Distortion Control in Thin Low Carbon Steel Plates Using Sequential Welding and Restraints

Pavana Yogesh Rao[1], Rajesh Kumar. S[2], Dr. B.S. Mohanty[3]

[1,2,3] Dept. of Mechanical Engineering, St. Joseph's College of Engineering, Jeppiar Nagar, Sholinganallur, Chennai, India

Abstract- Distortion control during and after welding is an important aspect of construction and quality. This paper, aims at distortion control during welding for butt welded joints using methods of sequential welding and welding by jigs and fixtures. First part consists of welding butt joint and controlling the distortion caused in plates of thickness of 4 mm and 8 mm. In sequential welding three welding sequences were created and executed. The second part consists of same sequences done again using stiffeners in 4mm and 8 mm thick plates as welding fixtures.

The above methods were compared to suggest the best practice for controlling distortion in real life**.**

Index Terms- Welding, Residual Stress, Distortion, Fixtures

I. LITREATURE REVIEW

The study discusses the evaluation and simulation of angular distortion in weld-ing joints, and the ways of controlling and treating them, while welding plates of (low carbon steel) type A-283-Gr-C through using shielded metal arc welding. The value of this distortion is measured experimentally and the results are com-pared with the suggested finite difference method computer program. Time de-pendent temperature distributions are obtained using finite difference method. This distribution is used to obtain the shrinkage that causes the distortions ac-companied with structural forces that act to modify these distortions. Results are compared with simple empirical models and experimental results. Different thickness of plates and welding parameters is manifested to illustrate its effect on angular distortions. Results revealed the more accurate results of finite difference method that match experimental results in comparison with empirical formulas. Welding parameters include number of passes, current, electrode type and geometry of the welding process. To examine the effect of welding fixture used to prevent the distortions during cooling process utilizing a gas metal arc welding method on cooling rate and distortions of welded structures.

The problems of distortion, residual stresses and reduced strength of structure in and around a welded joint are of major concern in the shipbuilding industry and in other similar manufacturing industries. The present paper deals with the theoretical analysis of transverse shrinkage in a welded butt joint. Angular distortion is a major problem and most pronounced among different types of distortion in the butt welded plates. This angular distortion is mainly due to non-uniform transverse shrinkage along the depth of the plates welded. Restriction of this distortion by restraint may lead to higher residual stresses. However, these can be reduced by providing initial angular distortion in the negative direction if the magnitude of angular distortion is predictable. It is difficult to obtain a complete analytical solution to predict angular distortion that may be reliable over a wide range of processes, materials, and process control parameters. In this study, the statistical method of three-factors, five-levels factorial central composite rotatable design has been used to develop mathematical models to correlate angular distortion with multipass GMAW process parameters. Direct and interaction effects of the process parameters were analyzed and presented in the graphical form. Further, these mathematical models help to optimize the GMAW process and to make it a cost-effective one by eliminating the weld defects due to angular distortion.

II. INTRODUCTION

Welding is an integral part of Steel Industry and is the backbone of Ship building industry, which in turn is critical for both maritime commerce and Naval Defence forces. Two of the major problems of any weld process are residual stress and distortion. To relieve some of the residual stresses caused by welding process, the structure deforms causing distortion. The tensile residual stress on the weld line reduces the fatigue strength and toughness.

In recent years, ship panel distortion has become a major problem. The increased use of thin (i.e. 10mm and below) plates in panel fabrications has resulted in significantly increased distortion. In case of naval vessels, a new class of lightweight surface combat ships is presenting special challenges to the shipbuilders due to the minimum thickness of plates (3 to 5mm) being used to fabricate deckhouse structures, shell plates, bulkhead panels, etc. The net result is increased man hours for fitting, flame straightening and rework following flame straightening. Flame straightening is used to bring back into compliance with the fairness requirements. However it induces additional costs towards labour, materials, repainting and time delays. On the other hand allowing the distortion to remain also carries with it consequences related to degraded performance, poor fit up, a decrease of the structural integrity and an overall bad appearance.

Competitiveness in cost and time can be increased by eliminating or mitigating these distortions during the fabrication process rather than allowing them to accumulate and then removing them.

III. EXPERIMENTAL PROCEDURE OF BUTT WELD FOR 4 MM THICK PLATES

NORMAL WELDING

Two plates of thickness 4 mm are cleaned and grooved in a single V butt joint. These two plates are kept 2 mm apart from each other and welded. Two opposite passes are used for this butt weld. DC straight polarity source has been used.

- SPECIFICATION OF PLATES :

Dimensions - 300 × 150 × 4 mm
V- groove angle - 60°
Material used - Low carbon steel (IS 2062)

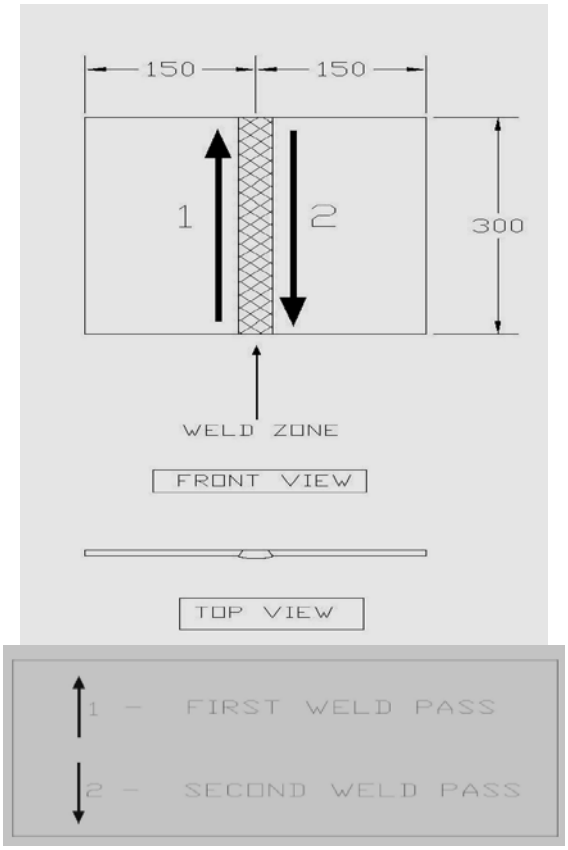
- WELDING PARAMETERS :

Number of Passes - 2 (opposite passes)

	FIRST PASS	SECOND PASS
CURRENT	80 A	120 A
ELECTODE DIAMETER	2.5 mm	3.15 mm
ELECTRODE TYPE	E6013	E6013
WELDING SPEED	2 mm/sec	2 mm/sec

DIAGRAM OF NORMAL WELDING

Figure 1: Image of Normal Welding of 4mm Thick Plates



All dimensions are in mm
Figure 2: 2-D View Normal Welding, 4mm Thick Plates

OBSERVATION OF PLATES AFTER WELDING:

After welding, angular and buckling distortion occurred in the plates. Two methods have been used to control these distortions i.e. sequential welding and using welding jigs and fixtures and kept all the parameters constant as used in normal welding while doing sequential welding and welding using jigs and fixtures.

IMAGE OF DISTORTION OF PLATES IN NORMAL WELDING

Figure 3: Distortion of Plates in Normal Welding, 4mm Thick Plates

IV. DISTORTION MEASUREMENT

The side in which distortion is less is to be fixed and the other side is taken into consideration for measurement as shown in figure below. A reference horizontal plane (flatness stone) has been fixed from which plates have been bended towards upward which is known as angular and buckling distortion. The distance between fatness stone and bending of plate gives the value of distortion. This same procedure is used for all butt weld of thickness 4 mm and 8mm.

METHODS FOR CONTROLLING DISTORTION IN BUTT WELD FOR 4 mm THICK PLATES

METHOD 1 : NORMAL WELDING USING JIGS AND FIXTURES.

In this normal welding was done using same welding parameters as mentioned above. But in this case the ends of plate have been fixed so that bending can be controlled. In this also two opposite passes will be used as shown in figure below.

DIAGRAM OF NORMAL WELDING WITH FIXTURE

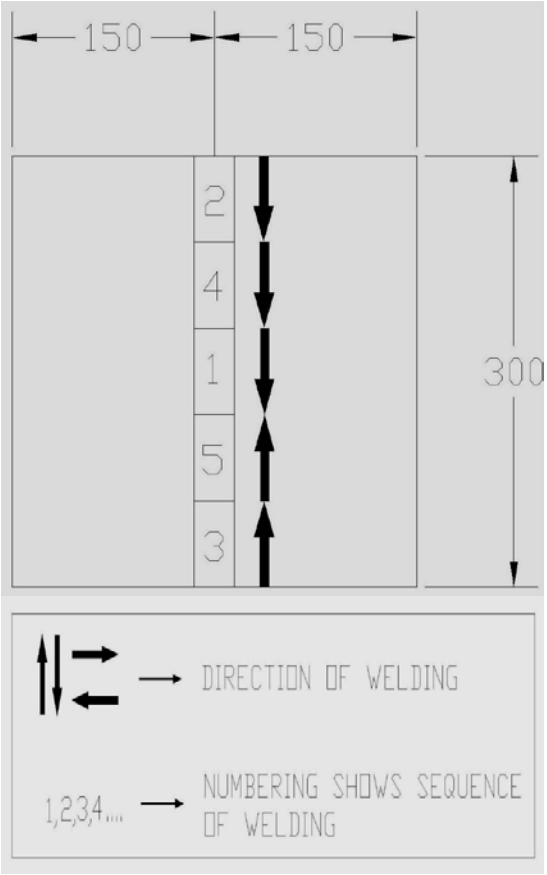
Figure 4: Image of Normal Welding of 4mm thick Plates with Fixture

METHOD 2 : SEQUENTIAL WELDING WITHOUT FIXTURES

- Welding sequence implies the order of making the welds in a weldment. The weld metal is placed at different points about the structure so that as it shrinks at one place it will counteract the shrinkage forces of weld already made.
- Here the weld line has been divided into five parts of 60 mm each as shown below and used three types of welding sequences for butt weld. Then the distortion of plates were measured and compared with various sequences to find out best sequence.
- All the welding parameters and plate specifications are same as mentioned previously.

COMMON WELDING SEQUENCES FOR BOTH 4 mm AND 8 mm THICK PLATES

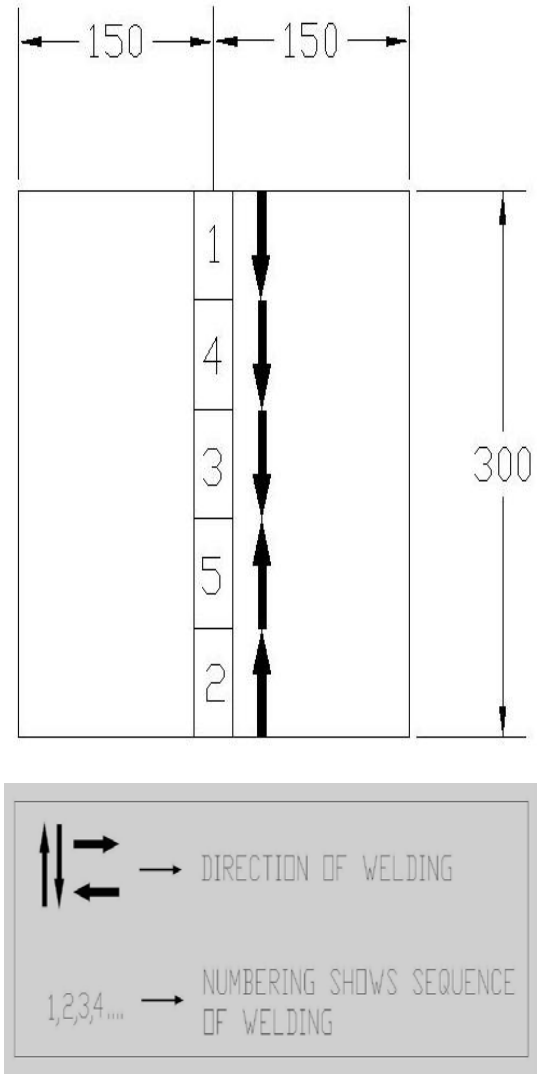
SEQUENCE 1



All dimensions are in mm

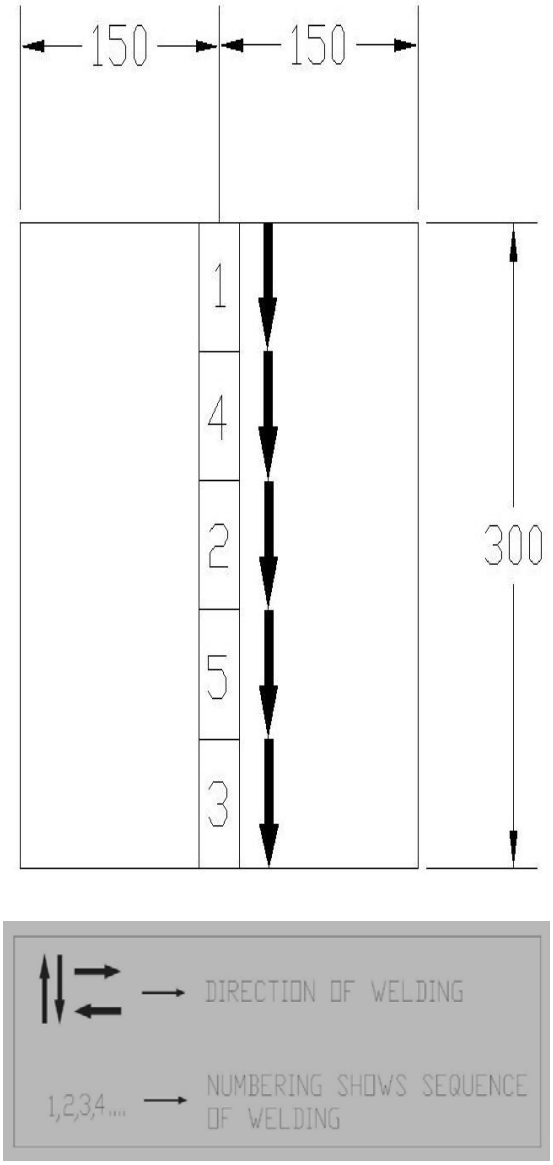
Figure 5: Welding without Fixtures Sequence 1

SEQUENCE 2



All dimensions are in mm
Figure 6: Welding without Fixtures Sequence 2

SEQUENCE 3



All dimensions are in mm
Figure 7: Welding without Fixtures Sequence 3

METHOD 3 : SEQUENTIAL WELDING WITH JIGS AND FIXTURES

- Here the weld line has been divided into five parts of 60 mm each and used same three types of welding sequences for butt weld as previously and also in addition to this, we have fixed the ends of plate using welding jigs. Then the distortion of plates was measured and compared with various sequences to find out best welding sequence with fixture.
- All the welding parameters and plate specifications are same as mentioned previously.

COMMON SEQUENCES FOR BOTH 4 mm AND 8 mm THICK PLATES USING WELDING JIGS

SEQUENCE 1 WITH JIGS AND FIXTURE

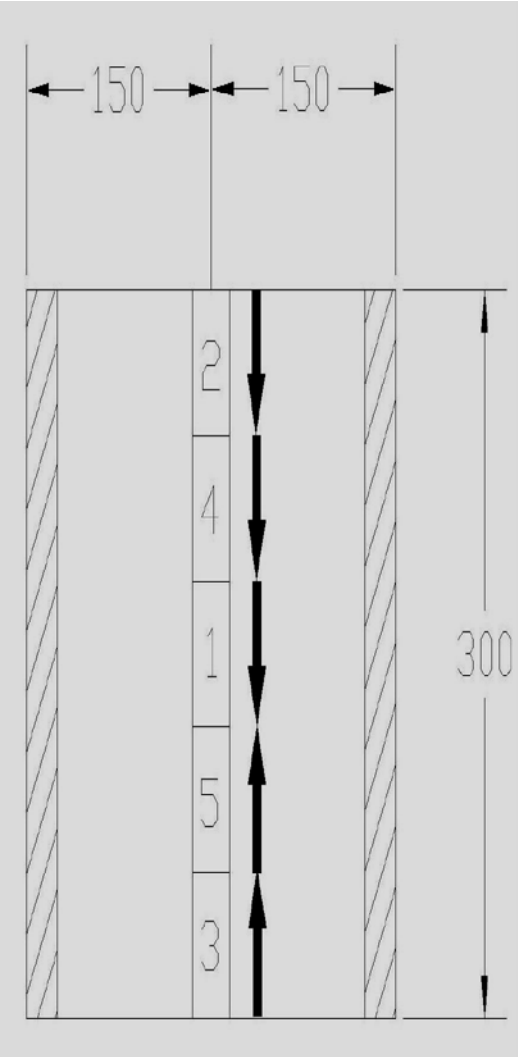


Figure 8: Welding with Fixtures Sequence 1

SEQUENCE 2 WITH JIGS AND FIXTURE

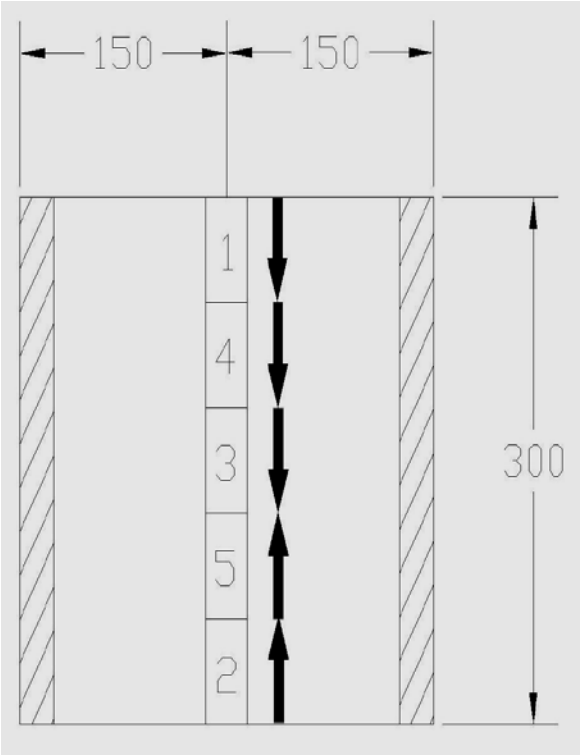
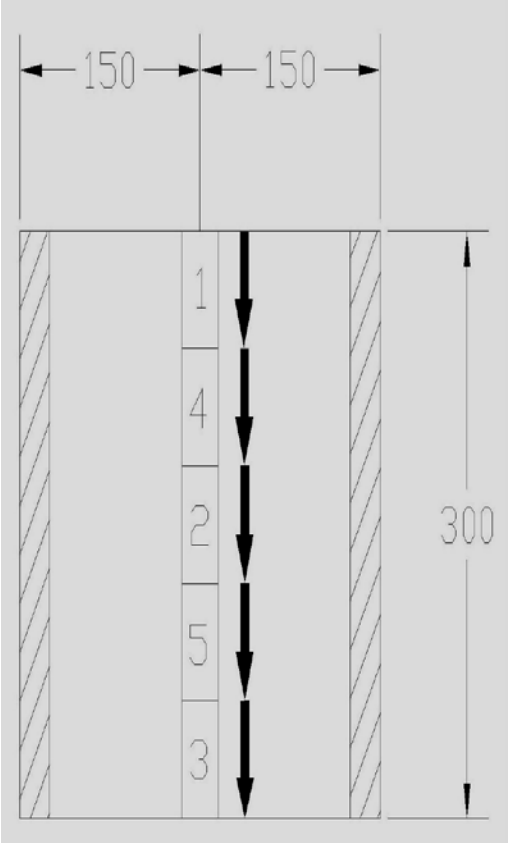


Figure 9: Welding with Fixtures Sequence 2

SEQUENCE 3 WITH JIGS AND FIXTURE



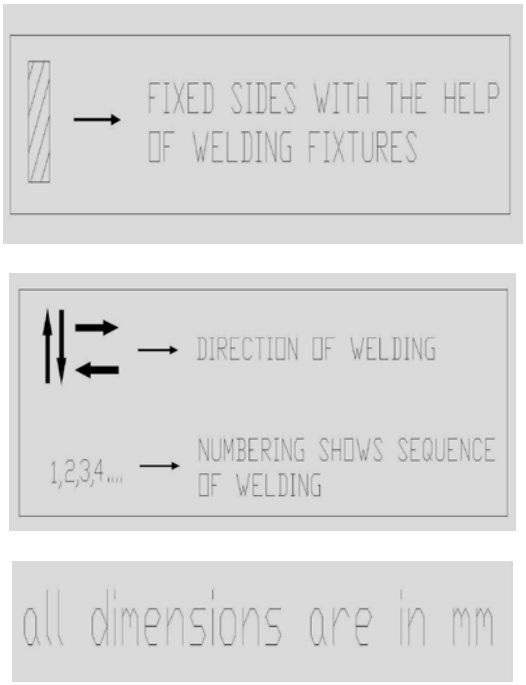
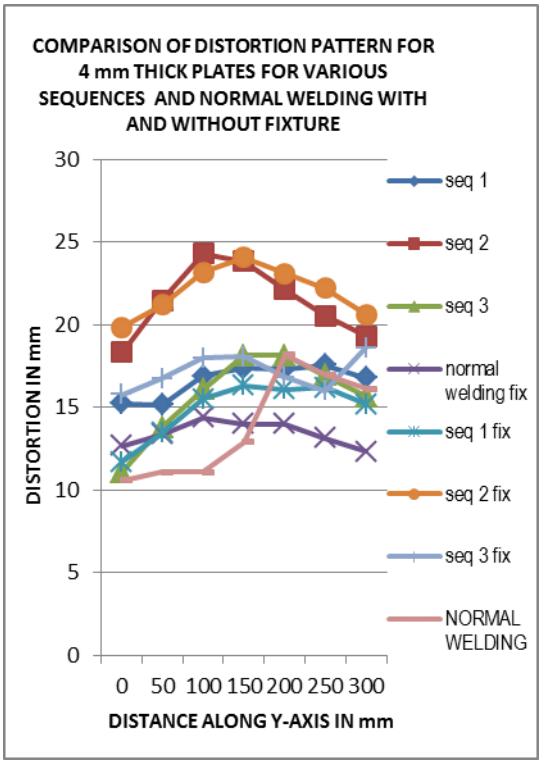
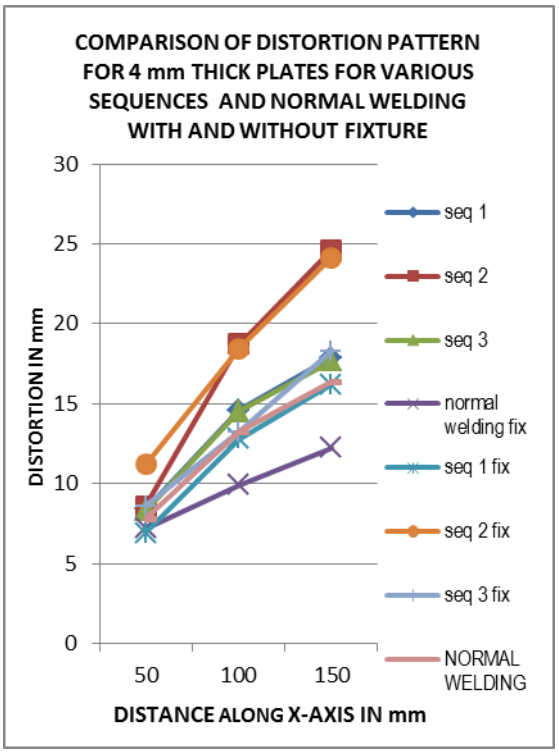


Figure 10: Welding with Fixtures Sequence 3

1. GRAPHS FOR 4 mm THICK PLATES



Graph 1: Comparison of Distortion Parameters for 4mm Thick Plates, distance along y-axis



Graph 2: Comparison of Distortion Parameters for 4mm Thick Plates, distance along x-axis

2. EXPERIMENTAL PROCEDURE OF BUTT WELD FOR 8 mm THICK PLATES

NORMAL WELDING

Two plates of thickness 8 mm are cleaned and grooved in a single V butt joint. These two plates are kept 2 mm apart from each other and welded. Two opposite passes are used for this butt weld. DC straight polarity source has been used.

- SPECIFICATION OF PLATES :

Dimensions - 300 × 150 × 4 mm
V- groove angle - 60°
Material used - Low carbon steel (IS 2062)

- WELDING PARAMETERS :

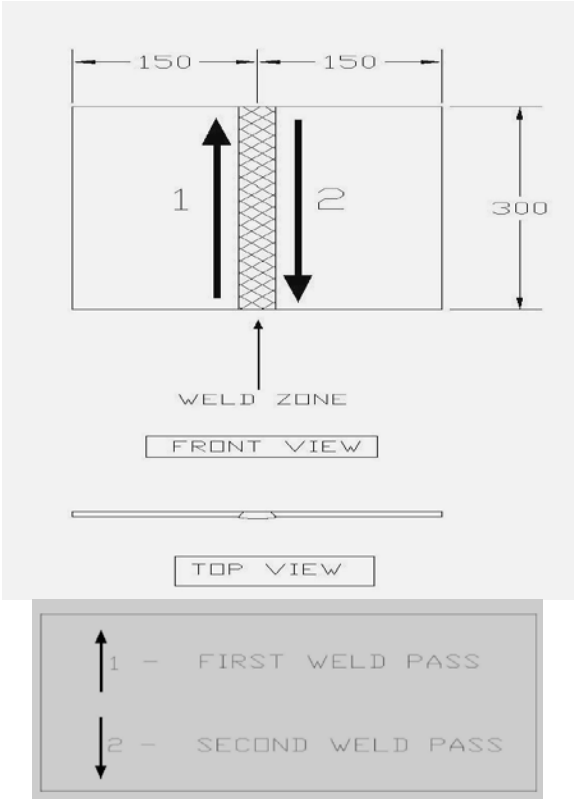
Number of Passes - 2 (opposite passes)

	FIRST PASS	SECOND PASS
CURRENT	115 A	170 A
ELECTODE DIAMETER	3.15 mm	4 mm
ELECTRODE TYPE	E6013	E6013

WELDING SPEED	2 mm/sec	2 mm/sec

DIAGRAM OF NORMAL WELDING

Figure 11: Normal Welding of 8mm thick Plates



All dimensions are in mm
Figure 12: 2-D View Normal Welding 8mm Thick plates

V. OBSERVATION OF PLATES AFTER WELDING

After welding, angular and buckling distortion occurred in the plates. Two methods to control these distortions were used i.e, sequential welding and using welding jigs and fixtures and kept all the parameters constant as used in normal welding while doing sequential welding and welding using jigs and fixtures.

IMAGE OF DISTORTION OF PLATES IN NORMAL WELDING

Figure 13: Distortion of 8mm Thick Plates in Normal Welding

METHODS FOR CONTROLLING DISTORTION IN BUTT WELD FOR 8 mm THICK PLATES

METHOD 1 : NORMAL WELDING USING JIGS ANG FIXTURES

In this, normal welding was done using same welding parameters as above. But in this case the ends of plate will be fixed so that bending can be controlled. In this also two opposite passes will be used as shown in figure below.

DIAGRAM OF NORMAL WELDING WITH FIXTURE

Figure 14: Image of Normal Welding of 8mm Thick Plates with Fixture

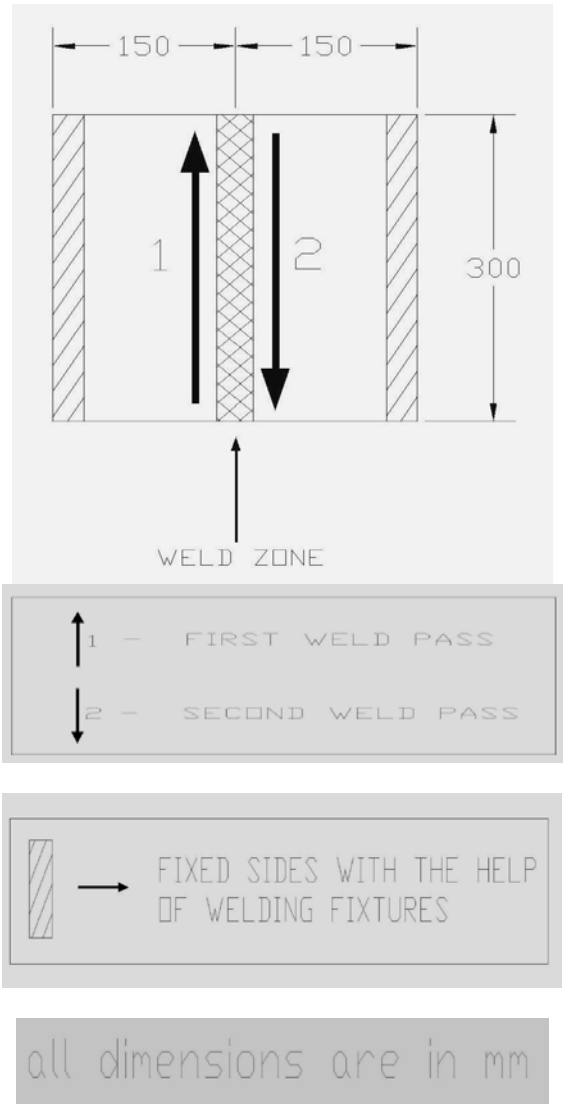


Figure 15: Normal Welding 8mm plates with Fixture

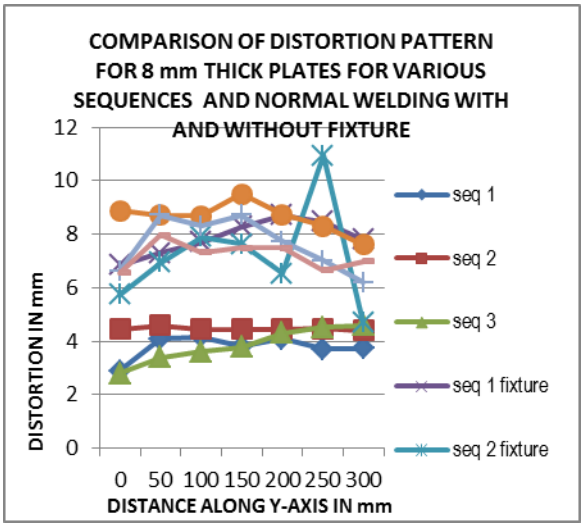
METHOD 2 : SEQUENTIAL WELDING WITHOUT FIXTURES

- Welding sequence implies the order of making the welds in a weldment. The weld metal is placed at different points about the structure so that as it shrinks at one place it will counteract the shrinkage forces of weld already made.
- Here the weld line has been divided into five parts of 60 mm each and used three types of welding sequences for butt weld. Then the distortion of plates were measured and compared with various sequences to find out best sequence.
- **All the welding parameters, plate specifications same as mentioned previously for 8 mm and welding sequences without fixtures are same as in case of 4 mm.**

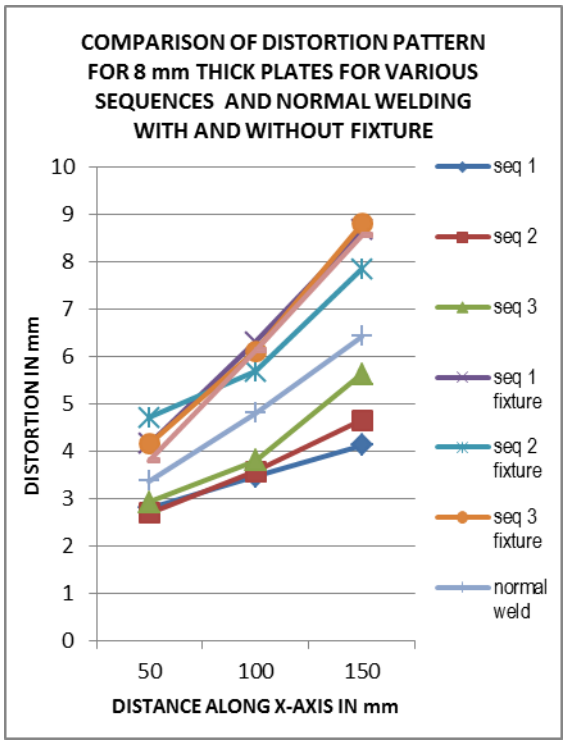
METHOD 3 : SEQUENTIAL WELDING WITH JIGS AND FIXTURES

- Welding sequence implies the order of making the welds in a weldment. The weld metal is placed at different points about the structure so that as it shrinks at one place it will counteract the shrinkage forces of weld already made.
- Here the weld line have been divided into five parts of 60 mm each and used same three types of welding sequences for butt weld as previously and also in addition to this the ends of plate have been fixed using welding jigs. Then the distortion of plates were measured and compared with various sequences to find out best welding sequence with fixture.
- **All the welding parameters and plate specifications are same as mentioned previously for 8 mm and welding sequences with fixtures are same as in case of 4 mm.**

11.2 GRAPHS FOR 8 mm THICK PLATES



Graph 3: Comparison of Distortion Parameters for 8mm Thick Plates, distance along y-axis



Graph 4: Comparison of Distortion Parameters for 8mm Thick Plates, distance along x-axis

VI. CONCLUSION

- For butt weld of 4 mm thickness, normal welding with fixture is the best practice in real life.
- For butt weld of 8 mm thickness, sequence 1 without fixture is the best practice in real life.
- As plate thickness increases distortion decreases.
- In site there cannot be the possibility of using fixtures during welding. This is often found in construction site of any project. So, the sequence welding is the only answer for lessening distortion in this situation.
- Whenever there is a possibility of using fixtures like in small brackets or in small fabrication works then fixture will be more suitable for butt weld of 4 mm thick plates.

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AUTHORS

First Author – Pavana Yogesh Rao
Second Author – Rajesh Kumar. S
Third Author – Dr. B.S. Mohanty