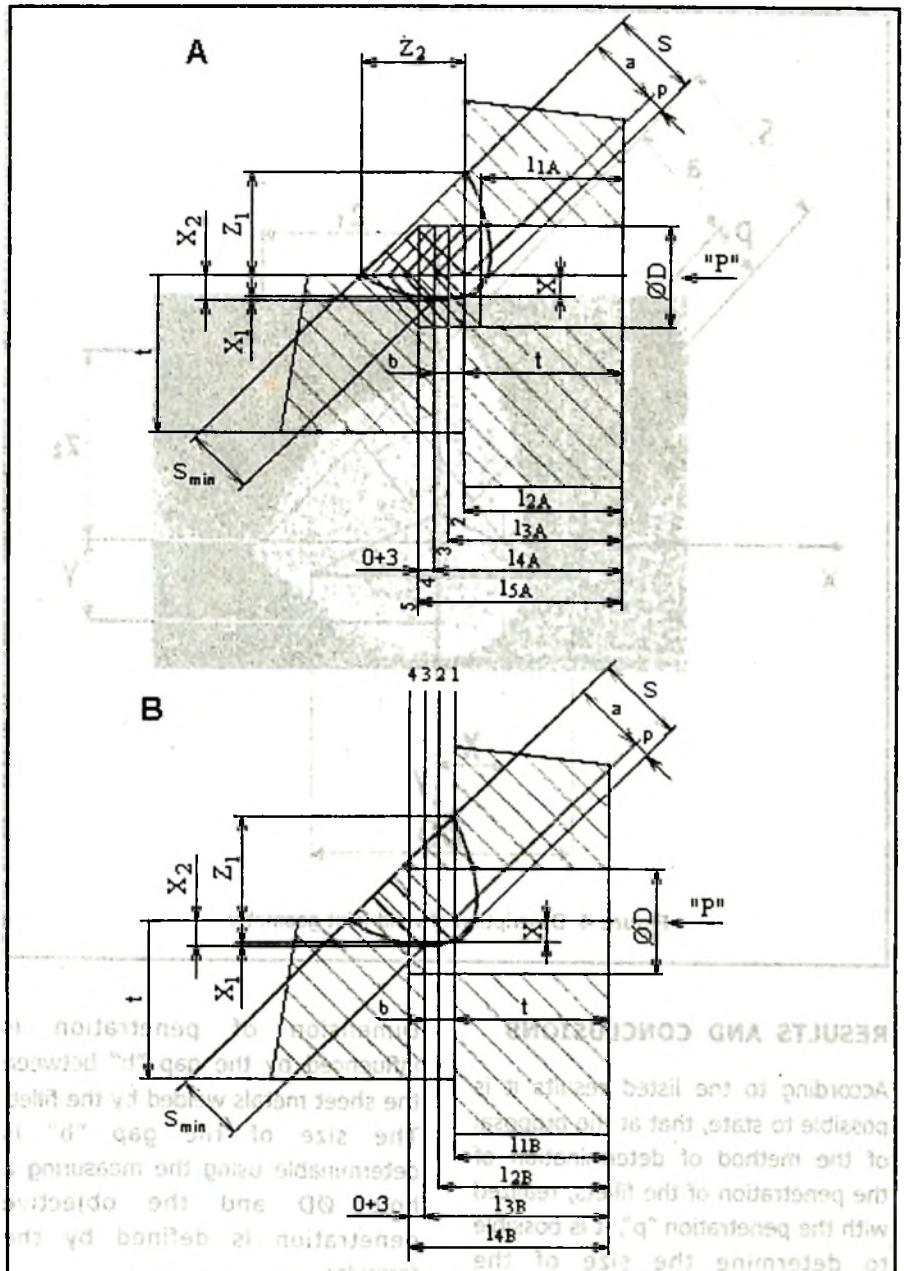

Figure 3 The characteristics for a weld joint symmetry evaluation

penetration determination are shown. These are:

The rating of the measuring hole surface in the direction "V", for the position of the points 1.,2 and the gap "b" determined weld metal penetration course.

At the macrostructure sample of the fillet (figure 4) the method of drilling of the measuring hole ØD, with a conic bottom, marked A, with the smallest depth of drilling 1 < t, is presented. The value of the angle of the presented weld is $\pm_x$ = 45°. In the text the measured dimensions and the calculated size are listed:

"p", p/a – the coefficient of penetration "k", "X" and "Y".

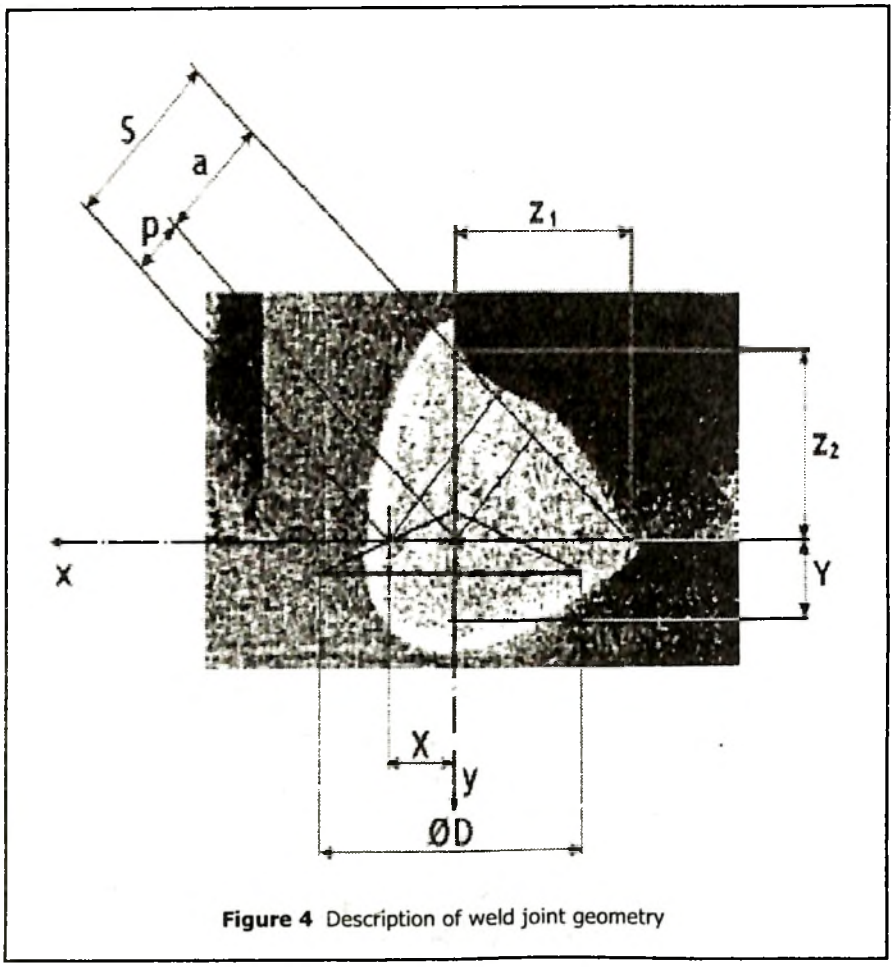

Figure 4 Description of weld joint geometry

RESULTS AND CONCLUSIONS

According to the listed results it is possible to state, that at the proposal of the method of determination of the penetration of the fillets, realized with the penetration "p", it is possible to determine the size of the penetration using the dimension "X", measured in the hole ØD, or determined by the available non – destructive testing method, radiological or ultrasonic.

Then it is possible to calculate the dimension "p" from the formula:

$$p = X \cdot \cos \pm_x \qquad (5)$$

The following relation defines the objective size of the penetration.

Dimension of penetration is influenced by the gap "b" between the sheet metals welded by the fillet. The size of the gap "b" is determinable using the measuring a hole ØD and the objective penetration is defined by the formula:

$$p_x = X \cdot \cos \pm_x - b \cdot \cos {}^2{}_x \qquad (6)$$

Objective size of the thickness of the weld with a deep penetration, "s_x" is dimensionally depended of the following parameters:

the height of the weld, "z_1",

the value defining the penetration X,

and the gap "b".

Then the objective size of parameter "s_x" is determinable from the next formula:

$$s_x = (z_1 + X) \cdot \cos \pm_x - b \cdot \cos {}^2{}_x \qquad .... (7)$$

For the proposal of the method of the determination of the penetration of the fillets the characteristic fact is, that the dimensions of the welds with penetration are being determined according to the taken value of the thickness of the weld with a deep penetration using the coefficient of penetration k = p/a >0,2 determined according to the conditions of the production and the skills of the welders. Then the height of the weld, "z" is determined using the thickness of the weld, "a", which can be educed from the expression s = a . (1+k).

In most cases, repair should have been superfluous because of regular, preventive maintenance. The proposed method offers relatively a simple and reliable solution based on the calculation of geometrical characteristics obtained through NDT methods or trivial test pit, respectively. According to the obtained results of the proposed method for determination of the weld penetration in the productive repairs of the pressure parts of the boilers, it is evident that introduced solution will increase the productivity of repairing boilers and prolong technical life of the pressure parts of the boilers.

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FORTHCOMING INTERNATIONAL EVENTS

International Institute of Welding Regional congress organized by South African Institute of Welding (SAIW)

SAIW will be holding the above conference at Stellenbosch (Near Cape Town) , South Africa between 8th to 10th March 2006.The theme of the congress is 'Welding and Inspection Technology for the Development of South Africa and will focus on subjects like Off-shore oil & gas exploration, extraction & beneficiation, Transportation, Power Generation, Construction , Petrochemical & refinery activities, Automotive industry& Food & beverage keeping in view the enormous volume of development activity being planned fin the lead up tp to the 2010 Soccer World Cup in South Africa.

69th Annual Assembly and International Conference of The international Institute of weldingat Quebec City Canada on August 27-September 2 ,2006.

This symposium is considered the principal showcase for manufactured tubing and the prime international forum for discussion of research, developments and applications in this field, which will be of interest to manufacturers of hollow sections or related construction products, architects, trade associations, design engineers, steel fabricators, owners or developers of tubular structures, researchers, academics and postgraduate students.Simultaneously, Booths will be available for exhibitors during the week of the AssemblyFurther information, as well as registration details, are available at the ISTS11 website, www.ISTS11.org.

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