EXPERIMENTAL ANALYSIS TO CONTROL WELDING DEFORMATION IN THIN PLATE

ALI Muhammad Taha, Damen Shipyard Galati and University of Liege, Belgium.

SUMMARY

Shipbuilding industries facing the problem of welding deformation for seven decades and trying to control this problem but the thin plates bring non-linear problems in the ship structure. Especially in the bulkhead of the ship structure that leads to welding deformation due to small members of the profiles. Mostly, the problem occurs in the construction of yachts building because clients need good outlook of the ship. Therefore, the development of a new effective method to reduce the welding deformation in the thin plate by optimization of welding sequences and plating method at the time welding process and this method is help to reduce the deformation and also help to increase the productivity of the shipbuilding process.

1. INTRODUCTION

1.1 BACKGROUND

Welding is a process to join metals with different arrangements of the plates. Welding induced the distortion in the thin plate. There are six types of welding distortion:

The objective of this research to analyse the welding deformation, welding deformation is caused by the welding distortion; the main factor of welding distortion is based on the following parameters which are given below:

- Longitudinal Shrinkage
- Transverse Shrinkage
- Angular Distortion
- Bowing and dishing
- Buckling
- Twisting

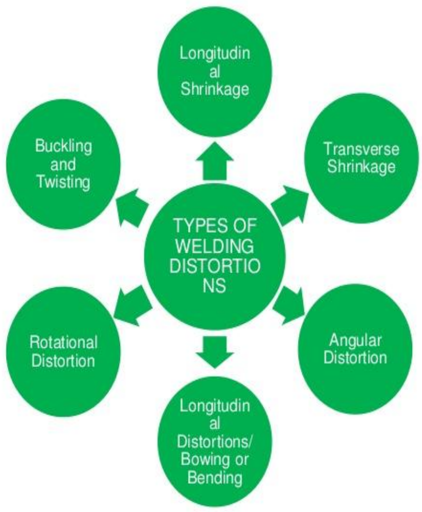

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Figure 1: Types of Distortion in welding [2]

After welding the shrinkage is towards the weld axis longitudinally is known as ***"Longitudinal Shrinkage".***

After welding the shrinkage is towards the weld axis longitudinally is known as ***"Transverse Shrinkage".***

"Angular distortion" is the change in the shape of the plate by the welding. Consider the But welding in which the top part of the welding is wider than the bottom part.

As we know that two or more than two distortions will occur at the same time when longitudinal Shrinkage occurs then there will be the bending of the plate. That`s why is known as ***"Bowing"***. This type of Distortion happens when the weld line and Neutral Axis of the structure do not coincide.

Mostly ***"buckling"*** is occurring in the thin plate. This type of distortion occurs away from the welding area this is due to the residual stress.

"Twisting" has also happened in the thin plate this is due to the low torsional resistance. Twisting of the plate occurs when the welding is done along the centre of the member. Due to this reason, the area tends to shrink and become shorter.

1.2 WELDING

In the shipping industry, different types of arc welding are used, which are shown***:***

1. Shielded Metal Arc Welding (SMAW)
   Electrode Type
   Arc between;
   - Base metal and
   - Covered electrode
2. Gas Tungsten Arc Welding (GTAW)
   Electrode Type
   Arc between;
   - Base metal and
   - Tungsten electrode
3. Gas Metal Arc Welding (GMAW) / MIG (Metal Inert Gas Welding)
   Electrode Type
   Arc between;
   - Base metal and

- Consumable electrode

4. Flux – Cored Arc Welding (FCAW)
   Electrode Type
   Arc between;
   - Base metal and
   - Consumable electrode

5. Submerged Arc Welding (SAW)
   Electrode Type
   Arc between;
   - Base metal and
   - Consumable electrode

Cheapest and easiest welding of Grade "A" material is given below:
1. SMAW i.e. Shielded Metal Arc Welding.
2. GMAW i.e. Gas Metal Arc Welding or MIG i.e. Metal Inert Gas Welding.
3. Oxyacetylene Welding. [3]

MAG welding also is known as GMAW (Gas Metal Arc welding). It is a really good method of welding in the thin sheet but in this method, you have put extra attention at the time of welding otherwise this type of welding cause deformation and burn.

This type of welding is also known as Gas Metal Inert Gas (MIG) welding. In this welding in which shielded gas is used to heat up the electrode to join the two metal plates.

The source for this welding is constant voltage and direct current. Now, a day this type of welding process is commonly used in the industry.

1.2 WELDING DISTORTION

Welding distortion occurs due to the non-uniform distribution of the heating and cooling cycle. Due to which welding complex strain is produced during the welding. This distortion is occurred in between weld bead and base metal plate.

1.2 (a) Cause of welding distortion

The welding distortion problem in the welded plate is varied due to the grade of steel plate due to the following reasons which are given below:

1. Heat Conductivity
2. Co-efficient of the Thermal Expansion
3. Modulus of Elasticity

1.2 (b) Control of welding distortion

The welding distortion is controlled by several methods after analysing and finding ways:

1. Elastic Pretraining
2. Clamping
3. Differential Heating

1.2 (c) Checks for welding distortion

To ensure that the plate doesn`t have any welding distortion then we have to follow the following steps:

1. Before Welding Procedure and Checks
2. During Welding Procedure and Checks
3. After Welding Procedure and Checks

2. OBJECTIVE OF THE ANALYSIS

To control the welding deformation by welding sequence, a transverse plating method and clamping technique.

3. WELDING PROCEDURE SPECIFICATION

The welding procedure is the documents which contain important values of welding parameters that help the welding process. We know that computational analysis has very less control in the welding procedure; this is because of the welding procedure totally experimental procedure.

Welding procedure sequence must follow the IACS code for the welding process. Engineer and welders are responsible to follow the WPS. WPS help to produce high-quality welds.
Welding procedure specification includes the following codes:

1. API code
2. AWS code
3. ASME code
4. ISO code
5. Foreign code

Welding procedure specification has important information in the datasheet regarding material properties which are:

1. Spec and Grade
2. Yield Strength
3. Tensile Strength
4. Elongation
5. Wall thickness
6. Size i.e. diameter

WPS contain informations about the welding process which are:

1. Which kind of welding i.e. MIG, TIG or so on.
2. Method of welding i.e. Manual, Semi-automated or automated.

WPS has also the information regarding welding process parameters which are:

1. Volts, Ampere and Travel Speed
2. Polarity
3. Travel direction
4. Wire welding transfer mode
    - Spray, Short Circuit, Plasma or Globular
    - Flux Core or Shielding Gas
5. Number of welders
6. Number of passes
7. Electrode size and group number
8. Electrode AWS specification

More details are mention in the WPS which help the engineer and welder to weld the plate. [4]

By this IACS Rule # 47, we can compare the normal and high strength hull structural steel grade.

Welding procedure specification parameters for this experimental analysis are:

1. Type of welding is MIG/MAG welding.
2. The angle of the electrode is **45°.**
3. Weld bead size is **5mm.**
4. Shielding gas percentage:
    a. Argon is **82%.**
    b. CO_2 is **18%.**
5. Gas flow rate is **13 lit/min.**
6. Feed wire rate is **7.5 m/sec.**
7. Current during welding is **240 Amperes.**
8. Voltage during welding is **24 volts.**
9. Clamping time in case study # 5 is **15 – 20 min**.

4. MODELLING

The model assumes to be a temperature dependent. It means that thermal analysis is used to be a source of mechanical behaviour in the TEP-FEM analysis.

The following mechanical and thermal properties are the dependents of temperature are given below:

1. Yield Stress
2. Elastic Modulus
3. Thermal Expansion and
4. Poisson`s ratio.

For modelling of the plate need the values of temperature at the time of welding and the material of the plate and profile. The same heat source and the same material of the model are used for the analysis in thermal condition for a fillet weld. This analysis performed by Barsoum et al. [5]

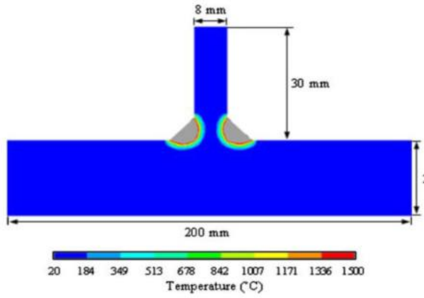

Figure 2: T-fillet welding performed to analysis thermal conditions in the thin plate. [5]

3.1 MATERIAL SELECTION

In the shipbuilding industry, two grade of steel is commonly used in the yacht building. First one is Grade "A" and the second one is Grade A36. Grade "A" Steel is most commonly used steel in the shipbuilding industry for the thin plate in yacht and ferry boats. This steel is mild and hot-rolled. Welding properties of this steel are excellent. [1]

3.2 COMPOSITION & PROPERTIES

Table 1: The chemical composition of Grade A steel. [6]

Element	**Max. wt./ Content %**
Fe	96.72
Mn	2.5
C	0.21
Si	0.5
P	0.035
S	0.035

Table 2: Thermal Properties of Grade A steel. [7]

Thermal Properties	**Metric**
Thermal Expansion	$11 \times 10^{-6}\,^{o}C^{-1}$
Thermal Conductivity	$0.084 \frac{W}{mm\ x\ ^{o}C}$
Specific Heat	$480 \frac{J}{Kg\ x\ ^{o}C}$
Initial Temperature	20 °C
Final Temperature	1500 °C

5. MODEL

The dimension of the base plate is considered in these case studies are 1000mm in width, 1500mm in length and 5mm in thickness of the base plate. These dimensions are taken from the yacht building panel. The longitudinal flat bar dimensions are also taken from the yacht building panel, the dimension of the flat bar is 65x5 mm^2 and 1500mm long. The transverse flat bar dimensions are also taken from the yacht building panel, the dimension of the flat bar is 50 x 5 mm^2 and 450mm long.

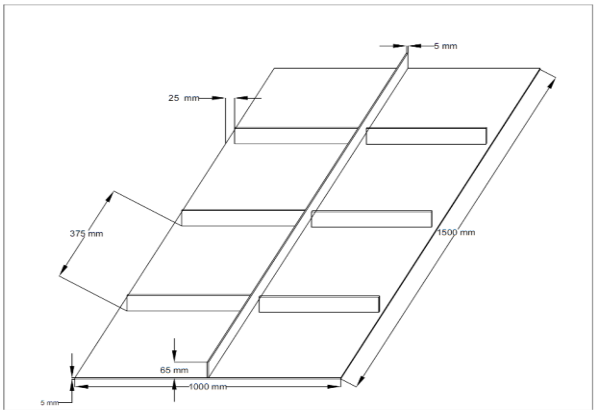

Figure 3: CAD Model with a base plate, one longitudinal flat bar and three transverse flat bars.

6. WELDING SEQUENCE

According to the thermal elastic plastic method, it explains the sequence of the welding which is used to reduce the deformation of the plate.

As we know that the sequence of the longitudinal frame:

First, we have to weld the stiffeners to the plate then the Frame is used to weld to the plate and at the end of the panel, we put the longitudinal Girder.

But from the different research by the scholar, they explain that if we change the sequence of the welding then we decrease the deformation of the plate.

They said that if we start from the girder and we can see the angular distortion of the plate. And as we know that if we want to reduce the deformation then we have to weld the plate and bar on the side of the girder.

So, we can weld the stiffeners to reduce the deformation that is angular distortion. After this, angular distortion is reduced. Then you can weld the frame to the panel plate to reduce the distortion more. [8]

The sequence of the welding this profile is shown below: [8]

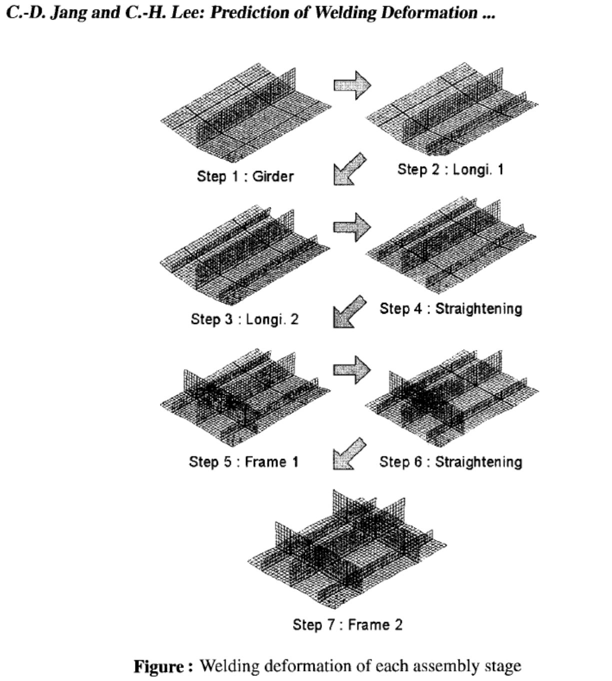

Figure 4: Welding deformation of each assembly stage. [8]

7. EXPERIMENTAL ANALYSIS & RESULT COMPARISON

Welding process and its complexities, it is required to perform a number of experiments to get the best possible result which is used to validate the analysis by the computational result. The same pattern of the computational method is used in the analysis for the large structure. Due to this reason, five case studies are performed which will represent in this paper. Out of that best possible result of one case study is used for the validation process. By this reason, different welding sequences from one to another case study or clamping time period are different in similar welding sequence. Different welding sequences are performed to reduce welding complexities. Complexity is occurred due to the temperature distribution in the model that is why different welding sequence is used to distribute the heat uniformly into the plate. It is another reason to perform different case studies.

In this method, uniform distribution effects of the thermal load affect the residual stress especially deformation. That is why five case studies are performed to analyse the best possible result of welding deformation. By comparing all case studies, one case study gives the best possible result of welding deformation.

For uniform thermal distribution, the thin plate is done through welding sequences. By this reason, different welding sequence is performed to reduce the welding deformation. These case studies are performed in the bulkhead panel of the ship.

In all five case studies different welding sequences are analysed which are given below:

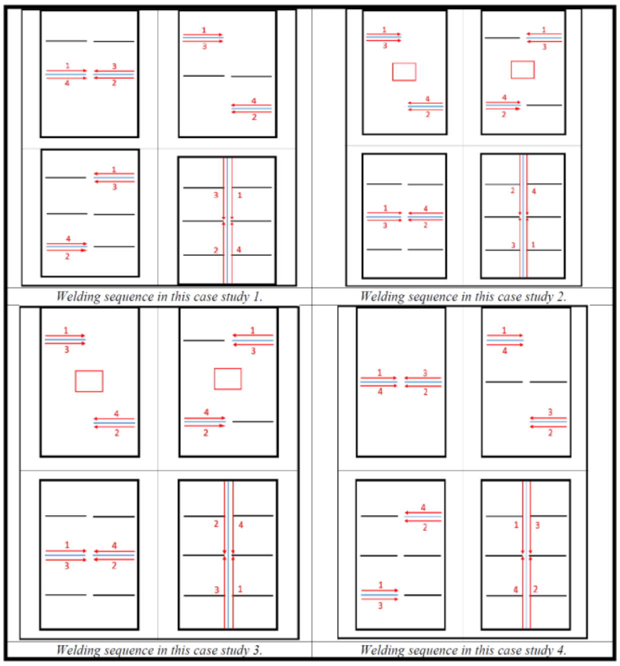

Figure 5: Welding sequences in the case study 1 to 4.

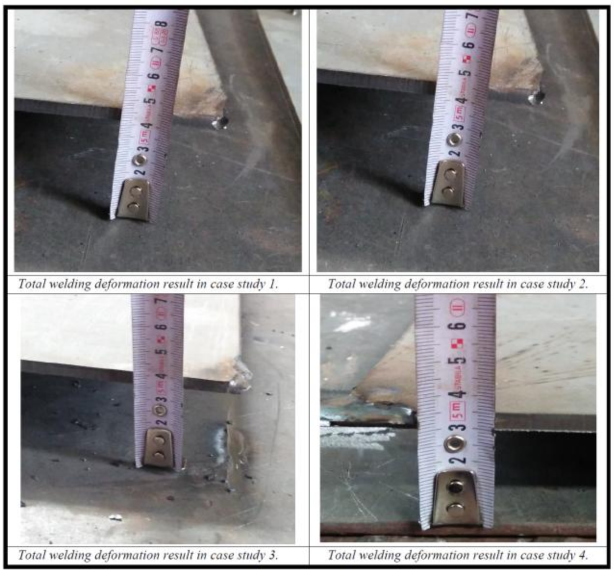

Figure 6: Total welding deformation result from case study 1 – 4.

Total welding deformation in the case study 1 is **43mm**.
Total welding deformation in the case study 2 is **42mm**.
Total welding deformation in the case study 3 is **37mm**.
Total welding deformation in the case study 4 is **30mm**.

Case Study # 5

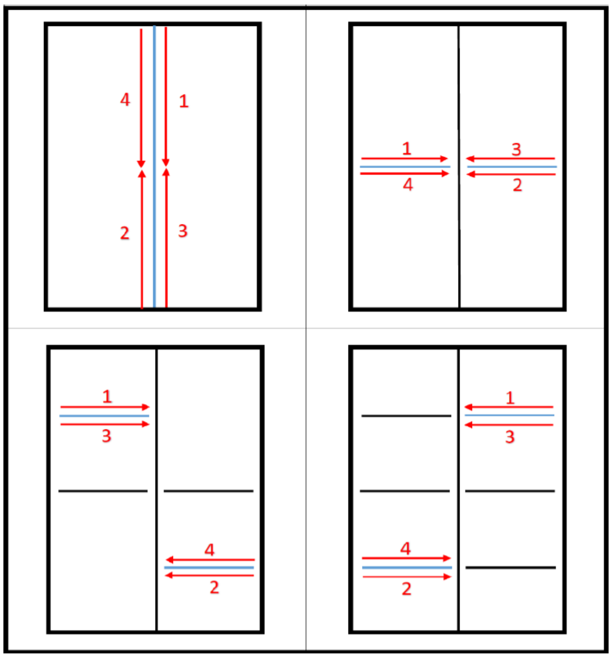

Figure 7: Welding sequence in the case study 5.

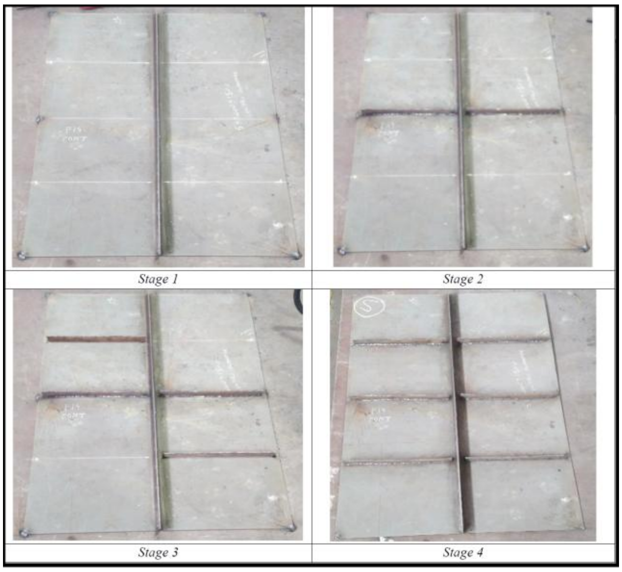

Figure 8: Welding process stages in the case study 5.

Total welding deformation in the case study 4 is **20.5 mm**.

This case study base plate is fixed from the corner of the plate during the welding process and after the welding, process plate is restraint up to 15 – 20 min after completion. Clamping method is essential to minimize the deformation in the thin plate.

After experimental analysis, it is proved that transverse plating method and time period of clamping during and after welding are increasing the productivity of the production.

8. VALIDATION

By the total deformation displacement results in the thin plate, welding sequence method is validated with the thermal elastic – plastic FEM method.

Experimental Result

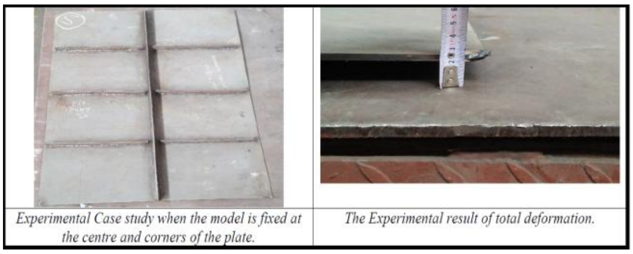

Figure 9: Total welding deformation result for case study 5.

In the experimental result, the maximum total welding deformation is 20.5 mm in case study 5, when the model is fixed from the corners and centre of the plate as shown in the above figure.

Computational Result

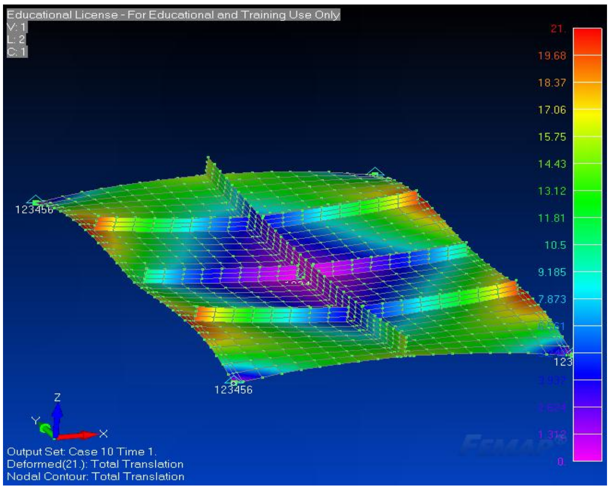

Figure 10: The computational result of total deformation. [1]

In this computational analysis, the number of nodes of the model is 1119 and number of elements are 1040.

In FEMAP this case study is to follow two steps to get von Mises stress or any mechanical physical parameters.

1st Step is used to analyse the thermal analysis i.e. temperature distribution in the plate and profiles.

And then 2nd step performs for the structural analysis by this analysis von Mises stress can be measured.

In the computational result, the maximum total welding deformation is 21 mm, when the model is analysed in the FEMAP software and the model is fixed from the corners and centre of the plate as shown in the above figure.

After experimental and computational analysis, the error between both the results is **2.4%**.

9. CONCLUSION

After validation of the experimental analysis and computational analysis, it is clearly shown that welding sequence in experimental analysis gives the good agreement of result with computational analysis which increases the productivity of the production process. The difference between computational analysis and experimental analysis is **2.4%** that one is too small that`s why it is neglected.

Through this welding sequence, **12-14%** of the production process of the bulkhead panel increases with respect to the labour cost and total time of production.

This welding sequence and computational results help to implement in the complex and large structures.

10. RECOMMENDATIONS & FUTURE WORK

To control the distortion during and after the welding process through:

- Eliminate the flaming fairing method control the distortion and use the inductive fairing method.
- Parallel heating method after completion of the welding process.
- Use the pre-machining concepts.

Techniques and methods can be analysed in future to control the welding deformation is “Influence of clamping in welding Deformation”.

Other virtual fabrication technology models have formed to analysis the welding deformation in the thin plate.

By this method or technique, shipyard work on their own virtual simulation or develop their own code to analyse the ship structure.

11. ACKNOWLEDGEMENTS

This study has been accomplished in the framework of EMSHIP – European Masters Course in Advanced Ship and Offshore Design (www.EMSHIP.EU), coordinated by University of Liege, Belgium. I acknowledged the support by the Research Centre of Naval Architecture Faculty from University of Galati and Damen Shipyards Galati.

12. REFERENCES

1. ALI M. T., Computational Analysis to Control Welding Deformation in Thin Plate, *Design & Operation of Passenger Ships, RINA, 2019.*

2. From the slide of *Nirma University*.

3. PAZOOKI A.M.A, HERMANS M.J.M., RICHARDSON I.M., Control of welding distortion GMAW of AH36 plates by stress engineering, *Int J Adv Manuf Technol 88:1431457,* 2017.

4. JOHN LUCAS, Welding Procedure Specification's (WPS), *UTI Corporation.*

5. BARSOUM I. B. Z., Residual stress effects on fatigue life of welded structures using FEM, *Engineering failure analysis (no. 16) 449 – 467,* 2009.

6. www.shanghaimetal.com/shipbuilding_plate-129.htm

7. IACS Rule # 47.

8. C.D. JANG and C.H. LEE, Prediction of Welding Deformation of Ship Hull Blocks, *Journal of Ship & Ocean Technology (No.4) 44-49, 2003.*