Structure's Strength Induced by Intermittent Welding

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ABSTRACT

Welding is the most important of the ship building and assembling process. There are several welding of joining parts on the ship structure components that do not require watertightness such as joining of side longitudinal and the side plate of the ship. In areas that's not required watertightness or oiltightness the structure components are joined by chain welding instead of continueous welding. The chain welding could become problem of weakness of structure's integrities due to incontinuous of strength of structure and this could lead to structural failure. Classification rules make limitation of ranges of *b/l* ratio of chain welding, where *b* is length of welding step and *l* is welded length. This study aims to determine the relationship between the intermittent weld distance (chain welding) and the strength of the welded components. The strength calculation and analysis is carried out by using the finite element method by modeling a sample of chain welding of joining the side longitudinal and the side plate. Modelling and calculation is done by Ansys™ software. It was found that the greater the ratio between the length of the welding step (*b*) and the length of weld (*l*) in the chain weld, the higher tensile stress of the web frame, side longitudinal, and side plates proportionally (relatively linear). In case of *b/l* > 6.35, the tinsile stress of side longitudinal has passed the BKI allowable stress. The maximum stress, in case of continuous welding and in case of *b/l* = 5 of chain welding, increased about 68.51%, further incase of *b/l* = 6.35, the maximum stress increased about 23.34%. Actually the stress in case of *b/l* = 6.35, the maximum stress is still less then allowed stress stated by BKI, that mean that safety factor according to BKI rules for ship construction is high.

***Keywords**: Chain weldin; tensile stress; weld-joint.*

1. INTRODUCTION

The welding technology for joining structural components of steel building such steel shipbuilding continously developed. Welding is an inseparable part of the growth of shipbuilding industrial improvements because it plays a major role in the production production and repair work as well as manufacturing of ship maschineries [1]. In the construction phase of large vessels, the welding jobs is approximately one third of the total workload of shipbuilding. The weigth of blocks or sections of ship's hull that have to be assembled which must be welded each other, are up to tens of tons and hence the construction is very complicated. Considering of so much welding work in the construction of a ship, most of the welding must be watertight and oiltigth. Some cases of w`elding for joining components do not need watertight, in this case for minimizing welding work, is applied chain weling, or intrupted welding instead of continuous welding [2].

The welding plan and process must be done carefully and precise in order to achieve better ship hull structures. In welding plan must really pay attention to the compatibility between the properties of welding, namely the strength of the joint and the material properties to be welded, the results of welding are as designed.

There are several welding parts on the ship's hull components that do not require tightness such as the joining of side longitudinals and side plate of the ship, usually in the areas that do not require tightness used chain welds to reduce production costs, but the problem is that welding intermitten can lead to reduce strength of structure and even cause of structural failure [3]

In the construction of ship's hull, the intermitten welding that is widely used is the type of chain welding (Fig. 1). For chain welds, the classification rules set the maximum length of the welded part which is not welded. The maximum range of length, in practice of shipbuilding, the shipbuilders use different ratio of intermittent weld. At the design stage, the weld joint must be planned in such a way that it can be practical carried out at the fabrication, put in the best possible position for welding and makes it possible to carry out the proper welding sequence. The weld connection and welding sequence must be planned so that the residual weld stress can be maintained minimum so that there is no excessive deformation [4].

All welded joints in the main support section must be designed to provide the smoothest profile possible without large external or internal notches, without discontinuities in stiffness and without obstructions to strain. This applies equally to welding subordinate components to the main support parts where the edge of the plate is free or the flange must, as far as possible, be free from the effects of notches caused by weld joints [4]. Angle welding joints in principle, thick weld angle should not be more than 0.7 times thicker than the thinner parts to be joined (generally thicker slats). Minimum weld neck thickness is calculated according to the formula BKI [4]

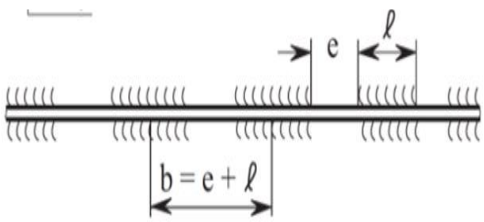

Fig. 1. Chain Welding [4]

It is designed that the surface of the angle weld be flattened with a smooth transition to the parent material. If evidence of fatigue strength is required, grinding of the weld (to remove the notch) may be needed depending on the category of notches. The welded material must penetrate minimally to near the theoretical root point. When a mechanical welding process is used which guarantees deeper penetration beyond the theoretical root point and if the penetration is maintained evenly and reliably on production conditions, approval can be given to these conditions and permitted in calculating the thickness of the weld neck. The deep size must be ensured according to Fig. 2 and by using the e_{min} factor that will be determined for each welding process through a weld procedure test. Neck thickness should not be less than the minimum neck thickness associated with theoretical root points [4].

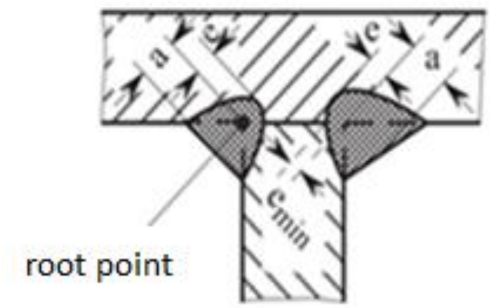

Fig. 2. Penetration of Engle Welding [4]

BKI [4] set that a minimum:

$$a_{deep} = a + \frac{2e_{min}}{3} \text{ [mm]} \quad (2)$$

Continuous reinforced angle-welds on both sides must be used in areas that receive very high dynamic loads (for example the joints of longitudinal and transverse from the engine foundation to the facing plate near the foundation bolts, except for single or double tapered welds required in this area. this area the size of a deep must be equal to 0.7 times thicker than the part to be welded according to rules of BKI [4].

The intermitten angle welded where welding placed opposite to one another (chain weldings) see Fig. 1. In water tanks and cargo tanks, and at the fuel tanks and at the bottom of the spaces where splashes of water may gather and on hollow components (e.g. rudder blade) which are threatened by corrosion, only continuous angle welding or welding with scalop may be used). This also applies to areas, construction or spaces that are exposed to extreme environmental conditions or that are exposed to corrosive loads. There should be no scalop in the area where the plate applied high local stresses (for example in the area of the front of the ship) and continuous welding should be prioritized if the load is mostly dynamic [4].

The thickness of the intermitten angle weld neck is determined according to the step ratio (pitch) *b/l* selected using the formula (see Fig. 1 and Fig. 2), according to BKI [4]:

$$a_u = 1.1a\frac{b}{l} \text{ [mm]} \quad (3)$$

where:

a = thick neck welding required angle [mm]

b = step = e + l [mm]

e = welding hose [mm]

l = angle weld length [mm]

The step ratio *b/l* cannot be more than 5, the maximum length of the non-welded part (*b* – *l*) in scalop and chain welds, or (*b*/2 – l) in zigzag welds should not be more than 25 times thinner thickness of the part to be welded. However, the scalop length cannot be more than 150 mm [4]. Overlap joints must be avoided whenever possible and may not be used for components that applied heavy loads. In the case of components that applied a low load the interconnected connection can be approved provided that, where possible, the direction is parallel to the main stress direction. The width of overlap must be 1.5*t* + 15 mm (*t* = thinner plate thickness). Unless other values are determined by calculation, the thickness of the angle welding neck "a" must be equal to 0.4 times the thickness of the thinner plate, provided that it must not be less than the minimum neck thickness required. Angle welding must be continuous on both sides and must meet at the end [4].

In the case of filling-weld (plugs), the plug must, where possible, form an elongated hole located in the direction of the main stress. The distance between the hole and the length of the hole can be determined in the same way as step "b" and the length of the "F" angle weld on the intermitten weld. The hole width must be at least twice the thickness of the plate and must not be less than 15 mm. The end of the hole must be half round. The thickness of the plate or beam sections which is located below it must at least be the same as the perforated plate and must stand on both sides up to a distance of 1.5 times the thickness of the plate with a maximum of 20 mm. If possible, only the necessary angle welds are welded, while other empty spaces are filled with suitable fillers [4].

The load of structure applied in this study is side load due to the analyzed intermittent welding model is on the side structure of the ship's hull, which are consists of side longitudinals, transverse framing, and side plating. Side load (*Ps*) calculation and derrtemined by formula set by [4]:

For elements those load centers are located below the load line:

$$P_S = 10(T - Z) + P_O.C_f.(1 + Z/T) \text{ [KN/m}^2\text{]} \quad (4)$$

For elements those load centers are above the load line:

$$P_S = P_O.C_f.(20/(10 + Z - T) \text{ [KN/m}^2\text{]} \quad (5)$$

where :

PS = *side load of ship' hull [KN/m2]*

T = *draught [m]*

Z = *vertical distance of center load above base laine [m]*

Po = *dynamics load base [KN/m2]*
= *2,1(Cb + 0,7) x Co x Cl xf* (6)

Cf = *distribution factor = 1,0*

Cb = *block coefficient*

Co = *wave coefficient*
= *(Lbp / 25 + 4,1) x Crw*
(for L < 90 m) (7)

Lbp = *Ship's Length[m]*

Crw = *ship operation factor = 1,0*

F = *probability factor = 1,0*

Cl = *length koefficient*
= *(Lbp/90)0,5*
(for L < 90 m) (8)

2. METHODOLOGY

The study was conducted in the Department Naval Architecture of Faculty of Engineering, Hasanuddin University, with data sources in the form of technical design and drawing of 100 TEUS container ship built bay PT Industri kapal Indonesia. The data, such as ship's particulars, dimension and configuration of ship's hull structure includes weld construction planning drawings, WPSs data (Welding Procedure Specification), building material, construction drawings (profile, midship section), are supplied by PT Industri Kapal Indonesia.

This research was conducted by numerical simulation by using Ansys software. The work steps in analyzing the strength of a intermitten welding are: structure modelling, defining material properties, setting boundry conditions, applying load, running calculation, and finally interpreting the output of calculation [5]

To analyze the strength of the chain weld, welding modeling needs to be done. Welding modeling carried out in this study by modeling a welding area that will represent an intermitten weld on a 100 TEUS container ship's hull where the variation of the model is the distance between the intermetten welds. The structure modeling process in Ansys software includes:

Defines the type and choice of elements (Element Type). For the model of the side plate structure and profile on the ship, shell elements namely shell 281 are used and for the welding model solid elements are used, namely solid 183. Shell element type 281 is chosen because the element type is more suitable for plate modeling and solid elements suitable for welding modeling. In addition shell and solid element types have six degrees of freedom on each node and allow the model to be analyzed at three-dimensional stresses, namely the stresses that occur on the *x*, *y*, and *z* axes.

Defining material properties by setting the modulus of elasticity and poisoning patio are made according to the material used in the components of the ship's structure. Modellin is done by making keypoints first then connecting with lines and then forming areas. In developing this ship's side structural model, set the length of the model is in the direction of the z axis, the width of the model in the direction of the x axis and the height of the model in the direction of the *y* axis.

The thickness of the plate and beam sections dimension are defined for each section according to data taken from ship design technical drawing as mentioned above. The welding area is modelled bay using glue that available in Ansys Features. Next step is meshing, all the areas in the model is divided into smaller elements, and the meshing fineness is applied 0.25 m for all areas.

Boundary conditions of model are set so it represent the real conditon of structure as far as possible, in this case the structure characterictics around the modeled structure are considered carefully. Last step of preprosessing of Ansys is appling or assigning of side load as was calculated manually according to [4] rules.

3. RESULT AND DISCUSSION

According to the objectives of this study, the effect length of intermittent welding on weld strength of chain welding joints associated with BKI rules. The variation of the intermittent welded were analyzed as can be seen in Table 1.

Tabel 1. Varying of intermittent welding.

No.	*b* (mm)	*l* (mm)	*b-l*	*b/l*
1	300	300	0	1
2	300	120	180	2.5
3	300	100	200	3
4	300	85	215	3.5
5	300	75	225	4
6	300	60	240	5
7	300	50	250	6
8	300	43	257	7

Restraints as representation of boundary condition of structure model are set on the model according to the real structure as designed and built by PT Industri Kapal Indonesia. Both sides which are bulkheads at frame 35 and frame 42, is fixed the support, be made fixed (line) direction of translation *x*, *z* translation, and the rotation on *y* set free. The confinement on web frame is the restraint of the node in the direction of translation *x*. Restraints on the side shell plate are set the line direction of the *z* rotation. The load is applied a uniform load, which is the vessel side load = 0.0416 N/mm^2 in the area of the ship's side plate (*x* axis).

The indicators of structure’s deformation and stress that occurs are the color gradation of Ansys output and finally the value of highest shift point. The maximum deformation is marked in red while the minimum deformation is marked in blue (Fig. 3)

The strucutre response tobe analyzed based deformation and stress as variable that occur due to the variation of the length of intermittent welding, so that the analyzed are deformation and the stress in direction of the *x*, *y*, *z* axis. The review point for stress analysis that occurs in chain welding is taken 3 points, namely on the side plate (side shell plate), on the longitudinal side, and on web frame.

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The maximum stress in *x* direction occured in web frame due to lateral load from side of hull structure, the web frame experienced a pressing from side longitudinal and side plate (see Fig. 4.)

The maximum stress in y direction occured in side plate due to lateral load from side of hull structure that make the plate deflect hence cause a high stress corresponed to the bending moment theory [6], the side plate also experienced a press load (see Fig 5)

The maximum stress in *z* direction occured in longitudinal, this is due to deflect of longitunal in *x* direction hence create stress in z direction. Longitudinal is direct support of side plate, and the longitunal it self is supported by web frame (see Fig 6)

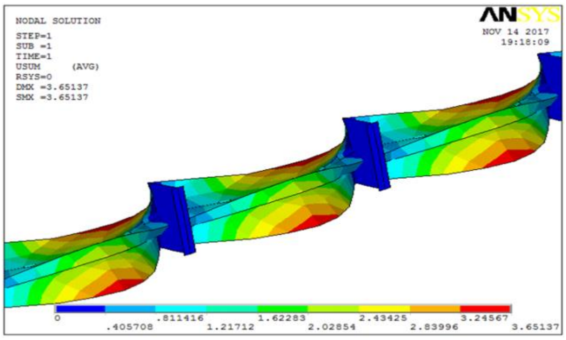

Fig. 3. Maximum deformation in x an y direction.(output AnsysTM)

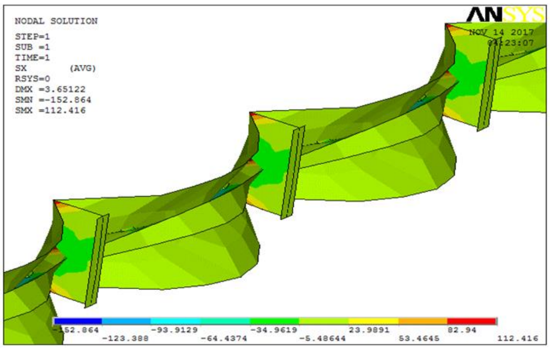

Fig. 4. Stress in x diection (output AnsysTM)

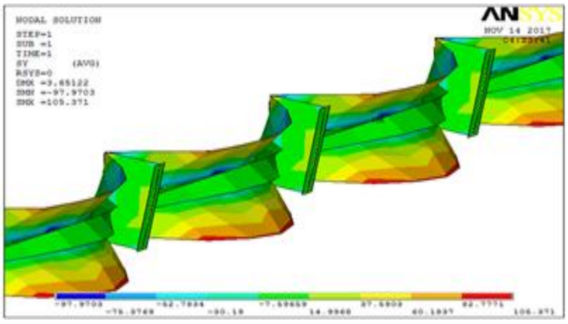

Fig. 5. Stress in y-direction (output AnsysTM)

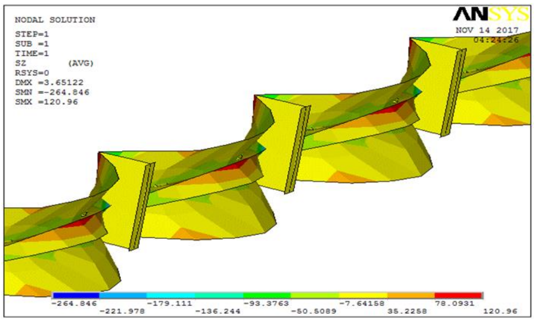

Fig. 6. Stress in z-direction (output AnsysTM)

It was found that the highest stress occurs on the *z* axis which is equal to 120.96 N/mm^2. This is because the load is given in the direction of the *x* axis so that the reaction caused is the largest stress in the direction of the z axis. The stress on all three directions of web frame, side plate, and side longitudinal as result of varying the ratio of *b/l* of chain welding can be seen in Fig 7, 8, and 9.

In case of stress in *x* direction, there is no stress in side longitunal (Fig 7), that mean the side load do not create stress in *x*-direction on side longitudinal.

Fig 7, 8, and 9 indicate the the increasing of ratio *b/l* in chain welding will increase the stress of all concersed structure components linearly, this corresponds to Turan [7] and McPherson [3].

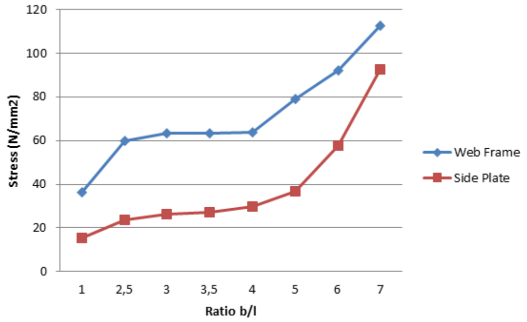

Fig. 7. Stress and b/l ratio in x-direction

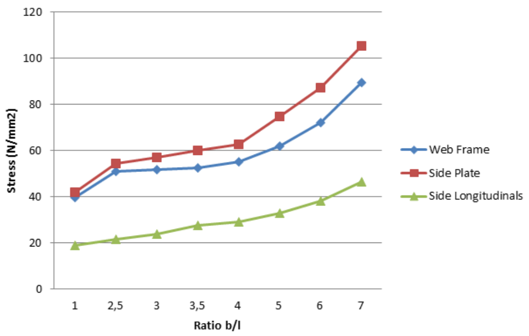

Fig. 8. Stress and b/l ratio in y-direction

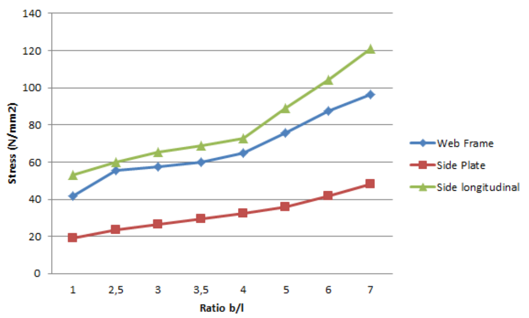

Fig. 9. Stress and b/l ratio in z-direction

3. CONCLUSION

The greater the ratio between the length of the welding step (*b*) and the length of the weld (*l*) in the chain weld results in the tensile stress on the web frame, side longitudinal, and the side plate increasing proportionally (relatively linear). The ratio between the lengths of the welding step (*b*) with the length of the weld (*l*) on the chain weld is greater than 6.35 m the stress on the longitudinal side has passed the BKI permit of maximum stress.

It was also found that full (full) welding into chain welding with a ratio of *b/l* = 5 increased the tensile stress by 68.51%; and then with a ratio of *b/l* = 6.35 there is a rise in tensile stress of 23.34%.

Research carried out based on the structure of 100 TEUS container ships using chain broken welds with a ratio of *b/l* = 2.5 with a weld length of 120 mm, it turns out that the length of the weld can still be reduced by 73 mm until the stress exceeds the permitted maximum stress set by BKI.

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