Advanced welding processes for distortion reduction: A Review

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Abstract - *As welding is a heat induced process, weldment has to undergo thermal cycles during the process. Localized heating in welding, results in non-uniform heating and cooling of the weldment. Due to this non-uniform expansion and contraction, residual stresses are developed in the weldment. This results in undesirable distortion. It negatively affect the quality of welded structure. So, now a days industries are eager to implement advanced welding processes as a remedy of this distortion. Various advanced welding processes and methods are reviewed in this paper on the target of distortion reduction. The processes mainly involved Cold Metal Transfer (CMT), Autogenous laser welding, Hybrid laser-GMA welding, Hybrid laser-magnetic welding and effects of welding process conditions on distortion. Various Comparative study among different welding processes as a response of distortion are reviewed. This paper will give brief outline on distortion and effects of process conditions on distortion.*

Key Words: Distortion, CMT, Laser welding, Hybrid laser welding.

1. INTRODUCTION

In automobile industries vehicle chassis is manufactured by welding process. Chassis is one of the critical part of the vehicle. In case of two wheeler, the chassis acts as a backbone of the vehicle. It plays crucial role in enhancing the functional quality and aesthetic quality of the vehicle. In order to fulfill the design requirement, chassis needs to be welded with stringent dimensional tolerances. Distortion will be the key parameter which affects the dimensional acceptance of the chassis. It is reflecting in fit and finish of the vehicle. This distortion will have negative effect on the performance, fatigue life and aesthetic quality of the chassis. Dealing with distortion is a key challenge for welding engineers and process developers in industries. The amount of distortion mainly depends on material properties, heat input, joint design, joint fit up, fixture design and type of welding process. Conventional arc welding processes are dominating almost all the automobile industries because of its high productivity, low cost and simple configuration. On the other hand, due to high heat input involved in these processes, the amount of distortion will be much higher. So additional, non-value added rework processes to be employed for rectification of welded structure. This will increase the manufacturing cost and increase the processing time.

1.1 DISTORTION

Weld distortion is defined as the undesirable change in size and shape of the component. The residual stresses induced in a material resulting in distortion either during welding or after welding depends on the clamping condition. The detrimental effects of this distortion are minimizing load carrying capacity, aesthetic quality issues, fits and tolerance issues and fit-up problems. As a result, the welded structure could not meet the intended design requirement. It affects vehicle's functional performance and aesthetic appearance. There are six different types of distortion [Fig-1] are usually exhibits in welding process which are listed below.

1. Longitudinal shrinkage
2. Transverse shrinkage
3. Rotational distortion
4. Angular distortion
5. Bending distortion
6. Buckling distortion

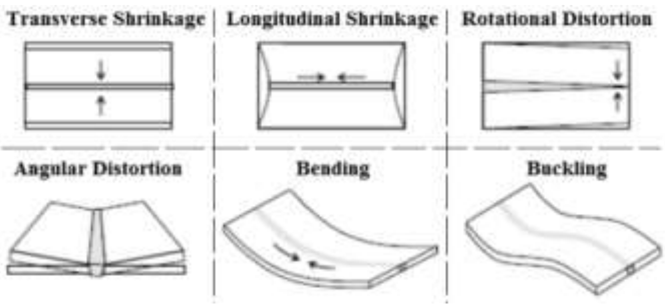

Fig-1: Types of weld distortion

This distortion can be controlled during design stage, manufacturing stage and after welding. This paper deals with distortion reduction methods in manufacturing stage i.e. during welding processes.

2. LITERATURE REVIEW

P. Colegrove *et al*, [2013] [1] demonstrated that influences of welding processes on the amount of distortion [Fig-2]. Comparative study has been taken among Submerged arc welding (SAW), DC Gas metal arc welding, Pulsed gas metal arc welding, Fronius Cold metal transfer, Autogenous laser welding and Laser hybrid welding. Among those processes autogenous laser welding exhibits less distortion with respect to heat input. But autogenous laser weld had significant undercut. They recommended that, this would be resolved by addition of filler wire.

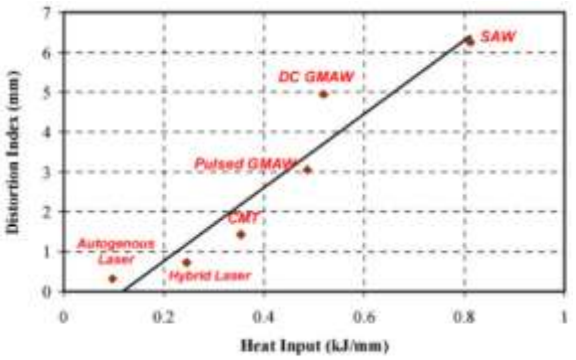

Fig-2: Distortion as a function of heat input in different welding processes [1]

Also they have concluded that fusion area will exhibit a linear relationship with heat input [Fig-3]. So, controlling the fusion area will results in reduction of distortion. As laser welding is high heat intensity process, which offers lower bead width and narrow HAZ. That leads minimal fusion area which in turn the result of less distortion. So, laser welding can offer less distortion comparatively with other processes. Next to the laser processes, CMT provides better benefits among other GMAW technologies.

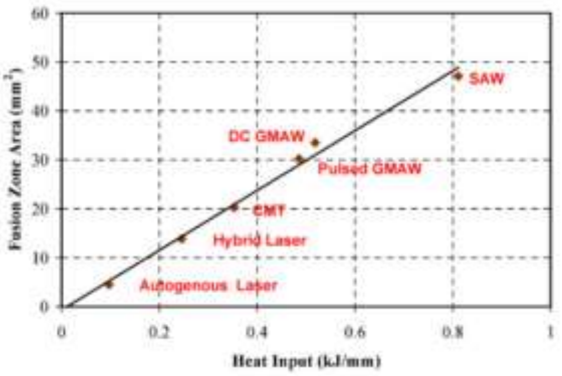

Fig-3: Fusion area as a function of heat input in different welding processes [1]

Chen Zhang *et al*, [2012] [2] has done comparative analysis among CMT welding, Laser welding (LW), Laser-CMT hybrid welding (LCHW), Laser-pulse MIG hybrid welding (LPHW). Experiment was carried out in AA6061-T6 sheets with the size of 100mm x 50mm x 2mm in butt joint configuration. All welded specimen undergone angular distortion. The amount of distortion in each processes were measured in terms of transverse weld displacement as shown in Fig-4.

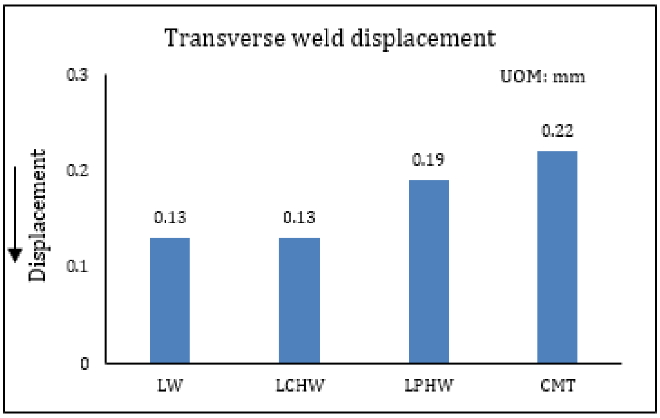

Chart-1: Transverse weld displacement in all welding processes

CMT welding exhibits large transverse deformation as 0.22 mm. Laser welding and Laser CMT hybrid welding exhibits lower deformation as 0.13 mm [Fig-4]. This is due to less heat input and even heat distribution between lower and upper portion of the welded specimen.

H. Pinto *et al*, [2015] [3] has done comparative analysis among CMT welding, Pulsed MIG welding and Laser hybrid welding. Microstructure formation and residual stress state are characterized. Analysis was carried out in $AlMg_3$ sheets with thickness of 1.5 mm. Results shows that, HAZ produced by CMT and Laser hybrid welding are almost not visible in optical microscope and Scanning electron microscope. Due to the low heat input, which will leads to minimal distortion.

Shuichi Tsumura, Koji Murakami & Koji Gotoh [2017] [4] has carried out comparative analysis between CO2 arc welding and laser arc hybrid welding. Experiment was done in T joint with thickness of 14 mm and 21 mm. They concluded that, laser arc hybrid welding can replace conventional arc welding and provides advantages of fully penetrated joints with superior strength and less angular distortion.

E.W Reutzel *et al.* [5] has demonstrated the ability of hybrid laser-GMA welding process in the aspects of distortion and productivity. Compared with Conventional arc welding, 71% less heat input in hybrid laser-GMA welding is sufficient for full penetration of 6 mm thick plate in butt joint configuration. No buckling distortion observed but minimal angular distortion was observed in the range of 0.1 to 1.3 mm. 12 mm thick plate can be welded in single pass weld in laser-GMA welding which will improve the productivity. But significant effort is required to optimize the process parameters to obtain better weld quality.

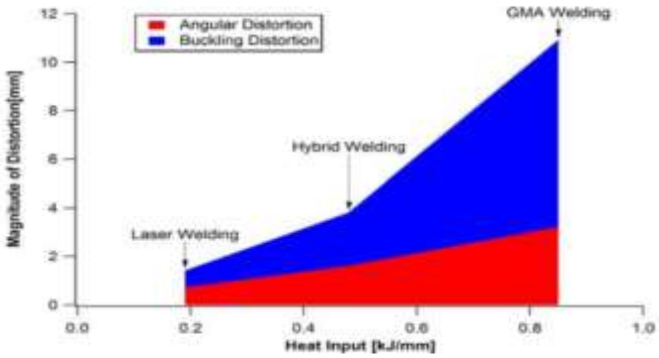

Fig-4: Magnitude of distortion as a function of heat input [5]

Youmin Rongx ***et al.*** **[2017] [6]** has analyzed the effect of integrated magnetic field with laser welding to study the effect on distortion. 316L steel with butt joint configuration was used for analysis. 100 mm x 50 mm x 3.8 mm plates were kept parallel to make butt joint configuration. Fiber laser IPG YLR-4000 was used and permanent magnet was placed under the sample parallel to the welding direction. Experiment was carried out in two cases. Case 1 - Without application of magnetic field and Case 2 – With application of magnetic field [Fig-6].

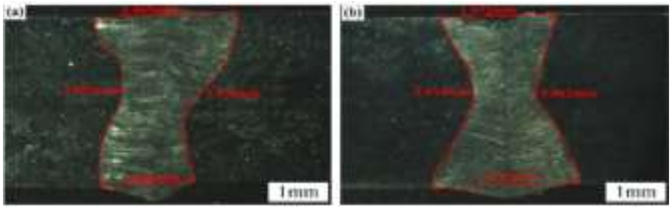

Fig-5: Weld bead geometry a) Case 1 b) Case 2 [6]

Weld depth was not affected by magnetic field. But it affected weld cap width and root width. Effect of magnetic field in terms of heat distribution was analyzed with the developed heat source model. Integration of steady magnetic field with laser welding reduces the distortion by 26.56%.

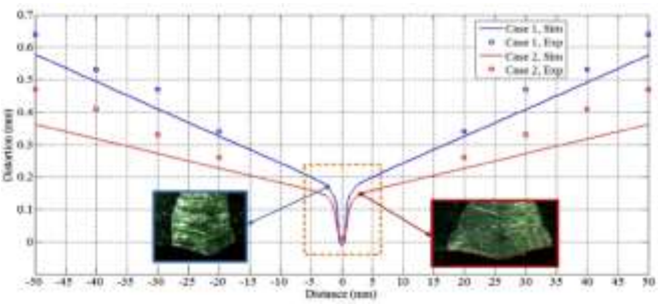

Fig-6: Comparison of simulation and experimental measurement of angular distortion [6]

Karl Fahlstrom et al. [2015] [7] has investigated the distortion in welding U-beam structure of boron steel. Welding heat input and welding sequence were varied to study the range of distortion. The process conditions such as welding sequence, cooling time, unclamping sequence, unclamping time and distortion were measured by optical measurement. The amount of distortion varied during welding, cooling and unclamping as shown in [Fig-8].

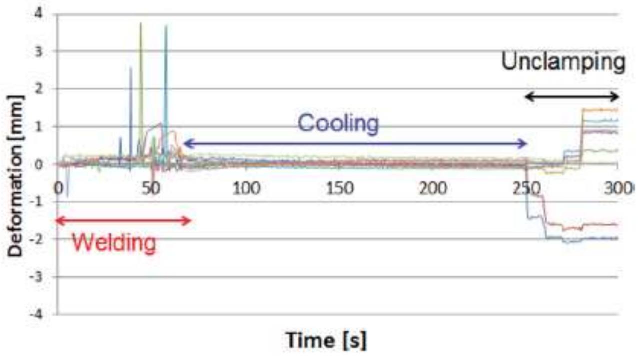

Fig-7: Range of deformation during process [7]

Heat input shows linear relationship with distortion. The final distortion measured as 0 to 8 mm.

Jiamin Sun ***et al.*** **[2014] [8]** has compared Laser beam welding and CO2 gas arc welding in the response of distortion and residual stress distribution. This has been examined both numerically and experimentally. Generally, the total heat input used in Laser beam welding will be far less than conventional arc welding process. The analysis was carried out in thin structure of low carbon steel. It has been examined that maximum deformation observed in CO2 gas arc welding was 8.7 mm whereas the deformation in LBW was only 0.23 mm. Almost 97% of reduction in weld deformation was observed in LBW process.

3. SUMMARY

From this study it is understood that advanced welding process are available on affordable range in terms of weld quality and productivity. Moving on from conventional arc welding into advanced processes will give numerous benefits in terms of distortion reduction and product delivery. Laser beam welding, Laser hybrid GMA welding and Laser magnetic hybrid welding process are offering better weld quality with less distortion than conventional arc welding. On the other hand, proving of these processes required significant amount of work and requires huge capital investment but it will benefits more than the expected. During process development stage in automobile industries all these advanced welding processes are needs to be considered for evaluation based on the applications.

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