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Optimize the Welding Speed to Control Angular Distortions under Pressure Restraining

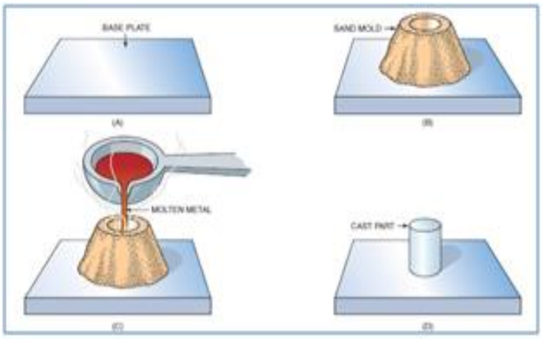
P.Ramu Naidu & V.Ravi Kumar

Abstract:

Welding distortion is one of the critical defects in the welded structures. Angular distortion is most pronounced which badly affects the welded structures. Non-uniform heating during welding develops this angular distortion. Various methods are available to control or minimize the welding distortions. One of the methods available to control this distortion is restraining, in which clamping pressure is applied on the deforming edges of the plates. In the present study, a 3-dimensional coupled transient thermal analysis is done for simulating the restraining phenomenon of welding. Time variable heat flow from starting point to end point of weld plate is analysis by using MatLab simulation. The developed transient thermal heat source was used to simulate the arc welding phenomenon. Verification of structural model was done by comparing the both conventional welding & welding under restraining pressure for considering three Case Studies, in this the welding speed is variable for all case studies. Finally we predict optimized welding speed for reducing welding defects.

1. INTRODUCTION

As methods of joining materials improved through the ages, so did the environment and mode of living for humans. Materials, tools, and machinery improved as civilization developed. Fastening together the parts of work implements began when someone attached a stick to a stone to make a spear or axe. Egyptians used stone tools to create temples and pyramids that were fastened together with an adhesive of gypsum mortar. Some walls that still exist depict a space-oriented figure that was as appropriate then as now an ibis-headed god named Thoth who protected the moon and was believed to cruise space in a vessel. Other types of adhesives were used to join wood and stone in ancient times. However, it was a long time before the ancients discovered a method for joining metals. Workers in the Bronze and Iron Ages began to solve the problems of forming, Casting, and alloying metals. Welding metal surfaces was a problem that long puzzled metal workers of that time period. Early metal-joining methods included such processes as forming a sand mold on top of a piece of metal and casting the desired shape directly on the base metal so that both parts fused together, forming a single piece of metal Fig 1.0 & 1.1.



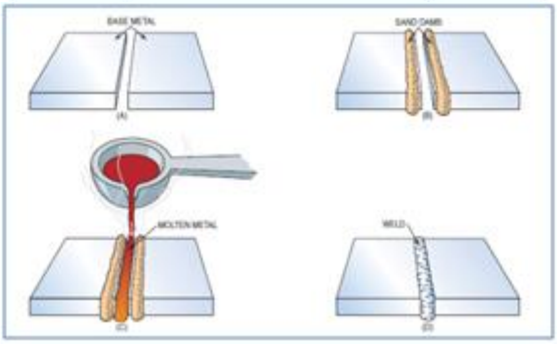


Fig 1.0 Direct casting: (A) base plate to have a part cast on it, (B) sand molded into shape desired, (C) pouring hot metal into mold, and (D) part cast is now part of the base plate.

Fig 1.1 Flow welding: (A) two pieces of metal plate, (B) sand dams to hold molten metal in place, (C) molten metal poured between metal plates, and (D) finished welded plate

Welding plays very crucial role in the field of construction of ships, boilers, bridges, nuclear reactors etc. because it has some advantages i.e. good mechanical properties, weight reduction and efficiency of the joint. And also welding has some disadvantages, due to improper welding conditions or welding parameters used to produce some defects i.e. distortions (angular distortions), residual stresses and cracks etc.

Distortions in weld plate are mainly because of three factors. First one is material related properties such as thermal, physical and mechanical properties (thermal conductivity, density, Young's modulus, Poison's ratio and yield strength). Second one is geometry of weld plate. Third one is type of welding process viz. heat input, weld sequence, weld clamping [1], pre heating and post-heating etc. residual stresses [2] occur due to the non uniform temperature distribution in the welded component. MatLab program is used to find temperature distribution and cooling rate in welding process. Finite element method (FEM) is used to predict distortions and residual stresses in welded plates.

1.1 Statement of the problem:

Welding plays vital role in construction field, weld joints fail due to some defects. Defects formed due to improper welding conditions. The major defects are distortions and residual stresses. So minimize these defects we applied pressure at the edges of the weld. We did analysis on both conventional welding and welding under restraining pressure.

1.2 Defects

The defects in the weld can be defined as irregularities in the weld metal formed due to incorrect welding parameters or wrong welding procedures or wrong combination of filler metal and parent metal.

Various welding defects can be classified as

1. Distortions
2. Residual stresses
3. Cracks

1.2.1 Distortions:

In fabrication of metallic structures, fundamental dimensional changes that occur during welding are often found. This is what we call "Weld Distortion"

Types of distortions

A. Transverse shrinkage
B. Longitudinal shrinkage
C. Angular distortion
D. Twisting
E. Buckling

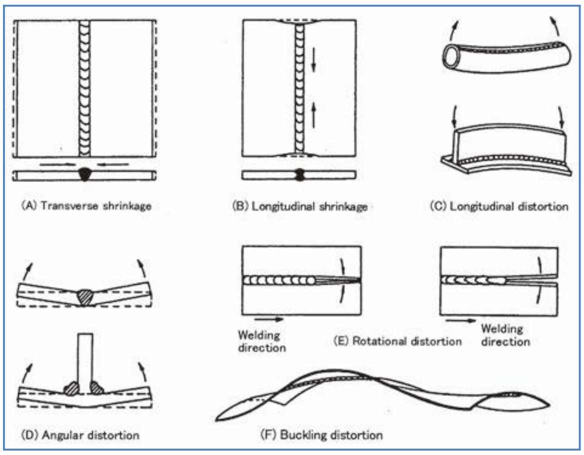


Fig1.2. various welding distortions

1.2.2 Prevention of welding distortions

In fusion welding, the groove preparation, the sequence of deposition, the order, etc. minimize weld distortion. There are various methods to prevent weld distortion by using a clamp, wedge, etc. as showed in below fig. In general, a structure to be welded has a number of welding lines. Therefore, welding in the wrong order leads to weld distortion and weld cracking. Thorough observation of welding method, the order of welding and choice of appropriate welding parameters are in great need in advance, taking into account the contractions and expansions caused by welding.

Distortion can be removed by producing adequate plastic deformation in the distorted member or section by thermal or mechanical methods, thermal or flame and/or mechanical straightening with a press or jacks. Preheating and post weld thermal treatments are also very effective.

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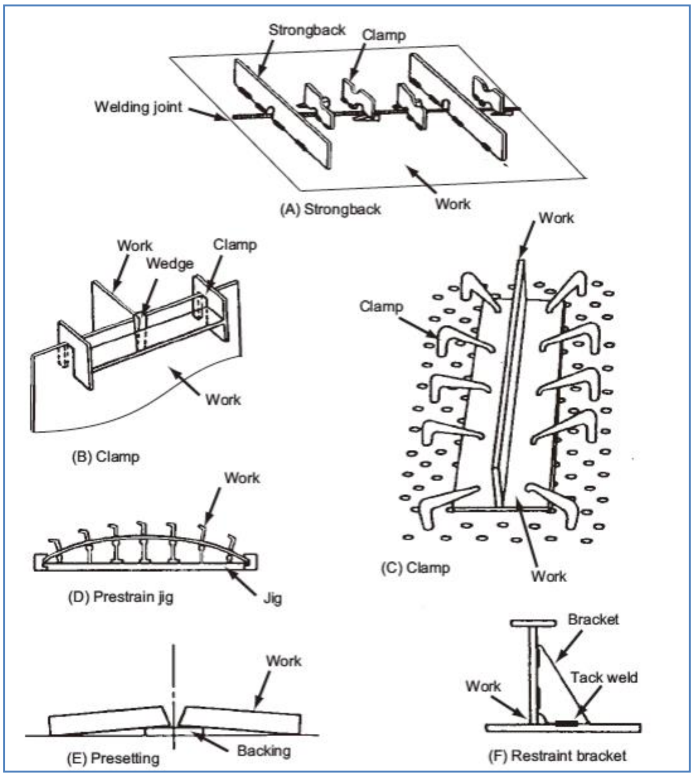


Fig.1.3 some methods to prevent distortions

2 ANALYTICAL APPROACHES FOR WELDING SIMULATION

2.1 Thermo Metallurgical Analysis of welding processes:

The thermal history induced by a welding process can be calculated by solving the fundamental equation of heat transfer

$$\rho \mathrm{Cp}T = \nabla . k\nabla T \sum_{i<j} Lij(T)pij$$

1.where ρ is the density of material, Cp is the specific heat, k is the thermal conductivity, T is the temperature, T is the temperature gradiant, Lij(T) is the latent heat (at temperature T) of the i→j transformation, pij is the phase proportion of i-th phase which is transformed into j-th phase in the time unit. The heat transfer boundary conditions of the problem are

$$q = -k\nabla T$$

2. Where q is the heat flux at the boundary, in the welding process, consists of a prescribed function of the time and space (heat source), convective and radiative heat loss, and zero flux in a symmetry plane.

2.2 TEMPERATURE DISTRIBUTION AND COOLING RATE IN FUSION WELDING PROCESS:

The analytical solution of Eq. (1) was given by Rosenthal (1941), who considered a point source moving on a semi-infinite plate under steady-state conditions, with temperature independent material properties, at convective and radiative heat loss and phase transformations neglected. In a reference system linked to the source, this solution is given by the following equation:

$$T = \frac{Q}{2\pi k} e^{-\lambda v \xi \frac{e^{\lambda v R}}{R}} + To \qquad 3$$

3.where T_0 is the reference temperature, R= (ξ2 + y2 + z2)$^{1/2}$ is the radial distance of a point of the plate from the source axis, v is the welding speed, t is the time, ξ = x – t is a moving coordinate, λ = 1/(2α) (where α is the diffusivity), and Q is the effective thermal power absorbed by the material. In the case of a line source in a plate of thickness H, the above relation becomes:

$$T = \frac{Q}{2\pi k} e^{-\lambda v \xi \frac{Ko(\lambda vr)}{H}} + To \qquad 4$$

4.Where K_o is the modified Bessel function of the second kind and zero order. In the case of arc welding, the effective thermal power equals to

$$Q = \eta VI$$

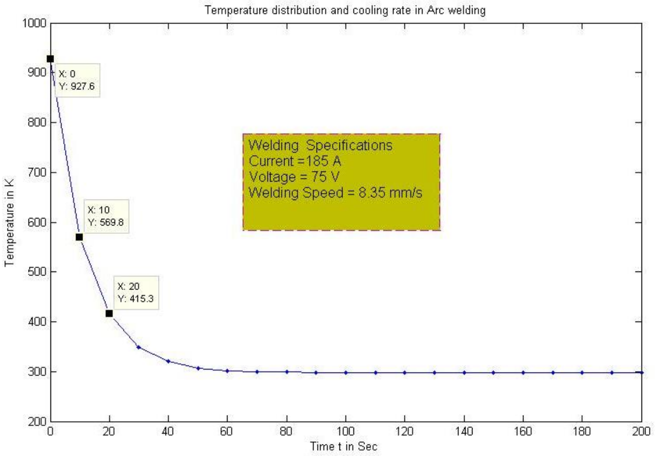
5.Where V is the arc voltage, I is the current intensity, and η is the arc efficiency. Eq. (4) can be easily solved by using Matlab.

APPENDIX-A

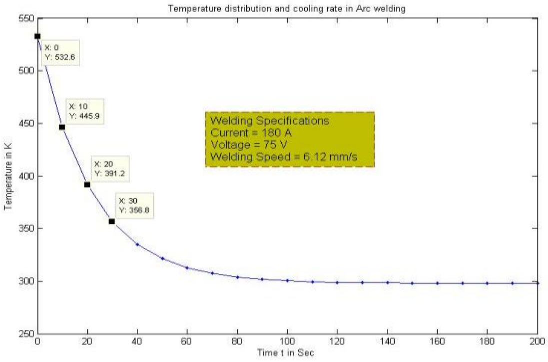
Welding Quality depends up on four parameters i.e. current, voltage, welding speed and welding method. Welding Voltage, welding current, welding speed plays a vital role in welding process.

In this paper we considering three cases viz. case-1, case-2 and case-3. In the cases we vary some of the parameters and some of the parameters are kept constant. In this paper we consider welding voltage is constant for all cases and remaining parameters will be vary.

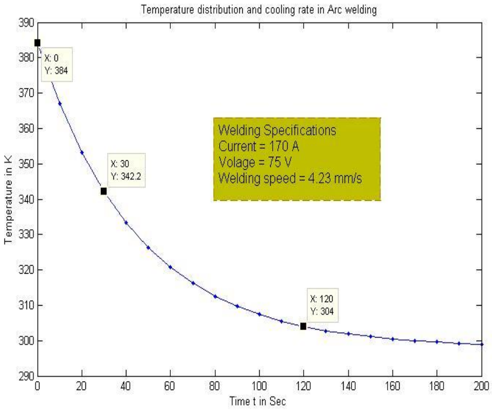
Cases	welding voltage in V	welding current in A	welding speed in mm/sec
case-1	75	185	8.35
case-2	75	180	6.12
case-3	75	170	4.23



Graph shows Temperature distribution Vs cooling rate in case-1



Graph shows Temperature distribution Vs cooling rate in case-2



Graph shows Temperature distribution Vs cooling rate in case-3

3. Finite Element Analysis for Welding

3.1 Numerical analysis is used for analysis the welding process for all three cases. All three case study parameters are described in previous chapter. The analysis is done for both conventional welding and welding under restraining pressure condition. Here coupled field analysis is done for both welding process, in order to analyze a weld structure first do a thermal analysis and then followed by static structural analysis and results are plotted below.

The output of analytical analysis is used as input for thermal analysis. The output of thermal analysis is used as thermal input load for mechanical analysis. In mechanical analysis the residual stress and distortion of weld plate are predicted.

3.2 Thermal Analysis

Imported

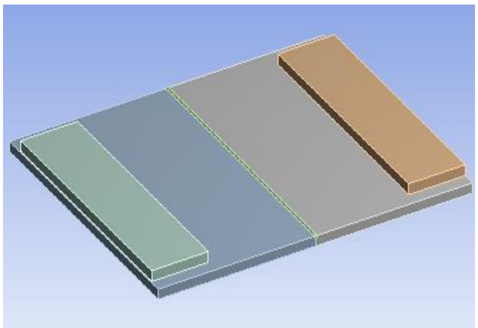


Fig3.0 imported weld structure from CATIA

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Case 1

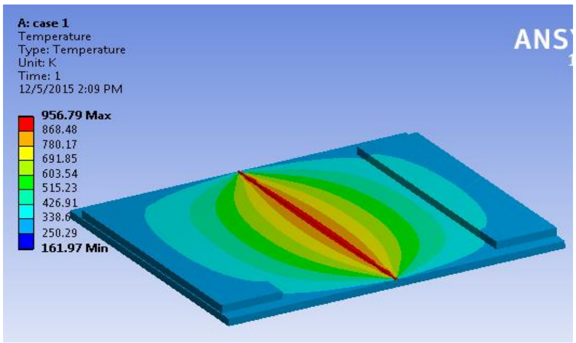


Fig 3.2 distributed temperature of the weld plate in 1st sec is 956.79K in case-1

Case2

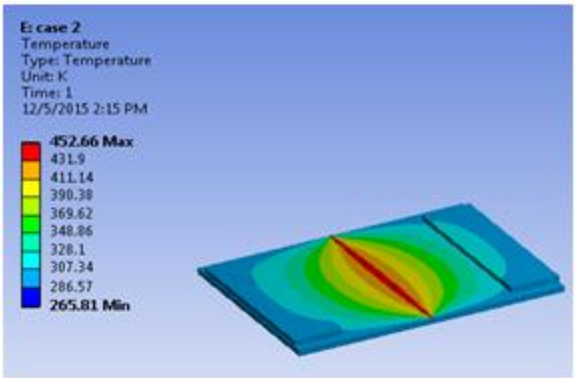


Fig3.4 distributed temperature of weld structure in the 1st sec is 452.66K in case-2

Case 3

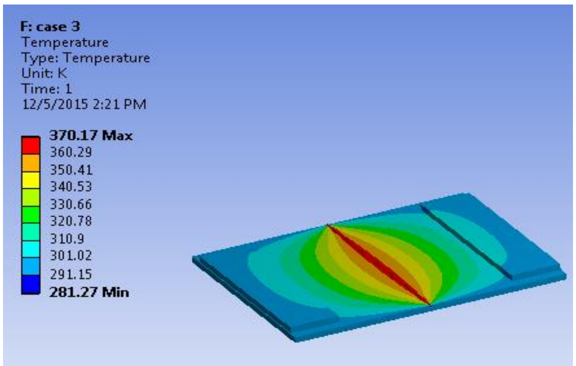


Fig 3.6 distributed temperature of the weld plate in 1st sec is 370.17K in case-3

3.3 Static Structural Analysis

Here also we conduct structural analysis for three cases without stamping and with stamping

3.3.1 Case-1 without stamping pressure

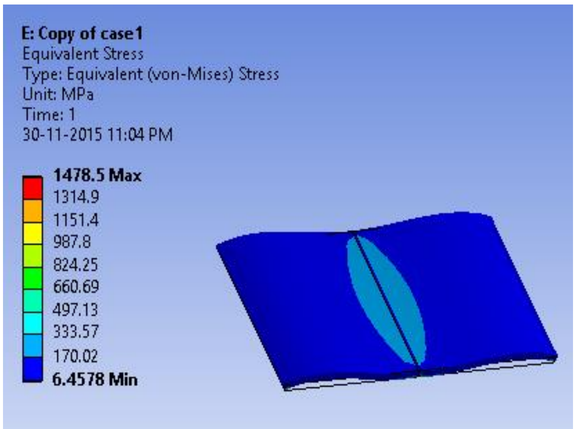
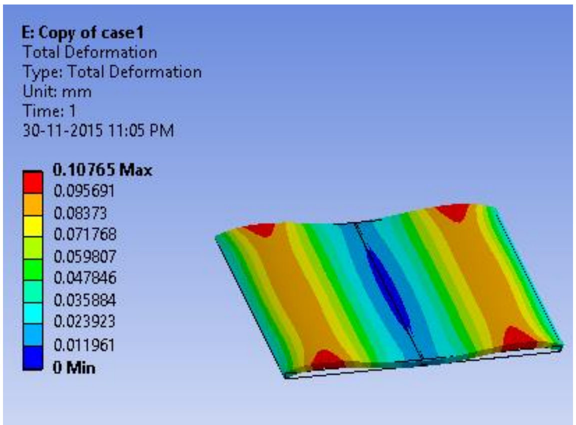


Fig3.9 von-mises stress of weld plate is 1478.5 MPa in 1st sec, without stamping condition in case-1.



3.3.3 Case-2 without stamping pressure

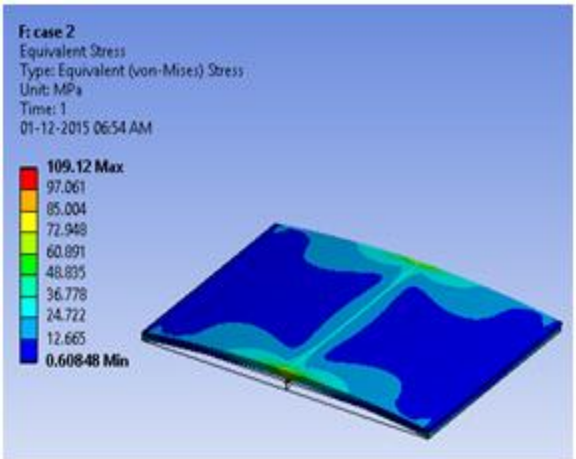


Fig3.10 total deformation of weld plate is 0.10765 mm in 1st sec, without stamping condition in case-1.

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3.3.2 Case-1 with stamping pressure

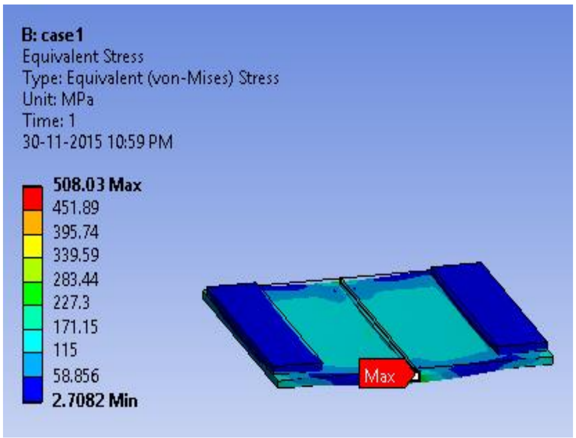


Fig3.12 von-mises stress of weld plate is 508.03MPa in 1st sec, with stamping in case-1.

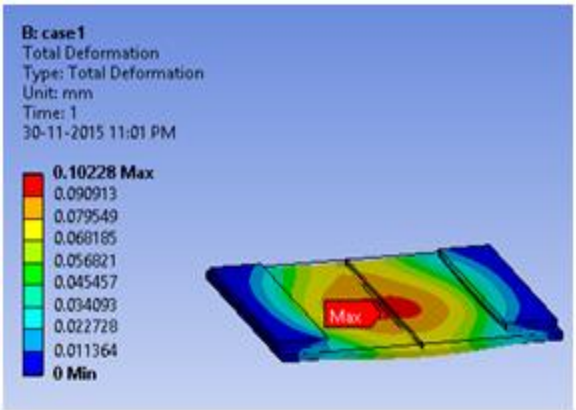


Fig3.13 total deformation of weld plate is 0.10228 mm in 1st sec, with stamping condition in case-1.

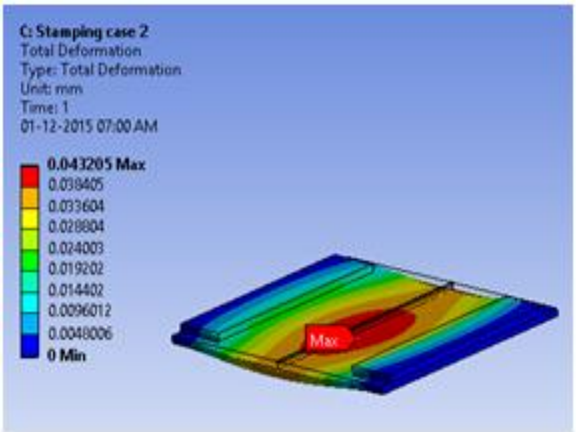


Fig3.16 von-mises stress of weld plate is 80.378MPa in 1st sec, with stamping pressure in case-2.

3.3.5 Case 3 without stamping pressure

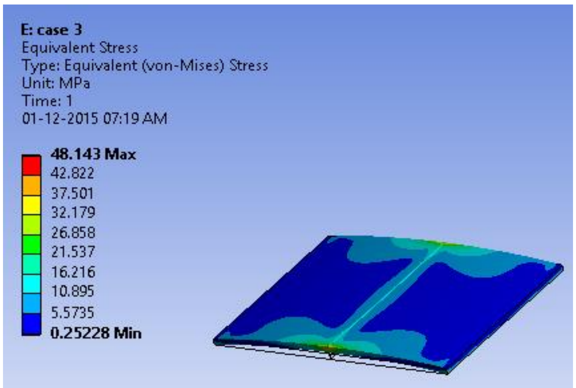


Fig3.18 von-mises stress of weld plate is 48.143MPa in 1st sec, without stamping pressure in case-3

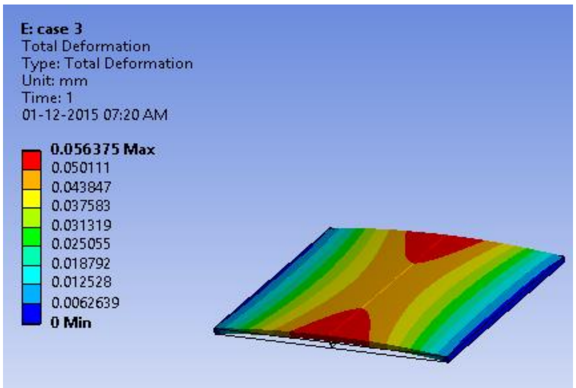


Fig3.19 total deformation of weld plate is 0.056375 mm in 1st sec, without stamping in case-3

3.3.6 Case 3 with stamping pressure

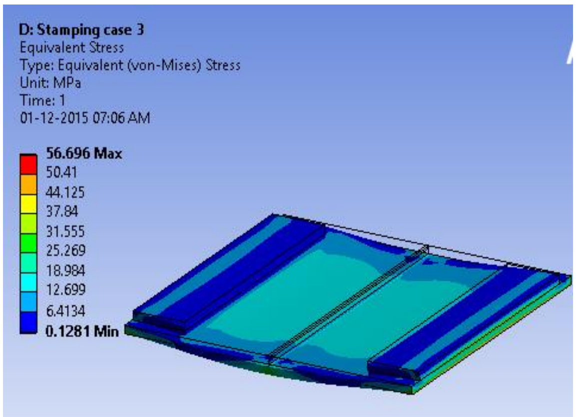
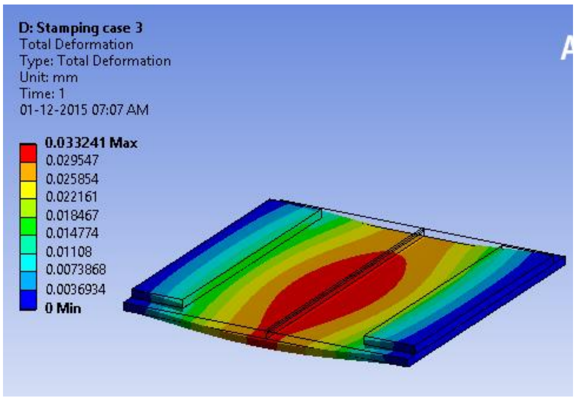


Fig3.20 von-mises stress of weld plate is 56.696MPa in 1st sec, with stamping pressure in case-3



4. Results and discussion

4.1 Thermal analysis

Thermal analysis results were observed and written as table.

Case	Max Temperature In K	Max Heat Flux In w/mm^2
Case-1	956.79	42.71
Case-2	452.66	10.754
Case-3	370.17	5.1322

From the thermal analysis results we have observed three cases, in case-1 temperature of the weld zone is 956.79 K that equal to 684 and heat flux is 42.71w/mm^2. The temperature at this case is below the recrystallization temperature of the material

In case-2 the temperature of the weld zone is 452.66 K that equal to 180 and heat flux is 10.75w/mm^2, the temperature at this case is below the recrystallization temperature and it is adequate to the welding.

In case-3 the temperature of the weld zone is 370.17 K that equal to 97 and heat flux is 5.13w/mm^2, the temperature at this case is below the recrystallization temperature and it is insufficient to the welding.

4.2 Structural analysis

Structural analysis results for three cases, without stamping and with stamping pressure were observed and written as table form. The properties vary without stamping and with stamping pressure conditions.

4.2.1 Case-1

Properties	Without Stamping	With Stamping
Imported body temperature in ^{0}C	687.669	687.67
Von-mises stress in MPa	1478.5	508.03
Normal stress in MPa	142.56	135.55
Shear stress in MPa	280.74	108.43
Total deformation in mm	0.10765	0.10228
Directional deformation in mm	0.10323	0.10225

We have observed that, Von-mises stress value is decreased by approx. three times when stamping pressure is applied, Normal stress value is decreased when stamping pressure is applied, shear stress value is decreased by below the half of the value when stamping pressure is applied and Total deformation is decreased when stamping pressure is applied but it is negligible. This paper is carried out for reducing distortions (deformation), but in this case we didn’t observe that and the residual stresses are decreased when stamping condition compare to the without stamping condition.

4.2.2 Case-2

Properties	Without Stamping	With Stamping
Imported body temperature in ^{0}C	180.2	180.2
Von-mises stress in MPa	109.12	80.378
Normal stress in MPa	49.995	43.158
Shear stress in MPa	23.257	27.111
Total deformation in mm	0.12066	0.043205
Directional deformation in mm	0.11995	0.043195

In this case we observed that, Von-mises stress value is decreased when stamping pressure is applied, Normal stress value is decreased when stamping pressure is applied, only Shear stress value is increased when stamping pressure is applied and total deformation is decreased by approx. half of the value when stamping pressure is applied. Here we have observed decrease in the deformation when stamping and also decreased residual stresses.

4.2.3 Case-3

Properties	Without Stamping	With Stamping
Imported body temperature in °C	97.3206	97.321
Von-mises stress in MPa	48.143	56.696
Normal stress in MPa	20.782	27.012
Shear stress in MPa	10.723	25.984
Total deformation in mm	0.056375	0.033241
Directional deformation in mm	0.056052	0.033238

In this case we have observed that, Von-mises stress value is increased when stamping pressure is applied, Normal stress value is increased when stamping pressure is applied, Shear stress value is also increased when stamping pressure is applied and Total deformation is decreased when stamping pressure is applied. In this case we had observed that decrease in deformation but residual stresses are increased.

5. CONCLUSION

In this work, numerical (MATLAB) code is used for order to simulate temperature distribution and cooling rate in welding process. Coupled field (thermal + structural) analysis is done using ANSYS software. Developed finite element model has predicted the thermo-mechanical results.

From the above results the verification of structural model was done by comparing the both conventional & under restraining welding for all three Case Studies Finally we observed that, case-2 is preferable for welding to optimize the angular distortions and at the same time residual stresses also minimized. If welding speed is high the molten material deposition will be low, so it tends to incorrect weld joint. If welding speed is low, it is a time, money waste process. So we selected optimum welding speed for welding process.

6. FUTURE SCOPE

In this paper we did analysis on two similar metals of flat plates. Recommended for the future work is, the coupled field analysis is can be done on dissimilar metals and different shapes

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Author Details

P. Ramu Naidu
M.Tech (CAD/CAM)
Mechanical Engineering In
Akula Sree Ramulu College of Engineering.

V. Ravi Kumar,
Head of the Department
Mechanical Engineering In
Akula Sree Ramulu College of Engineering.